Tephrochronology as a tool for active tectonics studies in peninsular Italy

Vesuvius. Camillo Ripaldi (2012)

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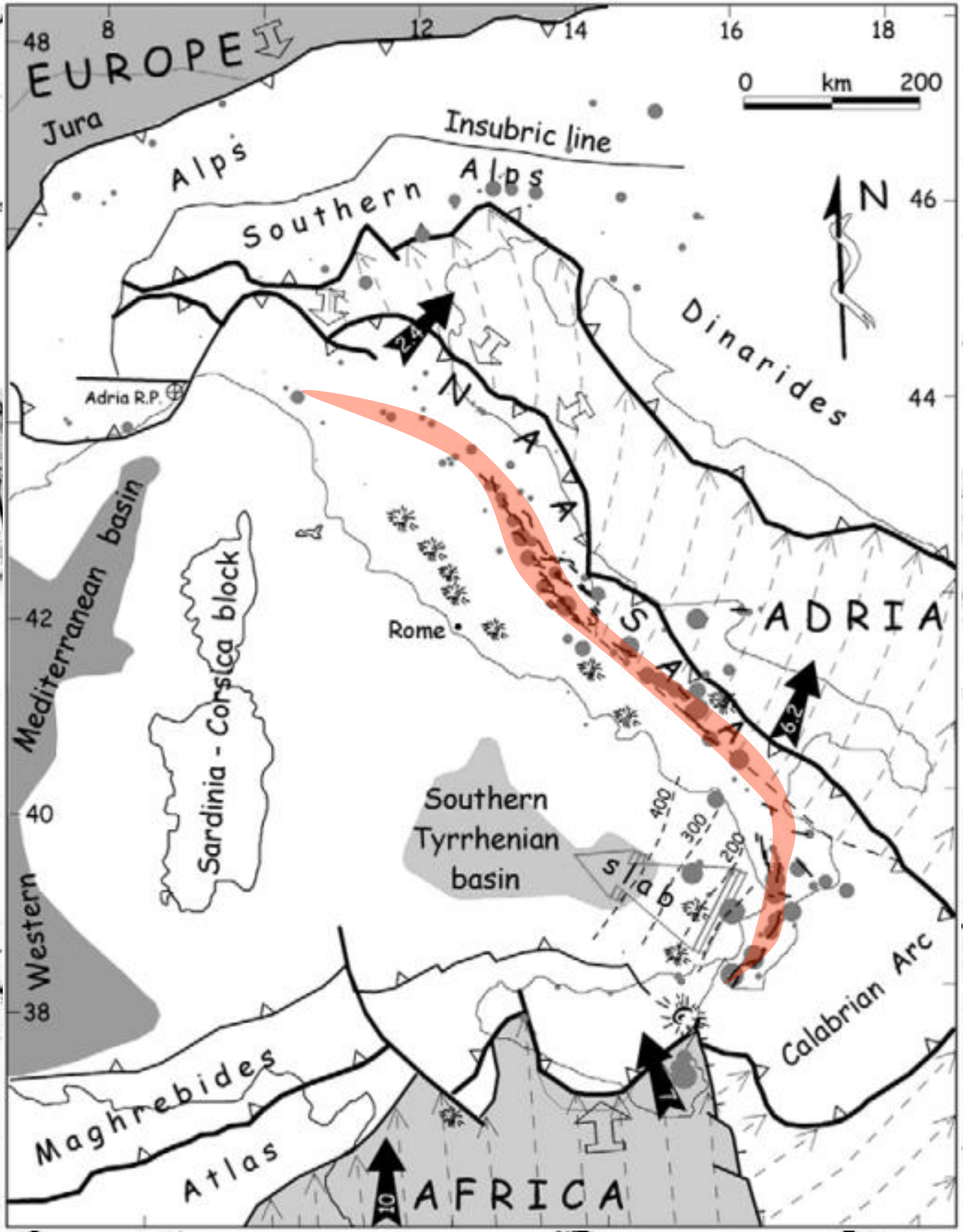
The study of the active tectonic is typically multidisciplinary. It in fact includes the application and integration of a number methodological approaches that provide with us knowledge and information on a series of spatial, temporal, and physical parameters that depict the architecture and the behavior of active and capable faults.

Among other, the chronological constraints are essential for evaluating:

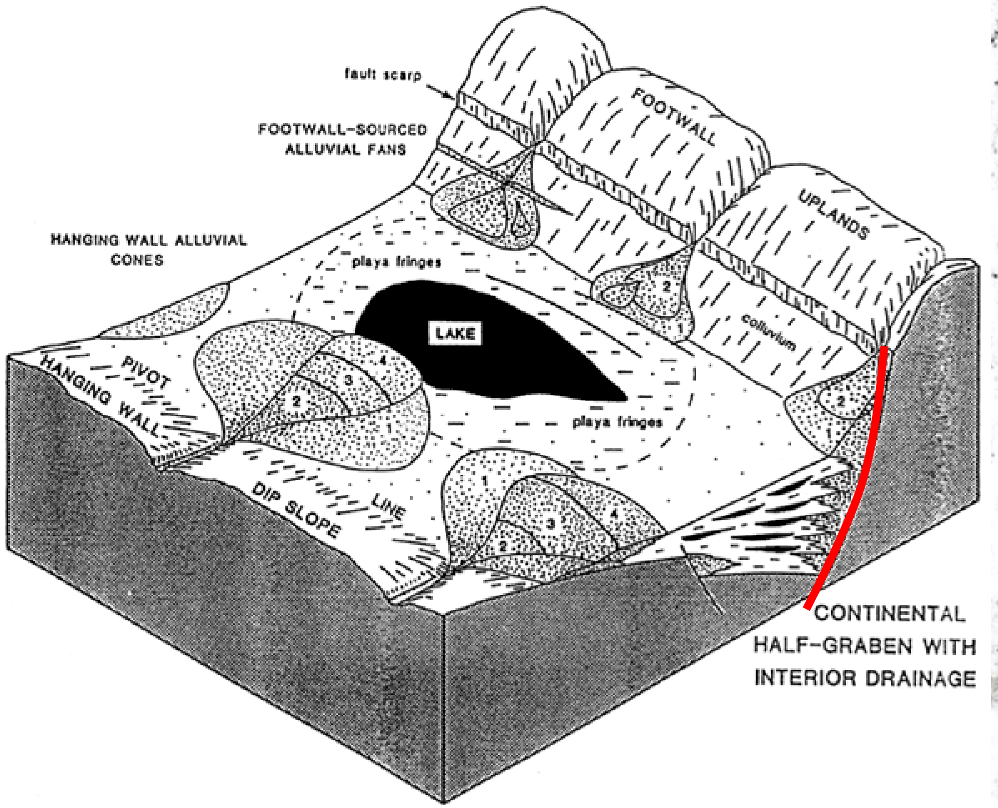
1) the general status of activity of a given structure,
2) its short- to long-term slip rate and its changes through time;
3) time recurrence of the fault ruptures;

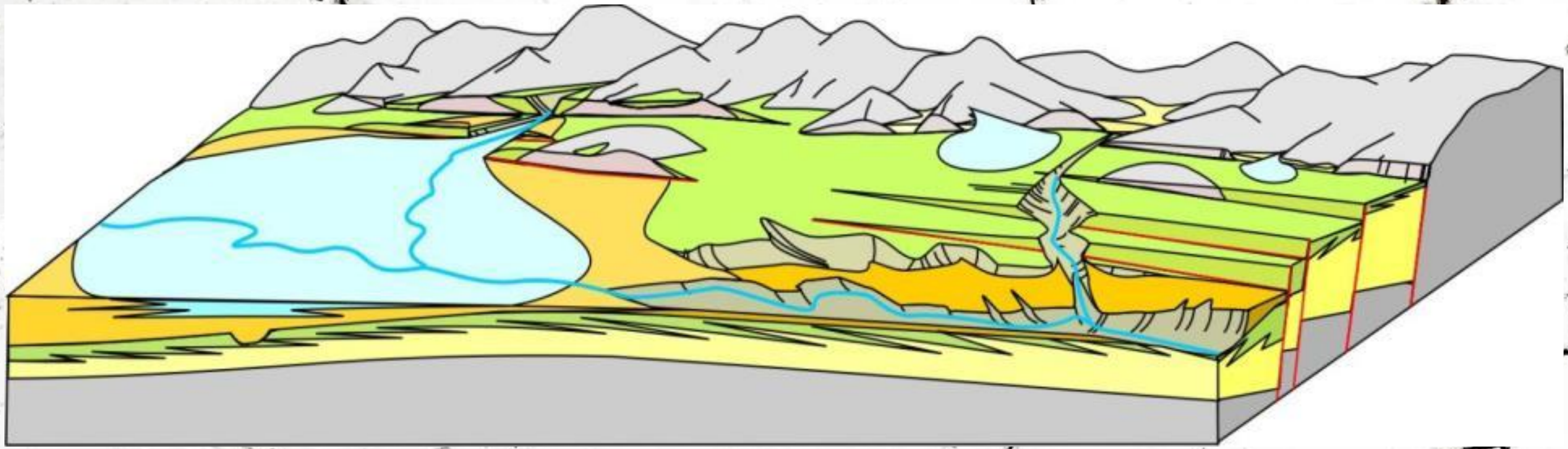
In the framework of the Mediterranean geodynamic, most of the Italian active and seismogenetic faults are located along the axis of the Apennine chain.



