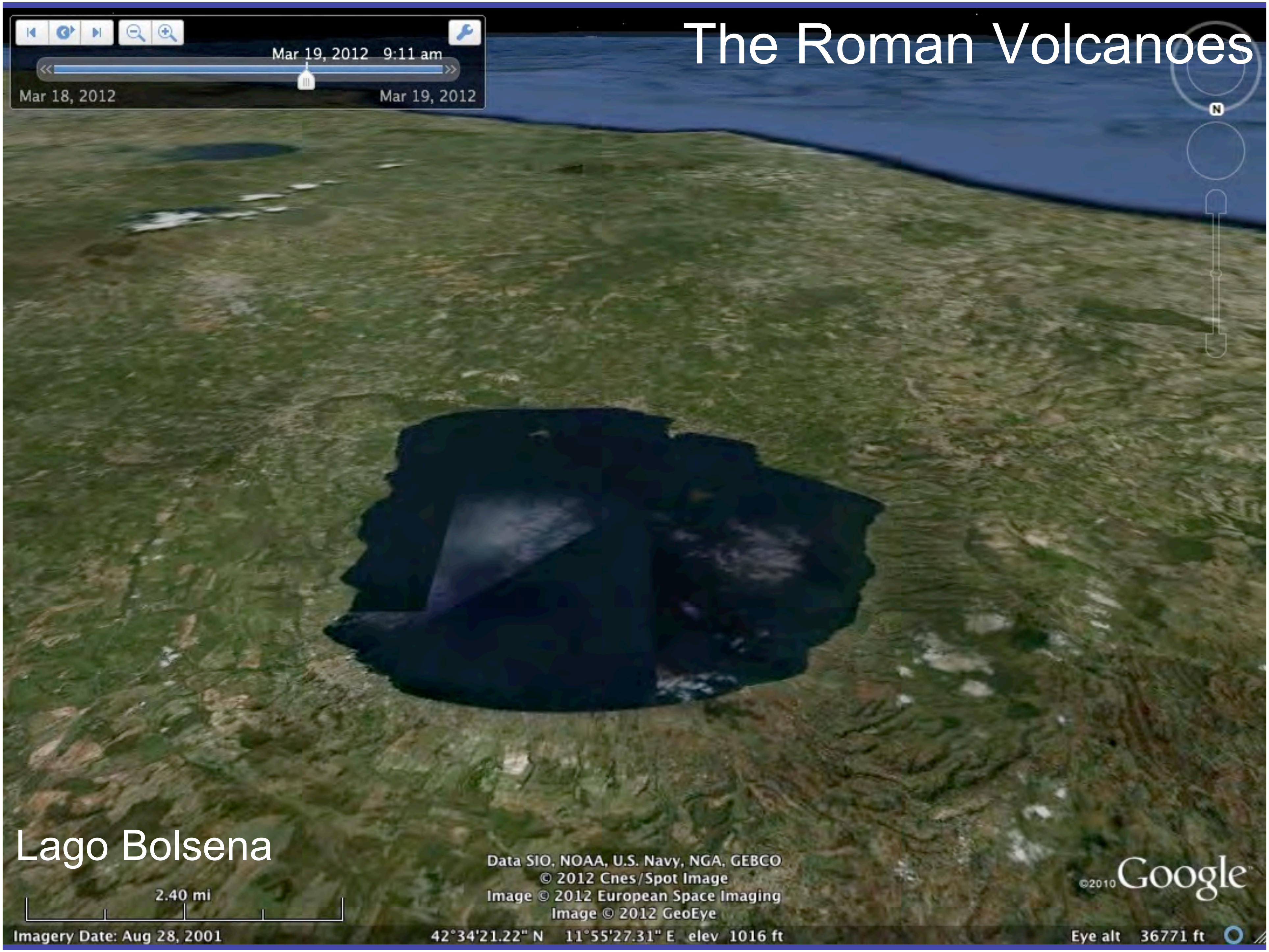
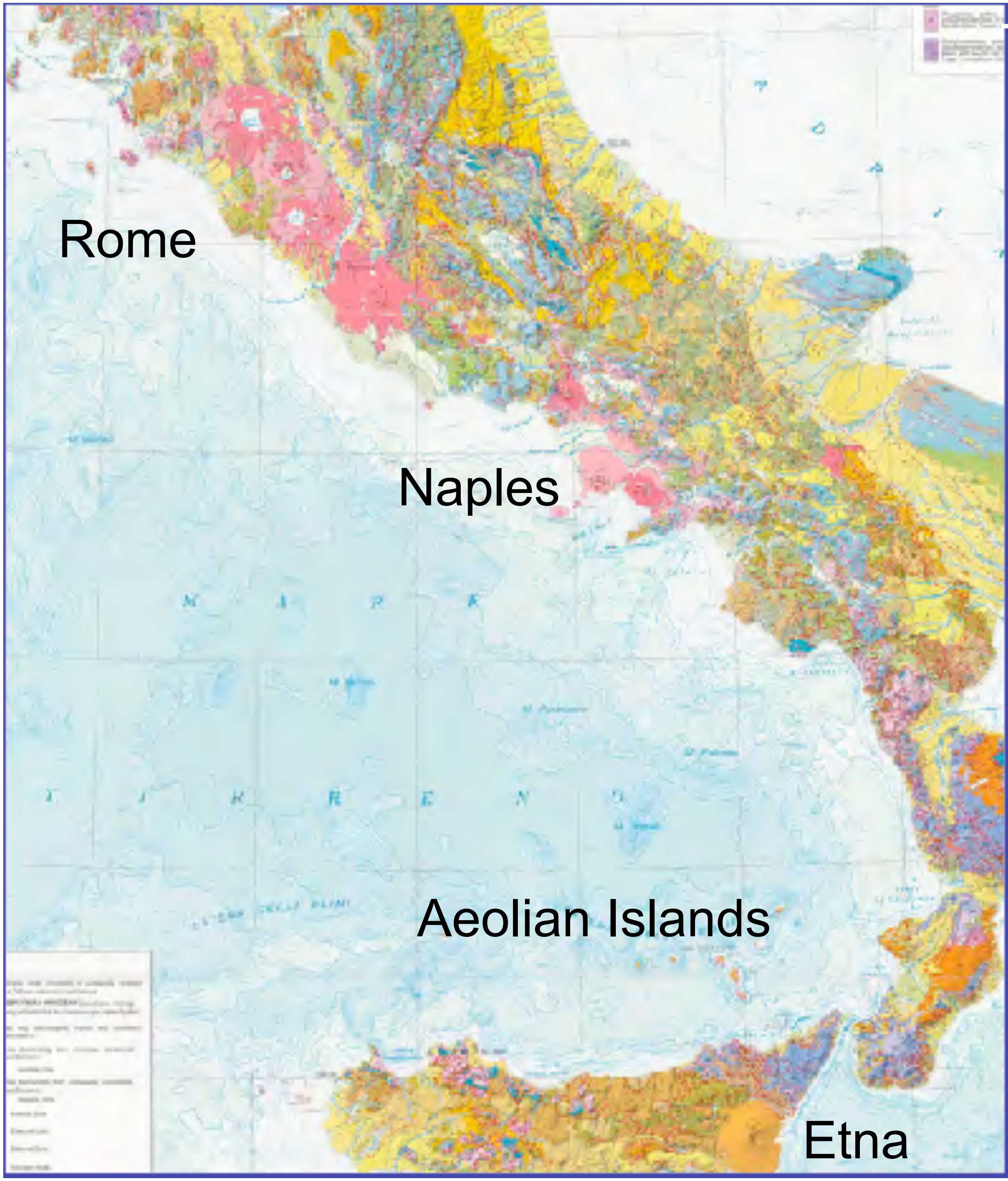
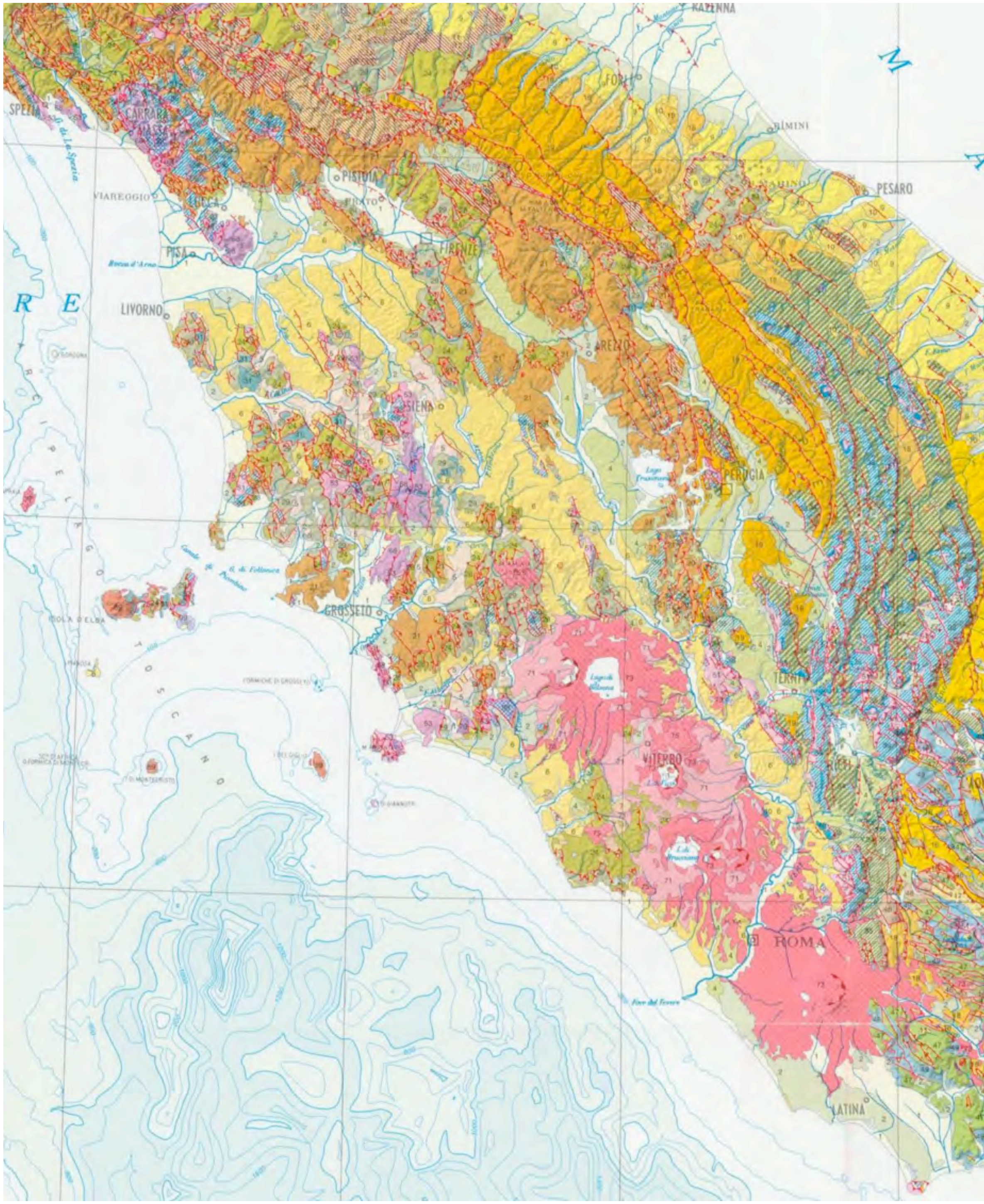
The Roman Volcanoes




APAT
Agenzia per la Protezione dell'Ambiente e per i Servizi Tecnici
Dipartimento Difesa del Suolo
Servizio Geologico d'Italia
GEOLOGICAL MAP OF ITALY
1:1 250 000 Scale
MAIN TECTONO-STRATIGRAPHIC UNITS

Three Volcanic Regions





Alpine Orogeny- and Tyrrhenian Basin opening-related Volcanism

Rhyolites, rhyodacites, trachytes and latites: lavas and pyroclastic rocks (71)
Andesites, latiandesites and alkaline basalts: lavas and pyroclastic rocks (72)
Tephrites, phonolitic K-tephrites, K-phonolites, foidites, melilitites and carbonatites: lavas, hyaloclastic and pyroclastic rocks (73)
Pleistocene-Holocene

Alkaline basalts with tholeiitic affinity: lavas
Pleistocene

Rhyolites, rhyodacites, pantellerites with subordinate quartz latites and trachytes: pyroclastic rocks and lavas (75)
Alkaline basalts; trachybasalts and andesites; lavas (76)
Pliocene-Pleistocene

Trachyandesites and basalts: lavas, pyroclastic and hyaloclastic rocks; locally interbedded carbonate sediments)
Upper Miocene

Rhyolites and calcalkaline rhyodacites: pyroclastic rocks (78)
Andesites and calcalkaline-to-shoshonitic basalts: lavas and pyroclastic rocks (79)
Upper Oligocene-Middle Miocene

Symbols

Dashed where inferred or buried

Edge of caldera

Undifferentiated tectonic contact

Normal fault

Strike-slip fault

Thrust and reverse fault

Rome, Calderas

http://eol.jsc.nasa.gov/

ISS005E11363

Anzio and Caldera, Rome to the left

http://eol.jsc.nasa.gov/

Caldera, Rome, Tiber, Airport

http://eol.jsc.nasa.gov/

ISS015E06963

Central Rome

http://eol.jsc.nasa.gov/

Rome, Tiber River, Villa Borghese

http://eol.jsc.nasa.gov/


Rome, underlain by volcanic ash flows

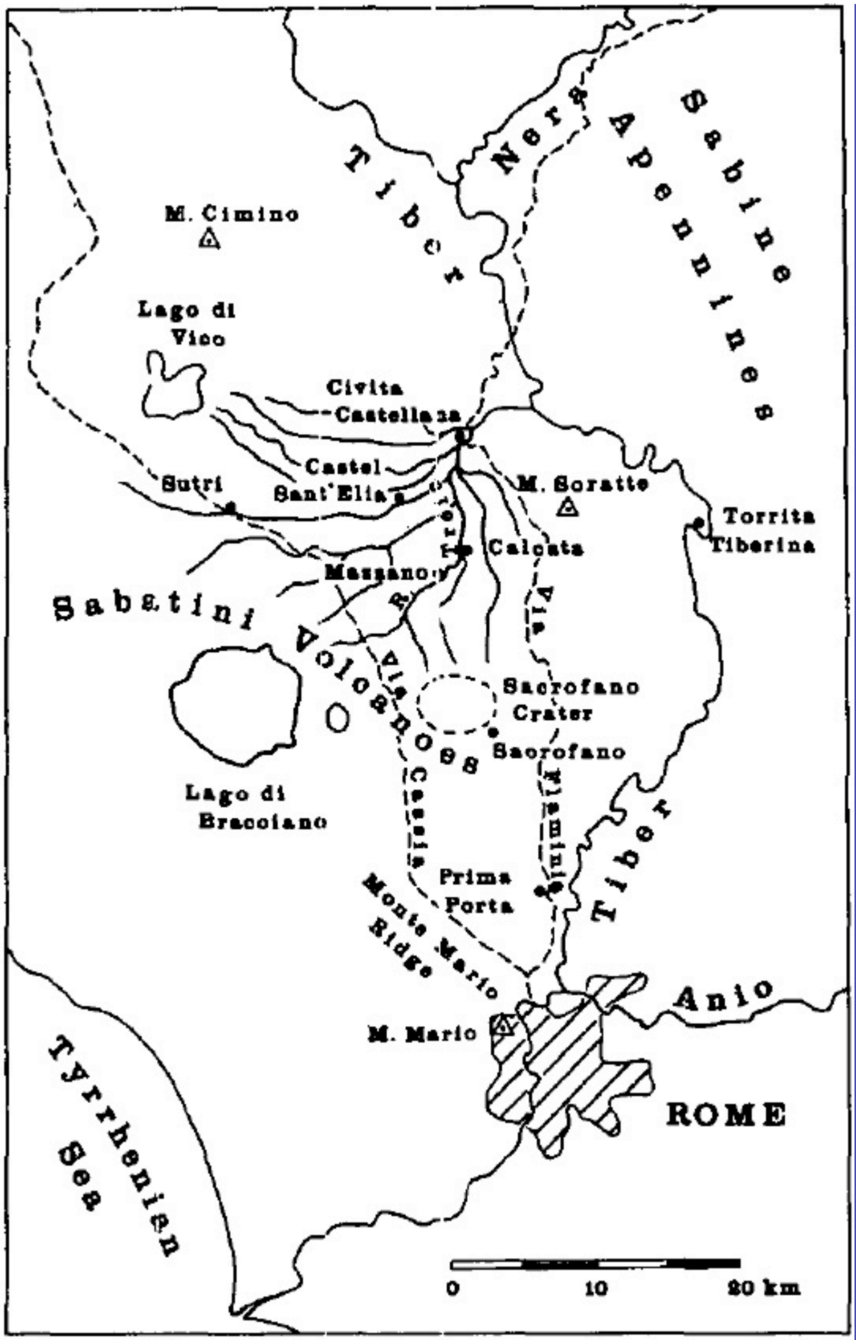


Figure 1. Location map. Rome and the Sabatini volcanic area.

