Geological cartography in volcanic areas: The case of Lipari Late Quaternary volcanism (Aeolian Islands)

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ABSTRACT

An approach to cartography in volcanic areas, in the example of the island of Lipari (Isole Eolie) is proposed. It involves stratigraphic units different for type and hierarchy: Unconformity Bounded Stratigraphic Units (supersynthems, synthems, subsynthems), lithosomes and lithostratigraphic units (formations and members). The use in parallel of these units allows geological peculiarity of volcanic products to be well evaluated: it accomplishes the task of either describing, documenting and interpreting the different rock types (with lithostratigraphic units) and defining the geometry of volcanic bodies (with lithosomes) or putting in evidence the articulate latero-vertical stratigraphic relationships between the volcanic bodies and the unconformities which bound them (with the integrated use of the suggested units). The UBSU units, in particular, provide a general stratigraphic framework which includes the more descriptive other units. UBSU units make easier to correlate products at a local and a regional scale and, moreover, put in evidence main volcanic activity periods. In the case of Lipari, main unconformities are related to processes which are "internal" to the volcanic edifice (connected to volcanic activity, to tectonic events or to subaerial reworking) but also to regional (or global) events, such as sea-level fluctuations.

AIMS

The goal of this paper is to describe a modern approach to the geological cartography in volcanic settings, based on an integrated use of UBSU, lithosomatic and lithostratigraphic units. The main resulting products are:
- a geological map, where litostratigraphic units are represented;
- a synthemic map, where the distribution of unconformities and related UBSU units is emphasized;
- a sketch map of lithosomes, where main lithosomes are represented, with the purpose to show the distribution of volcanic edifices.

KEY WORDS

Stratigraphic units, volcanic areas, Lipari, marine deposits.

RIASSUNTO

Viene proposto un metodo di rappresentazione cartografica in aree vulcaniche, nell'esempio dell'isola di Lipari (Isole Eolie), che prevede l'impiego di unitˆ stratigrafiche differenti Per tipo e gerarchia: Unconformity Bounded Stratigraphic Units (supersintemi, sintemi e subsintemi), litosomi e unità litostratigrafiche (formazioni e membri). L'utilizzo in parallelo di tali unità consente di interpretare al meglio la peculiarità geologica dei depositi vulcanici e, in particolare, consente sia di documentare ed interpretare i differenti litotipi (tramite l'utilizzo delle unità litostratigrafiche), sia di descrivere la geometria e la genesi dei corpi vulcanici (tramite le unità litosomatiche), che di mettere in evidenza le complesse relazioni stratigrafiche latero-verticali tra i corpi stessi e le incorformità che li delimitano (tramite l'utilizzo integrato delle suddette unità e delle unità UBSU). Le unità UBSU, in particolare, forniscono un quadro stratigrafico generale entro cui le altre unità a carattere descrittivo sono inserite, facilitano le correlazioni a scala locale e regionale e, in più, permettono di evidenziare i principali periodi di attività vulcanica. Nel caso di Lipari, le principali incorformità sono ricondotte non soltanto a processi "interni" di modificazione dell'apparato vulcanico (collegati all'attività vulcanica, ad eventi tettonici, o a processi di rimodellamento secondario in ambiente subaereo), ma anche ad eventi a scala regionale (o globale), quali le variazioni del livello del mare.

Age (ka)	Strat. range	Informal lithostratigraphic units		lithosomes	UBSU Subsynthems	UBSU Synthems
~1.3 (4) ~1.4 (5) 1.4 ± 0.4 (1)		**Fossa delle Rocche Rosse formation** **frr$_2$ member -** Tongue-like, obsidian-rich flowing-dome with well developed flow foliation (consisting of interbanded obsidian, spherulitic and lithic rhyolite layers), basal carapace and ramp structures (spectacularly visible along the coast between Porticello and Acquacalda); the surface (well exposed along the road from Porticello to Acquacalda) is typically blocky and rough, and is characterized by curved cracks and ogive structures. HKCA rhyolite in composition. **frr$_1$ member -** Poorly bedded, massive pyroclastic breccia (up to 15 m thick) mostly consisting of obsidian clasts and minor pumices. Thinly bedded lapilli tuff layers are interbedded. HKCA rhyolites.	frr$_2$ / frr$_1$	M. Pilato	CHIRICA RASA	VALLONE FIUME BIANCO
		Sciarra dell'Arena formation **sa$_3$ member -** Isolated remnants of obsidian-rich lava flows, occurring along the Rocche Rosse crater rim. HKCA rhyolites. **sa$_2$ member -** Widespread pumiceous pyroclastics (up to 150 m thick) building the pumice cone of M.Pilato. The unit mainly consists of coherent, poorly medium bedded lapilli tuffs and subordinately of tuff layers with accretionary lapilli (in the upper part). Rare bread-crust bombs, horizons rich in lava and obsidian blocks, and few sand-wave structures occur. HKCA rhyolites. **sa$_1$ member -** Poorly and thickly bedded pumiceous pyroclastic breccia (up to 10 m thick), building a small cone. HKCA rhyolites.	sa$_3$ / sa$_2$ / sa$_1$	M. Pilato		
1.6 ± 0.4 (1)		**Pirrera formation** **pir$_2$ member -** Tongue-like, obsidian-rich flowing-dome, with well developed carapace and foliation. HKCA rhyolite in composition. **pir$_1$ member -** Poorly bedded, massive tuff breccia (up to 7 m thick) consisting of pumiceous clasts and minor lava and obsidian clasts: at places, a slight normal grading and plane-parallel or cross-stratification structures occur. In the upper portion, some lapilli tuff and tuff layers are interbedded. HKCA rhyolite in composition.	pir$_2$ / pir$_1$	Forgia Vecchia		
					se+hi+au+ps — l$_g$	
		Pomiciazzo formation Large endogenous, obsidian-rich, flowing-dome (diameter of at least 800 m) with at least three well-visible lobes along the coastal sector of Pomiciazzo: the dome shows well developed flow foliation. HKCA rhyolite in composition.	po	Vallone del Gabellotto	COLLE S.ELMO	
8.6 ± 1.5 (4) 11.4 ± 1.8 (4)		**Vallone del Gabellotto formation** Widespread pumiceous pyroclastic succession (up to 130 m thick at V.^{ne} del Gabellotto), consisting of medium to thickly bedded, cross-stratified lapilli tuffs and tuff breccias and massive or normal graded tuff layers; minor lava and obsidian clasts occur. These deposits are characterized by large-scale wavy (and minor planar) bedforms with wavelength up to 25 metres (at V.^{ne} del Gabellotto): at V.^{ne} Fiume Bianco, the wavelength shows a westwards range from metric to decimetric. HKCA rhyolites. An obsidian pebble near Acquacalda gave an age of 21±4 ka (1) that predate the beginning of volcanic activity in the NE sector of the island: however, that pebble can not be attributed to any outcropping stratigraphic unit.	vg	Vallone del Gabellotto	COLLE S.ELMO	
						se+au+ch — L$_4$

Age (ka)	Informal lithostratigraphic units		lithosomes	UBSU Subsynthems	UBSU Synthems
					se+au+ch — L$_1$
	Bertaccia formation **ber2 member -** Clastogenic lava flows (average thickness of 4 metres), typically consisting of flattened and deformed spatter fragments. CA andesites. **ber1 member -** Pyroclastic succession (up to 65 m thick) building a tuff-cone. It consists mainly of medium plane-parallel bedded lapilli tuffs with intraformational channels, locally lithic-rich: a massive lithic-rich pyroclastic breccia (at the bottom), and a scoriaceous lapilli tuff layer (at the top) occur.	ber$_2$ / ber$_1$	Chiesa Vecchia		PALEOLIPARI
	Belvedere formation (bel) Pyroclastics (bel$_1$ member) and lavas (bel$_2$ member) building the top portion of the T.Carrubbo edifice. The unit, CA andesite in composition, is characterized by the occurrence of millimetric anphibole phenocrysts. **bel$_2$ member -** Massive lava flow (10 m thick) with blocky carapaces and jointing. **bel$_1$ member -** Poorly sorted, non-coherent, thickly bedded, welded scoriaceous tuff breccia. At the base, a discontinuous, poorly sorted, massive pyroclastic breccia with an intercalated, thinly bedded, hydromagmatic lapilli tuff layer with bomb-sags occur.	bel$_2$ / bel$_1$	Timpone Carrubbo		
	Scoglio Bianco formation Lavas (sb$_1$ member) and pyroclastics (sb$_2$ member) building the main portion of the T.Carrubbo edifice. **sb$_2$ member -** Pyroclastic succession (up to 45 m thick)consisting of poorly sorted, thickly and plane-parallel bedded tuff breccias, passing upwards to thinly bedded, plane-parallel and cross-stratified lapilli tuffs. In places (e.g. at Spiaggia Valle Muria) the unit is strongly fumarolized. CA andesite in composition. **sb$_1$ member -** Massive and blocky lavas; a squat dome (diameter of 15 m) and a 15 m thick succession of "compound lavas" also occur. Coherent, thickly bedded and normal graded, scoriaceous tuff breccias are discontinuously intercalated. All the products are widely and intensely fumarolized. CA basaltic andesites.	sb$_1$ / sb$_2$	Timpone Carrubbo		
	Monterosa formation (mo) Well-sorted, normal and reverse graded, black/yellow scoriaceous lapilli tuffs and tuff breccias (*pyroclastic member*) and massive lava flows with well developed carapaces and jointing structures (*lavic member*). They build the top portion of the two scoria cones of Pietra Campana and U Mazzuni. CA basaltic andesites.	mo	Monterosa		
	Pignataro di fuori formation Well-sorted, coherent, thickly and normal-graded bedded, welded scoriaceous pyroclastic breccia, with intercalated thinly bedded lapilli tuff layers and massive lava flows. A rhythmic alternation of thin lava flows and welded scoriaceous layers is present at the base of the unit. The unit (up to 80 m thick) forms the main portion of the two coeval scoria cones of Pietra Campana and U Mazzuni. From CA basaltic andesite/andesite to HKCA basaltic andesites in composition.	pf	Monterosa		
	Sciarra di Monterosa formation Pyroclastics (*pyroclastic member*) and lavas (*lavic member*). The pyroclastics (30 m thick) consist of thinly bedded lapilli tuffs gradually passing upwards to thickly bedded, welded scoriaceous lapilli tuffs: they build a tuff ring. The lavas are massive and fumarolized and comprise a neck. CA basaltic andesites.	sci	Monterosa		
127.0 ± 9.5 (average) (8) 150 ± 10 (average) (8) 223.0 ± 0.9 (7)	**Bagni Termali di S. Calogero formation** Pyroclastics (*pyroclastic member*) and lavas (*lavic member*). The pyroclastics consist of lower well sorted, loose scoriaceous lapilli tuffs and of upper massive or very thickly bedded, poorly sorted, welded scoriaceous pyroclastic breccias. The lavas are thick (up to 25 metres) and massive, with a discontinuous basal carapace and well developed columnar joints in the upper portion. From CA basaltic andesites to andesites.	bt	Monte Mazzacaruso		
	Timpone Ospedale formation Massive pyroclastic breccia (*pyroclastic member*) with the same lithological features of the M.Mazzacaruso formation. The deposit builds the N-S-aligned spatter cones of T. Pataso, T. Ospedale and Valle di Pero. Thick (30 m max), massive and locally columnar jointed lava flows (*lavic member*) occur. CA basaltic andesites except the Sc.° le Torricelle lava flow, which is HKCA basaltic andesite.	to	Timpone Ospedale		
	Monte Mazzacaruso formation Very thickly bedded, massive pyroclastic breccia (*pyroclastic member*), mainly composed of unvesiculated and less scoriaceous lava clasts; thin and discontinuous lava flows and thinly bedded lapilli tuff layers are frequently intercalated. Thick (up to 35 m) massive lava flows (*lavic member*) occur. CA basaltic andesites.	maz	Monte Mazzacaruso		
	Vallone dei Lacci formation Medium bedded, plane-parallel stratified lapilli tuffs (*pyroclastic member*), building a tuff ring, and massive lavas (*lavic member*). These deposits are strongly fumarolized. CA basaltic andesites.	vla	Monte Mazzacaruso		
	Bonanno formation Massive and blocky lavas, which are often strongly brecciated. Thinly bedded lapilli tuffs are frequently intercalated to the unit. In the sector of Chiesa Vecchia, two massive lava flow (10 and 15 m thick) with well developed flow foliation and columnar jointing occur. The unit is often strongly fumarolized. HKCA andesites, except one massive lava flow along the coastal cliff north of Fuori del Pertuso, which is CA basaltic andesite.	bo	Pietrovito		
	Costa d'Agosto formation Pyroclastic succession (up to 60 m thick) representing the remnant eastern flank of a tuff cone and consisting of thinly, plane-parallel lapilli tuffs and massive tuffs and of a basal discontinuous, lithic-rich pyroclastic breccia; at places, tufaceous breccias occur. In places, the pyroclastics are fumarolized. CA andesite.	ca	Pietrovito		
	Fuori del Pertuso formation Alternation of thin (average thickness of 2 m), massive lava flows and well-sorted, welded scoriaceous layers (up to 2.5 m thick), building three NNE-SSW aligned spatter cones: the crater facies is represented by a poorly stratified, welded scoriaceous pyroclastic breccia. CA basaltic andesites.	fp	Fuori del Pertuso		
	Timpone Croci formation Highly fumarolized and brecciated lavas (at Timpone Croci) and clastogenic lavas (near Marina di Porto Salvo). HKCA basaltic andesite in composition.	tcr			
	Pietra del Bagno formation Highly brecciated lavas representing the neck of a submerged volcanic centre. HKCA basaltic andesites.	pb			