The Apennine active faults often bound and drive the evolution of continental sedimentary basins hosting thick alluvial-fluvial-lacustrine successions.

The investigation and dating of this sediments is thus vital for studying the recent active tectonic. However, until recently these sediments were hardly datable and beyond the applicability limit of the radiocarbon (i.e., c. 40 ka), the chronological framework of the continental deposits were essentially relied on assumptions and qualitative regional cross correlations.
The recent development of the tephra study in Central Mediterranean however is changing this frustrating circumstance.

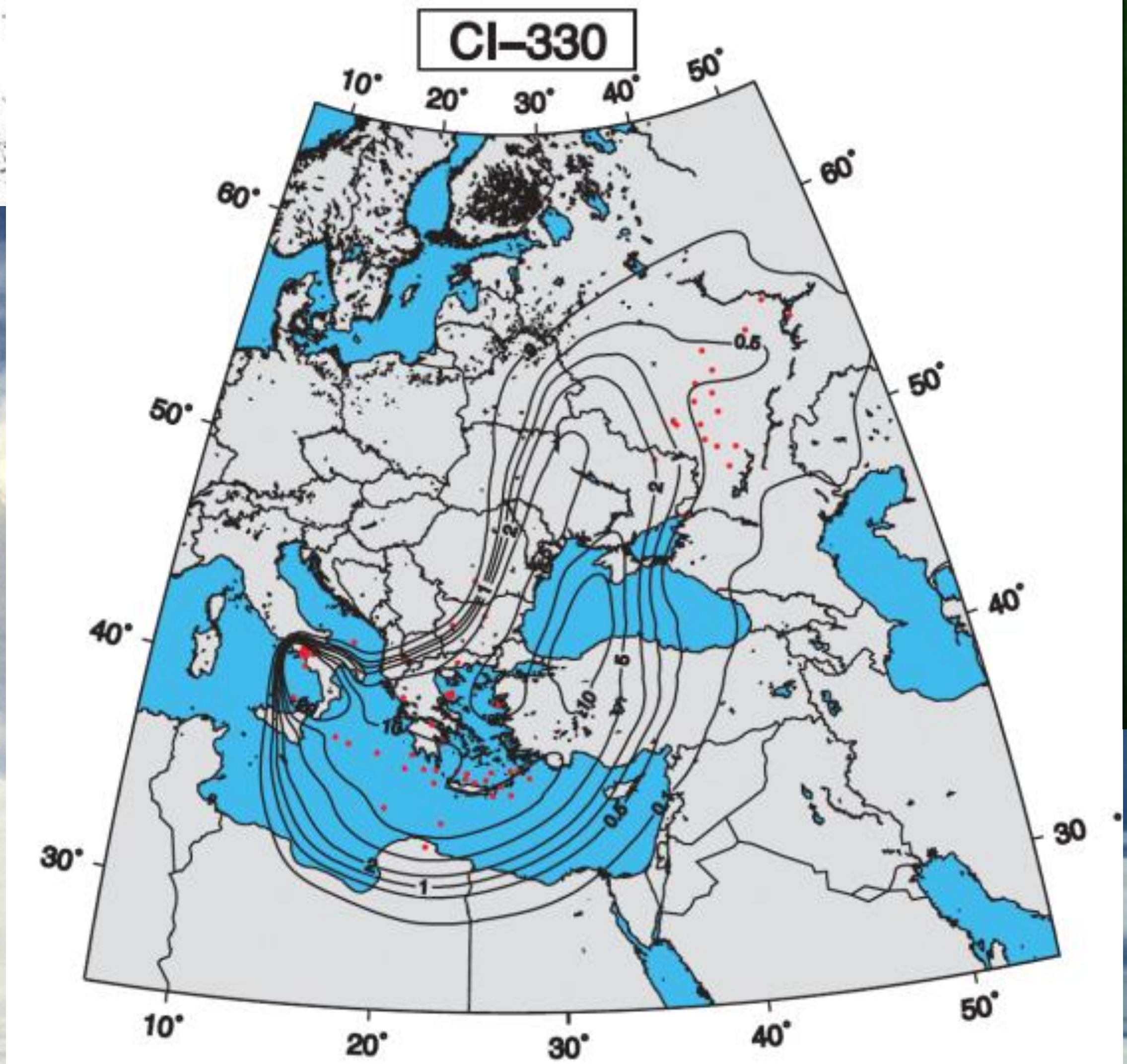




During explosive eruption Plinian or co-ignimbrite clouds can rise to tens of kilometers into atmosphere. The volcanic particles can be then transported by wind up to thousands of kilometers from the source and finally synchronously deposited as tephra layers in different sedimentary settings.

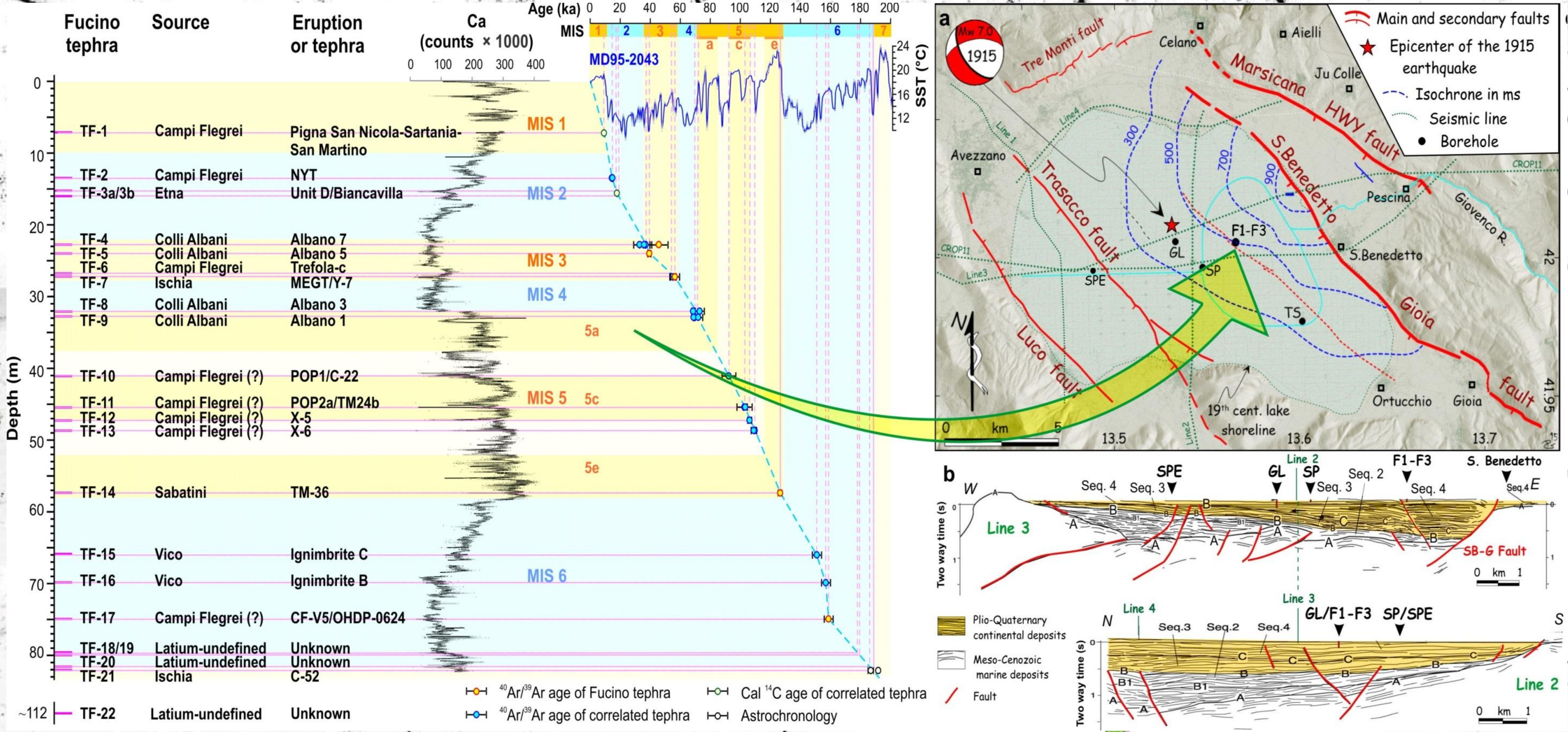
On the western side of the backbone of the Italian peninsula are in fact located a number of volcanic centers that were characterized by an intense explosive volcanic activity.

