

Origin and metamorphic reworking of the **Buca della Vena Tl-rich orebody (Alpi Apuane)**

This research was supported by
MIUR-SIR 2014 project "THALMIGEN"



Foto N. Hobbs

Simone Vezzoni - vezzoni@dst.unipi.it

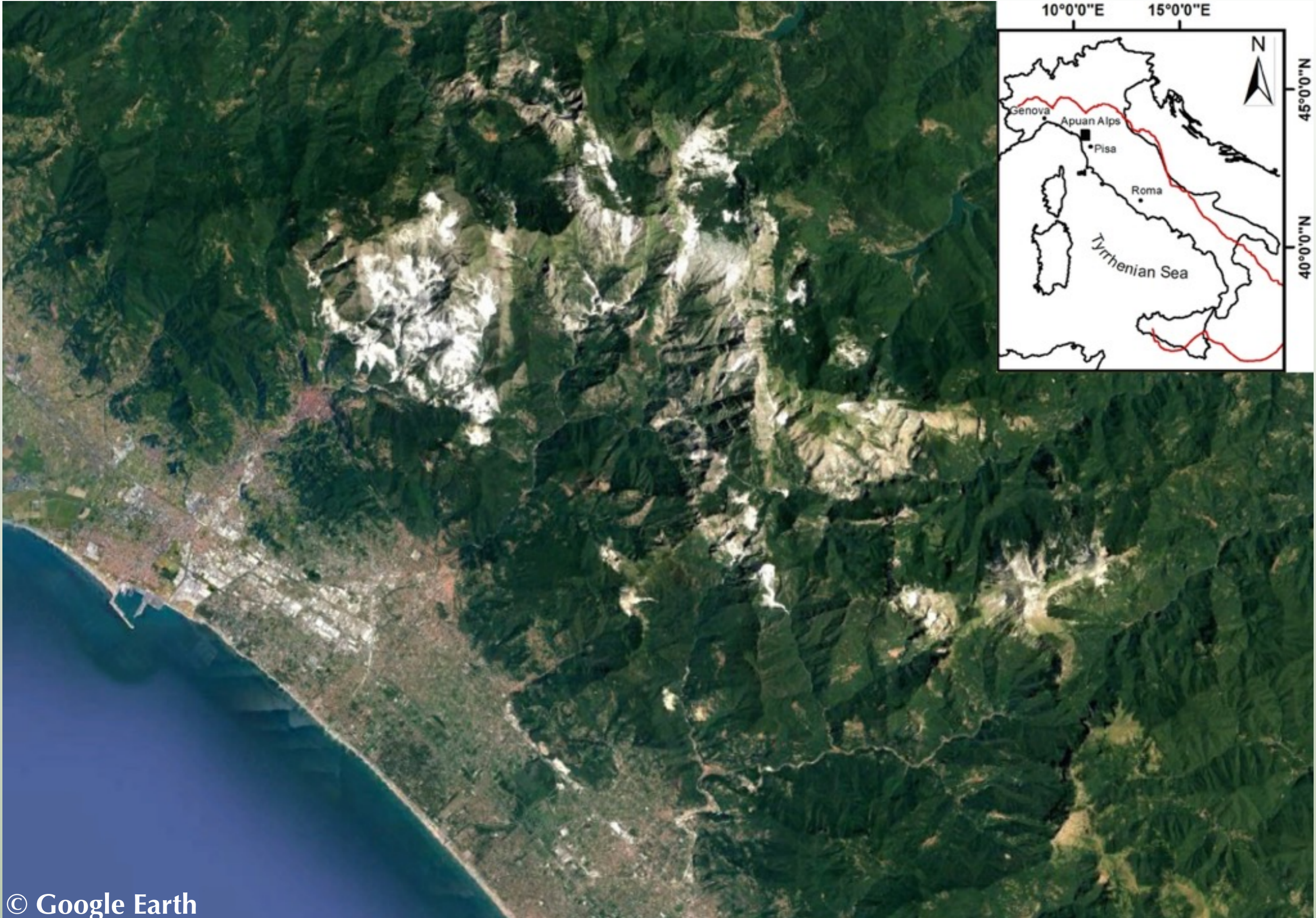
D. Pieruccioni, A. Dini, G. Molli, C. Biagioni