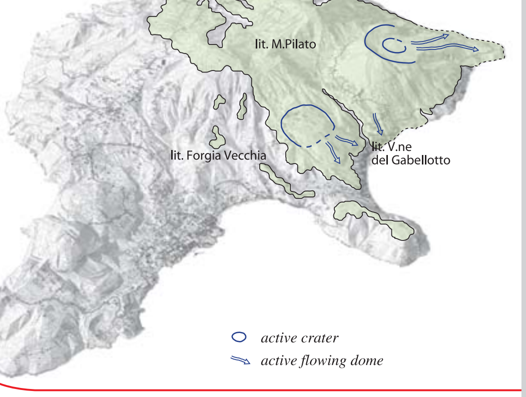
REFERENCES 1) Bigazzi and Bonadonna, 1973; 2) Calanchi et al., 2002; 3) Colella and Hiscott, 1997; 4) Cortese et al., 1986; 5) Crisci et al., 1981; 6) Crisci et al., 1983; 7) Crisci et al., 1991; 8) Gillot, 1987; 9) Keller, 1980; 10) Keller and Morche, 1993; 11) Losito, 1989; 12) Lucchi, 2000; 13) Lucchi et al., 2001; 14) Lucchi et al., 2003a.

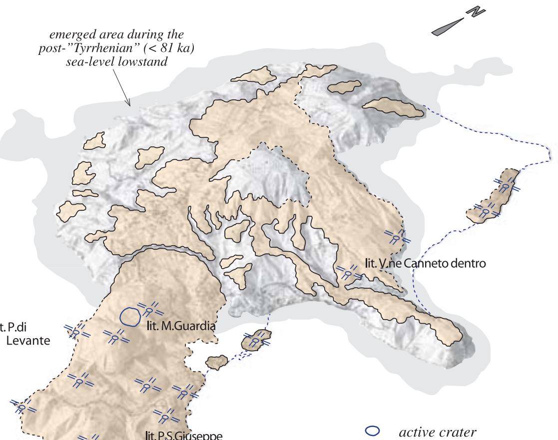
LEGEND

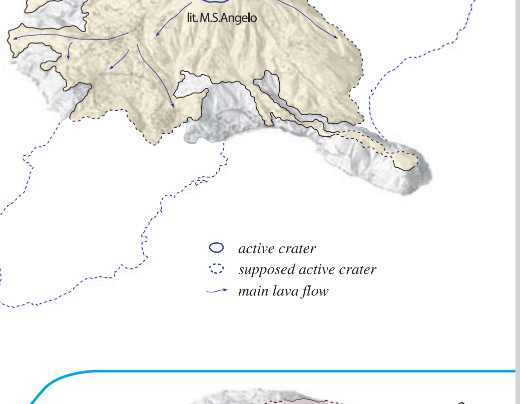
Age (ka)	Informal lithostratigraphic units		lithosomes	Unconformity Bounded Stratigraphic Units — Subsynthems	Synthems	Supersynthems
					VALLONE FIUME BIANCO	
					se+au+ch — L$_4$	
	Capo Rosso formation Three N-S-aligned, endogenous lava domes: they are strongly fumarolized but, at places, show well developed flow foliation structures. HKCA rhyolite in composition.	cr	Vallone Canneto dentro	VALLONACCIO	VALLE MURIA	PUNTA LE GROTTICELLE
	Colla formation **co$_2$ member -** Squat endogenous lava dome with well developed flow foliation. A small isolated lava dome, broadly N-S-aligned to the first one, is related to the same unit. HKCA rhyolites. **co$_1$ member -** Poorly bedded, normal graded, obsidian lithic-rich, pumiceous pyroclastic breccia. HKCA rhyolites.	co$_2$ / co$_1$	Vallone Canneto dentro	VALLONACCIO		
	Castello formation Small, N-S-aligned, endogenous lava domes with well developed flow foliation structures. HKCA rhyolites.	cas	Vallone Canneto dentro	VALLONACCIO		
				se+au+pa — l$_f$		
13.0 ± 0.2 (9) 16.8 ± 0.2 (5) 20.3 ± 0.7 (6) 20.5 ± 0.2 (6)	**Mauro formation** Pale reddish-brown, thickly bedded, massive ash tuffs ("*Upper Brown Tuffs*"; 6, 11) with similar lithological and petrochemical features of the Pianoconte formation. In the east Lipari, near V.^{ne} Canneto Dentro, a medium bedded, lithic-rich, pumiceous lapilli tuff layer, HKCA rhyolite in composition, is intercalated to the unit.	l2 / ma	Varesana	QUATTROCCHI		
				se+au — l$_e$		
	Punta di Costa formation Three endogenous lava domes, aligned in a NNW-SSE direction: they are rich in xenocrysts and locally show typical flow foliation structures. The dome of Punta S. Giuseppe shows a pit crater, where the small resurgent dome of Punta di Costa blowed up. HKCA rhyolite in composition.	pco	Punta S.Giuseppe	URNAZZO		
	M.Giardina formation Three endogenous lava domes (M.S.Lazzaro, M.Guardia, and M.Giardina) aligned in a NNW-SSE direction: they show well developed flow foliation (consisting of interbanded obsidian and lithic rhyolite layers) and rampart structures. The dome of M.Giardina is topped by a poorly sorted, massive tuff breccia (**gi$_1$ member**), formed of prevalent obsidian clasts and related to a crater in the sector of Fossa di M.Giardina. HKCA rhyolites.	gi$_1$ / gi	Monte Guardia	URNAZZO		
	M.Guardia formation Widespread pumiceous pyroclastics ("*Monte Guardia sequence*"; 3), consisting of massive tuff breccias in crater facies, northwards passing to distal facies made up of thinly/medium bedded lapilli tuff and tuffs, which first display a plane-parallel and then a cross-stratification with wave-length from metres to tens of centimetres. HKCA rhyolites.	gu	Monte Guardia	URNAZZO		
				se+au+pa — l$_d$		
22.5 ± 1.1 (6) 22.6 ± 0.3 (5) ~23 (10) 23.5 ± 0.9 (6)	**Pianoconte formation** "*Lesser Brown Tuffs*" (6, 11). A widespread, normal graded lapilli tuff layer (*lpt*), correlated to the "*Lower Pollara Tuffs*" (volcanic activity of Pollara, at Salina; about 23 ka; 10), is intercalated.	lpt / pi	Varesana	SCOGLIERA SOTTO IL MONTE		
	Falcone formation **fa$_2$ member -** Endogenous lava domes (up to 70-80 m thick) with well developed flow foliation. HKCA rhyolites, except a HKCA dacite lava body (very rich in xenocrists) at P. della Crapazza. **fa$_1$ member -** Widespread pumiceous pyroclastics (up to 15 m thick), consisting of massive pyroclastic breccias in proximal facies northwards passing to thinly bedded and cross-stratified tuffs (distal facies). HKCA rhyolites.	fa$_2$ / fa$_1$	Capparo			
37.0 ± 1.8 (11) 39.2 ± 2 (11) 40.5 ± 2.2 (11)	**Pianoconte formation** "*Lesser Brown Tuffs*" (6, 11).	pi	Varesana			
40.0 ± 2.5 (8) 41.0 ± 3.8 (8) 42.0 ± 0.3 (7)	**Punta del Perciato formation** **pe$_2$ member -** Pumiceous pyroclastics, consisting of thinly bedded, plane-parallel and cross-stratified lapilli tuffs and massive tuffs (distal areas) and of a massive pyroclastic breccia (proximal areas). HKCA rhyolites. **pe$_1$ member -** Two endogenous lava domes (up to 70 m thick), aligned in a NNW-SSE direction. HKCA rhyolites.	pe$_2$ / pe$_1$	P. di Levante			
55 (10)	**Pianoconte formation** "*Lesser Brown Tuffs*" (6, 11). A massive, 30 cm thick, tuff layer (*il*) correlate to the "*Ischia layer*" (55 ka; 10).	il / pi	Varesana			
67-70 (10)	**Chiesa dell'Annunciazione formation** Two widespread pyroclastic layers. The lower layer, up to 6 m thick decreasing from NW to SE, is a thickly to thinly bedded, scoriaceous/pumiceous lapilli tuff. The upper layer is a medium bedded, normal graded, well sorted scoriaceous/pumiceous lapilli tuff (1 m thick). CA basaltic andesites to andesites, they correlate to the "*Grey Porri Tuffs*", volcanic activity of M. dei Porri at Salina (age of 67-70 ka; 10).	ann	Valle di Pero			
	Pianoconte formation Massive, reddish-brown ash tuffs ("*Lesser Brown Tuffs*"; 6, 11), formed by glass fragments and locally rich in millimetric euhedral Cpx crystals; carbonized wood fragments are present in places. The deposits, CA basaltic andesites to andesites, are known as "*Brown Tuffs*" and are widespread in most of the Aeolian archipelago (11). Near V.^{ne} dei Lacci, W Lipari, a medium bedded, normal graded, 20 cm thick, pumiceous lapilli tuff layer (*l1*), CA andesite in composition, is probably related to volcanic activity of M. dei Porri at Salina.	pi / l1	Varesana			
						se+ch — U$_{II}$
81 (2, 13, 14)	**Punta della Galera formation** Coarse (dmax=1 m), poorly sorted conglomerate with rounded pebbles, occurring in two small outcrops at Monterosa, east Lipari. These conglomerates are correlated to the ones of the Punta delle Fontanelle formation (III order ancient shoreline) owing to the elevation of the underlying marine platform (2-3 m asl), even if field stratigraphical constraints allow to assess only a generic attribution to the *Tyrrhenian* stage (MIS 5, 124-81 ka; 2, 13).	pg	Punta Palmeto	PUNTA DELLE FONTANELLE	FONTANELLE	CALA FICO
	Punta delle Fontanelle formation Coarse, poorly sorted conglomerate (1.5-2 metres thick) with rounded pebbles, lying on a sharp erosional surface. The unit is related to the III order ancient shoreline (12 m asl; 2, 13) attributed to the Tyrrhenian eustatic highstand corresponding to MIS 5a (81 ka; 2, 13).	fo	Punta Palmeto	PUNTA DELLE FONTANELLE		
				me+hi — l$_c$		
	lo Inzolfato formation Three massive, thick (up to 50 m at Cala Sciabeca, for a total thickness of about 100 metres) lava flows with well developed carapaces (up to 20 m) and onion-skin type foliation; locally columnar joints occur. A squat (15 m thick) lava-dome (**inz$_1$ member**) near P. del Legno Nero is related to the same unit. HKCA andesites.	inz$_1$ / inz	M.Chirica -Costa d'Agosto	CALA SCIABECA		
92 ± 10 (7)	**Chiappe Lisce formation** **ch$_2$ member -** Two squat blocky lava flows with thin basal carapace. HKCA andesites. **ch$_1$ member -** Pyroclastics (up to 20 m thick) building the top of the M.S.Angelo cone. The crater facies is a non-coherent, poorly bedded pyroclastic breccia with bread-crust bombs; along the flanks of the cone, the unit passes to thinly bedded, plane-parallel and cross-stratified lapilli tuffs. At the foot of the SW flanks of M.S.Angelo, lensoid shaped, poorly bedded, tufaceous breccia deposits (up to 20 m thick) become prevalent (**ch$_3$ member**).	ch$_3$ / ch$_2$ / ch$_1$	Monte S.Angelo	CALA SCIABECA		
				se+hi — l$_b$		
100 (2, 13, 14)	**Punta del Cugno Lungo formation** Coarse, poorly sorted conglomerate with rounded pebbles (average thickness of 2 m, locally up to 15-20 m), lying on a sharp erosional surface. Well sorted and thinly stratified rounded sands (**cla member**) occur at Cala Sciabeca, forming a lensoid shaped body (up to 20 m thick). The unit is related to the II order ancient shoreline (23-27 m asl; 2, 13) attributed to the Tyrrhenian eustatic highstand corresponding to MIS 5c (100 ka; 2, 13).	cla / cl	Punta Palmeto	PUNTA DEL CUGNO LUNGO		
					me — L$_3$	
104.0 ± 3.5 (7) 105 ± 19 (12)	**Pulera formation** Widespread, thick (up to 20 metres), blocky lava flows with well developed carapaces: these lavas are characterized by the presence of millimetric cordierite and garnet xenocrysts "cordierite-bearing lavas". HKCA andesites to dacites.	pu	Monte S.Angelo	FOSSA DELLA VALLE	BRUCA	
	Serra Pirrera formation Reworked, "leaf-bearing pyroclastics" with the same lithological and petrochemical features of the T. Pataso formation. The primary deposits (up to 60 m thick) diffusely occur in the SW sector of M.S.Angelo, Along the W coast, near Cala Sciabeca, these pyroclastics are reworked to the marine sands of cl$_a$ member.	sp	Monte S.Angelo	FOSSA DELLA VALLE		
				se+ps — l$_a$		
	Timpone Pataso formation Reworked, "leaf-bearing pyroclastics" consisting of structureless amalgamated beds of grey lapilli tuffs: the leaves are aligned at the top of the beds. The primary deposits often outcrop as relics in the massive beds and consist of thinly bedded, cross-stratified lapilli tuffs with rare accretionary lapilli; well sorted scoriaceous lapilli tuff layers are intercalated. Near Marina di Porto Salvo, symmetrical ripple structures occur. HKCA andesites. S of T.Pataso, a lensoid shaped body (100 m thick) represents the filling of a "tectonic" lake (**tp$_a$ member**): it consists of leaf-bearing pyroclastic layers alternated to aphanitic chert layers.	tp$_a$ / tp	Monte S.Angelo	TIMPONE DEL GRADO		
					se+hi+au — L$_2$	
124 (2, 13, 14)	**Scoglio le Torricelle formation** Coarse, poorly sorted conglomerate with rounded pebbles, occurring between P. del Legno Nero and V.^{ne} dei Lacci with average thickness of 2 m (locally up to 20-25 metres) and lying on a sharp erosional surface. S of Bruca, the unit outcrops at 0-6 metres asl due to tectonic displacement. The unit is related to the I order ancient shoreline (43-45 m asl; 2, 13) attributed to the Tyrrhenian eustatic highstand corresponding to MIS 5e (124 ka; 2, 13).	st	Punta Palmeto		SCOGLIO LE TORRICELLE	
						me — U$_I$
127 ± 8 (7)	**Timpone del Corvo formation** Blocky lava flows (up to 15 metres thick): well developed sub-spherical flow foliation is visible in places. The lavas are strongly fumarolized in the sector of Fossa di Faurdo. HKCA andesites.	tc	Monte S.Angelo - Timpone del Corvo		PIANO GRANDE	
	Timpone Ricotta formation Thinly/medium, plane-parallel bedded pyroclastics (up to 40 m thick), consisting of an alternation of massive tu ffs and cross-stratified lapilli tuffs; the lower portion is rich in lava lithics. At T. Croci, scoriaceous layers, lava lithics and bomb sags (N120°E) are present. Near Marina di Porto Salvo, the unit consists of a lensoid shaped, well bedded tufaceous breccia, rich in lithics and with rip-up structures. CA basaltic andesites to andesites.	tr	Monte S.Angelo - Timpone del Corvo			
	Vallone di Bezzotti formation **vb$_2$ member -** Massive lavas (locally strongly fumarolized), CA basaltic andesite in composition. **vb$_1$ member -** Thinly to medium bedded pyroclastic succession (up to 40 m thick), consisting of a non-rhythmic alternation of normal graded tuff layers and cross-stratified or normal graded (sometimes reverse graded), loose black scoriaceous lapilli tuff layers. Fumarolized pyroclastic breccias occur in crater areas. CA basaltic andesites.	vb$_2$ / vb$_1$	Monte Chirica			
	Vallone Malopasso formation Rhythmic alternation of massive lava flows (average thickness of 2.5 m, up to 10 m) and well sorted, welded scoriaceous layers (average thickness of 3 m). The unit has a maximum thickness of 70-80 m. At P. del Legno Nero a welded scoriaceous pyroclastic breccia, building a spatter cone, occurs. CA basaltic andesite in composition.	vma	Monte Chirica			
					se+au+ch — L$_1$	
					PALEOLIPARI	

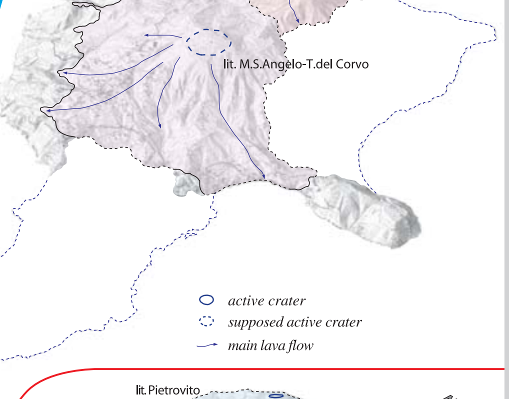
UNCONFORMITIES
au - angular unconformity
ch - change of eruptive style and/or location of centres
hi - hiatus
me - marine erosion
pa - paraconformity
ps - paleosoil
se - subaerial erosion