Alvarez 1973

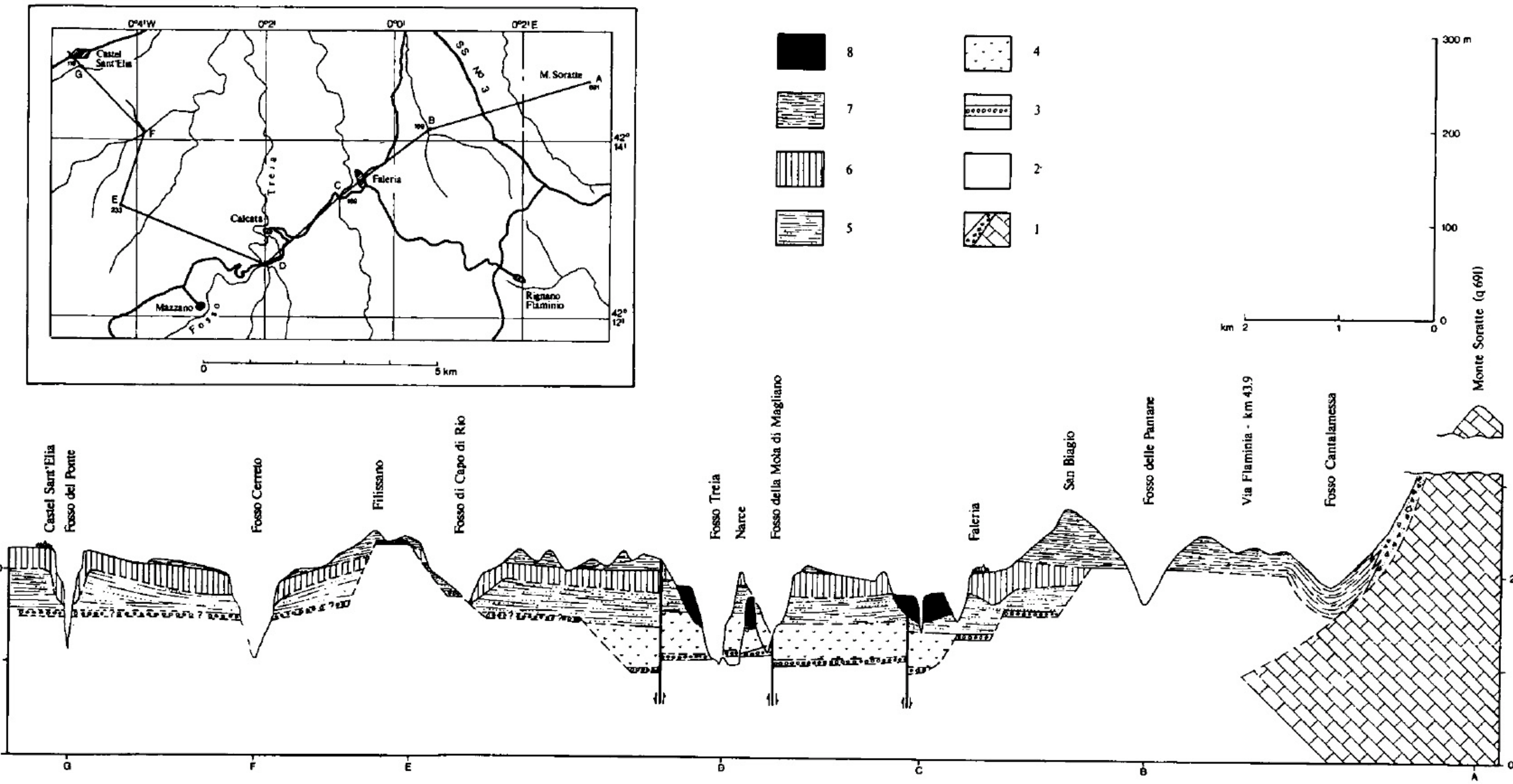


Figure 2. Cross section from Castel Sant'Elia to Monte Soratte, showing the "Paleotiber" valley. 1. Mesozoic limestones and slope debris. 2. Pliocene sediments. 3. Paleotiber gravel and silt. 4. Tufo Giallo della Via Tiberina (yellow ash-flow tuff). 5. Tufi Stratificati Varicolori di Sacrofano (stratified air-fall tuffs). 6. Tufo Rosso a Scorie Nere (red ash-flow tuff with black scoriae). 7. Tufi Stratificati Varicolori de' La Storta (stratified air-fall tuffs). 8. Tufo Giallo di Sacrofano (yellow ash-flow tuff). Nomenclature from Mattias and Ventriglia (1970).

Alvarez 1973

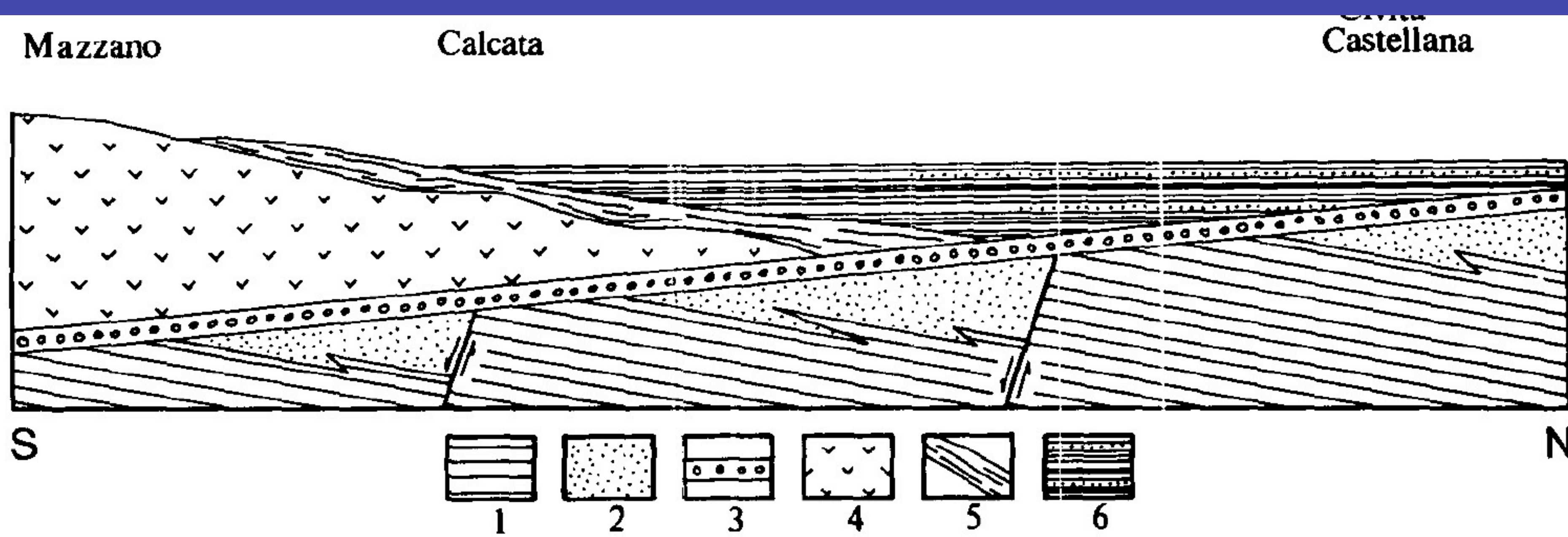


Figure 3. North-south stratigraphic relations between Mazzano and Civita Castellana after damming of the Paleotiber. 1. Pliocene clays. 2. Pliocene sands. 3. Paleotiber gravel and silt. 4. Tufo Giallo della Via Tiberina. 5. Mud-flow deposits. 6. Lake beds.

Alvarez 1973

Alvarez 1973

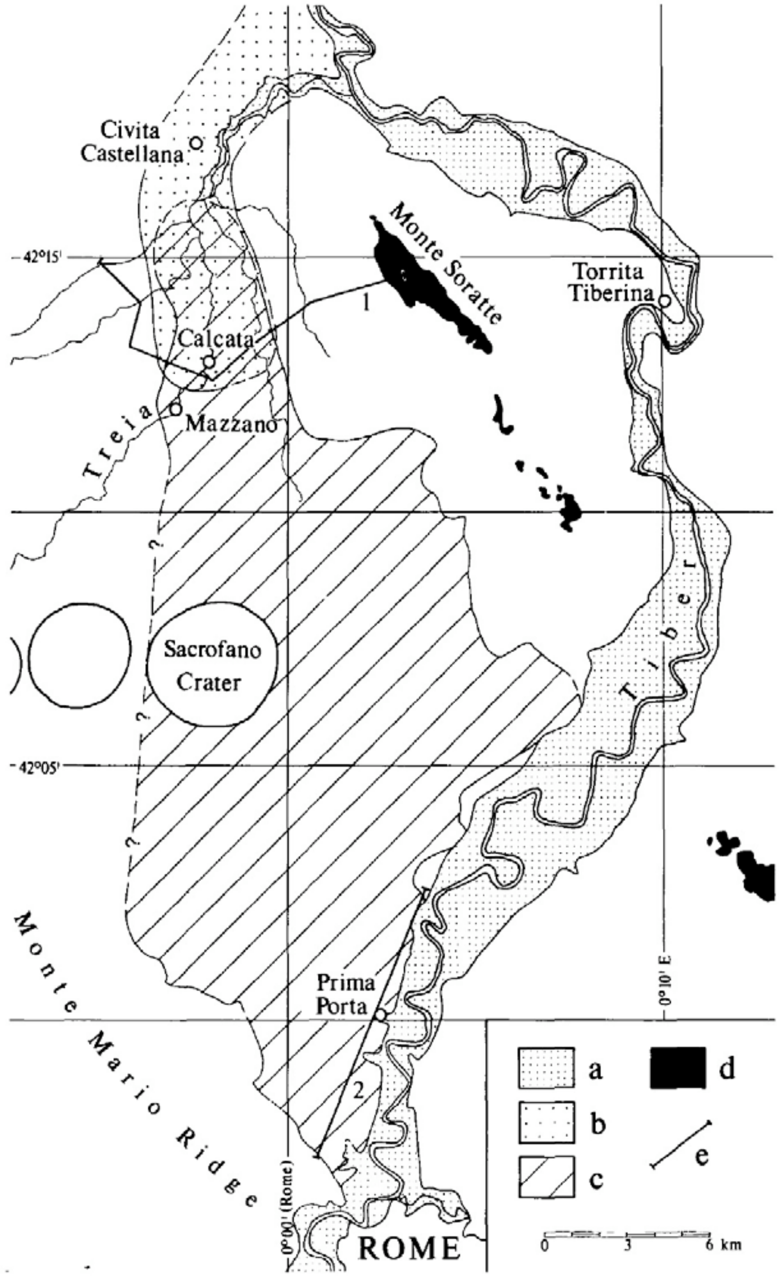
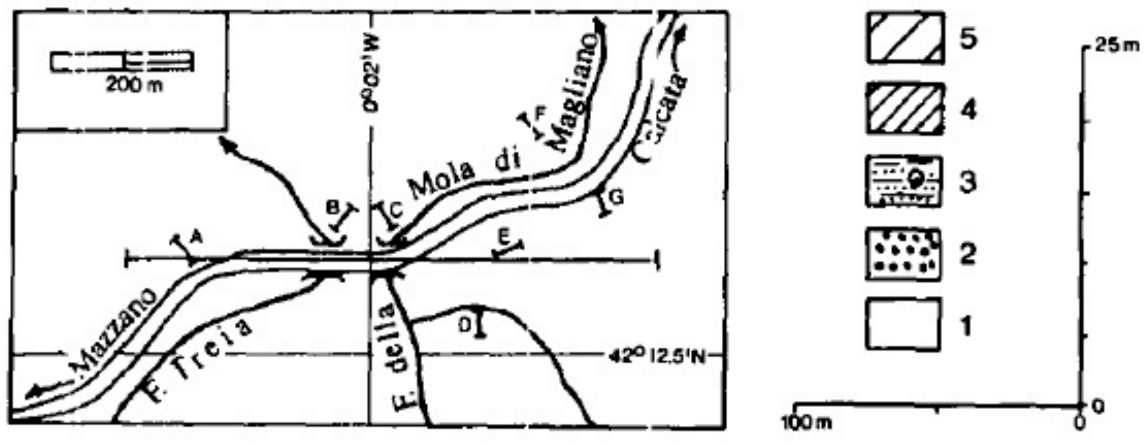
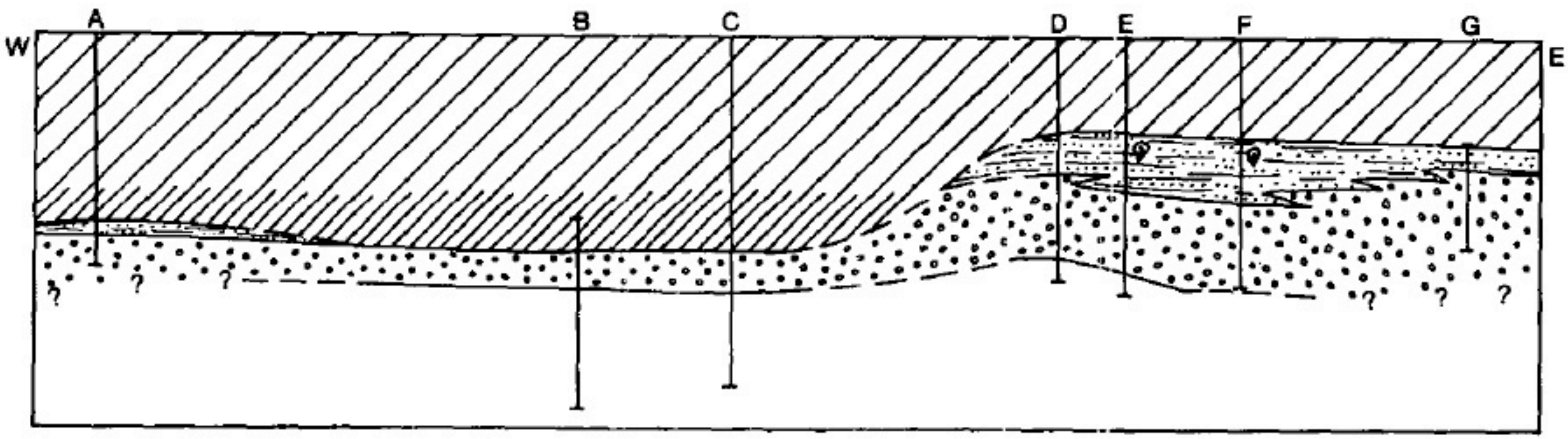


Figure 4. The ancient and modern Tiber valleys between Civita Castellana and Rome. a. Floodplain of the modern Tiber. b. Extent of lake beds deposited after damming of the Paleotiber. c. Extent of the Tufo Giallo della Via Tiberina. d. Mesozoic limestones. e. Cross sections. (1) This paper, Figure 2. (2) Bonadonna (1968, Fig. 10), width of the buried valley near Prima Porta (one portion of a longer cross section).