Until some years ago the most common answer would have been not! But the recent development in tephra study allow now to answer, yes, maybe, let us see what we can do.



What we can do?

The tephrochronological method consists in determining the peculiar geochemical features, a kind of chemical fingerprinting, that allow an unambiguous recognition and tracing of tephra layers in different

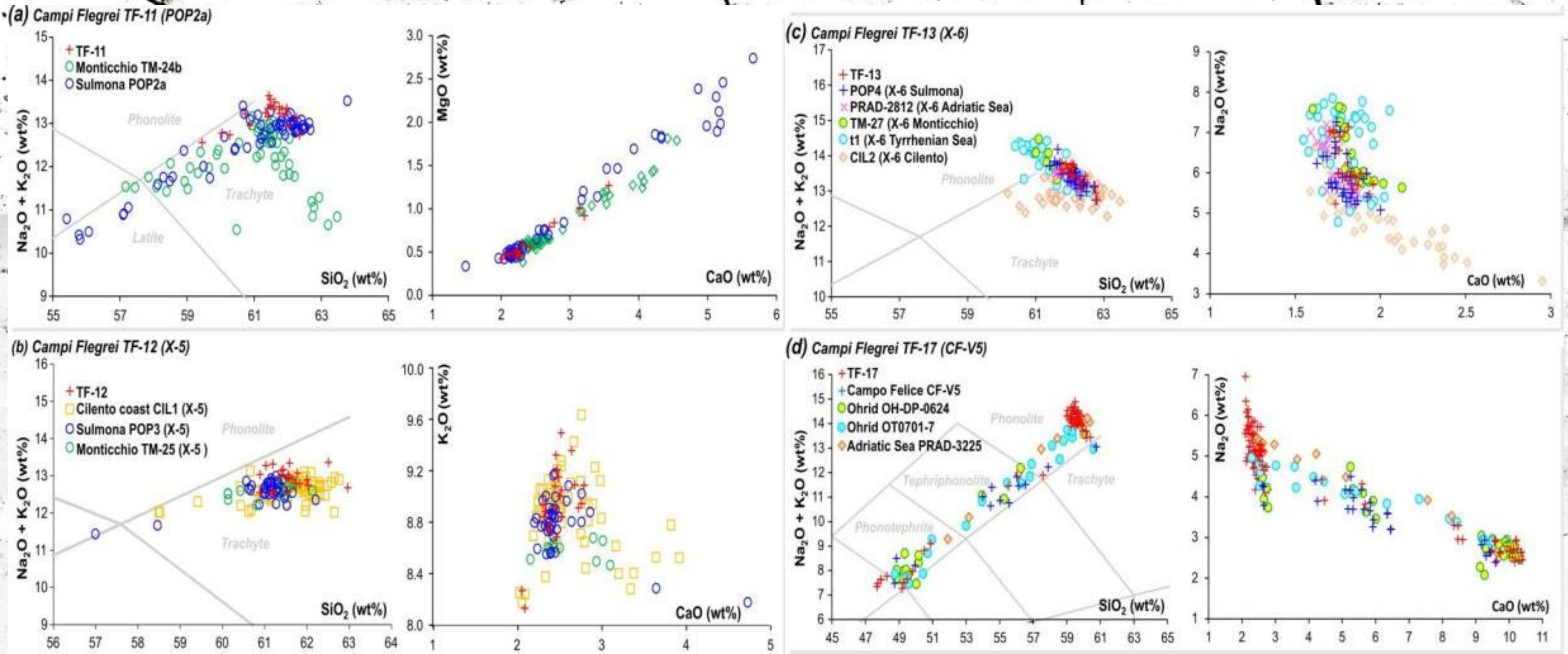


The primary geochemical fingerprinting, on which we base the tephra recognition, is the major element composition of the glass determined by electron microprobe analysis.

This analysis provide the composition of the glass in terms of oxides of several elements

Unit	Tufo Pisolitico di Trigoria								Tufo di Bagni Albule							
Setting	Carapelle (site 1)[a]			Colli Albani[a]			Acerno (site 14)[h]		Sulmona (site 2)[b]			Oricola (site13)[e]			Colli Albani[c]	
Population	a			a			a		a			a			a	
N° analyses	11	s.d.		6	s.d.				27	s.d.		7	s.d.		7	s.d.
SiO_2	43.77	0.36		43.17	0.18		43.91		44.73	1.18		45.62	0.70		45.74	0.85
TiO_2	1.10	0.02		1.19	0.02		1.28		0.82	0.10		n.d.	0.00		0.76	0.12
Al_2O_3	16.89	0.33		16.37	0.24		16.73		19.48	0.71		19.03	0.33		19.16	0.15
FeO	10.08	0.29		10.47	0.28		10.04		8.17	0.79		8.36	0.52		7.80	0.21
MnO	0.31	0.02		0.31	0.04		0.26		0.36	0.05		0.32	0.04		0.30	0.04
MgO	3.32	0.09		3.32	0.23		3.29		1.45	0.14		1.54	0.13		1.40	0.06
CaO	12.30	0.39		12.97	0.08		12.35		10.90	1.18		11.53	0.73		10.20	0.50
Na_2O	5.00	0.12		5.35	0.19		6.04		5.59	0.65		4.95	0.30		5.49	0.29
K_2O	6.66	0.17		6.34	0.09		6.1		8.31	0.91		8.42	0.79		8.93	0.31
P_2O_5	0.57	0.09		0.52	0.07		n.d.		0.18	0.03		0.23	0.04		0.21	0.04
F	0.51	0.07		0.69	0.10		n.d.		0.85	0.21		0.13	0.05		0.86	0.15
Cl	0.17	0.03		0.18	0.02		n.d.		0.18	0.03		0.13	0.02		n.d.	
SO_3	0.63	0.23		0.69	0.05		n.d.		0.75	0.27		0.80	0.11		0.85	0.10
Original	96.83	0.81		96.09	0.34				96.73	1.34		95.56	1.07		98.02	0.76
K_2O/Na_2O	1.33	0.02		1.19	0.22		1.01		1.53	0.41		1.70	0.18		1.63	0.13

Although the classical classification diagrams (e.g. Total Alkali Silica, TAS) commonly do not allow an easy and unambiguous discrimination, by plotting these compositional data in different covariant diagrams, we are able to evidence more precisely analogies and differences among tephra, and thus often to correlate the investigated layer to a specific proximal or distal dated counterpart.