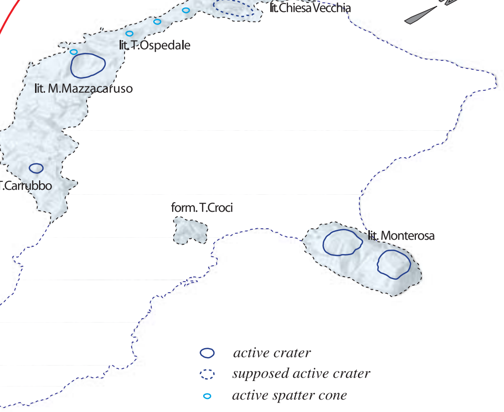
Volcano-stratigraphic schematic maps











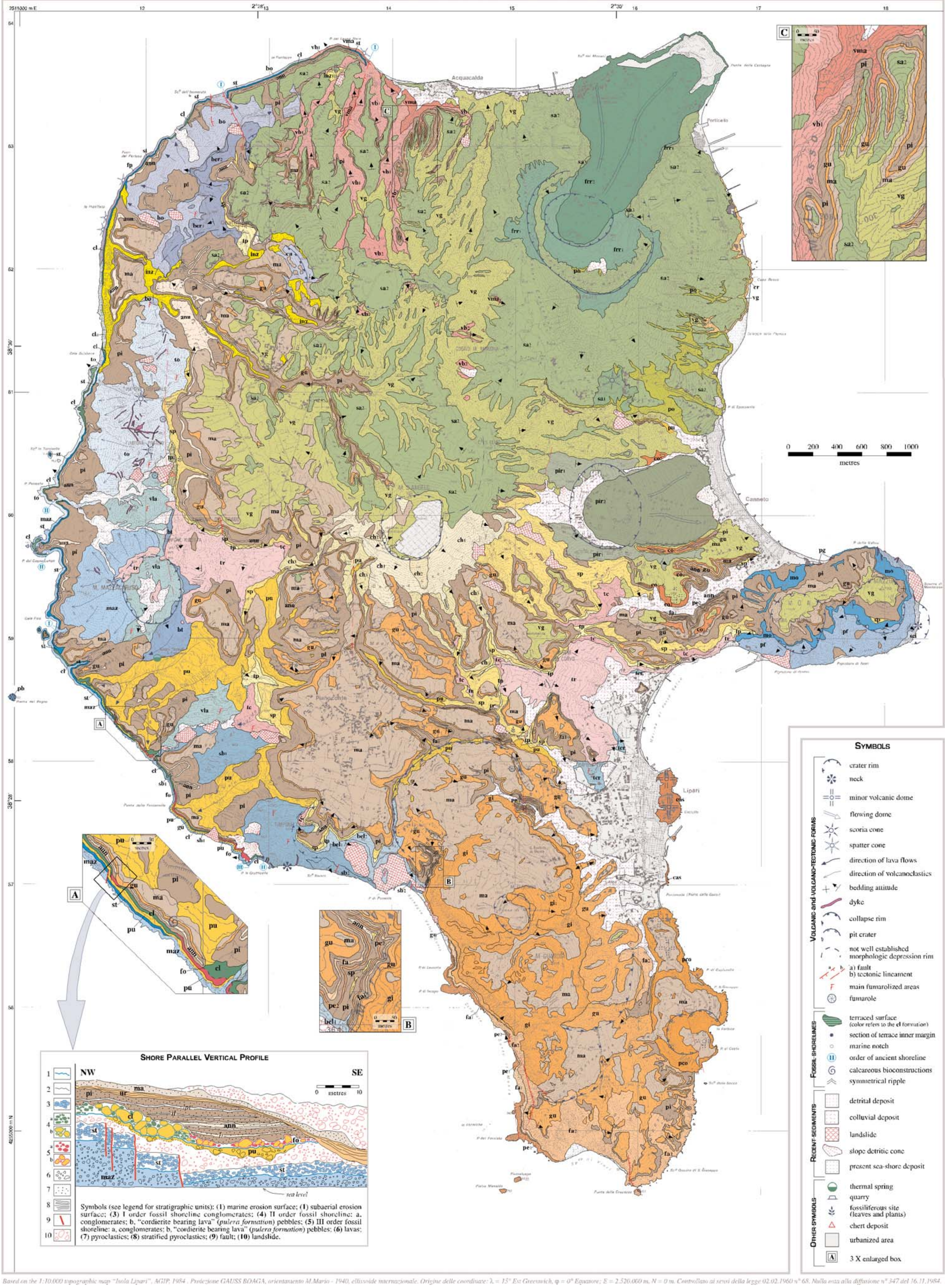


Fig. 1 - *Geological map of the island of Lipari, Aeolian Islands (from* TRANNE et alii, *2002a, modified).*

GEOLOGICAL SETTING

Lipari is the largest island of the Aeolian Archipelago (Fig. 2), a ring-shaped Quaternary volcanic structure consisting of seven main islands (Alicudi, Filicudi, Salina, Lipari, Vulcano, Panarea and Stromboli) and minor seamounts emplaced on thinned continental crust in the Southern Tyrrhenian Sea. With Salina and Vulcano, the island of Lipari is part of the central sector of the Aeolian Archipelago, where volcanism started around 0.4 Ma BP and is still active at Lipari (580 AD) and Vulcano (1888-90 AD). Fumaroles, hot springs and shallow seismicity characterise large submarine and on-land areas. A NNW-SSE-striking fault system (known as the "Tindari-Letojanni" system and comprising the northern tip of the larger-scale Malta escarpment fault system) affects the volcanoes of this central sector, which are aligned along a NNW-SSE-striking structural depression.

The island of Lipari is the emerged portion of a broad volcanic edifice rising about 2000 m above the sea floor. It is mainly made up of volcanic products ranging in age from pre-Tyrrhenian (about 223 ka BP) to late Roman times (580 AD). Its magmatism is strongly controlled by regional fault systems; the oldest and more primitive CA basalt-andesite volcanic products appear to be associated with N-S and E-W fracture systems and are characterised by strombolian falls and eruption of low viscosity lavas, whereas younger high-K andesitic and rhyolitic magmas produced stronger explosive activity and eruption of viscous lava flows or domes, primarily along the NNW-SSE tectonic alignment.

CARTOGRAPHY IN VOLCANIC AREAS

Cartography in volcanic areas must be based on an objective stratigraphic approach and on the same stratigraphic, morphologic and structural criteria which are used in classical geological cartography (Pasquarè *et alii*, 1992). This approach has only recently been applied to Italian volcanic areas (Pasquarè *et alii*, 1992; Lanzafame *et alii*, 1994; Manetti *et alii*, 1995; Calanchi *et alii*, 1999; Tranne *et alii*, 2002a, b; Lucchi *et alii*, 2003), while more often lithological and chemical-petrographical criteria had been prevalently used. At times, volcanological criteria have been adopted for volcanic areas cartography in order to use "eruption and volcanic activity units" sensu Fischer & Schmincke (1984) as mapping units; nevertheless, these units require a high degree of interpretation, and are better used in detailed volcanological papers rather than in map-making, where more descriptive units should be preferred (Tab. 1). The application of a stratigraphic approach to a volcanic area should conform to current stratigraphic rules, in particular as regards the choice of the stratigraphic units to be used in geological survey and in map-making (AA.VV., 1983; Pasquarè *et alii*, 1992). In this sense, cartography in volcanic areas must involve the use of stratigraphic units of different type and hierarchy; UBSU (supersynthems, synthems, and subsynthems), lithosomes and lithostratigraphic units (formations and members). Peculiar stratigraphic units are sometimes proposed for use in volcanic areas only, testifying to the innate propensity of volcanologists to overvalue the specificity of volcanic settings. For example, De Rita *et alii* (2000) suggested the use of "eruptive units" (thus altering the meaning already given by Fischer and Schminke, 1984) as a particular kind of UBSU to be employed exclusively for volcanic products. We believe that the proliferation of peculiar stratigraphic units should be avoided and that sharing standard stratigraphic units can favour a better correlation between different environments. What is more, a careful and flexible use of standard stratigraphic units can fully reproduce the unquestionable peculiarity of volcanic products, which are characterised by a greater diversity of rock types than any other surface environment and are conditioned by specific origin (often with a punctiform source, e.g. a crater), by emplacement dynamics and, in particular, by the very marked episodic nature of eruptive events.

Unconformity Bounded Stratigraphic Units: Supersynth.	Synthems	Subsynthems		Lithosomes
Punta le Grotticelle	Vallone Fiume Bianco	Chirica Rasa	18	**Monte Pilato lithosome** Pumice cone which develops in two different successive phases of volcanic activity. During the first one, which is shown by the products of *Sciarra dell'Arena formation*, widespread pumiceous pyroclastics build a cone (at least 150 m high, diameter of about 1 km). These pyroclastics are interweaven and coeval to the ones of the Forgia Vecchia lithosome. During the second phase of activity, witnessed by the *Fossa delle Rocche Rosse formation*, pyroclastics made up of obsidianaceous clasts build a freatic crater (*frr1 member*) and a large flowing dome (*frr2 member*) overflows the north-eastern rim of the former pumice cone.
			17	**Forgia Vecchia lithosome** Small phreatomagmatic cone (pumiceous pyroclastics, *pir1 member*) and lobate flowing dome (*pir2 member*) wich owerflows (towards east) by the crater located in the sector of Forgia Vecchia. The unit is sovraimposed on the eastern flank of Monte S. Angelo lithosome.
		Colle S.Elmo	16	**Vallone del Gabellotto lithosome** Tuff cone (at least 100 m high) formed by pumiceous pyroclastics (*Vallone del Gabellotto formation*) located in the sector of Vallone del Gabellotto, where it is highly eroded and widely covered by recentmost volcanics. A large, lobate flowing dome (*Pomiciazzo formation*) overflow the eroded, eastern rim of the cone.
	Valle Muria	Vallonaccio	15	**Vallone Canneto dentro lithosome** Four scattered N-S-aligned small lava domes (diameter max about 200 m) outcropping along the eastern coast of Lipari. From S to N, they occur in the sector of Castello (*Castello formation*), at V.ne Canneto dentro (*Colla formation*), and nearby Sp. della Papesca (*Capo Rosso formation*). Only the effusion of the *Colla formation* dome is preceded by an explosive phase testified by pumiceous pyroclastics (*co1 member*).
		Quattrocchi		**Varesana lithosome** "*Upper Brown Tuffs*".
		Urnazzo	14	**Punta San Giuseppe lithosome** Three NNW-SSE-aligned lava domes related to the third phase of domic effusion in the southern sector of Lipari.