Figure 5. The bed of the Paleotiber, reconstructed from outcrops along the Mazzano-Calcata road. 1. Pliocene sediments. 2. Channel gravel of the Paleotiber. 3. Paleotiber flood-plain silt with terrestrial gastropods. 4. Tufo Giallo della Via Tiberina, basal water-laid facies. 5. Tufo Giallo della Via Tibernia, normal facies.





Alvarez 1973

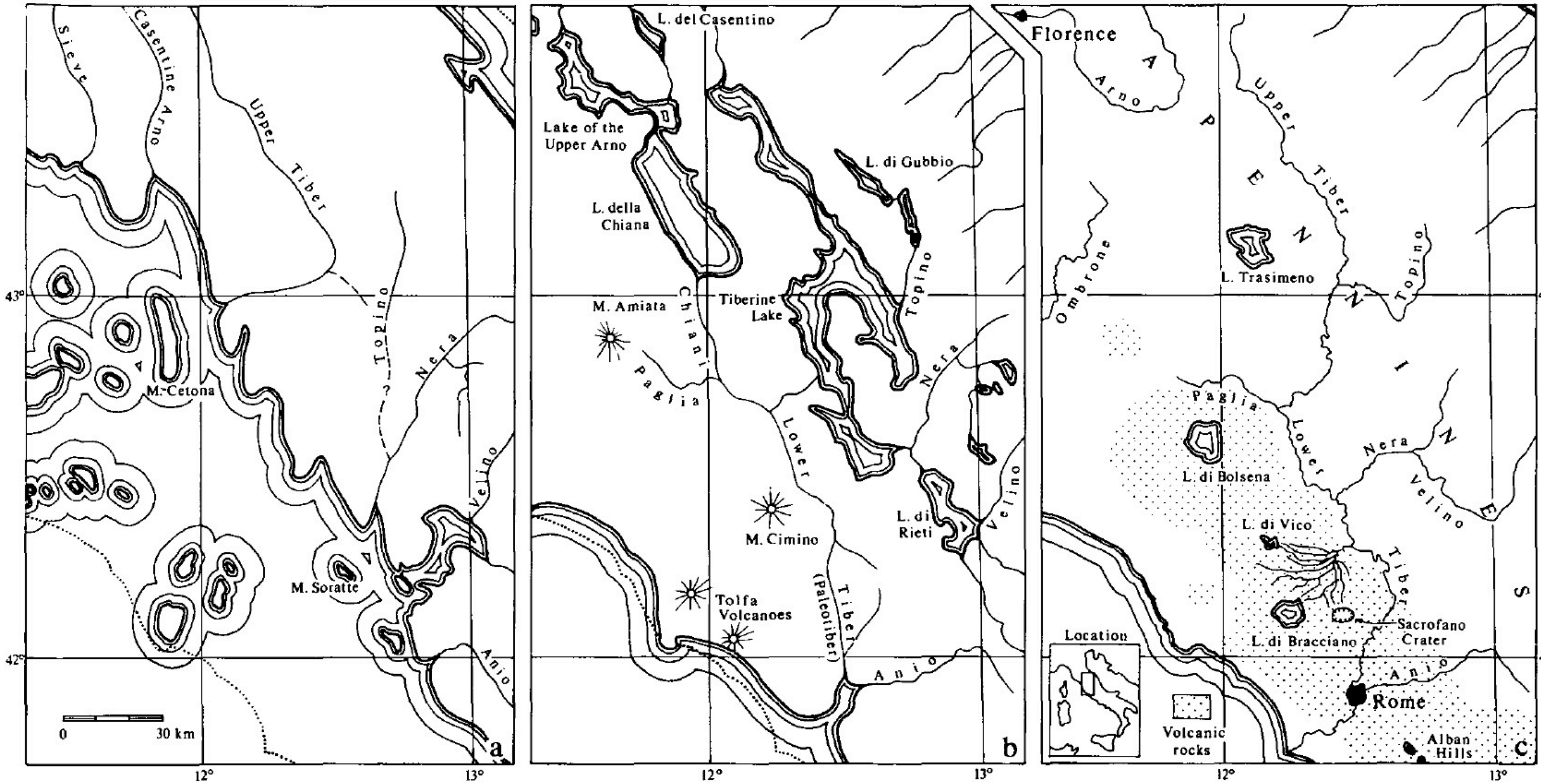


Figure 6. Evolution of the Tiber drainage system (based largely on Merla, 1944). a. Pliocene paleogeography, modern coastline dotted for comparison. b. The early Pleistocene, after formation of the intermontane lacustrine basins and emergence of the lower Tiber region. c. Present situation, after capture of part of the Tiber system by the Arno, disappearance of most of the intermontane lakes, and diversion of the lower Tiber by volcanic products. The Treia drainage system is shown in the angle between Lago di Vico, Lago di Bracciano, and the Sacrofano Crater.

Alvarez 1973

Giordano et al 2006

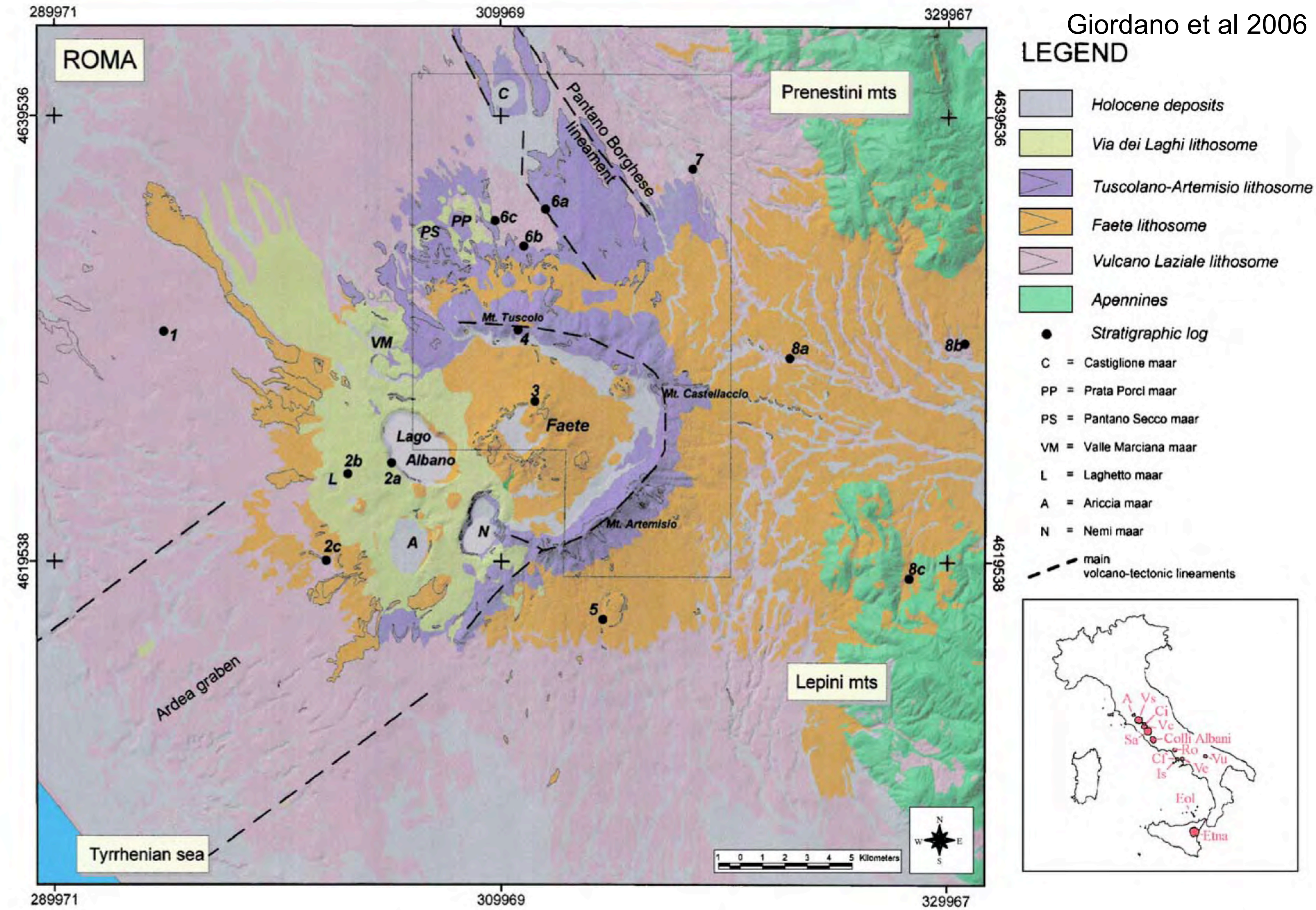
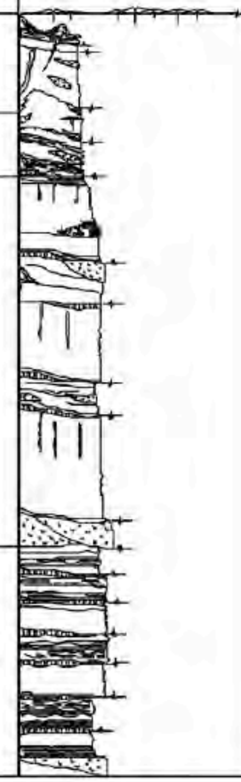


Fig. 1. Simplified geological map of the Colli Albani volcano, showing the four recognised lithosomes (see text). Black lines contour lavas. The inset-box indicates the area of the geological map shown in Fig. 5. Geographic coordinates refer to the UTM 33 system. Abbreviations in the box to the right indicate the Quaternary volcanoes: A — Amiata dome; Vs — Vulsini caldera complex; Ci — Cimini domes; Vc — Vico stratovolcano; Sa — Sabatini caldera complex; Ro — Roccamonfina stratovolcano; Cf — Campi Flegrei caldera complex; Is — Ischia stratovolcano; Ve — Vesuvio

Table 1
Comparison of stratigraphy proposed by Alberti et al. (1967), Fornaseri et al. (1963), De Rita et al. (1988a,b) and the present study. Average eruption rates for lithosomes described in this paper are given in brackets

Alberti et al. (1967)	Fornaseri et al. (1963)	De Rita et al. (1988)	This paper
Manifestazioni eruttive finali (Last eruptive phase)	Attività freatomagmatica degli apparati eccentrici (Eccentric Phreatomagmatic phase)	Fase idromagmatica finale ($\sim 1\ km^3$) (Final hydromagmatic phase)	Via dei Laghi lithosome ($10^{-3} km^3/1\ ka$)
Sistema eruttivo esterno (External eruptive system)	Ultimo periodo dell'attività centrale (Last period of central activity)	Fase delle Faete ($6\ km^3$) (Faete phase)	Faete lithosome ($4*10^{-1} km^3/1\ ka$)
Sistema eruttivo centrale (Central eruptive system)	Prodotti dell'attività del periodo TA (Tuscolano-Artemisio deposits)	Fase Tuscolano-Artemisia ($280\ km^3$) (Tuscolano-Artemisio phase)	Tuscolano Artemisio lithosome
	Complesso dei tufi inferiori (Lower tuffs)		Vulcano Laziale lithosome ($> 1 km^3/1\ ka$)
	Primi prodotti del Vulcano Laziale (Vulcano Laziale Early products)		*Pisolitic tuffs* succession



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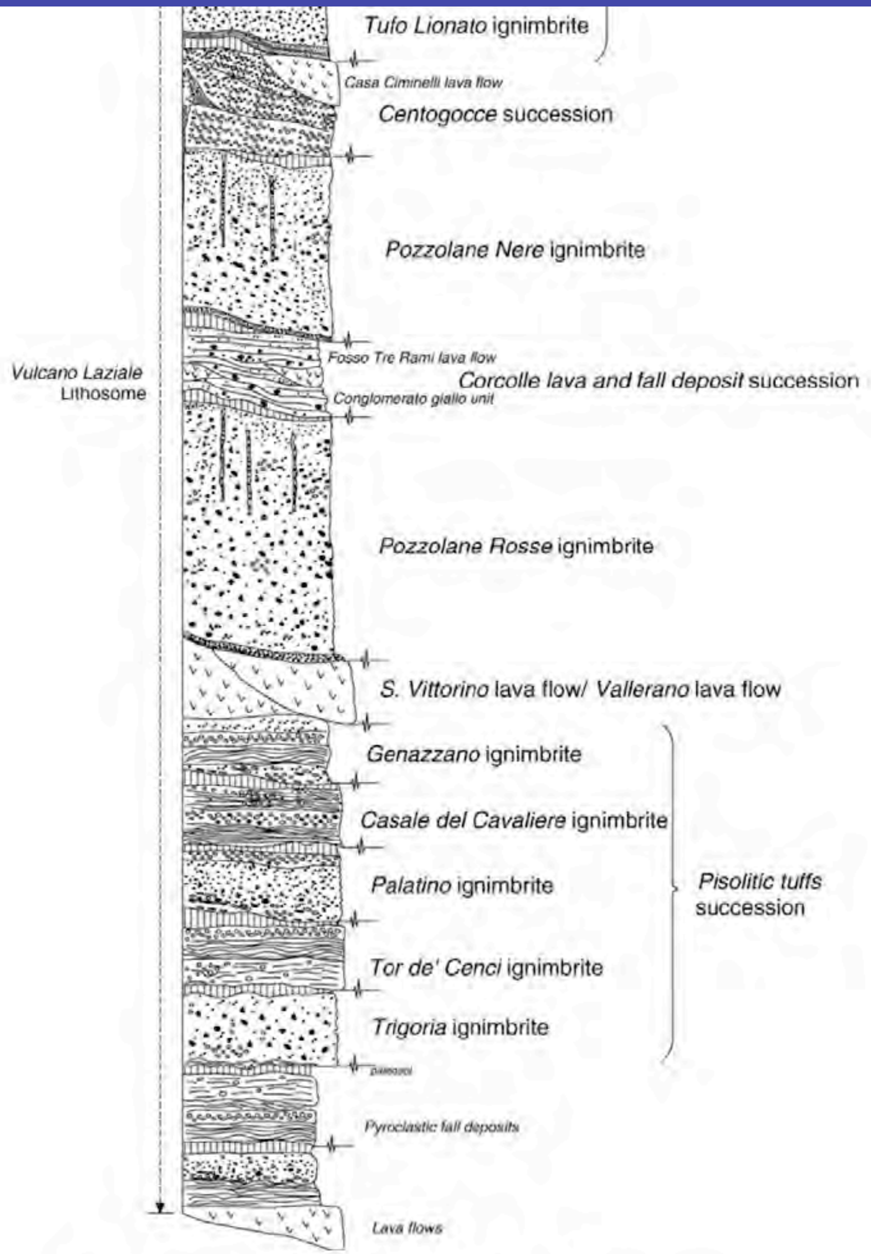
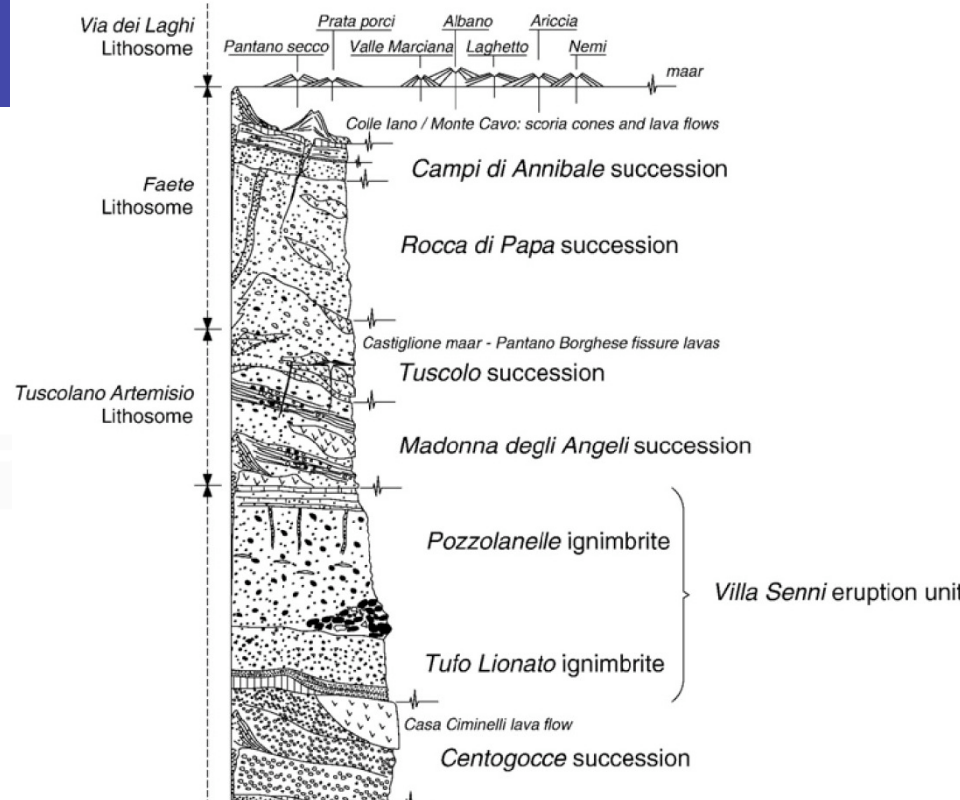


Fig. 2. Composite stratigraphic column of Colli Albani lithosomes.