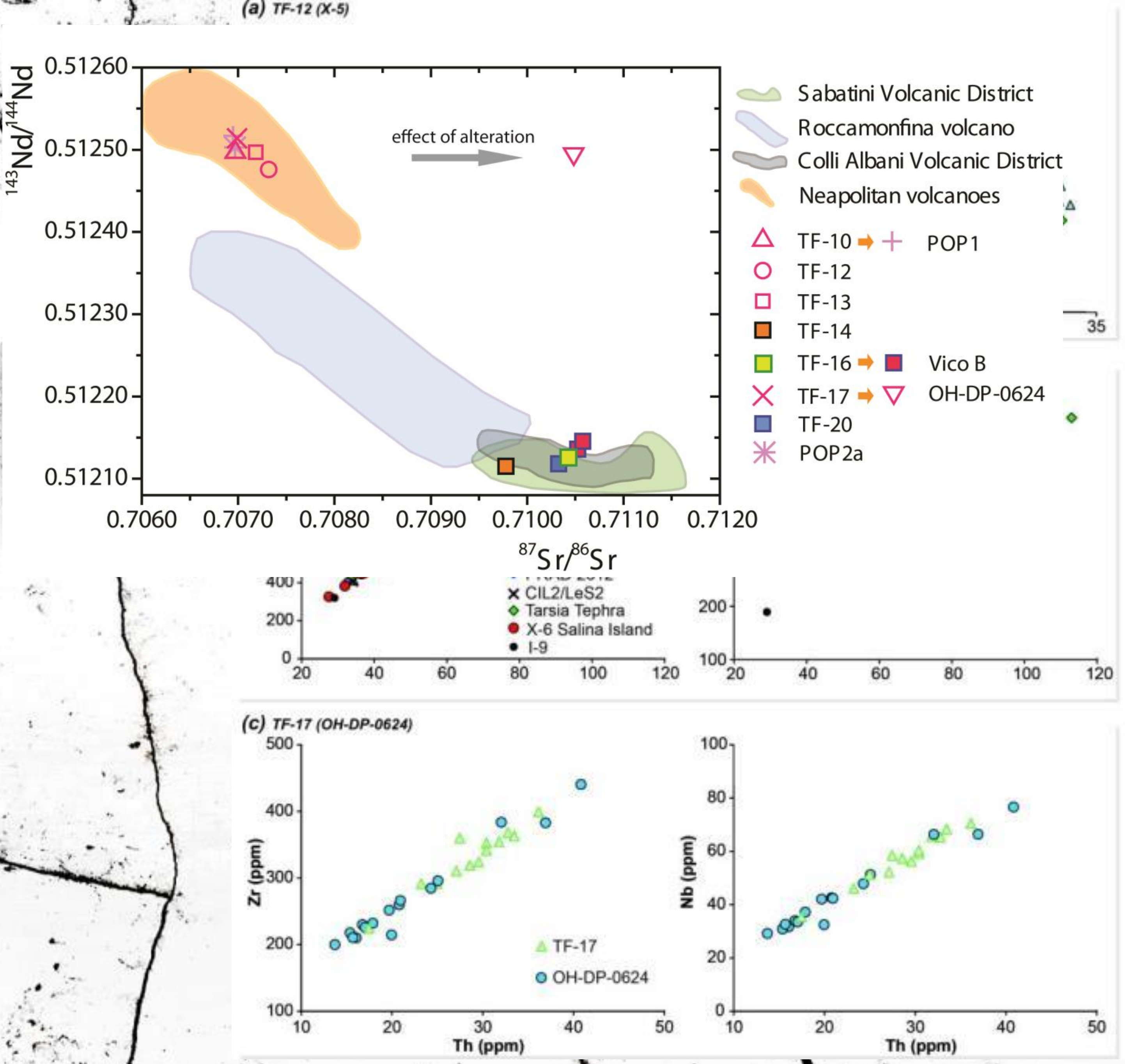


Other important integrative geochemical analyses comprise:

Trace element glass composition acquired by Laser Ablation Inductively Couple Plasma Mass Spectrometry

Sr-Nd isotope analyses on mineral and/or glass phases

Major and trace elemental analyses on mineral phases

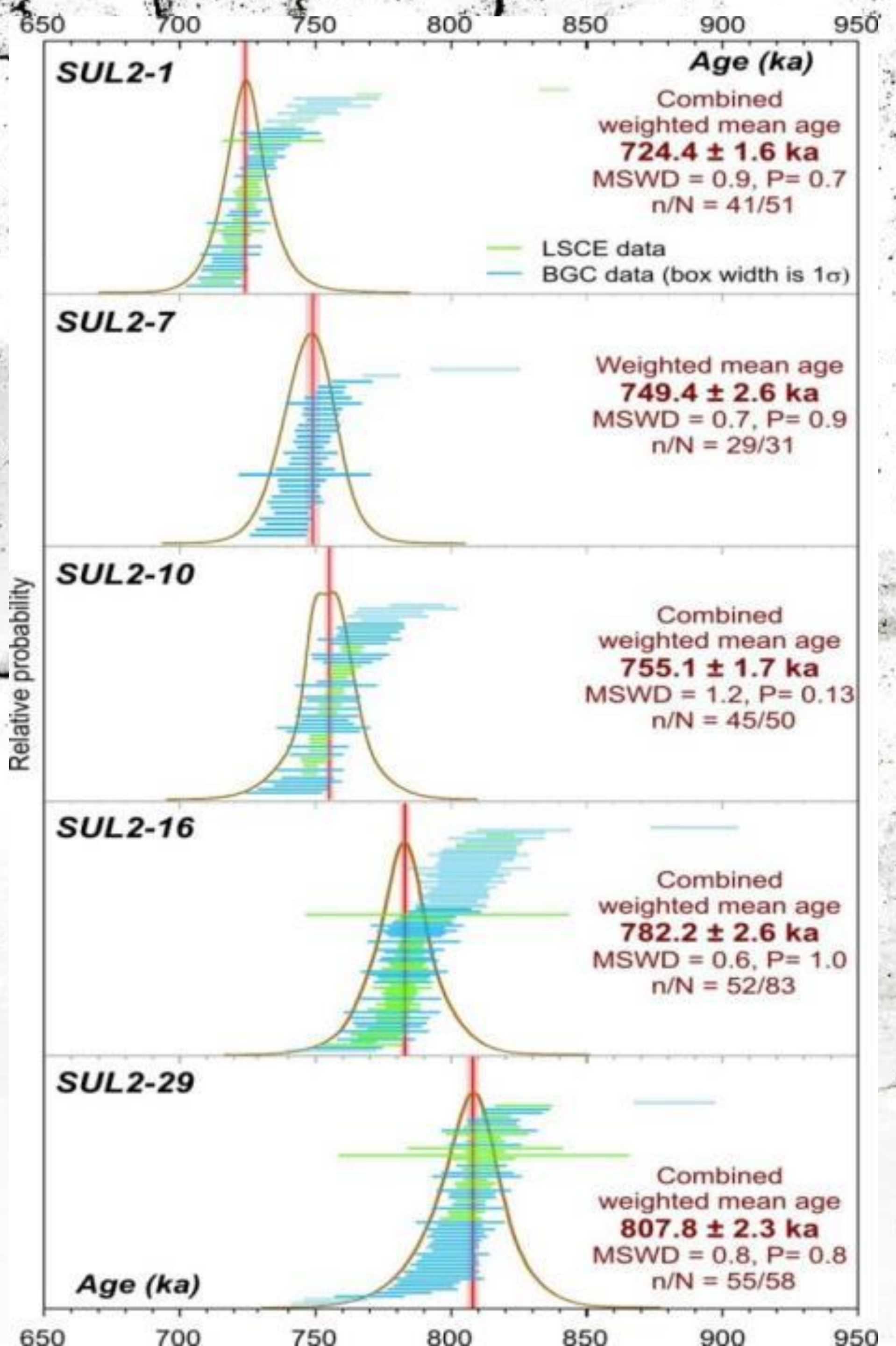


All these analyses provide indications for the indirect dating of tephra, i.e., they allow to assign the age of an eruptive unit dated elsewhere, in proximal volcanic or distal setting

The recent development of the sensitivity of the last generation of the mass spectrometers, allows however also the direct dating of tephra by 40Ar/39Ar single crystal fusion method.