			13	**Monte Guardia lithosome** Three NNW-SSE-aligned lava domes of M.Giardina, M.Guardia and M.S.Lazzaro (*M.Giardina formation*) related to third phase of domic effusion in the southern sector of Lipari. On the top of the M.Giardina dome, a freatic crater occur (*gi1 member*). The effusive phase is preceded by a strong explosive one with the emplacement of very widespread pumiceous pyroclastics (*M.Guardia formation*) which building a large tuff ring widely eroded in the western sector.
		Scogliera sotto il Monte		**Varesana lithosome**
			12	**Capparo lithosome** Large lava dome (*fa2 member*) occurring nearby Falcone and related to second phase of domic effusion in the southern sector of Lipari. The effusive phase is preceded by a strong explosive one (pumiceous pyroclastics of *pe2 member*) which determines the building of the a tuff ring actually eroded and covered by recentmost deposit.
				Varesana lithosome
			11	**Punta di Levante lithosome** Two NNW-SSE-aligned lava domes (*pe1 member*) related to a first phase of domic effusion in the western-southern sector of Lipari . A final explosive hydromagmatic phase determines the emplacement of pumiceous pyroclastics (*pe2 member*) and the whole destruction of the southernmost dome.
				Varesana lithosome
				Valle di Pero lithosome Widespreasd pyroclastic layers of exotic provenance which are correlated on petrochemical basys to the "*Grey Porri Tuffs*" of Salina.
				Varesana lithosome Tabular hydromagmatic pyroclastics of exotic provenance known as "*Lesser Brown Tuffs*" and widespread in most of the Aeolian Archipelago.
Cala Fico	Fontanelle	Punta delle Fontanelle		**Punta Palmeto lithosome** Marine deposits and forms (*Punta delle Fontanelle* and *Punta della Galera formations*) of the III order ancient shoreline attributed to the eustatic highstand corresponding to MIS 5a.
		Cala Sciabeca	10	**Monte Chirica-Costa d'Agosto lithosome** Massive lava flows (*Lo Inzolfato formation*) which overflow the western crater rim of the M.Chirica stratocone and are related to its final effusive activity.
				Monte S.Angelo lithosome
		Punta del Cugno Lungo		**Punta Palmeto lithosome** Marine deposits and forms (*Punta del Cugno lungo formation*) of the II order ancient shoreline attributed to the eustatic highstand of MIS 5c.
	Bruca	Fossa della Valle / Timpone del Grado	9	**Monte S.Angelo lithosome** Stratocone (about 500 m high, diameter of 2 km) costituted by pyroclastics and lavas. It develops in a time span of at least 10 ka with successive eruptive phases spaced out by significant hiatus. The basal portion is made up of hydromagmatic pyroclastics known as "leaves bearing pyroclastics" (*Timpone del Grado* and *Fossa della Valle formation*) and of massive lavas known as "cordierite-bearing lavas" (*Pulera formation*). The top portion of the crater consists of hydromagmatic pyroclastics and squat lavas (*Chiappe Lisce formation*).
	Scoglio le Torricelle			**Punta Palmeto lithosome** Marine deposits and forms (*Scoglio le Torricelle formation*) of the I order ancient shoreline attributed to the eustatic highstand corresponding to MIS 5e.
	Piano Grande		8	**Monte S.Angelo-Timpone del Corvo lithosome** Large tuff cone (diameter of about 2 km) widely buried by recentmost deposits. It's formed by hydromagmatic pyroclastics (*Timpone Ricotta formation*) and by massive lavas (*Timpone del Corvo formation*) overflowing the crater rim.
			7	**Monte Chirica lithosome** Stratocone (600 m high, diameter of 1,5 km, average slope gradient of 25°) costituted, in the basal portion, by an alternation of lavas and scorias (*V.ne Malopasso formation*) related to strombolian activity. The top portion consists of hydromagmatic pyroclastics related to a "lateral blast" explosive phase and of massive lavas related to the final effusive activity (*V.ne di Bezzotti formation*).
	Paleolipari		6	**Chiesa Vecchia lithosome** Asymmetric tuff cone (about 70 m high) upwards evolving to a spatter cone made up of scorias and clastogenic lavas. The volcanic edifice, which is testified by the products of *Bertaccia formation*, occurs in the sector of Chiesa Vecchia.
			5	**Timpone Carrubbo lithosome** Lava cone occurring in the sector of T.Carrubbo, made up of massive and blocky lavas, minor scorias and by hydromagmatic pyroclastics building the flank of a buried tuff cone (*Scoglio Bianco formation*): the lavic neck occurs in the coastal cliff south of P. delle Grotticelle. At the top, scorias and lavas related to strombolian and effusive activity of a crater located nearby T.Carrubbo occur (*Belvedere formation*).
			4	**Monterosa lithosome** Scorias, lavas and subordinate hydromagmatic pyroclastics building a poligenic volcanic centre which occupies the cape of Monterosa. Its main portion consists of the two twin scoria cones of Pietra Campana and U Mazzuni, which developed during two successive eruptive phases of strombolian and effusive activity (*Pignataro di Fuori* and *U Mazzuni formations*). At the base, in the sector of Sciarra di Monterosa, the remnants of a highly eroded tuff ring evolving to a scoria cone occur (*Sciarra di Monterosa formation*).
				Monte Mazzacaruso lithosome
			3	**Timpone Ospedale lithosome** N-S-aligned spatter cones of T.Pataso, T.Ospedale and Valle di Pero are costitued by autoclastic and massive lavas . These products, and the interweaven and coeval volcanics of the M.Mazzacaruso lithosome spatter cone, are all related to the same fissural eruptive activity.
			2	**Monte Mazzacaruso lithosome** Poligenic volcanic centre in the sector of M.Mazzacaruso. It includes hydromagmatic pyroclastics building a basal tuff ring (*V.ne dei Lacci formation*), autoclastic and massive lavas building a spatter cone (*M.Mazzacaruso formation*), and, at the top, lavas and scorias related to final strombolian and effusive eruptive activity (*Bagni termali di S.Calogero formation*).
			1	**Pietrovito lithosome** The unit includes the remnants of a volcanic centre in the area of Pietrovito, which was affected by a volcano-tectonic collapse event. The original volcanic structure is testified by the occurrence of the inner portion of the flank of a tuff cone nearby Costa d'Agosto (*Costa d'Agosto formation*). Widespread massive and blocky lava flows (*Bonanno formation*) are related to the effusive phase of this cone.
				Fuori del Pertuso lithosome Three N-S-aligned spatter cones in the coastal sector of Fuori del Pertuso formed by scorias and lavas (*Fuori del Pertuso formation*): they are related to the same hawaiian-strombolian fissural eruptive activity.
				Pietra del Bagno lithosome Neck of a completely submerged volcanic centre represented by brecciated lavas (*Pietra del Bagno formation*), whom occurrence is outlined by morphologic submerged features.