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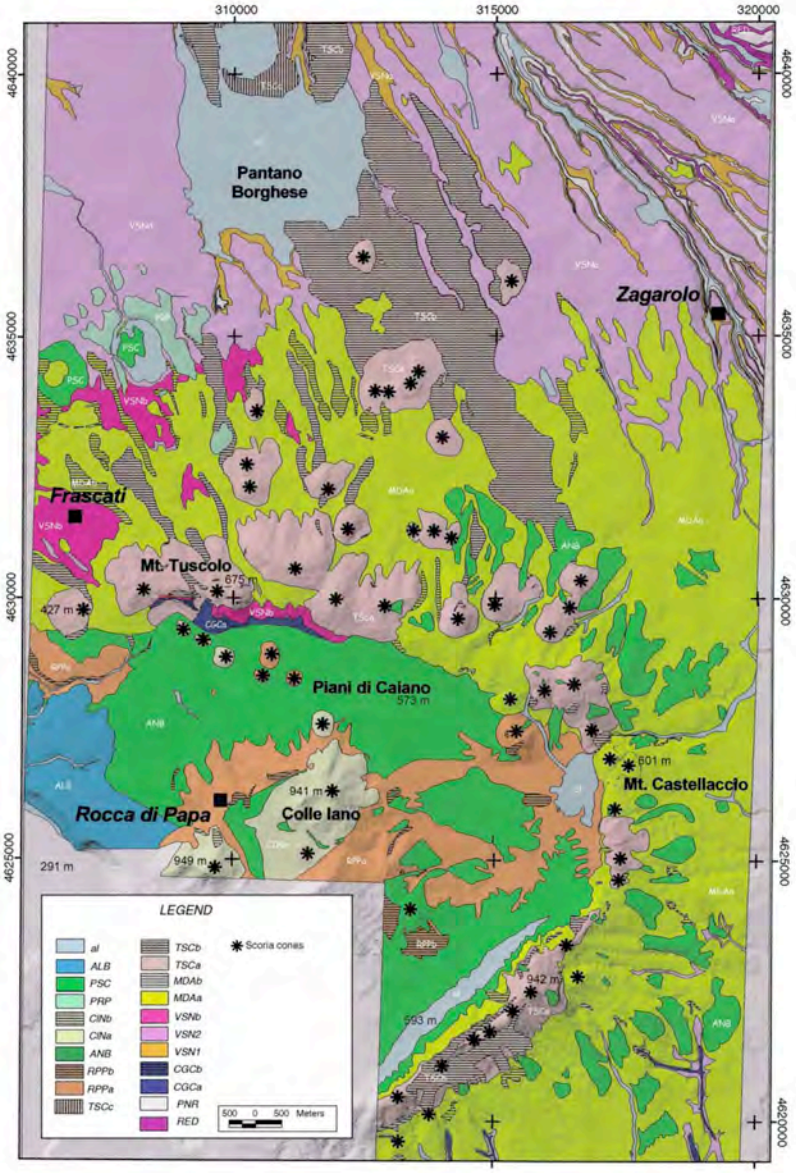

Fig. 5. Geological map of the caldera area (see Fig. 1 for location); Legend: al—Holocene alluvial deposits; ALB — Albano maar phreatomagmatic succession; PSC — Pantano Secco maar phreatomagmatic succession; PRP — Prata Porci maar phreatomagmatic succession; CIN — Colle Iano succession: (a) pyroclastics; (b) lava; ANB — Campi di Annibale phreatomagmatic succession; RPP — Rocca di Papa succession: (a) pyroclastics; (b) lava; TSC — Tuscolo succession: (a) pyroclastics; (b) lava; (c) Castiglione maar succession; MDA — Madonna degli Angeli succession: (a) pyroclastics; (b) lava; VSN — Villa Senni Eruption Unit: (1) Tufo Lionato ignimbrite; (2) Pozzolanelle ignimbrite; (3) co-ignimbrite breccia; CGC — Centogocce succession: (a) pyroclastics; (b) lava; PNR — Pozzolane Nere ignimbrite; RED — Pozzolane Rosse ignimbrite.

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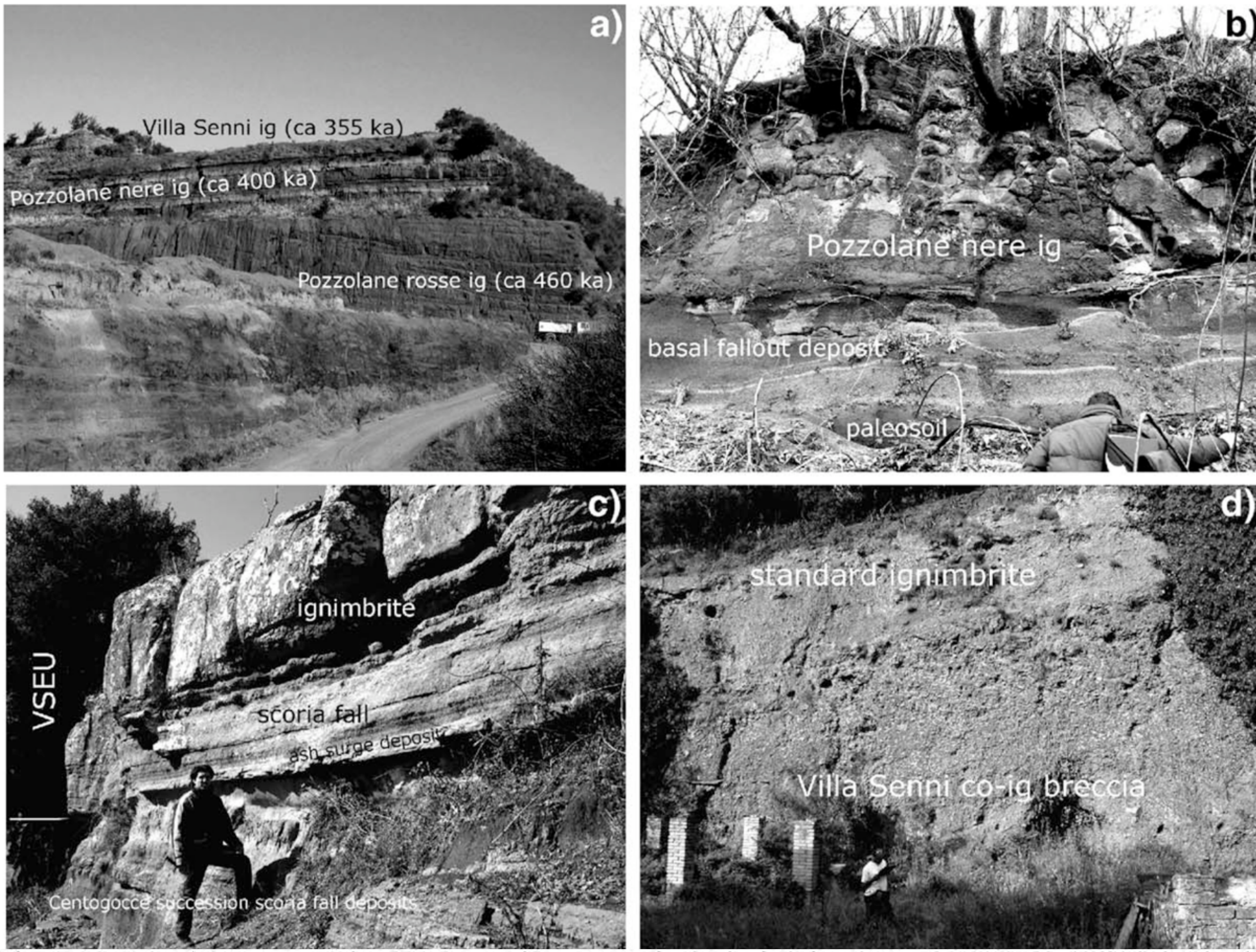

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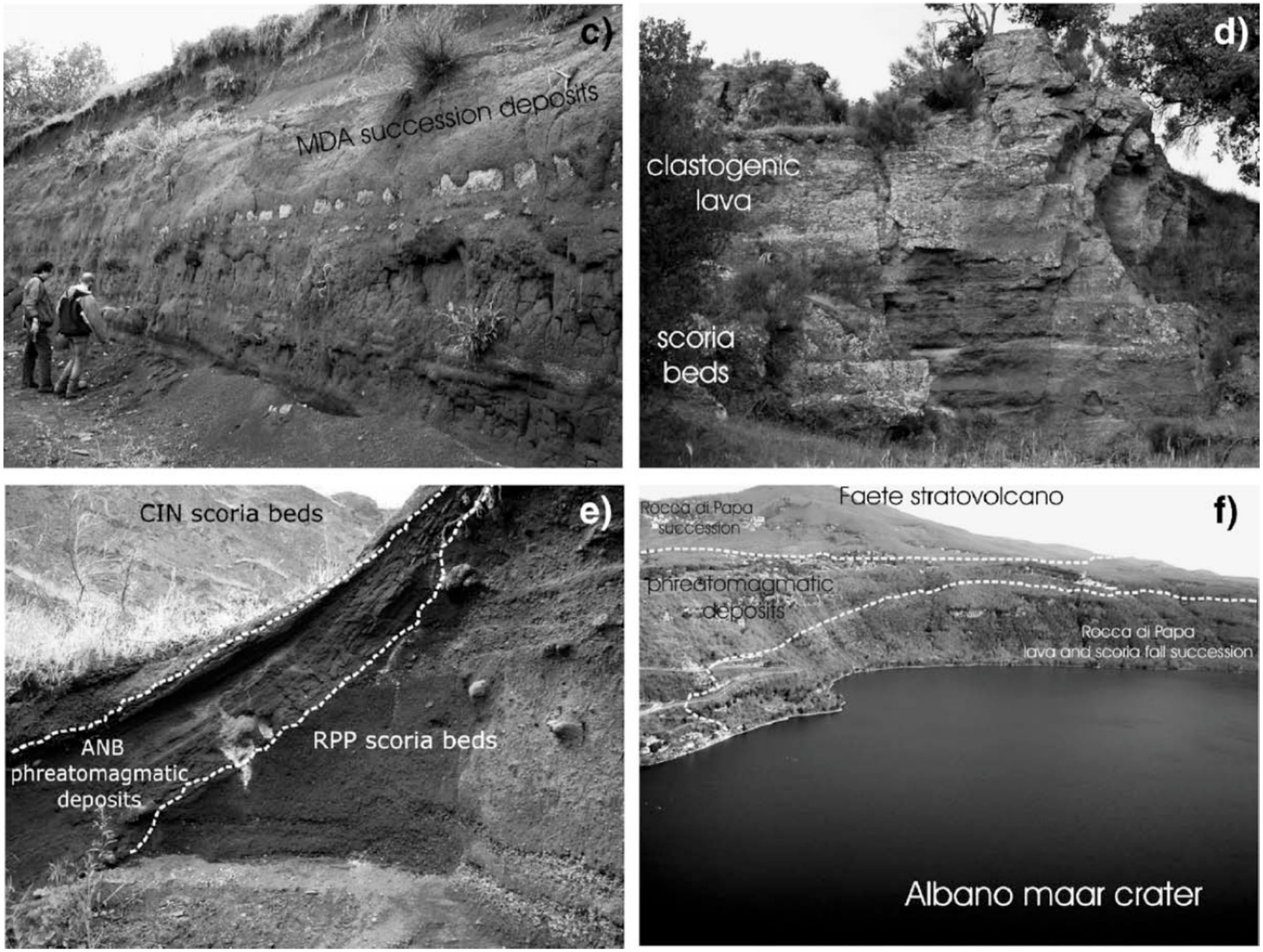
Fig. 4. (a) Bulgarini Quarry, 20 km NE from caldera centre in the ignimbrite plateau (4644834N; 315225E). The dark colour of the ignimbrites reflects the mafic composition ($SiO2 \leq 50\%$); (b) the plinian scoria lapilli fallout deposit at the base of the Pozzolane Nere ignimbrite is 160 cm thick at Valle Castiglioni locality, 18 km E of the caldera centre (4618774N; 328273E); (c) the base of the Villa Senni Eruption Unit (VSEU) at Tuscolo locality along the caldera wall, is made by a 20 cm thick ash-surge deposit, overlain by 100 cm of stratified scoria lapilli fallout deposit, overlain by the proximal co-ignimbrite breccia facies of the VSEU ignimbrites (4629642N; 309633E); (d) the proximal co-ignimbrite breccia of the VSEU-Pozzolanelle ignimbrite (Frascati locality 4631867N; 306555E) is made of xenolith blocks and spatter rags, grading laterally and vertically into the standard ignimbrite facies; (e) the top of the Centogocce succession at the caldera wall is made by decimetre to metre thick, well sorted, plane-parellel



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(Lariano locality; 4621193N; 318738E); (c) at more distal locations, the scoria fallout beds are decimetre size and small-lapilli to ash-size interbedded to thick paleosoils (Colle Carnarolo locality; 4633934N; 319173E); (d) the scoria and lava cones of the Tuscolo succession are made of welded scoria grading to clastogenic lava (Tuscolo locality; 4630115N; 309687E); (e) the top of the Faete edifice (Rocca di Papa succession) is truncated by an erosional unconformity overlain by phreatomagmatic deposits of the Campi di Annibale succession, in turn overlain by the scoria fallout deposits of the Colle Iano cone (Malepasso locality; 4626764N; 311586E); (f) the Albano maar lake looking eastward with the Faete stratovolcano in the background.