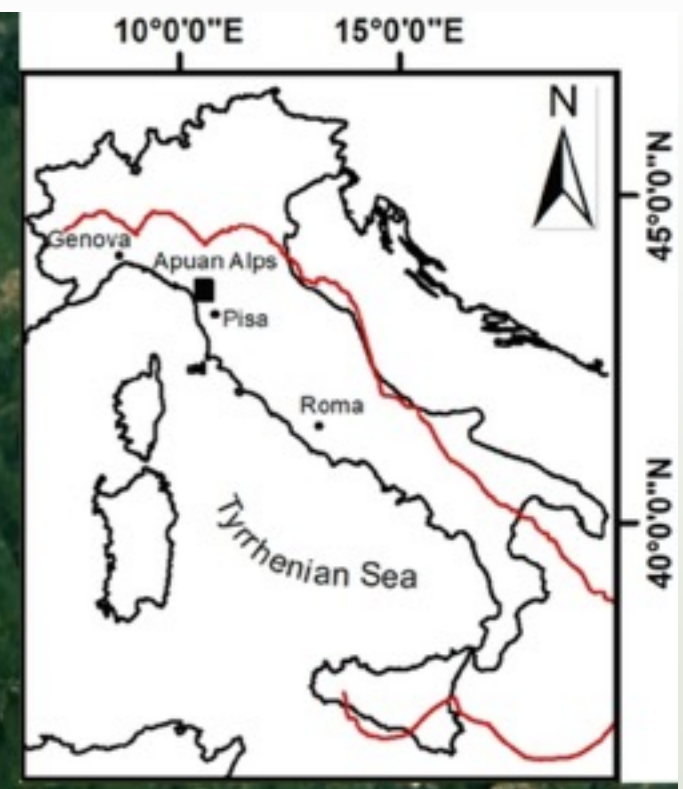
DIPARTIMENTO DI SCIENZE DELLA TERRA

UNIVERSITÀ DI PISA

Alpi Apuane



Alpi Apuane



Buca della Vena
■

Buca della Vena

Main features (pre-2007)

Size:

180000-300000 t

Mineralogy:

baryte+Fe-oxides±pyrite

Mining activity:

XV? - end of the '80s



Photo: L. Tinagli

Buca della Vena

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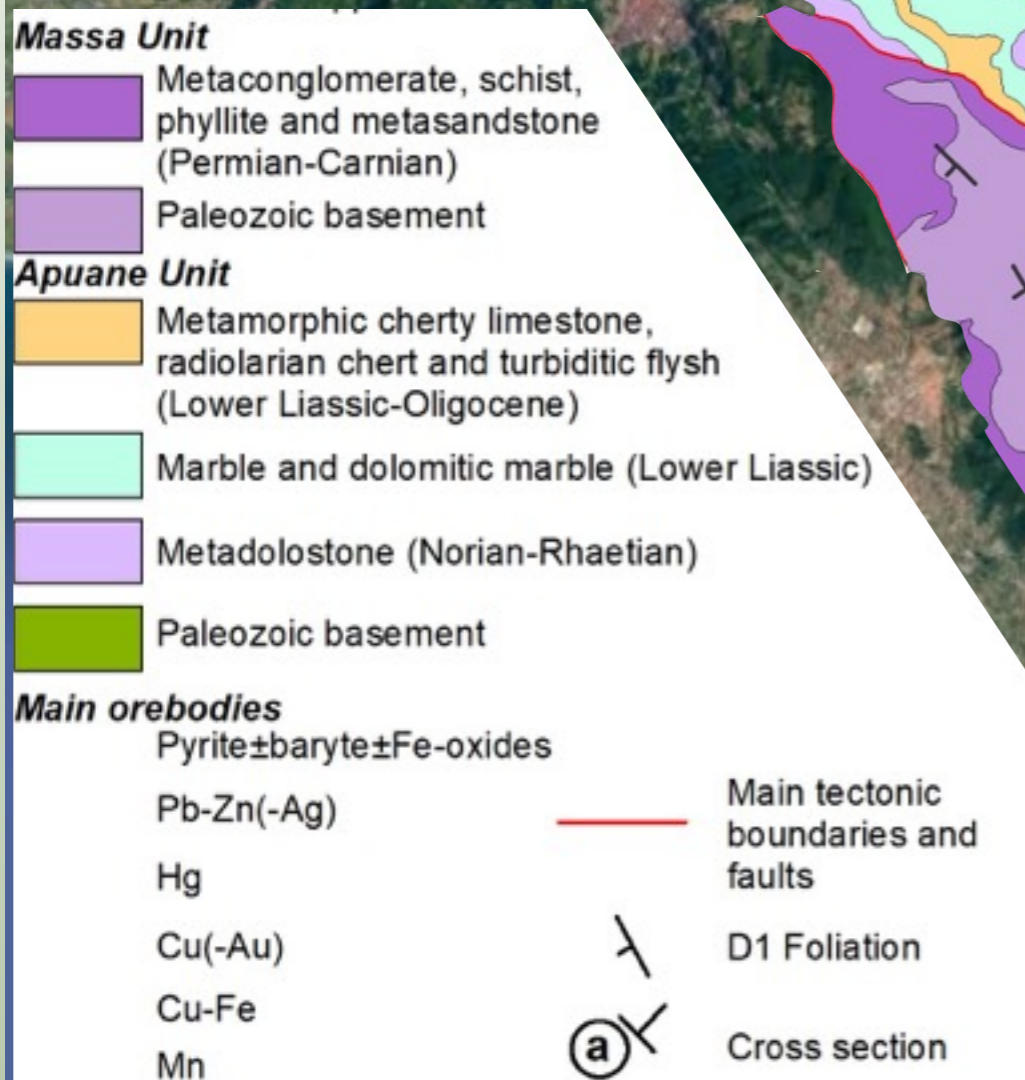
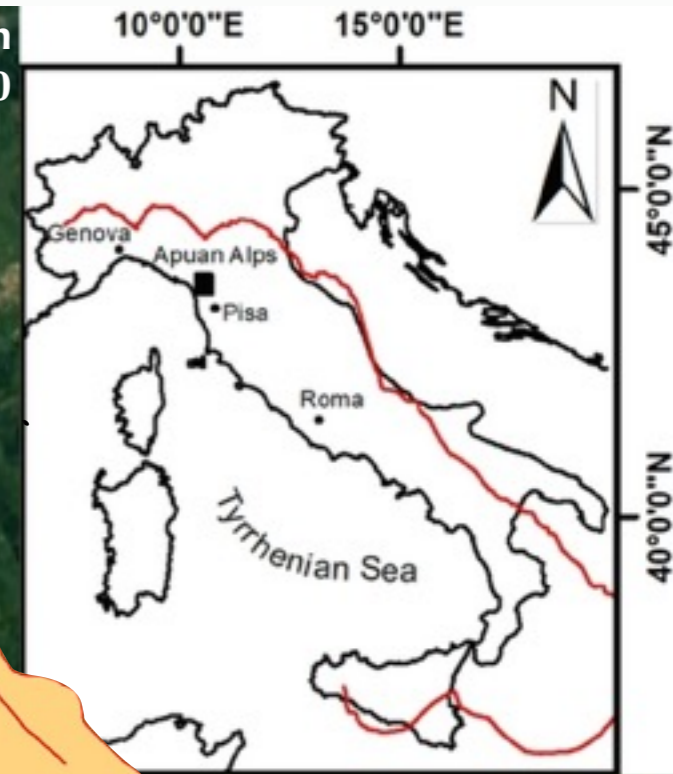