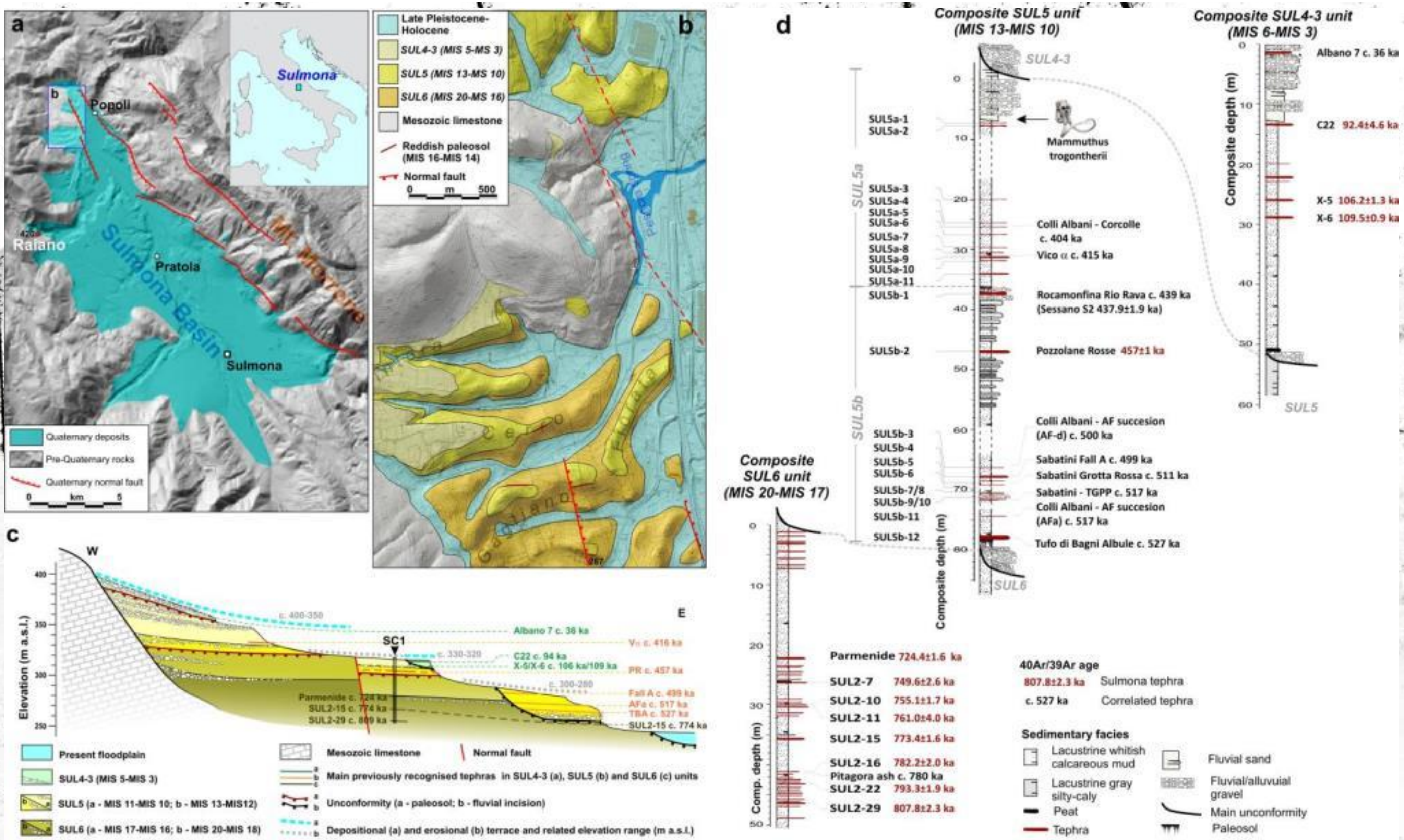
The high sensitivity allows the application of the method also on very fine K-rich crystal (100 micron or less). The accuracy, precision and reproducibility of the ages obtained with this method is really high, and its application on distal setting is becoming a routine, indispensable procedure.

Indeed, the combination of the indirect, based on geochemical fingerprinting, and of the direct 40Ar/39Ar dating is recently enormously improved the tephrochronology as robust and reliable geochronological tool.



Study cases in Central and Southern Apennine: Sulmona basin

The Sulmona tectonic basin is boubed to east by the Mt. Morrene Fault system and its infill contain one of the most rich and well-studied tephra succession with tens of layers dated directly and indirectly dated between 800 and 14 ka.

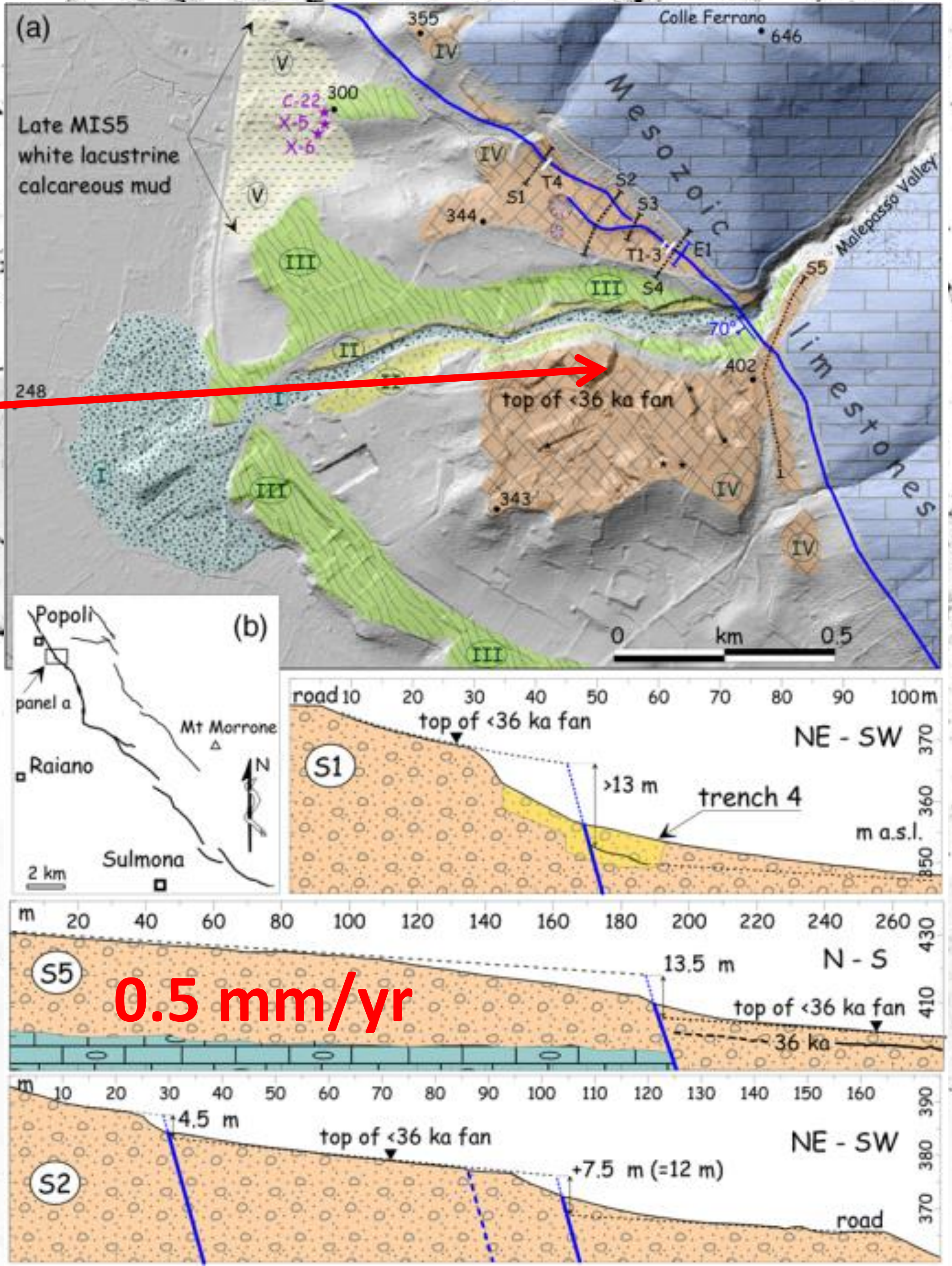


Study cases in Central and Southern Apennine: Sulmona basin

The Mt. Morrone Fault crosses and displaces the apical portion of an alluvial fan system contain at its top a peculiar bleakish reworked tephra layer.

Its chemically composition matches that of the glass from the most recent eruption of the Colli Albani dated to c. 36 ka.