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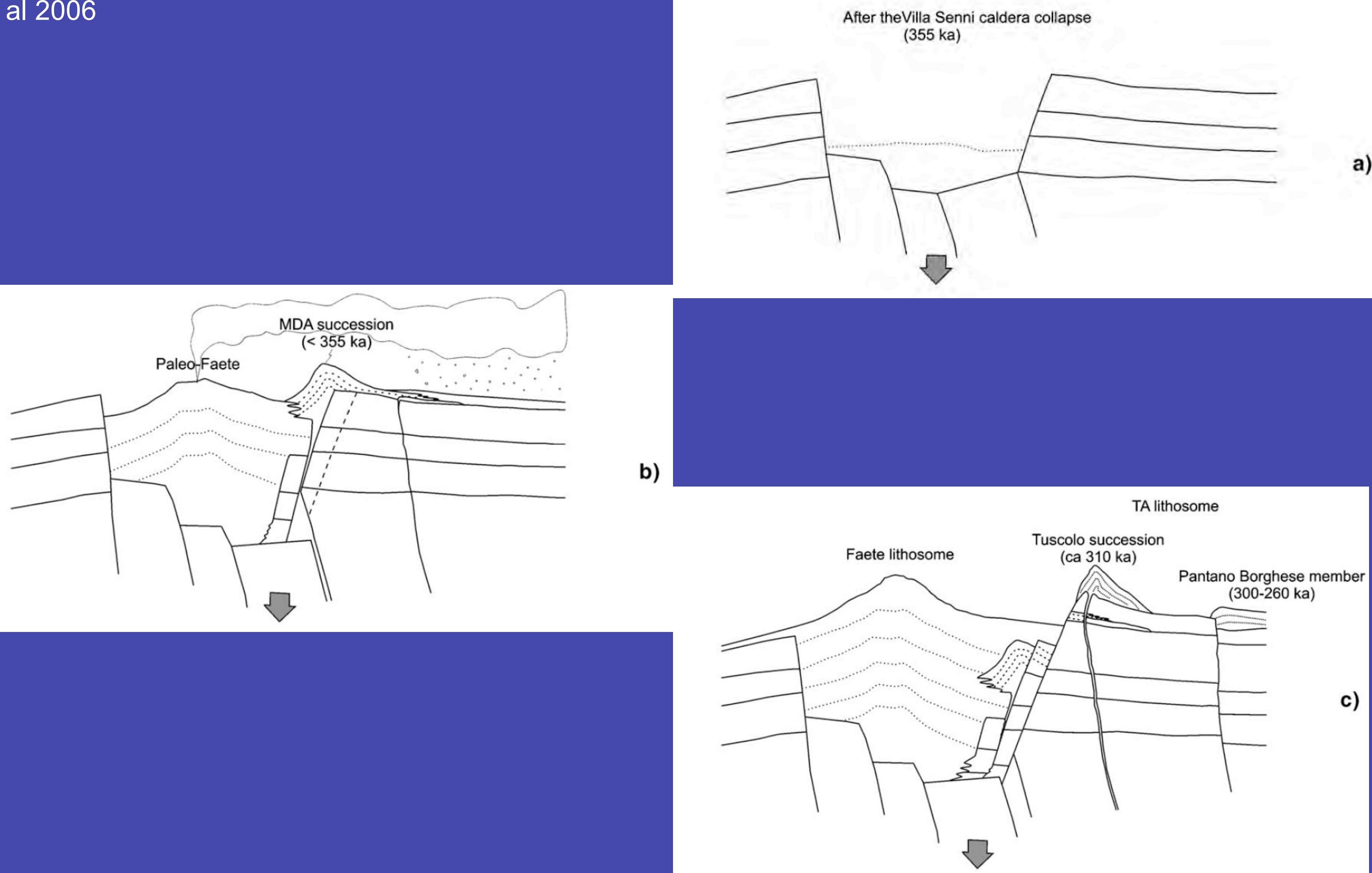

Fig. 9. Reconstruction of the volcano-tectonic events that determined the stratigraphic and structural setting of the present day Colli Albani caldera wall; (a) the VSEU piecemeal caldera collapse; (b) emplacement of the MDA succession, made of interfingering peri-caldera fissure scoria and lava cones with paleoFaete violent strombolian and sub-plinian; (c) volcano tectonic collapse of the caldera wall; outward migration of peri-caldera fractures from the Tuscolo succession to the final Pantano Borghese member.

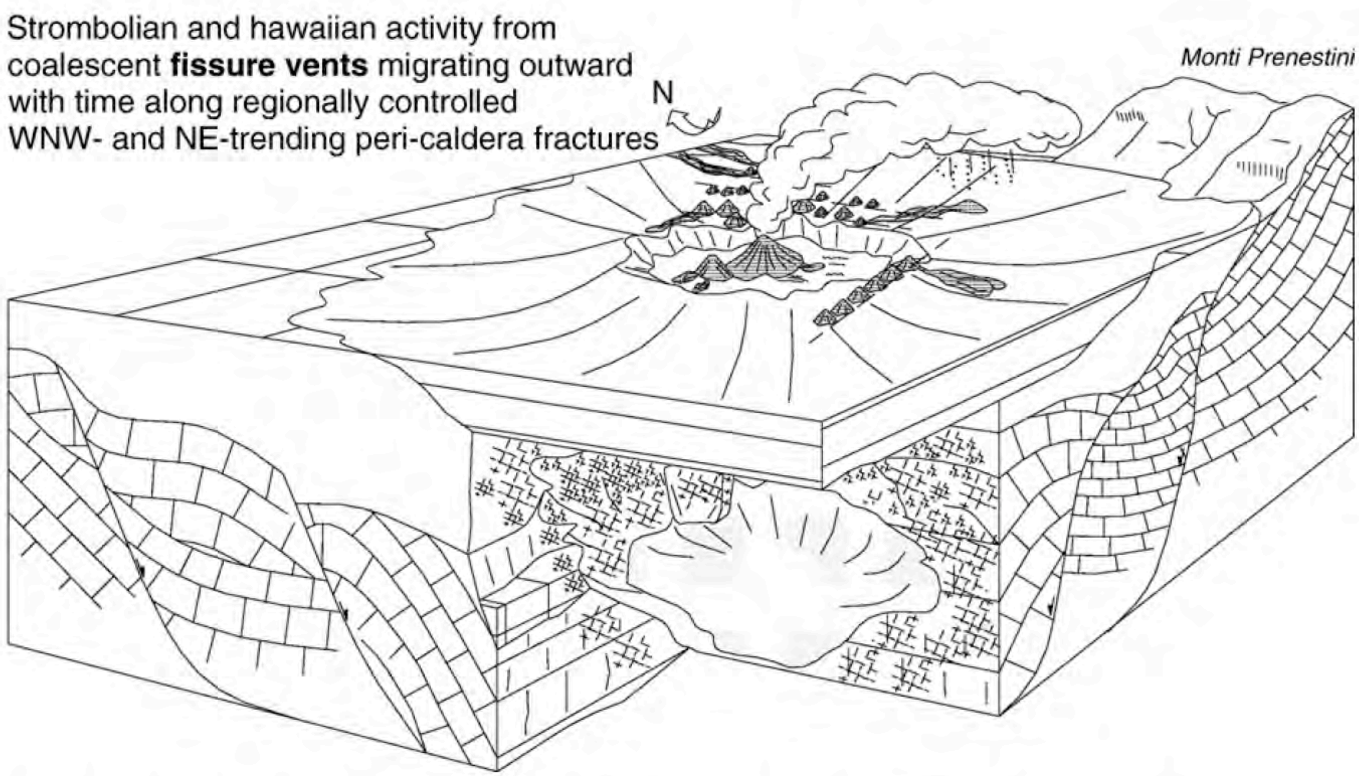

Fig. 10. Reconstruction of the structure of the Tuscolano-Artemisio lithosome between ca. 355 and 260 ka. After the Villa Senni ignimbrites caldera collapse at 355 ka, the caldera floor underwent continuous downsagging, with significant reduction of recharge of the magma chamber. The deflation promoted the progressive outward activation of peri-caldera fissures, controlled by the structure of the basement.

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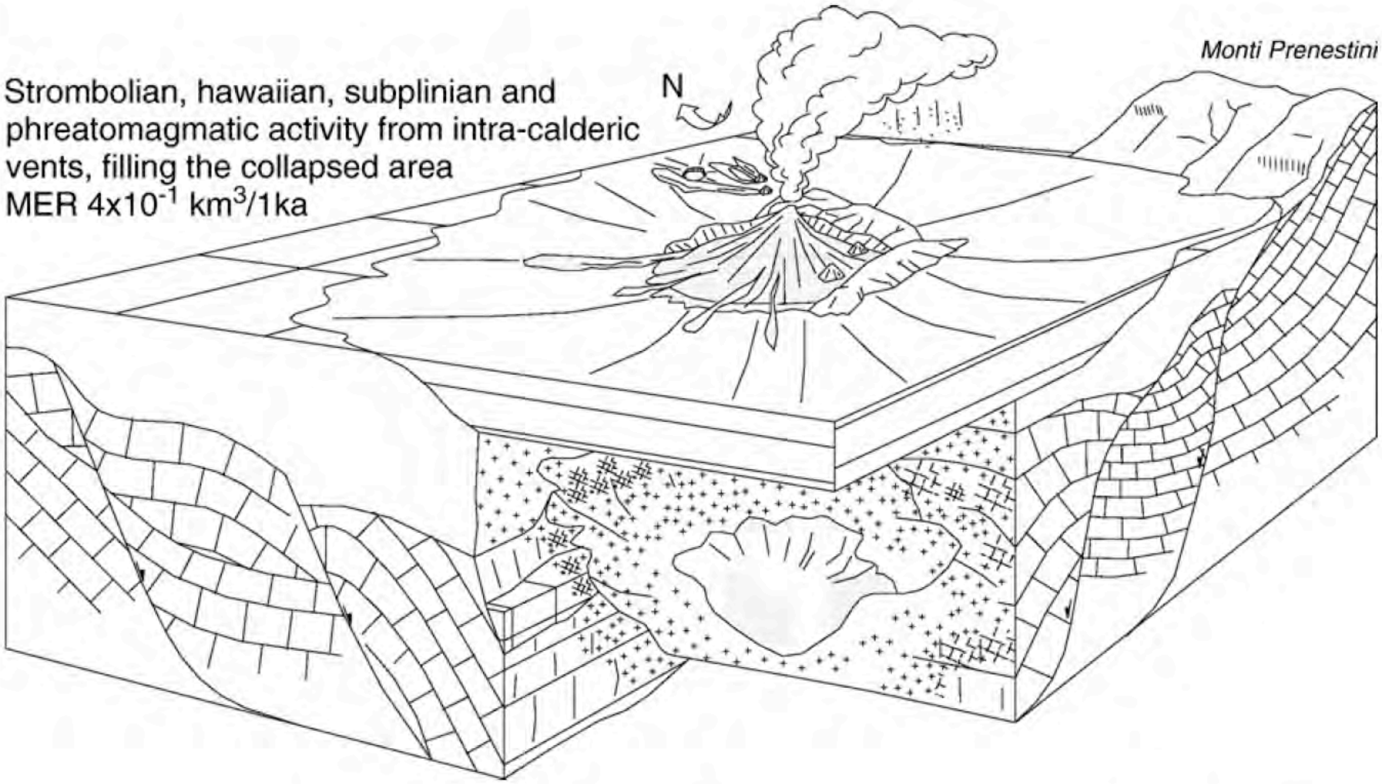

Fig. 11. Reconstruction of the structure of the Faete lithosome (?350–< 260 ka), characterised by the formation of the central stratovolcano within the caldera, with effusive to strombolian to sub-plinian activity. The final stage was characterised by summit phreatomagmatic eruptions and scoria cones. The reduction of magma recharge likely promoted the progressive crystallisation of the magma chamber.

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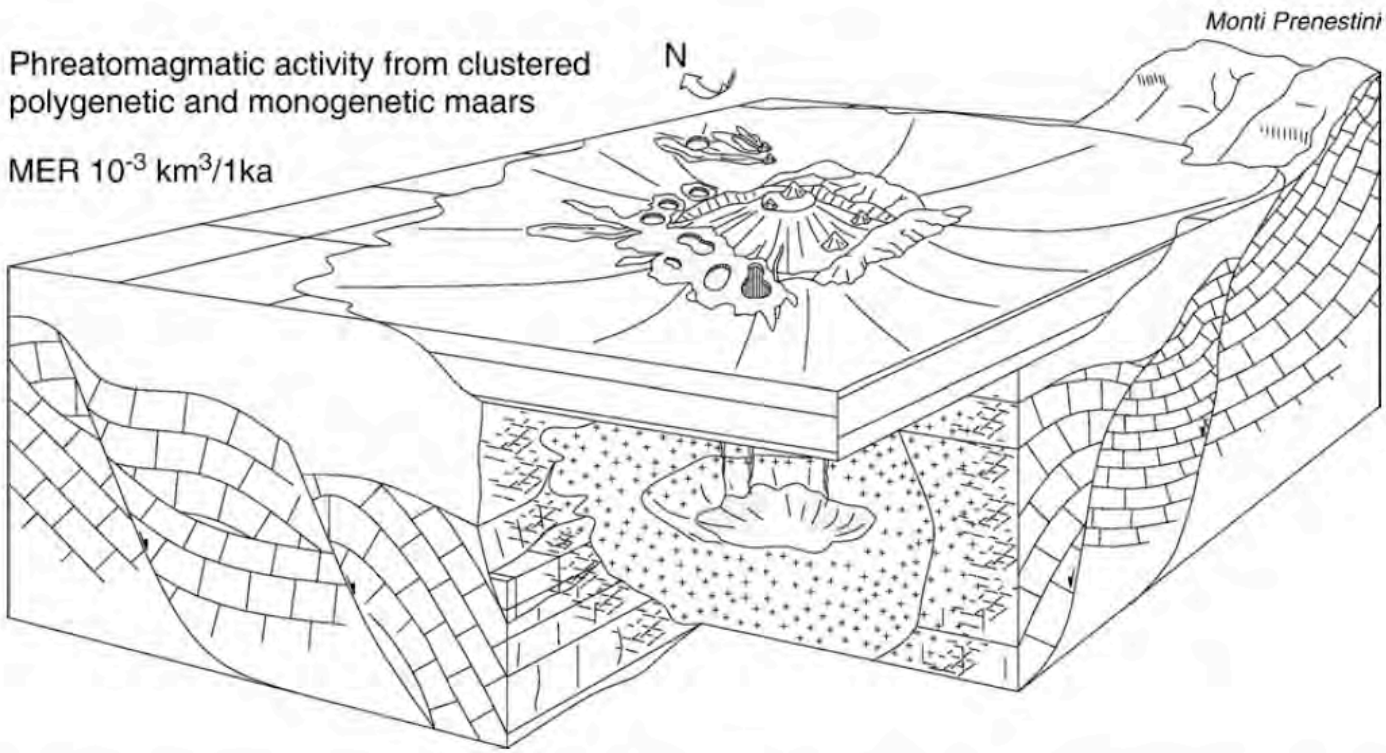

Fig. 13. Reconstruction of the structure of the Via dei Laghi lithosome (ca. 200 ka-Holocene). Activity became eccentric and was characterised by small volume phreatomagmatic maar forming eruptions localised above the subdued carbonatic horst of Ciampino, which hosts a substantial aquifer recharged at depth from the Apennines (Monti Prenestini). The main magma chamber was mostly crystallised at this stage.