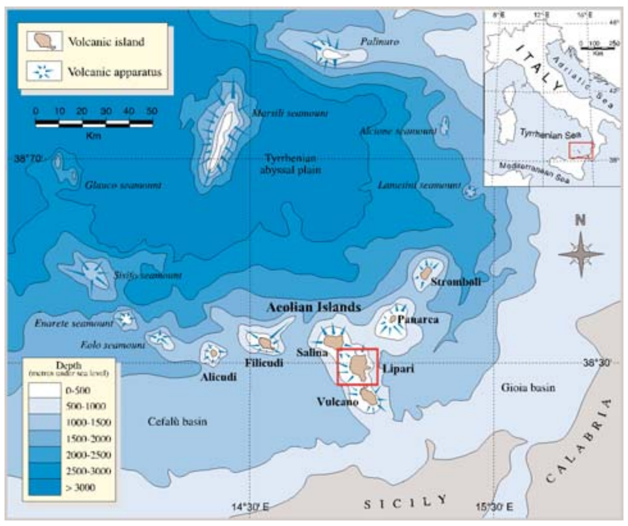


Fig. 2 - *Bathymetry of the Southern Tyrrhenian Sea and location of the Aeolian Archipelago.*

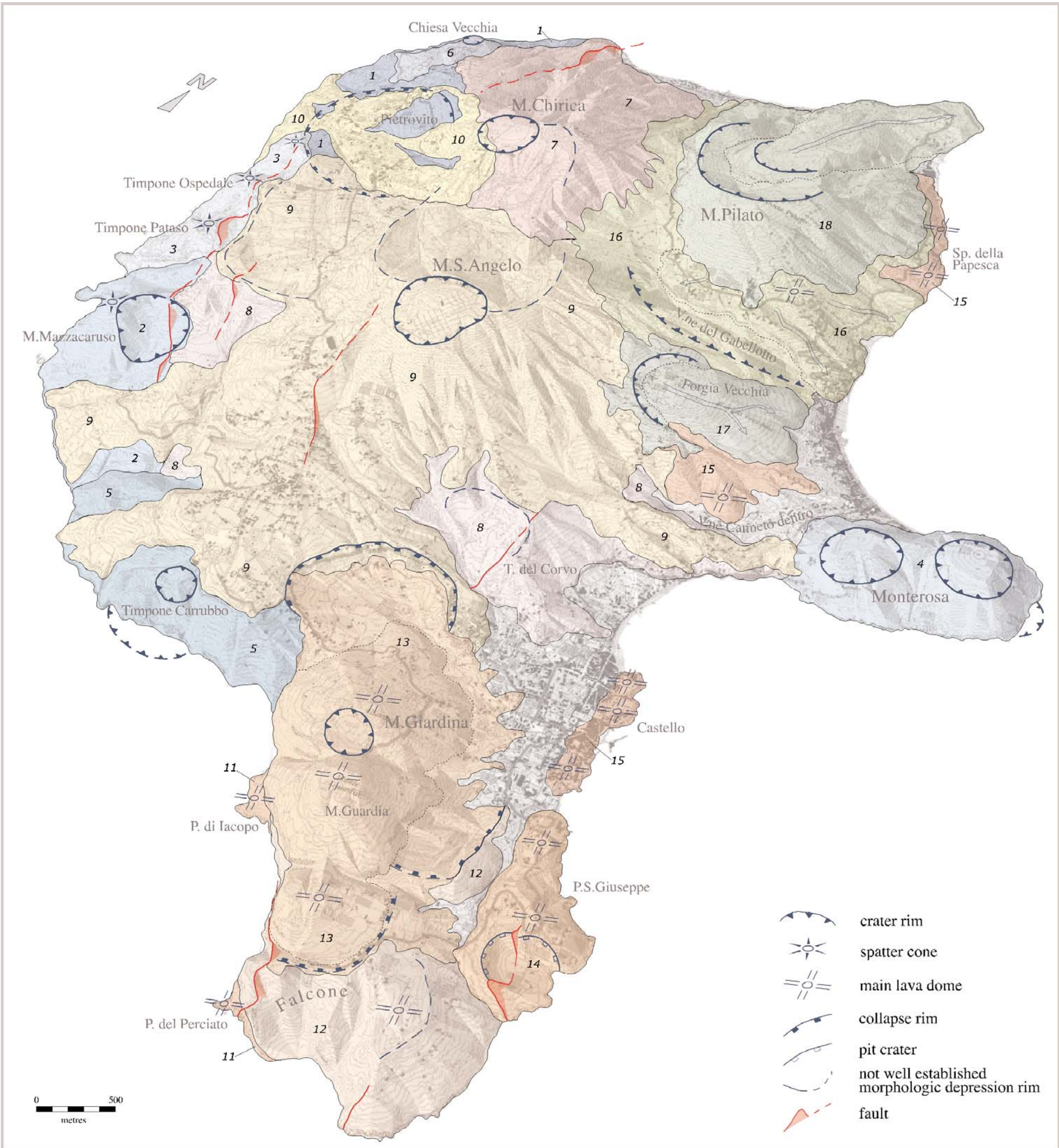


Fig. 3 - *Sketch map of the lithosomes of the island of Lipari (3D morphological map courtesy of "Piano dei Beni Culturali Eoliani - V. Cabianca, M. Carta"). In the picture, the distribution of the main lithosomes is shown.*

THE GEOLOGICAL MAP OF LIPARI

At Lipari, a purely stratigraphic approach was adopted with the aim of producing a geological map based on current shared stratigraphic, morphological and structural criteria (PASQUARÈ *et alii*, 1992). The stratigraphic units which were fundamental tools during field work and map-making were UBSU, lithosomes and lithostratigraphic units used in parallel (Fig. 1).

The choice of units to be mapped should take into account the geological nature of volcanic products, which usually show evident and clear lithological features.

Therefore, the lithostratigraphic criterion was adopted in order to reproduce the great diversity

Tab. 1 - *Summarizing scheme of the units which may be used in the geological study of a volcanic areas.* UBSU, *lithosomes and lithostratigraphic units should be used in the map-making whereas eruption and volcanic activity units (*sensu FISCHER & SCHMINKE*, 1984) should be used in volcanological works.*

UNITS TO BE USED IN GEOLOGICAL MAP-MAKING		
UNCONFORMITY BOUNDED STRATIGRAPHIC UNITS	LITHOSOMES	LITHOSTRATIGRAPHIC UNITS
SUPERSYNTHEMS **SYNTHEMS** SUBSYNTHEMS	LITHOSOMES	GROUPS **FORMATIONS** MEMBERS

UNITS UTILIZED FOR DETAILED VOLCANIC ANALYSES	
VOLCANIC ACTIVITY UNITS	ERUPTION UNITS
sensu Fisher and Schminke, 1984	
ERUPTIVE PERIODS **ERUPTIONS** ERUPTIVE PHASES ERUPTIVE PULSES	PYROCLASTIC FALLOUT UNIT PYROCLASTIC FLOW UNIT LAVA FLOW UNIT LAHAR UNIT etc...

of rock types which occur on the island of Lipari. These include primary volcanic deposits, e.g. lavas and pyroclastics, autoclastic volcanics and epiclastic deposits. Particular attention has been devoted to the characterization of epiclastic deposits which are often ignored in the map-making of volcanic areas. In the case of Lipari, marine deposits (conglomerates, sands and fossils) occur interlayered with volcanics; they have been lithologically characterised according to suggestions for sedimentary rocks and have been considered for all intents and purposes as stratigraphic elements.