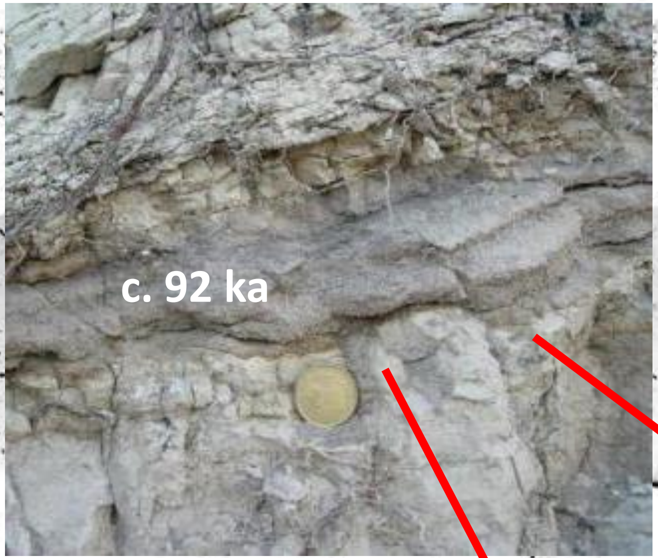
This widely dispersal tephra allowed thus date the top of the alluvial fan and to evaluate the slip rate of the fault system over the last 36 ka.

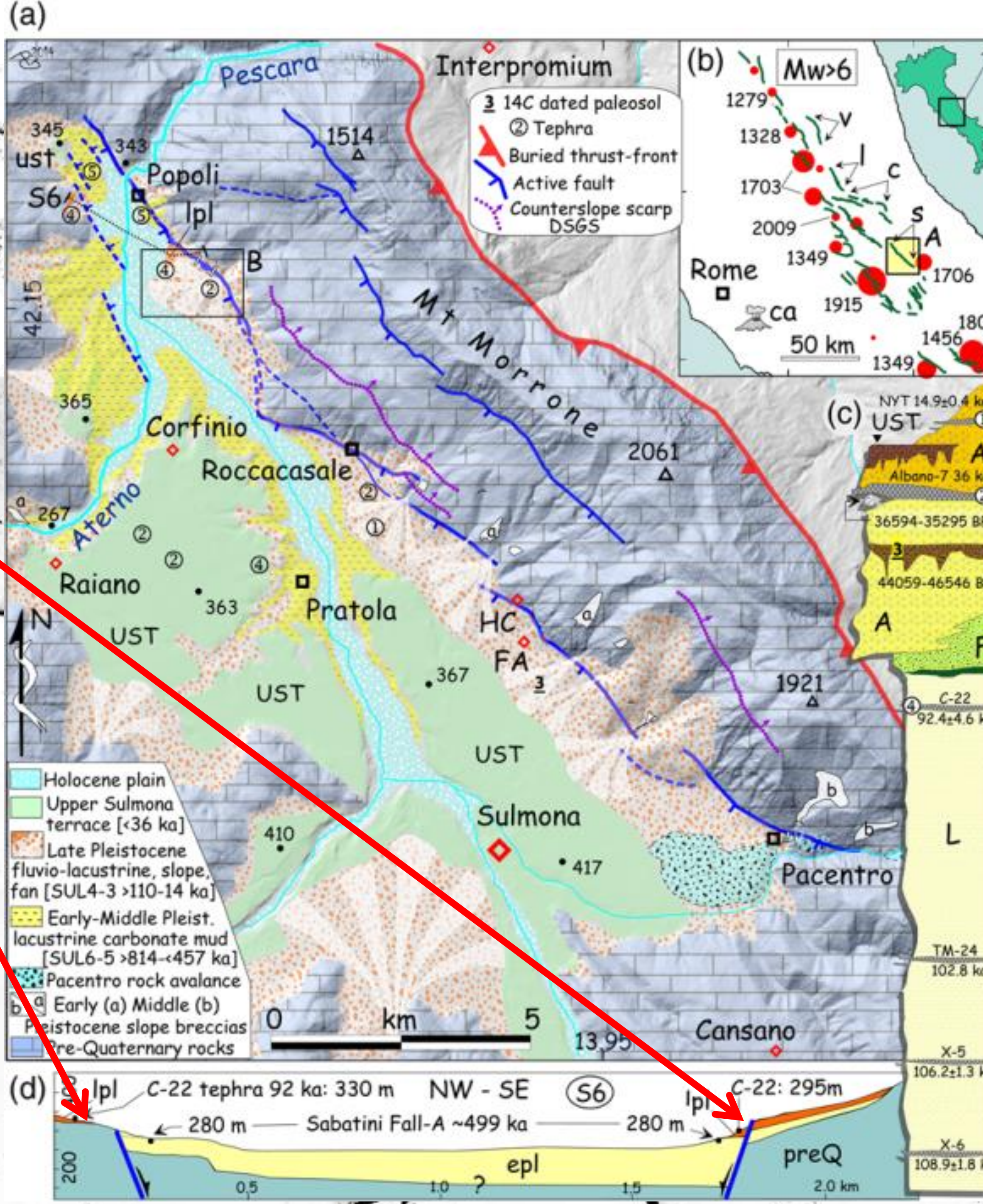


Study cases in Central and Southern Apennine: Sulmona basin

Again in Sulmona basin, the recognition of a the C-22 tephra, a Tyrrhenian marker dated at Sulmona at c. 92 ka, in lacustrine sediments on the footwall and hanging-wall of the fault

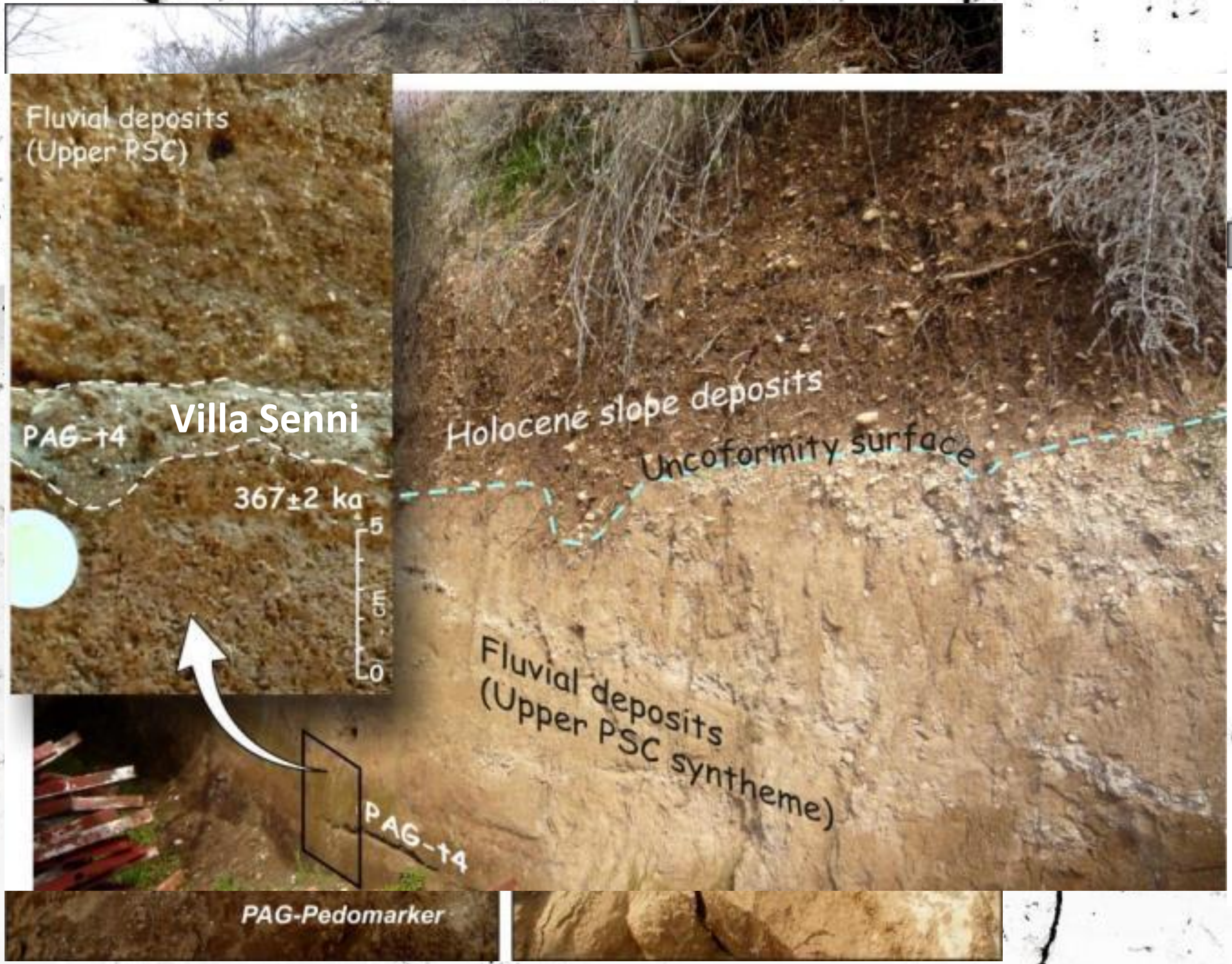
allowed to extend the evaluation of the slip rate back to 92 ka, which resulted again on the order of c. 0.5 mm/yr