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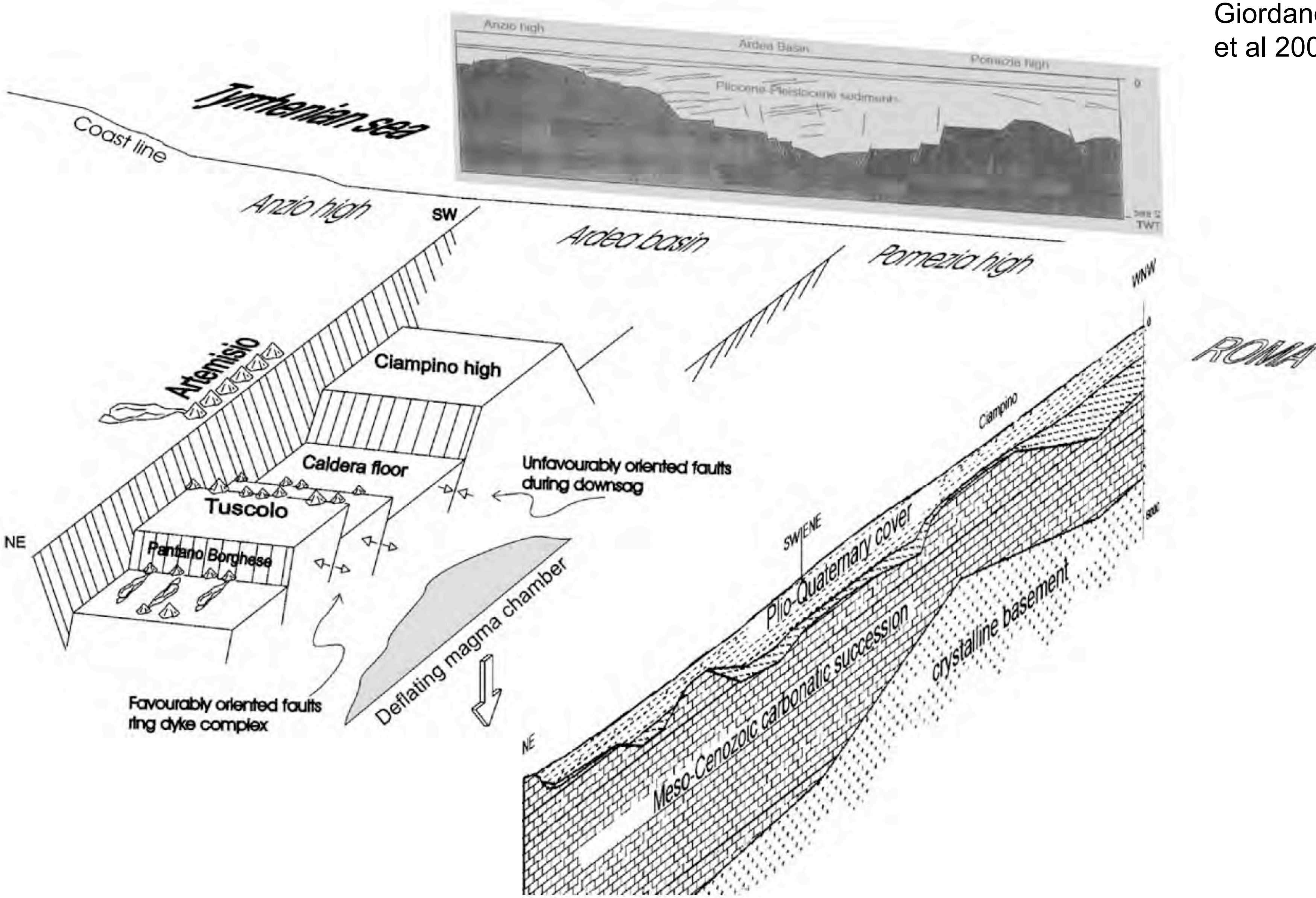
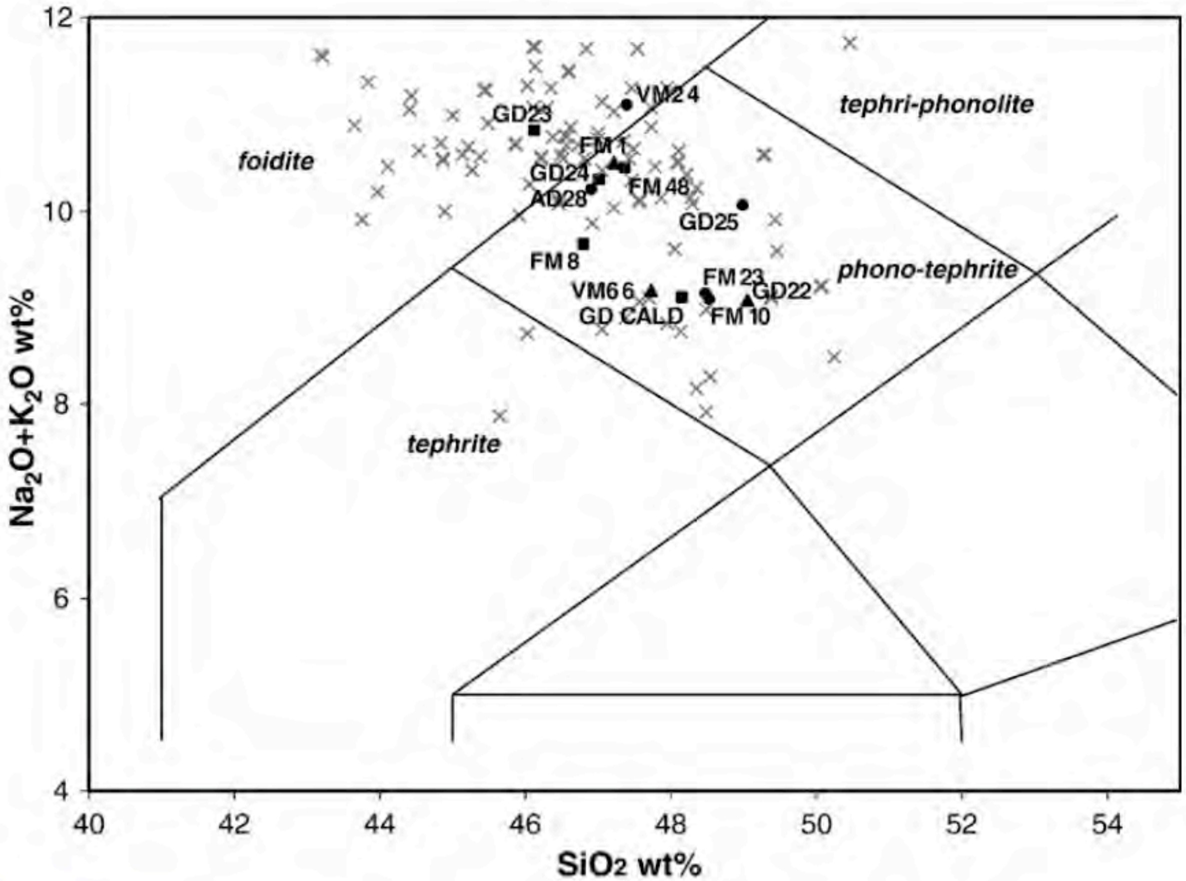


Fig. 12. Interpretative block diagram of the volcano-tectonic structure of the caldera of the Colli Albani. The NW-trending Tuscolo and Pantano Borghese fissures opened during caldera downsag because of outward dipping and therefore favourably oriented for ring-dyke intrusion, in contrast with the orientation of the Ciampino high bounding faults, thus explaining the asymmetry of peri-caldera fissures. Fault dips are consistent with the inversion of the gravimetric profile shown to the right (from Di Filippo and Toro, 1995). The NE-trending Artemisio fissure corresponds to the master fault of the Ardea basin, as interpreted from offshore seismic profiles (Faccenna et al., 1994a,b).

Final Note: Colli Albani Chemical Compositions



ʼig. 15. TAS diagram (Le Bas et al., 1986). Legend: ■ lavas from Centogocce succession; ● lavas from Madonna degli Angeli succession; ▲ lavas rom Tuscolo succession. Crosses plot data from literature (Fornaseri et al., 1963; Peccerillo et al., 1984; Trigila et al., 1995).

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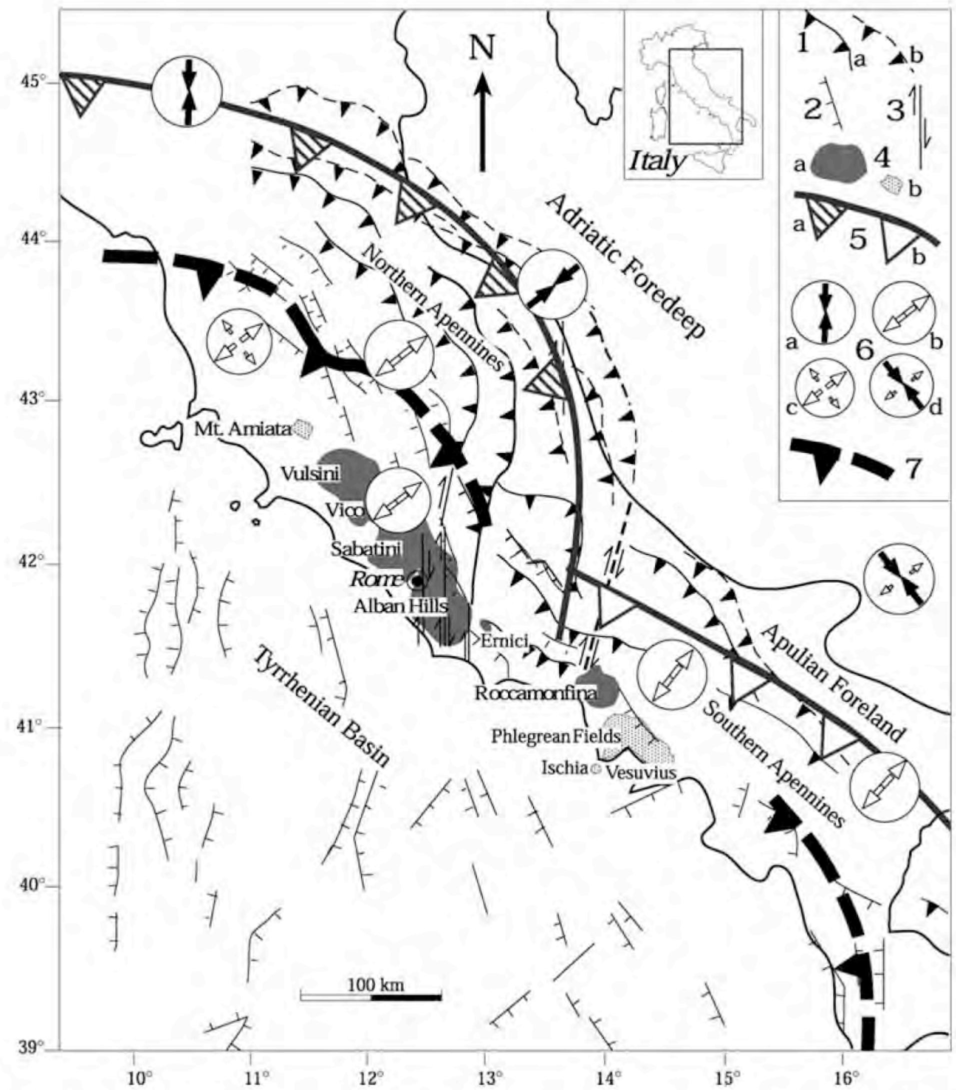

Figure 1. Location and structural sketch of the Tyrrhenian margin of Italy showing the Quaternary volcanoes of the Roman Comagmatic Province and main tectonic features. Legend: 1) Surface (a) and subsurface (b) thrust fronts [from *Patacca et al.*, 1990]; 2) Extensional faults [from *Patacca et al.*, 1990]; (3) Strike-slip faults; 4) Volcanoes and volcanic districts of the Tyrrhenian margin: Roman Comagmatic Province (a) and cited in the text (b); 5) Structural arcs characterized by active compressional fronts (a) and inactive thrust fronts (b) [from *Montone et al.*, 1999]); 6) Summary of stress data for Italy [from *Montone et al.*, 1999]: a) compression ($S_H$max direction), b) extension ($S_H$min direction), c) strike slip, d) radial extension; 7) Eastern outline of the downgoing slab in the depth range 35–100 km, inferred from tomographic study of the velocity structure of the upper mantle [from *Lucente and Speranza*, 2001].

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Table 1. Published K/Ar and $^{40}Ar/^{39}Ar$ Ages of Volcanics From the Roman Comagmatic Provinces[a]

Age, ka	Method	Sample Type	Volcanic District	Deposit Type	Unit/Sample Name/(Locality)	Reference	In Statistic
26 ± 2	Ar/Ar	leucite	Alban Hills	tephra	tephra in Albano Lake sediment	*Villa et al.* [1999]	no
37 ± 2	Ar/Ar	leucite	Alban Hills	pyroclastic surge	Peperino di Marino - *Lapis albanus*	*Karner et al.* [2001c]	no
40 ± 10	K/Ar	sanidine	Vulsini	unknown	trachyte/TSL/(San Lorenzo Nuovo)	*Nicoletti et al.* [1981]	no
41 ± 1	Ar/Ar	leucite	Alban Hills	scoria fall	Albano/AH-9/(Santa Procula)	*Marra et al.* [2003]	no
45 ± 6	Ar/Ar	leucite	Alban Hills	tephra	tephra in Albano Lake sediment	*Villa et al.* [1999]	no
50 ± 10	K/Ar	sanidine	Vulsini	pumice	trachyte/VS43/(Arlena di Castro)	*Nicoletti et al.* [1981]	no
53 ± 27	Ar/Ar	groundmass	Roccamonfina	unknown	53T MgL/(Masseria Robetti)	*Radicati di Brozolo et al.* [1988]	no
70 ± 2	Ar/Ar	leucite	Alban Hills	pyroclastic surge	Giuturna/AH-2	*Marra et al.* [2003]	no
70 ± 2	Ar/Ar	leucite	Alban Hills	basal scoria fall	Albano/AH-2/(Albano Lake)	*Marra et al.* [2003]	no
85 ± 9	K/Ar	sanidine	Sabatini	pyroclastic surge	Tufo di Baccano/VSA13	*Fornaseri* [1985]	no
96 ± 8	K/Ar	bulk rock	Roccamonfina	unknown	58T LaTr/(Teano road)	*Radicati di Brozolo et al.* [1988]	yes
120 ± 6	Ar/Ar	Sanidine	Vico	pyroclastic flow	Vico Ignimbrite D?	*Turbeville* [1992]	yes
127 ± 2	K/Ar	groundmass	Vulsini	lava flow	Bisentina Island/PS41PA	*Nappi et al.* [1995]	yes
130 ± 10	K/Ar	sanidine	Vulsini	pyroclastic flow	trachyte/VF4/(Bagnoregio)	*Nicoletti et al.* [1981]	yes
133 ± 59	Ar/Ar	bulk rock	Roccamonfina	lava dome	10T La/(Gli Araesi)	*Radicati di Brozolo et al.* [1988]	no
138 ± 2	Ar/Ar	sanidine	Vico	pyroclastic flow	ignimbrite D/V85-27/ (Ronciglione-Caprarola road)	*Laurenzi and Villa* [1987]	yes
146 ± 9	K/Ar	groundmass	Vulsini	lava flow	Monte Becco/VUL6/(La Botte)	*Metzeltin and Vezzoli* [1983]	yes
147 ± 2	Ar/Ar	leucite	Alban Hills	pyroclastic surge	Ariccia/AH-1G/(Ariccia Crater)	*Marra et al.* [2003]	yes
150 ± 30	K/Ar	leucite	Vulsini	unknown	tephritic phonolite/BS26/(Proceno)	*Nicoletti et al.* [1981]	no
150 ± ?	?/Ar	unknown	Vico	pyroclastic flow	ignimbrite C	*Sollevanti* [1983]	no
151 ± 3	Ar/Ar	sanidine	Vico	pyroclastic flow	ignimbrite C/VS85-17/ (Viterbo-Canepina road)	*Laurenzi and Villa* [1987]	no
154 ± 2	Ar/Ar	leucite	Vico	pyroclastic flow	ignimbrite C/VS85-17/ (Viterbo-Canepina road)	*Laurenzi and Villa* [1987]	yes
155 ± 11	Ar/Ar	sanidine	Vulsini	pyroclastic fall	Pitigliano Tuff/PF4	*Turbeville* [1992]	yes
155 ± 24	K/Ar	groundmass	Roccamonfina	lava dome	49T La/(Monte S. Croce)	*Radicati di Brozolo et al.* [1988]	yes
157 ± 3	Ar/Ar	sanidine	Vico	pyroclastic flow	ignimbrite B/V85-19bis/ (Fabbrica-Ronciglione road)	*Laurenzi and Villa* [1987]	yes
158 ± 11	Ar/Ar	sanidine	Vulsini	pyroclastic fall	Pitigliano Tuff/PF4	*Turbeville* [1992]	yes
158 ± 5	K/Ar	groundmass	Vulsini	lava flow	Selva del Lamone/VUL12/(Lamone road)	*Metzeltin and Vezzoli* [1983]	yes
166 ± 4	K/Ar	sanidine	Vulsini	pyroclastic flow	Unit A/VUL7/(Case Collina)	*Metzeltin and Vezzoli* [1983]	yes
166 ± 4	K/Ar	sanidine	Vulsini	pyroclastic flow	Unit A/VUL8/(Case Collina)	*Metzeltin and Vezzoli* [1983]	no
175 ± 2	K/Ar	leucite	Alban Hills	lava flow	tephritic leucitite/Al23/ (Ponte Divino Amore)	*Bernardi et al.* [1982]	no
178 ± 4	K/Ar	leucite	Vulsini	pyroclastic flow	Unit A/VUL8/(Case Collina)	*Metzeltin and Vezzoli* [1983]	yes
178 ± 24	Ar/Ar	leucite	Alban Hills	basal scoria fall	Nemi/AH-4	*Marra et al.* [2003]	yes
180 ± 40	K/Ar	bulk rock	Vulsini	lava flow	Latite/VS36/(Vulci)	*Nicoletti et al.* [1981]	no
182 ± 5	K/Ar	groundmass	Vulsini	pyroclastic flow	Unit A/VUL/(Case Collina)	*Metzeltin and Vezzoli* [1983]	yes
187 ± 8	Ar/Ar	sanidine	Vulsini	pyroclastic flow	Montefiascone ignimbrite	*Turbeville* [1992]	yes