Only those geological bodies having lithostratigraphic significance have been represented in the geological map (Fig. 1). The lithostratigraphic units introduced (formations and members) are listed in the legend according to the reconstructed stratigraphy (Fig. 1) and have been described in their main lithological and petrochemical features (objective or paraobjective units). The concept of facies has been, used in the case of pyroclastic deposits, to describe the lithological and sedimentological changes induced by distance from the source area (crater, proximal and distal facies). When the stratigraphic position of the formations is not clear, often owing to bad outcropping conditions, the range of stratigraphic variability is graphically represented in a special column using vectors. If available from literature, the age of the formations is highlighted in the last column right of the legend (all references are properly reported).

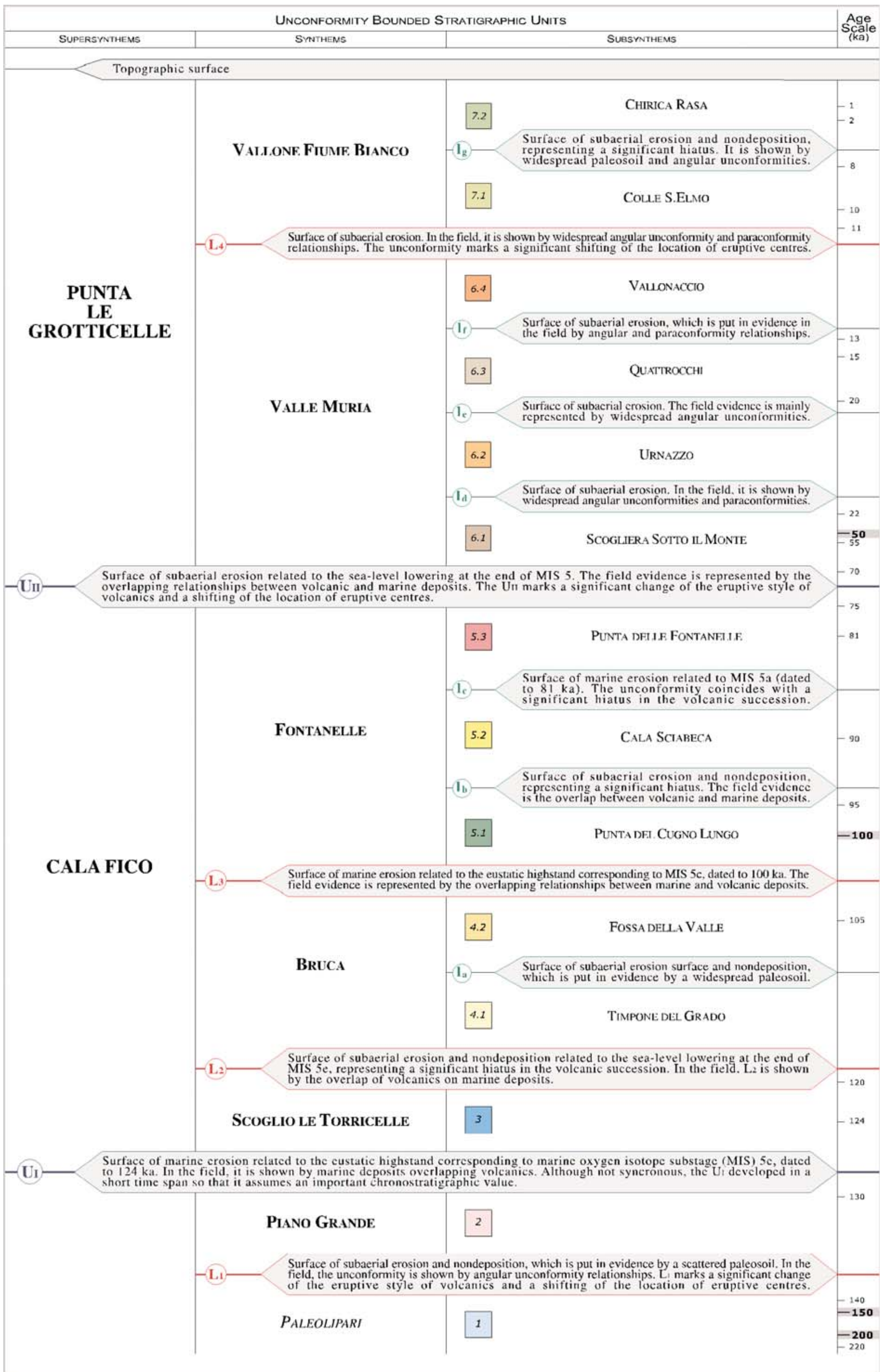
The detail of cartographic representation obviously depends on the scale of the map. In this work, we draw a geological map at a scale of about 1:25,000 (Fig. 1), including enlarged boxes at a higher scale (3x enlarged) showing particular sectors of the island where somelithostratigraphic units or significant stratigraphic relationships a require better representation. A reconstructed shore-parallel, vertical profile has been drawn for a limited sector of the western coast to highlight certain particularly significant stratigraphic relationships which cannot be easily represented on the map.

The lithosomes in the central column of the legend are based on morphological criteria and show the geometry of geological bodies strongly related to specific genetic processes. The morphological factor is particularly important in volcanic areas, where it considerably contributes to the definition of mappable units, to the attribution of volcanics to eruptive centres and to the reconstruction of the geological evolution of volcanic products. In the case of Lipari, the morphology of both volcanics and marine deposits has been evaluated. As regards marine deposits, the lithosomes consist of terraced bodies related to marine sedimentation/erosion processes.

The evaluation of elevation above the present sea-level, and of main morphological parameters, has allowed the attribution of marine deposits to successive sea-level highstands corresponding to marine oxygen isotopes 5a, 5c and 5e.

This attribution shows that a careful morphological study can help clarify the relative chronology between different morphogenetic events, thus integrating stratigraphic data (Pasquarè *et alii*, 1992). As regards volcanic deposits, lithosomes almost always coincide with volcanic edifices. Lithosomes are dimensionless units and can either identify large polygenic volcanic edificies, such as stratovolcanoes, or single monogenic eruptive centres, such as tuff rings, tuff cones, spatter cones, lava domes etc; a lithosome can even correspond to a single lava flow whose evident morphology can be indicative of genesis from a specific source (Fig. 3). Lithosomes should not depend on hierarchical ties, and in their definition attention must simply be paid to avoiding their excessive proliferation, which would reduce their meaning. As regards exotic tephras, lithosomes correspond to tabular bodies with geometrical features which indicate a provenance from eruptive centres not located on the island of Lipari; in these cases, the relationship with the source area is established only on the basis of textural and petrochemical features. For example, the Valle di Pero lithosome consists of pyroclastics whose morphology indicates an undefined exotic source, which has been identified in the Monte dei Porri eruptive centre at Salina purely on the basis of indisputable petrochemical features.

Lithosomes are used in parallel with lithostratigraphic units (Fig. 1). A lithosome often includes two or more lithostratigraphic units representing different lithological bodies having an homogeneous morphology (e.g. the M. Chirica lithosome includes the V.ne Malopasso and V.ne Bezzotti formations). Nevertheless, a lithosome may easily correspond to a single lithostratigraphic unit (Fig. 1). While lithostratigraphic units are mainly significant in the vertical subdivision of a stratigraphic succession, lithosomes can emphasize the vertical-lateral relationships of a geological body with a specific morphology which may be mutually intertongued with one or more bodies of different lithic constitution (Wheeler & Mallory, 1953). In this sense, lithosomes are particularly useful towards discriminating complex stratigraphic successions of interlayered deposits coming from different sources. A jigsaw graphic representation is used in the legend to show the geometrical relationships between different lithosomes, such as in the case of the Varesana one, which is intertongued



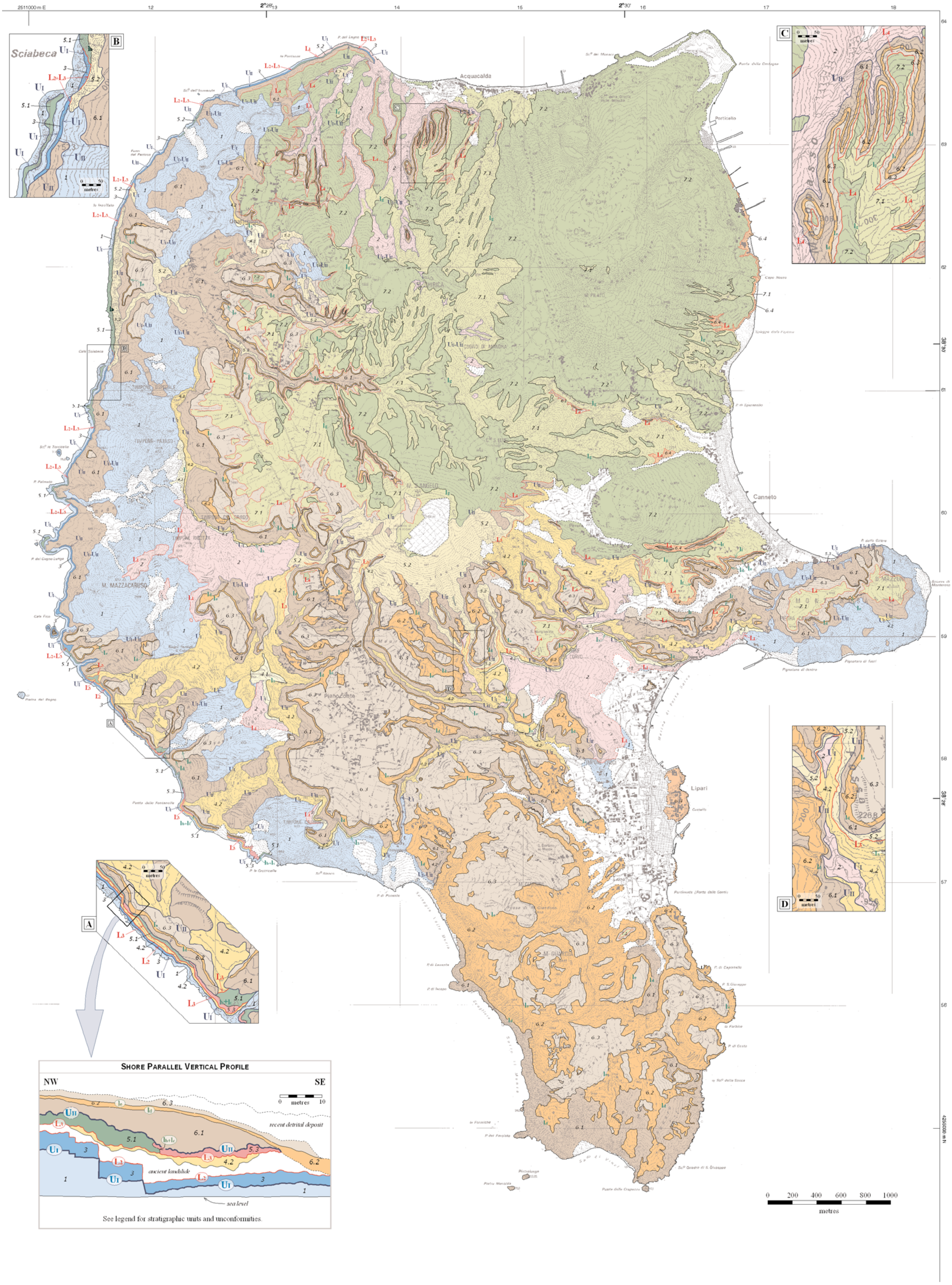


Fig. 4 - *Synthemic map of the island of Lipari, Aeolian Islands, showing the distribution of the main unconformities on the island of Lipari and of the relative UBSU stratigraphic units. In the enclosed legend, the nature and field evidence for the detected unconformities are described.*

with other lithosomes (Figs. 1 and 8).
In actual fact, the legend attached to the geological map (Fig. 1) is not just included for descriptive purposes, as it also enables the relationships between the different stratigraphic units adopted to be highlighted and, in this sense, it provides an articulate but well-constructed, synoptic table of the different criteria (lithostratigraphic, morphological and purely stratigraphic) used to characterize the volcanic succession of Lipari. The integrated use of UBSU, lithosomes and lithostratigraphic units fully accomplishes the tasks of describing, documenting and interpreting different rock types (using lithostratigraphic units) and defining the geometry of volcanic bodies (using lithosomes), or of highlighting the stratigraphic relationships between volcanic bodies and their bounding unconformities (with UBSU).