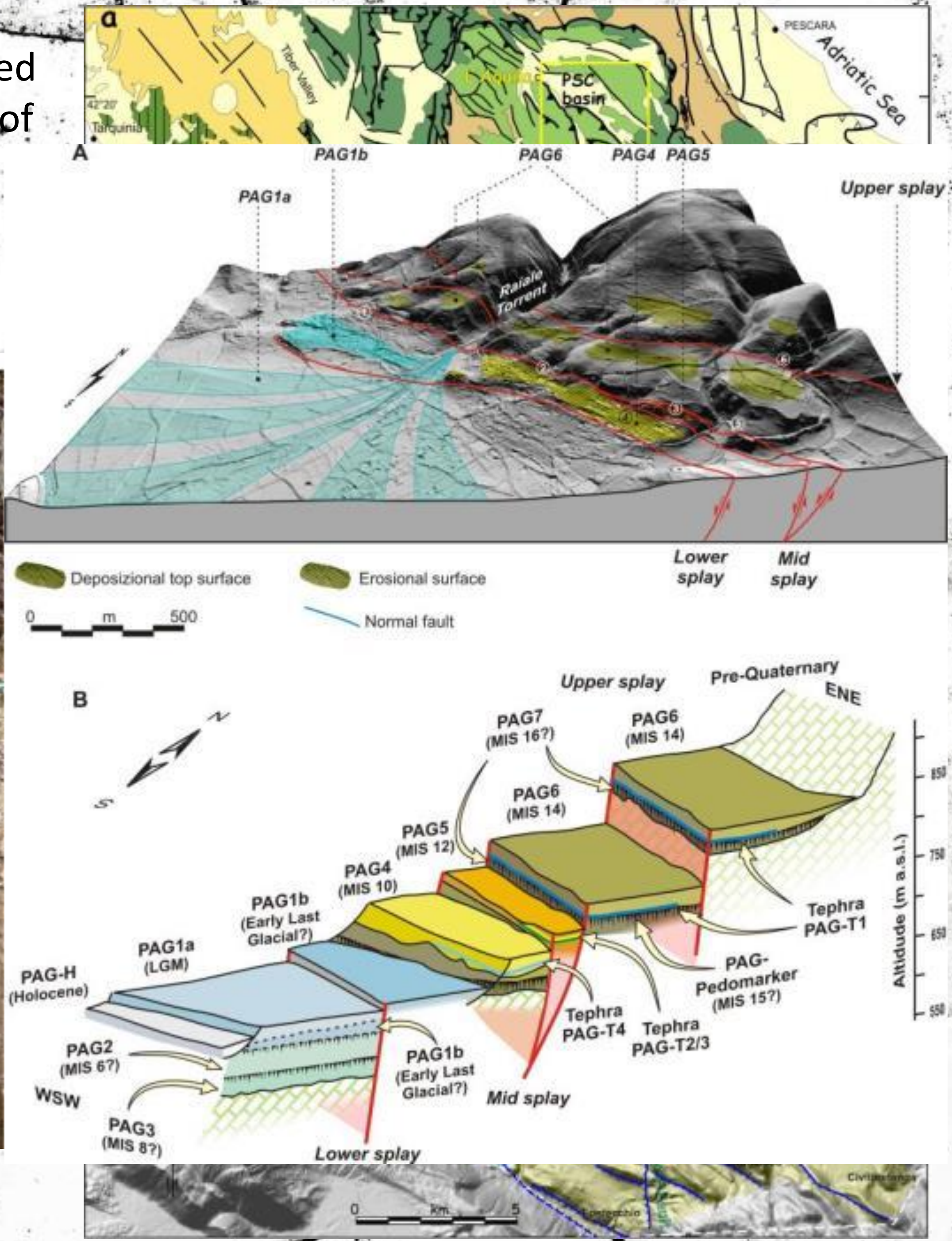




0.5 mm/yr

In the area of the 2009 L'Aquila earthquake, the identification of several Middle Pleistocene tephra in the sedimentary infill of the basin, provided fundamental chronological constrain to evaluate the long-term slip rate of the fault system and the overall Quaternary tectonic-sedimentary evolution of the basin.



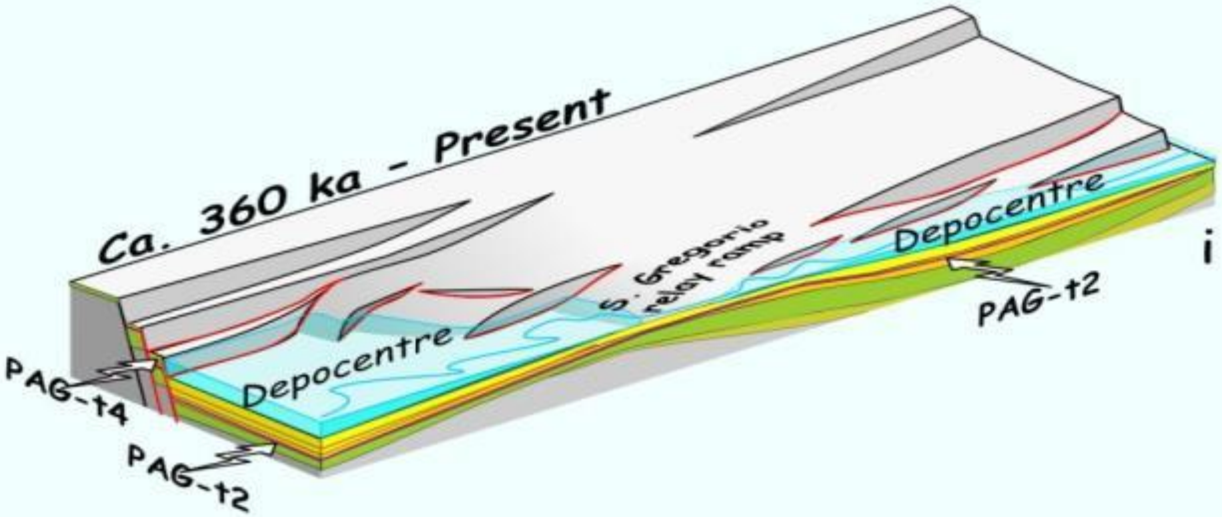


Overall Quaternary tectonic-sedimentary evolution of the Paganica-Castelnuo-San demetrio basin.