Marra et al 2004

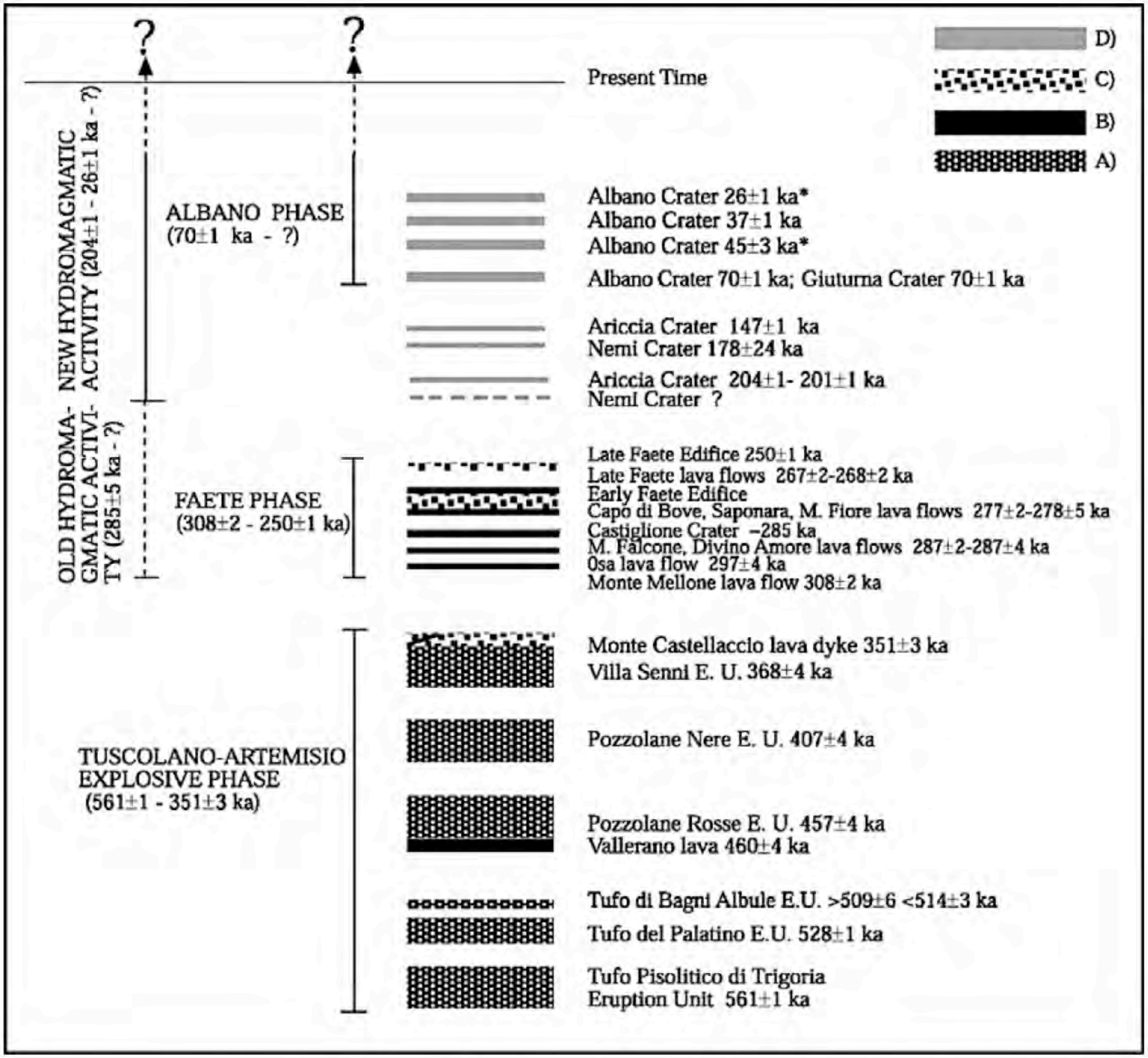


Figure 2. Stratigraphic sketch and age of the Alban Hills products (modified from *Marra et al.* [2003], Figure 7) showing the three main eruptive phases outlined by previous works. References of the $^{40}Ar/^{39}Ar$ ages (1σ error) of the erupted products are reported in Table 1. A) Pyroclastic flows; B) Lava flows; C) Air fall deposits; D) Hydromagmatic deposits.

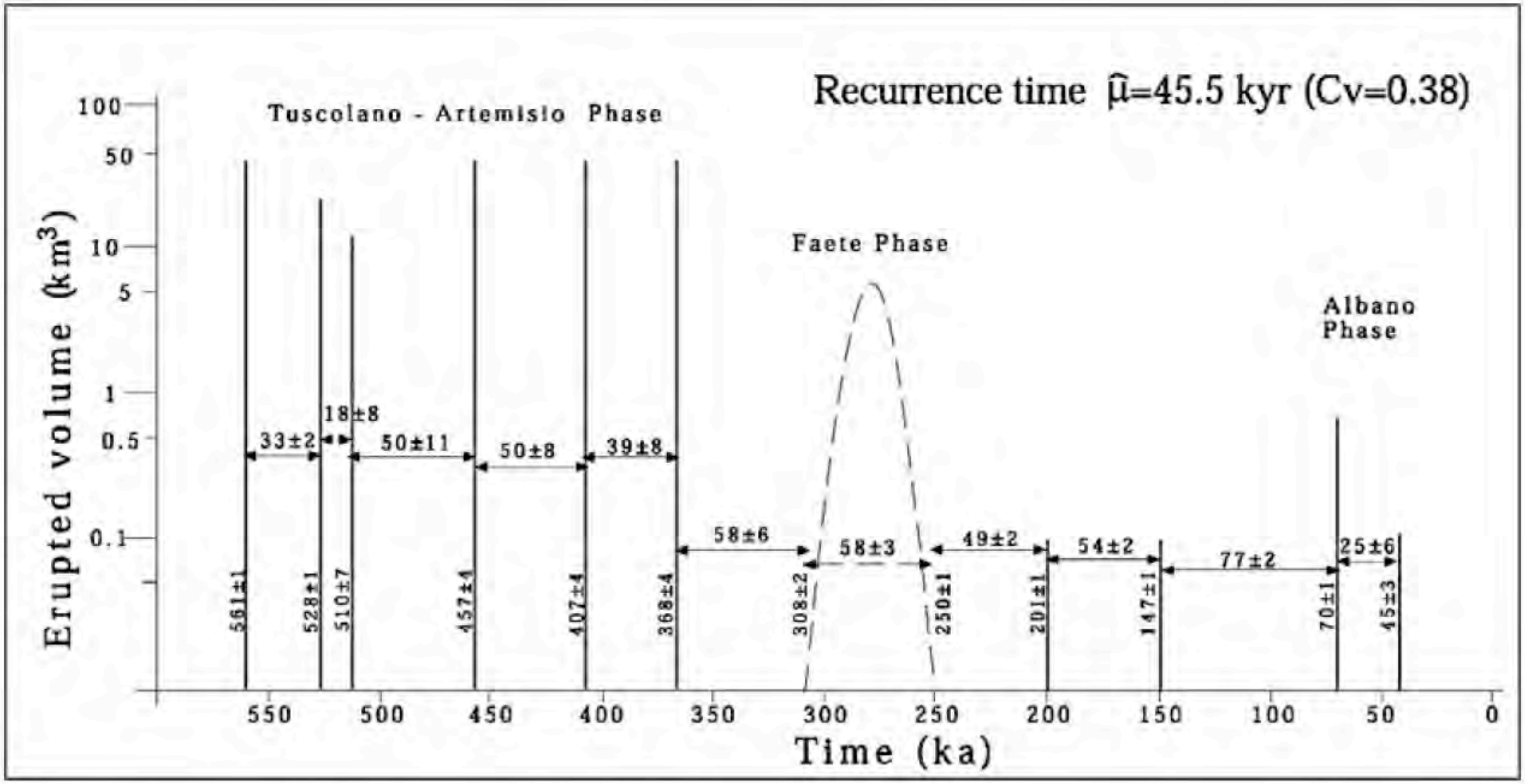


Figure 3. A $^{40}Ar/^{39}Ar$ eruptive history of the Alban Hills. Indicative erupted volumes, on logarithmic scale, are reported versus ages. Each vertical line corresponds to a single eruptive cycle. Note that the many, closely spaced eruptions of the Faete Phase (see Figure 2) corresponds to one eruptive cycle. See text for calculation of the recurrence time $\hat{\mu}$ and Cv.

Marra et al 2004

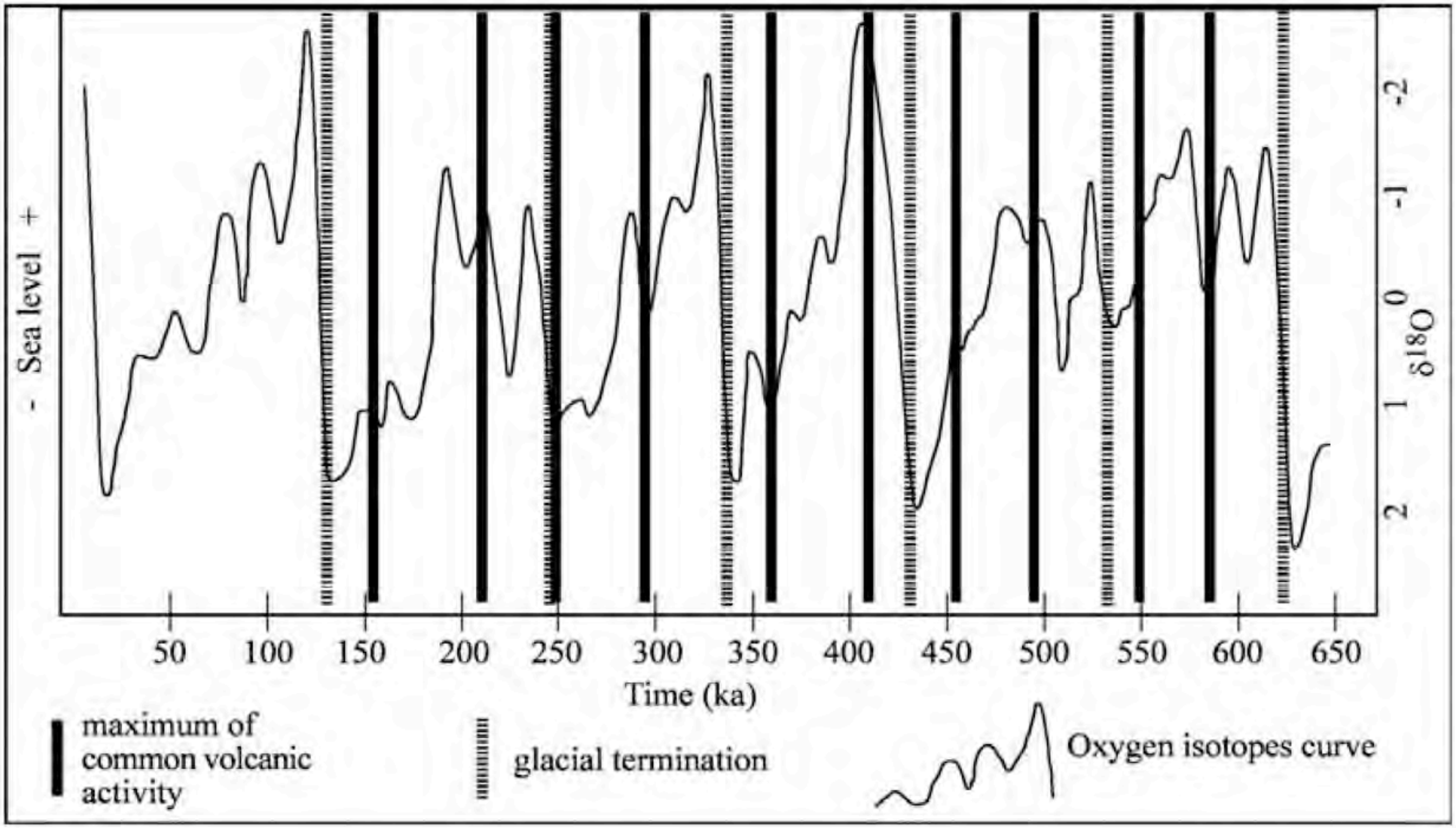


Figure 5. The occurrence of the major eruptive cycles in the volcanic districts of the Tyrrhenian margin of Italy, as inferred from Figure 4, is compared to sea level fluctuations induced by glacial-interglacial cycles, as inferred from the oxygen isotopes curve [from *Bassinot et al.*, 1994].

Marra et al 2004

What processes alter crustal composition?

- Magmatism: partial mantle melting
- Sedimentation
- Metamorphism

How do we melt the mantle?