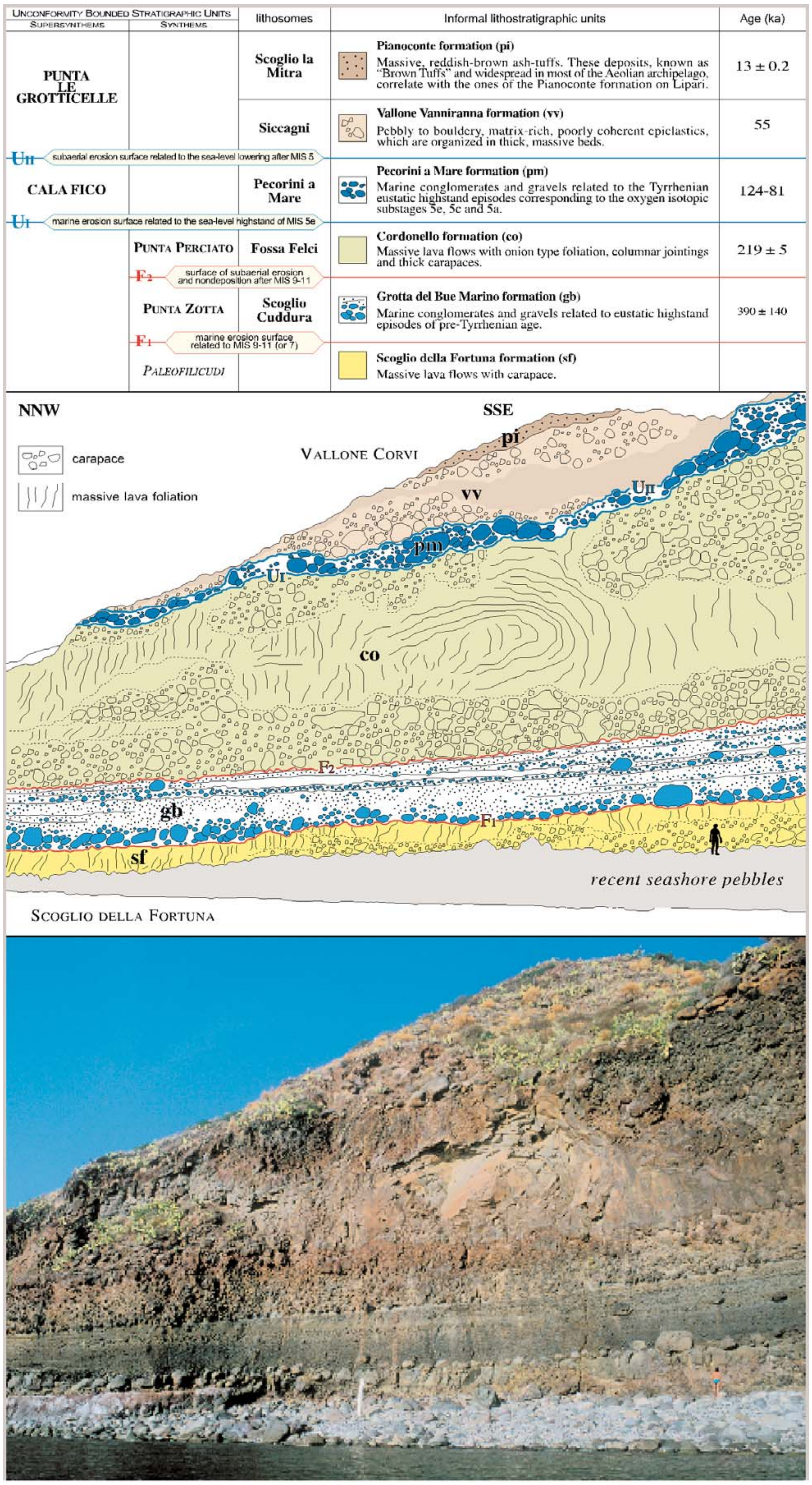


Fig. 5 - *Shore-parallel, vertical profile along the north-western coast of Filicudi, at Scoglio della Fortuna. In this sector, a natural stratigraphic section displaying the main unconformities of the stratigraphy of Filicudi is exposed. In particular, marine conglomerates of Tyrrhenian age (MIS 5) and of generically pre-Tyrrhenian age (>MIS 5) occur. The occurrence of Tyrrhenian marine deposits has allowed the correlation of the first-order unconformities UI and UII, which have been already defined on the island of Lipari, whereas the pre-Tyrrhenian deposits have allowed the definition of two other significant unconformities (F1 and F2) in the stratigraphy of Filicudi.*

The use of UBSU units should be given priority in volcanic areas (Pasquarè *et alii*, 1992), because volcanic successions are particularly rich of unconformities as a consequence of the strongly episodic nature of eruptive events. UBSU units are shown on the left-hand side of the legend and define the general stratigraphic framework in which the descriptive lithosomatic and lithostratigraphic units are included (Fig. 1). UBSU units are useful tools towards defining correlations at a local and regional level. Moreover, they allow the main intervals of volcanic activity (characterised by a homogeneous eruptive style, or similar location of volcanic centres) to be defined. In the last column on the left-hand side of the legend, volcano-stratigraphic schematic maps are drawn to highlight these intervals and, in particular, the location of active eruptive centres; these pictures are not necessarily connected to specific stratigraphic units, but are useful to show the main building periods of the island of Lipari.
UBSU stratigraphy should be represented in a special thematic map (Fig. 4), to be attached to the geological map, in which particular emphasis should be given to the distribution and characterization of main unconformities (and related UBSU units) in the geological evolution of the island of Lipari. This fulfils the need to show the association of volcanic products on the basis of their source or of the corresponding eruptive periods; to this requirement should be given precedence over a mere lithostratigraphic descriptive distinction (Pasquarè *et alii*, 1992). After all, the synthemic map already provides an effective synthesis of the geological evolution of Lipari, which is typically characterised by several relatively short stages of volcanic activity spaced out by longer quiescent stages, resulting in the formation of main unconformities in its volcanic succession.
These unconformities are described in a special legend according to whether they are the result of subacqueous or subaerial erosion (erosional vacuity), nondeposition (hiatus), or a combination of these two processes.
The unconformities (documented by angular unconformities or paraconformities relationships, etc.) have different areal and temporal significance and have been related to "internal" processes of modification of the volcanic edifice (connected to volcanic activity, tectonic events or to reworking processes in subaerial environment) but also to regional (or "global") events such as fluctuations in sea-level.
The utmost care has been taken in identifying, documenting and understanding the real stratigraphic significance of unconformities, thus defining the hierarchy of the UBSU units introduced (Supersynthems, Synthems and Subsynthems). In particular, the areal extendibility of unconformities has been considered to be the most significant criterion to be taken into account. In this sense, two first-order unconformities (UI and UII) were defined on Lipari and then correlated at a regional scale on the islands

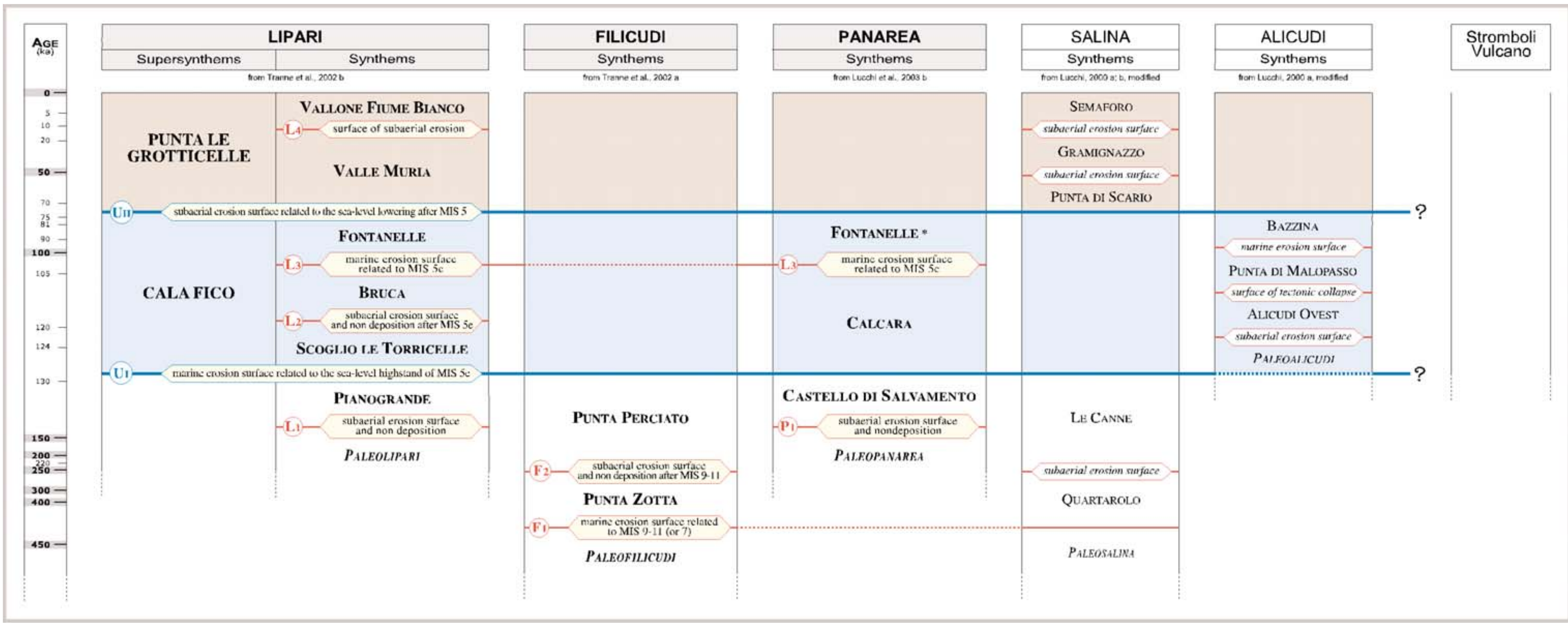


Fig. 6 - *Scheme of* UBSU *stratigraphic correlations in the Aeolian Islands. The correlation of main unconformities and* UBSU *units has been already defined for the islands of Lipari (*TRANNE *et alii, 2002a), Filicudi (*TRANNE *et alii, 2002b) and Panarea (*LUCCHI *et alii, 2003), and is proposed for the island of Salina and Alicudi (*LUCCHI*, 2000a, b), where stratigraphic field work is still in progress Stromboli and Vulcano data are not available.*

of Filicudi (Fig. 5), Panarea, Salina and Alicudi, taking into account stratigraphic relationships between volcanic products and marine deposits of Tyrrhenian age (CALANCHI *et alii*, 2002). UI is the marine erosive surface related to the sea-level highstand corresponding to marine-oxygen isotopic substage 5e (124 ka), whereas UII consists of the subaerial erosive surface related to the sea-level lowering at the end of marine isotope stage 5 (age < 81 ka). The UI and UII unconformities, which developed over a short time span, have a relevant chronostratigraphic significance, as well as regional significance, and have enabled the introduction of two major UBSU stratigraphic units, called the Cala Fico and Punta le Grotticelle Supersynthems (Figs. 1 and 4). These units have been correlated to the islands of Panarea, Filicudi and Salina and should provide stratigraphic constraints for the whole Aeolian Archipelago (Fig. 6).