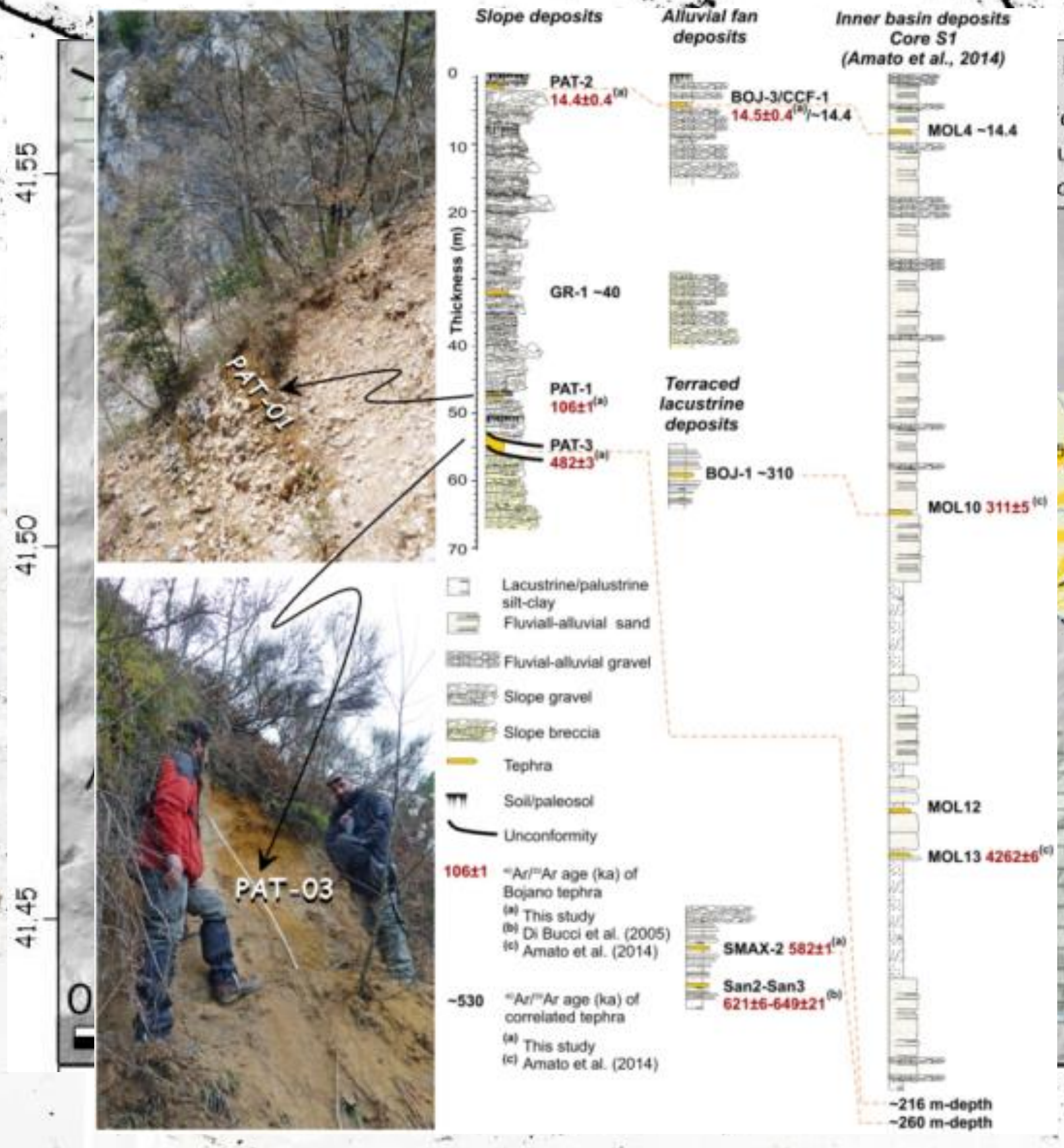
Ca. 360 ka-Late Pleistocene

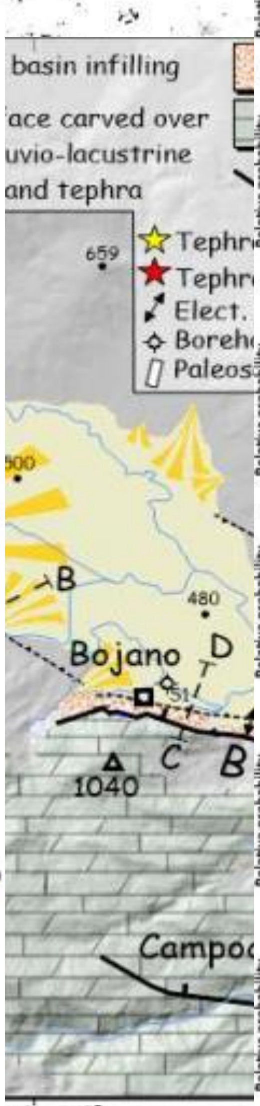
Persisting prevalence of the fault activity along the the Paganica-San Gregorio segment.

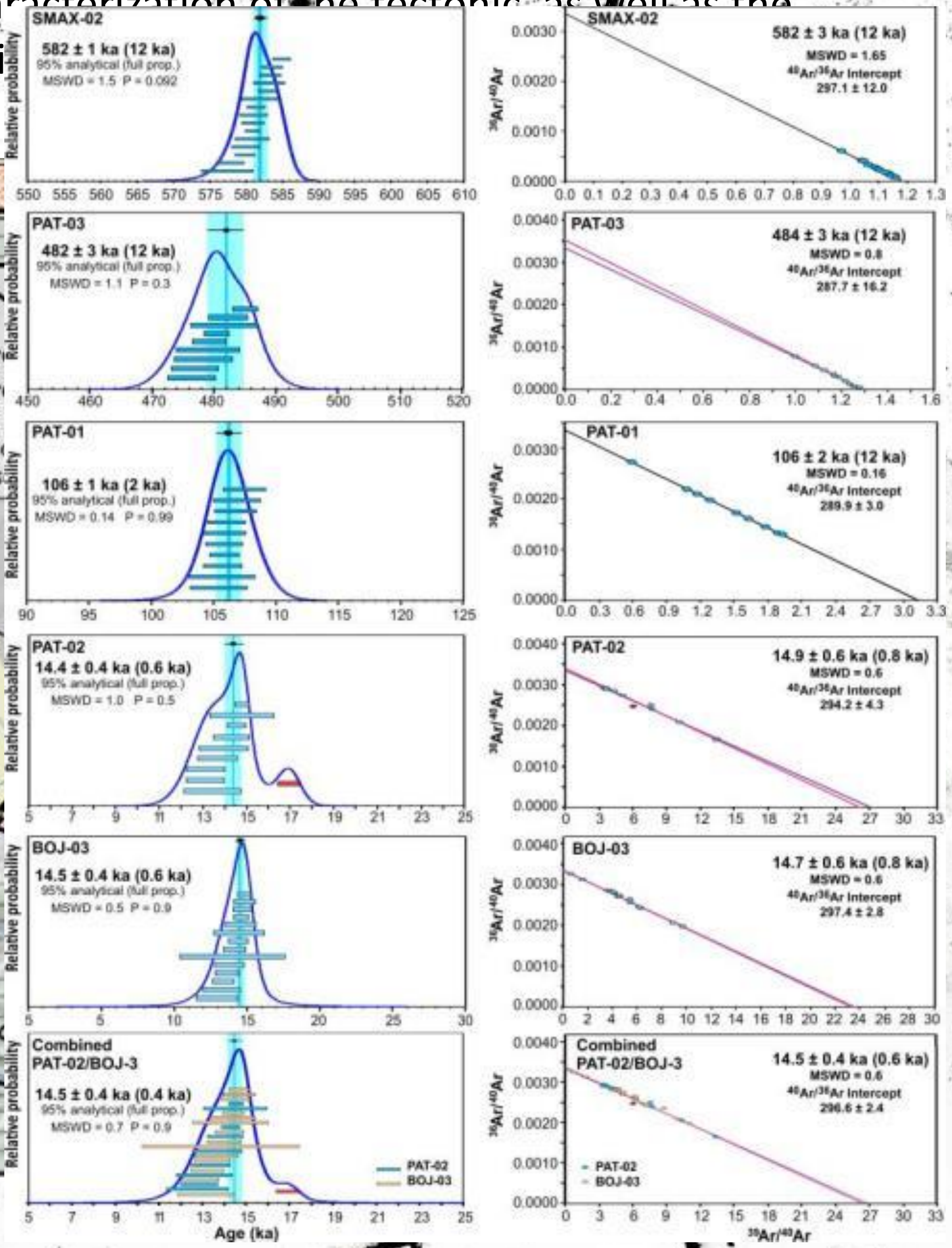
Deposition of the late alluvial fan complex. Furtehr denutation of the *San Mauro* basin.



Finally, in Bojano basin, southern Italy, the recognition of several tephra layers spanning the wide temporal interval of c. 580-14 ka, most of which directly dated by Ar/Ar method, allowed the characterization of the tectonic, as well as the associated Bojano basin sedimentary-tectonic evolution since the early Mi







The tephrochronological constraints, evidenced an uneven rate and distribution of tectonic strain for the fault segments composing the ~28 km-long N-Matese fault system over time. After a strong tectonic activity occurred after ~580 ka along the presently buried fault segments bounding the Bojano plain, at least since 310 ka slip rates progressively decreased, dying out during the Late Glacial-Holocene. Conversely, the piedmont fault system, running paralleling the northern Matese flanks, after the slowdown of its activity during the 480-110 ka time span, restarted, with a consistent slip rate >0.5 mm/yr and up to >1 mm/yr, at least for the last 110 kyr.