- Add water
- Add heat
- Reduce pressure

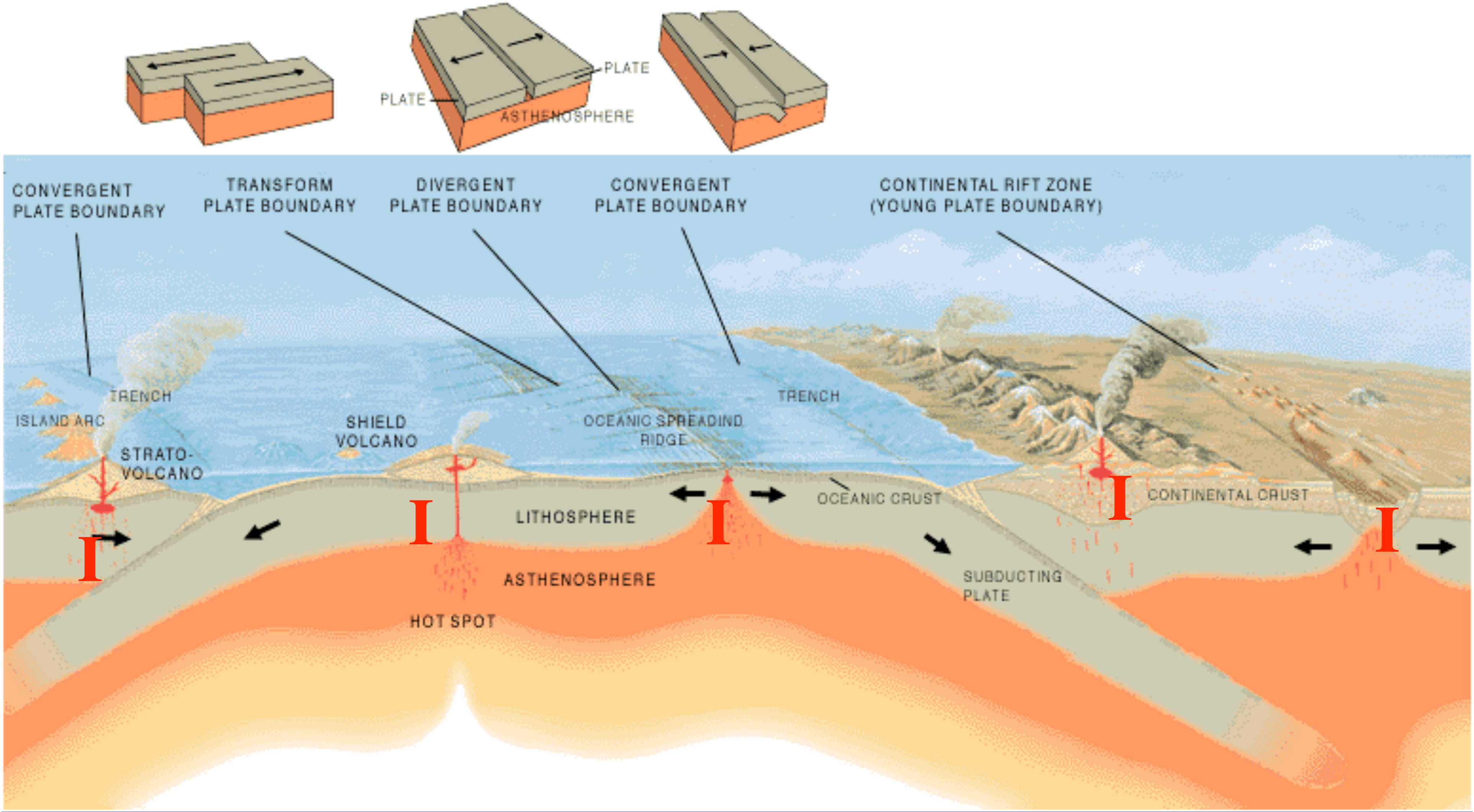
Magmatism produces these major element averages:

Chemical analyses of some representative Igneous Rocks

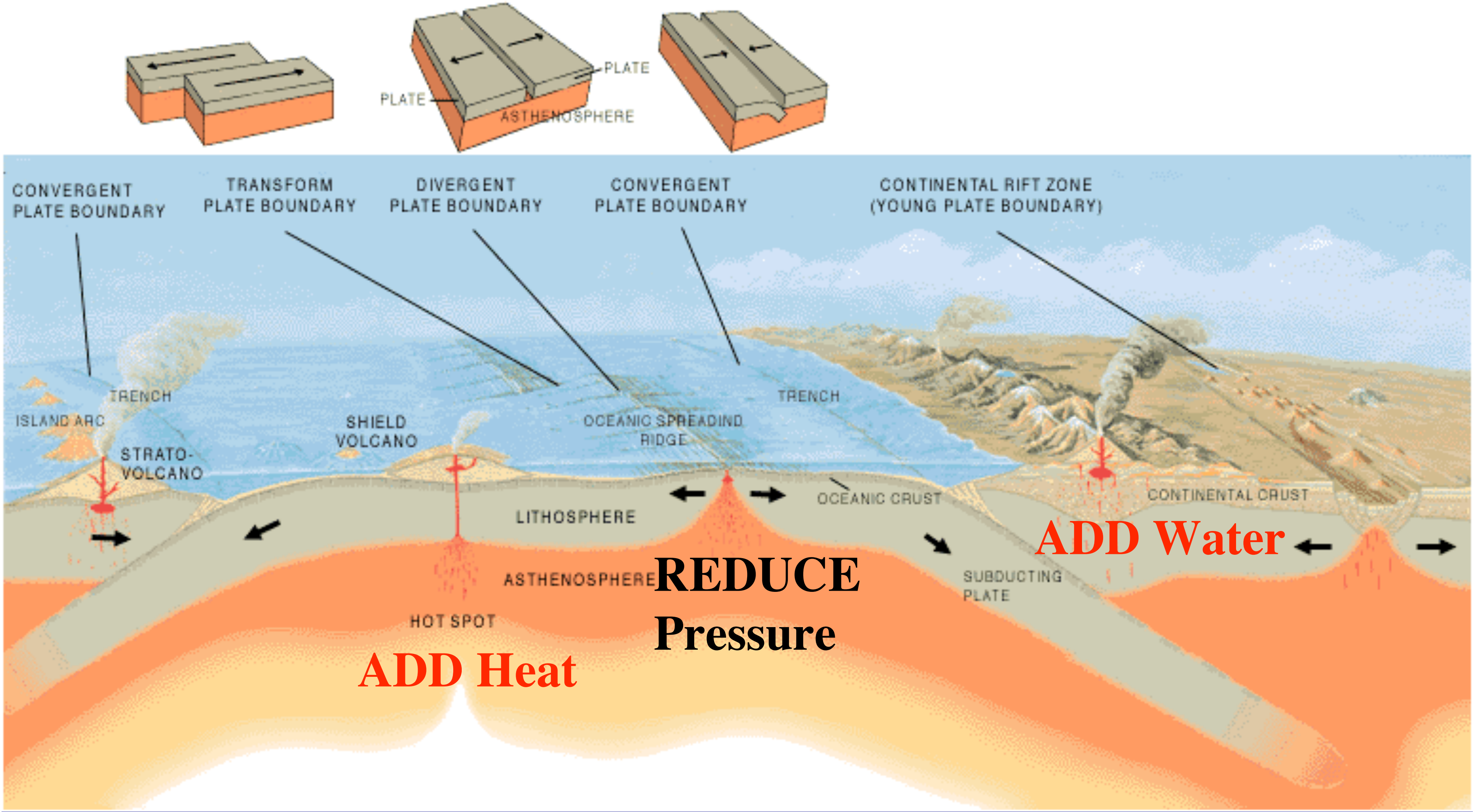
	Ultra-Basic	Basic	Intermed	Felsic	Intermed
	Peridotite	Basalt	Andesite	Rhyolite	Phonolite
SiO_2	42.26	49.20	57.94	72.82	56.19
TiO_2	0.63	1.84	0.87	0.28	0.62
Al_2O_3	4.23	15.74	17.02	13.27	19.04
Fe_2O_3	3.61	3.79	3.27	1.48	2.79
FeO	6.58	7.13	4.04	1.11	2.03
MnO	0.41	0.20	0.14	0.06	0.17
MgO	31.24	6.73	3.33	0.39	1.07
CaO	5.05	9.47	6.79	1.14	2.72
Na_2O	0.49	2.91	3.48	3.55	7.79
K_2O	0.34	1.10	1.62	4.30	5.24
H_2O^+	3.91	0.95	0.83	1.10	1.57
Total	98.75	99.06	99.3	99.50	99.23

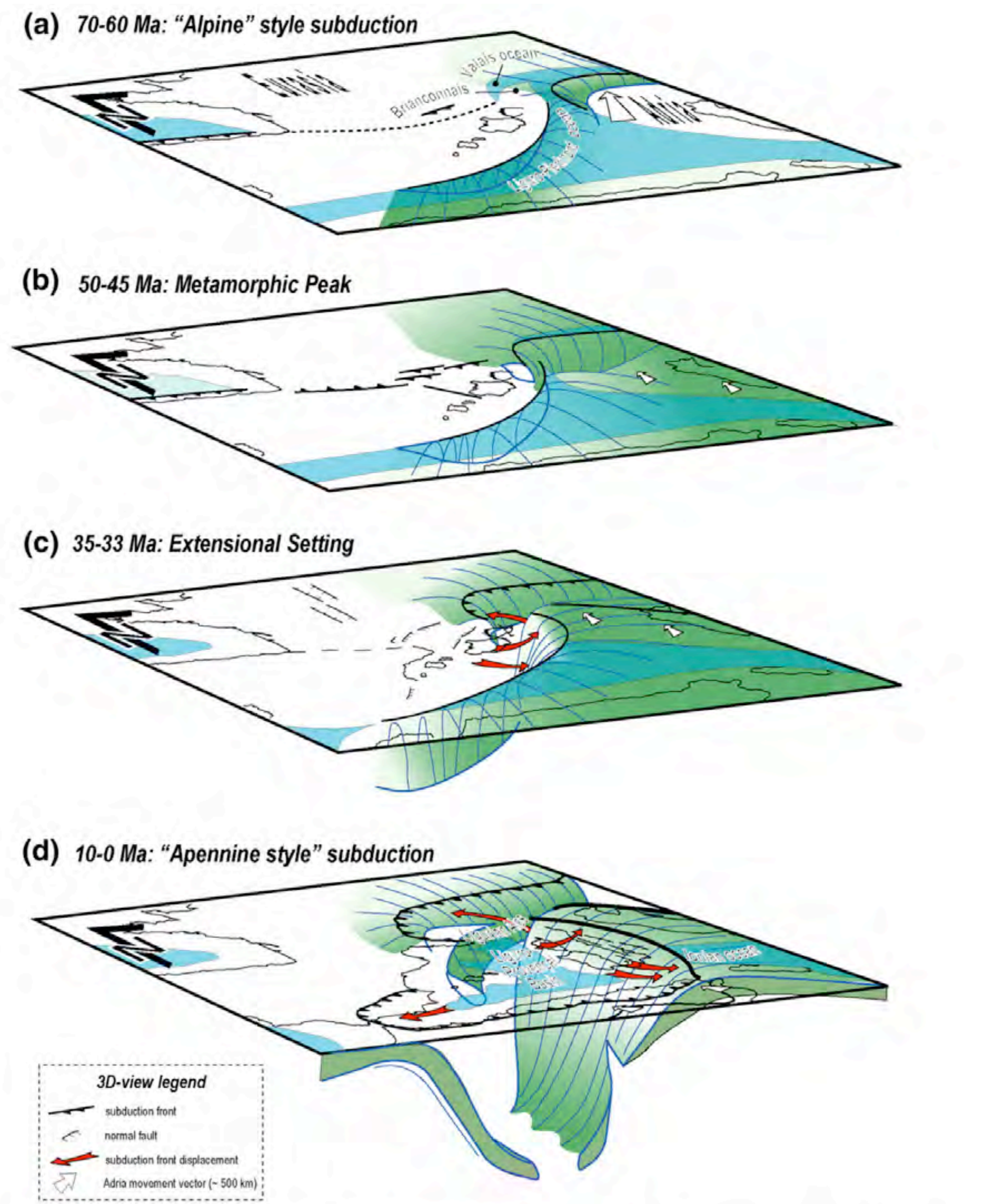
This slide from: www.whitman.edu/geology/winter/ Petrology/Ch%2008%20Major%20Elements.ppt

The beginning: How and where do we make igneous rocks?



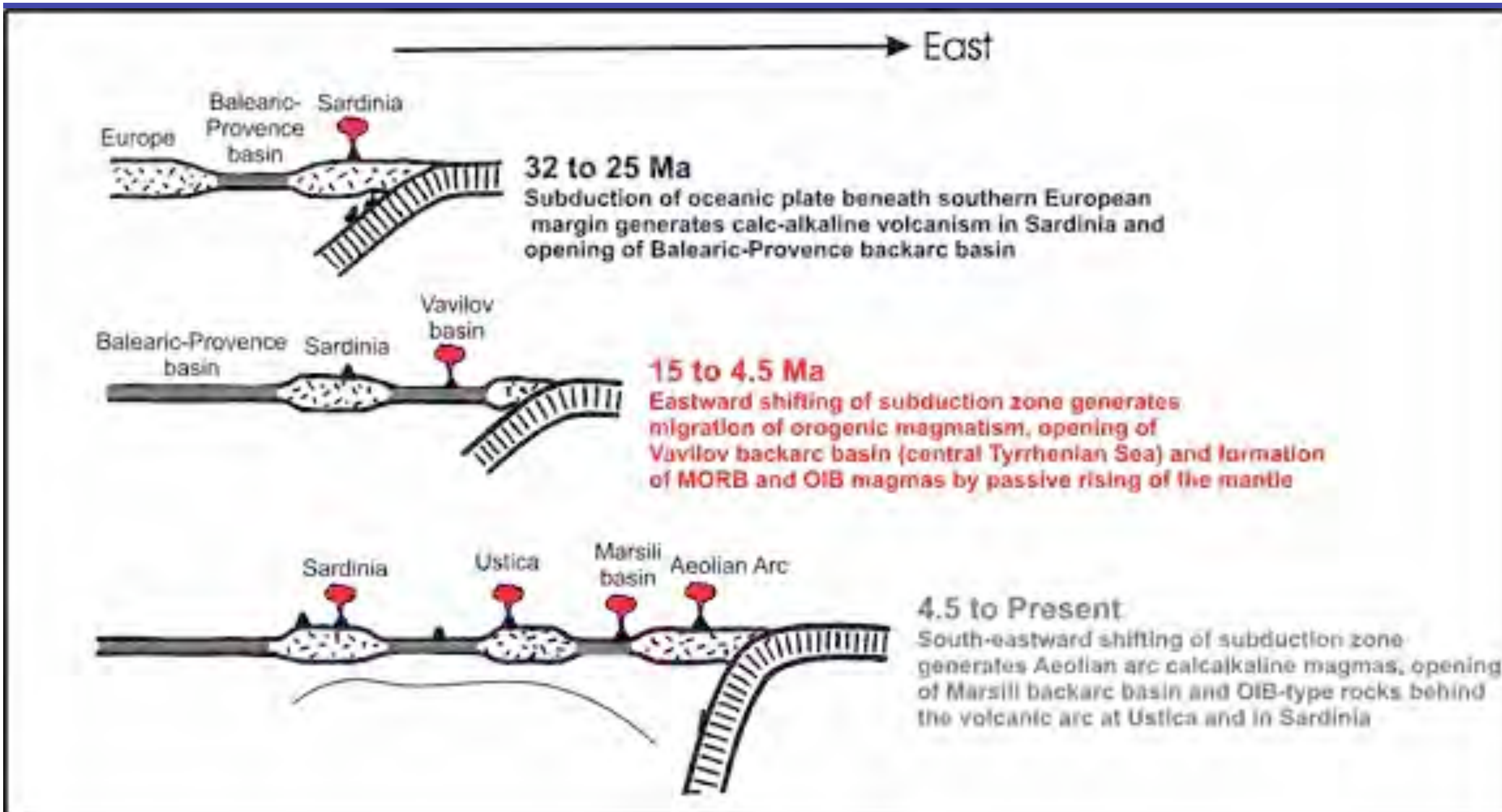
Magmatism begins with PARTIAL MELTING of the mantle.
It is easy: the mantle is very close to its partial melting point.





Vignarolli et al 2008

hematic 3D-view of the kinematic reconstruction of the Alps–Apennines belt system, showing as the two orogenic segments progressively separated and



http://www.mantleplumes.org/Italy2.html