Four second-order unconformities (L1, L2, L3 and L4) have been introduced and, together with UI and UII, enable six synthems and the informal Palaeolipari unit (comprising volcanic products whose bottom unconformity is not visibile; Fig. 1) to be defined.

These second-order unconformities should have stratigraphic significance for the whole island of Lipari; they are the result of marine or subaerial erosion processes, or of nondeposition stages, and are documented by stratigraphic relationships between marine and volcanic deposits or between different volcanics. Finally, seven third-order unconformities (l1--l7) have been introduced, allowing eleven subsynthems to be defined.

These third-order unconformities represent minor hiata and/or erosive stages having

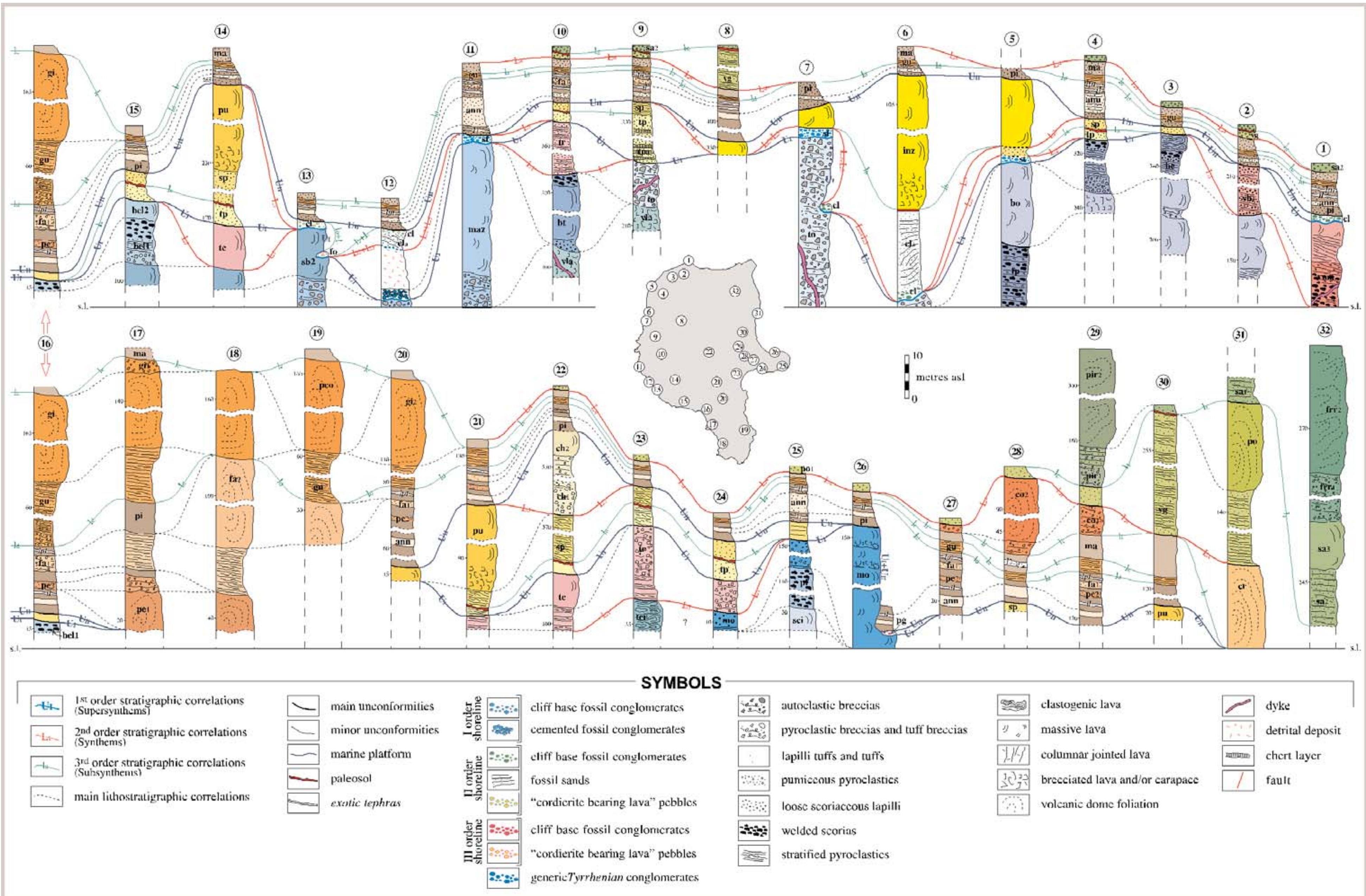


Fig. 7 - *Summary scheme of correlation of composite schematic stratigraphic sections of the island of Lipari. The sections are applied to the entire island for the purpose of representing every stratigraphic unit defined in the geological map; in particular, the UBSU correlations and main lithostratigraphic correlations are shown.*

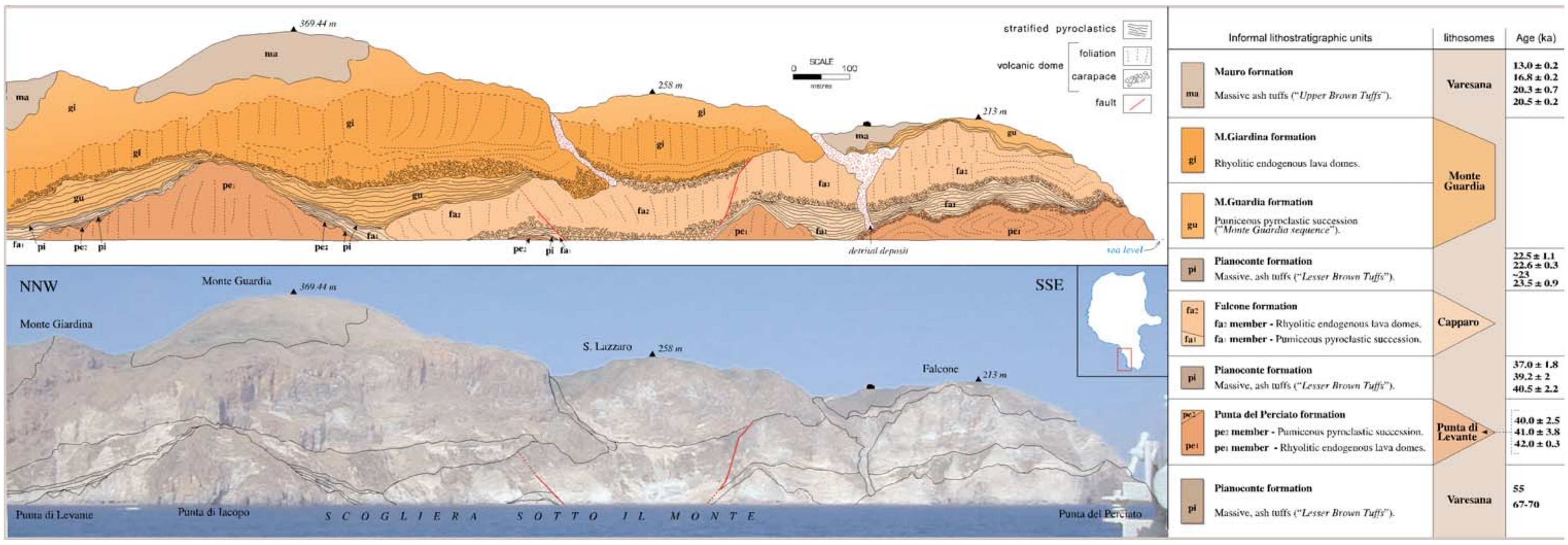


Fig. 8 - *Shore-parallel, vertical profile along the southern coast of Lipari, in the sector between Spiaggia Valle Muria and Punta del Perciato. Here the coastal cliff shows a natural stratigraphic section of volcanics related to the Valle Muria Synthem. In particular, the interlayering between volcanic products of local and exotic provenance and the intertonguing between different lithosomes is clearly visible.*

stratigraphic significance for limited sectors of the island.

TABLE OF CORRELATIONS

Geological cross-sections of sectors of the study area are generally attached to geological maps. We believe the use of these sections in volcanic areas not to be very effective, owing to the unquestionable peculiarity of volcanic products, whose behaviour is highly conditioned by rheologic characters, by distance from the source and by physical and morphological features of the emplacement environment. All these elements determine an extreme variability, even in limited areas, in the horizontal and vertical distribution of volcanic products (PASQUARÈ *et alii*, 1992). Consequently, too high a degree of interpretation would be required in drawing up stratigraphic relationships in non-outcropping portions of these sections, and an excess of subjectivity introduced in this kind of representation. Conversely, we suggest highlighting the stratigraphic relationships in the studied area using a scheme of correlation of composite schematic stratigraphic sections (Fig. 7), applied to the entire island in order to represent the lithostratigraphic units defined in the geological map and the relationships with all recognized unconformities. A summary correlative scheme, such as the one shown, enables to represent actual field stratigraphic relationships with greater objectivity.

SHORE-PARALLEL VERTICAL PROFILES

Drawing reconstructed, shore-parallel, vertical profiles in limited and significant sectors of a study area can prove an effective tool towards showing the stratigraphic relationships between geological bodies, in particular when these relationships cannot be easily represented on the map. Moreover, these reconstructed profiles show how the parallel use of UBSU and lithosomatic and lithostratigraphic units can provide a clear and effective stratigraphic framework which can better illustrate an actual, significant stratigraphic setting. This approach is described for the southern sector of Lipari (Fig. 8), where the reconstruction of a "natural geological section" shows the main stratigraphic relationships between the geological bodies in a stratigraphic succession consisting of exotic tephras known as "Brown Tuffs" (Varesana lithosome) and interlayered pyroclastics and lavas related to the Punta di Levante, Copparo and Monte Guardia lithosome.

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