Scientific interest declined

Photo: L. Tinagli

Alpi Apuane ores

Molli, 2004 modified from Carmignani & Kligfield, 1990

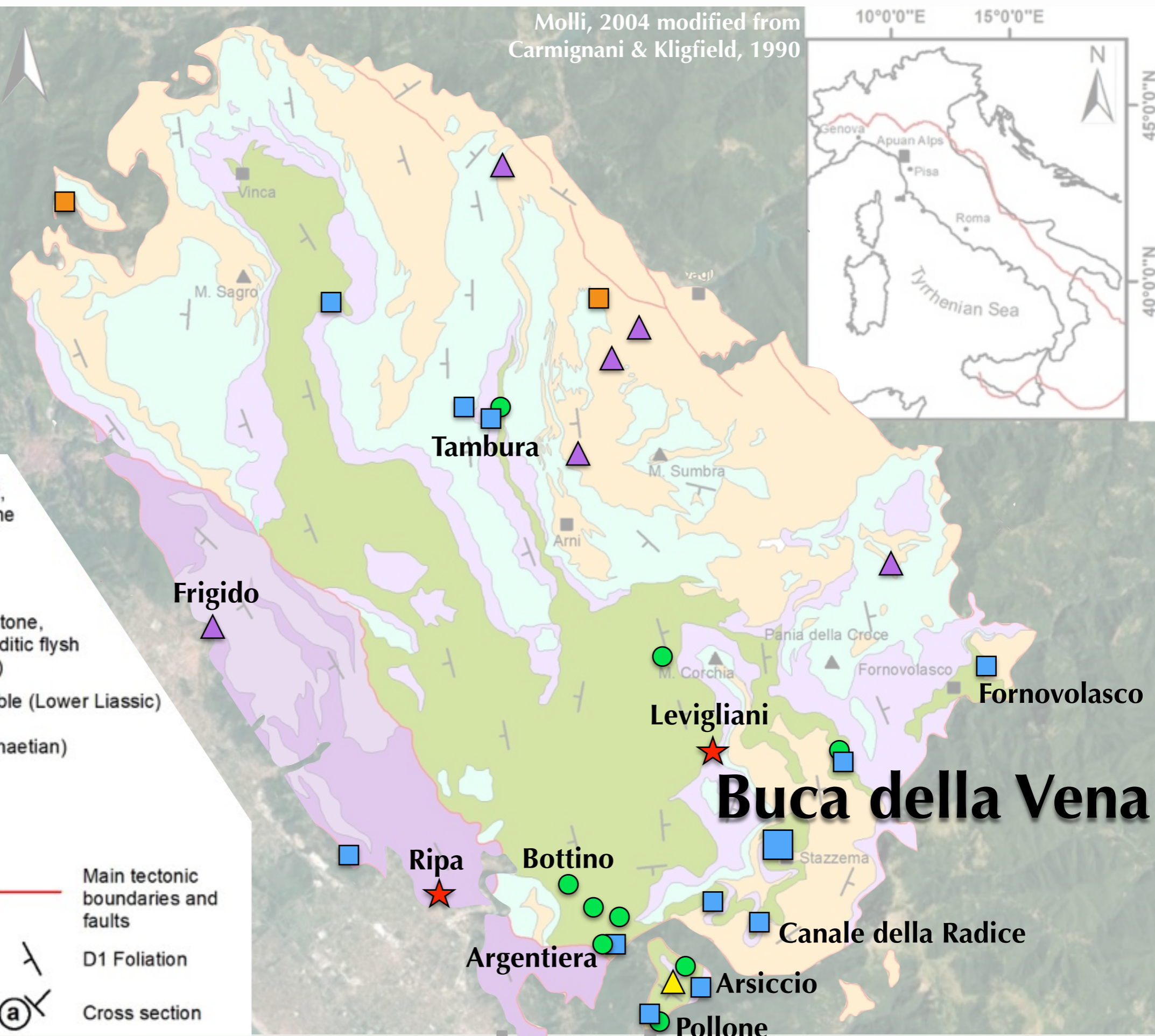
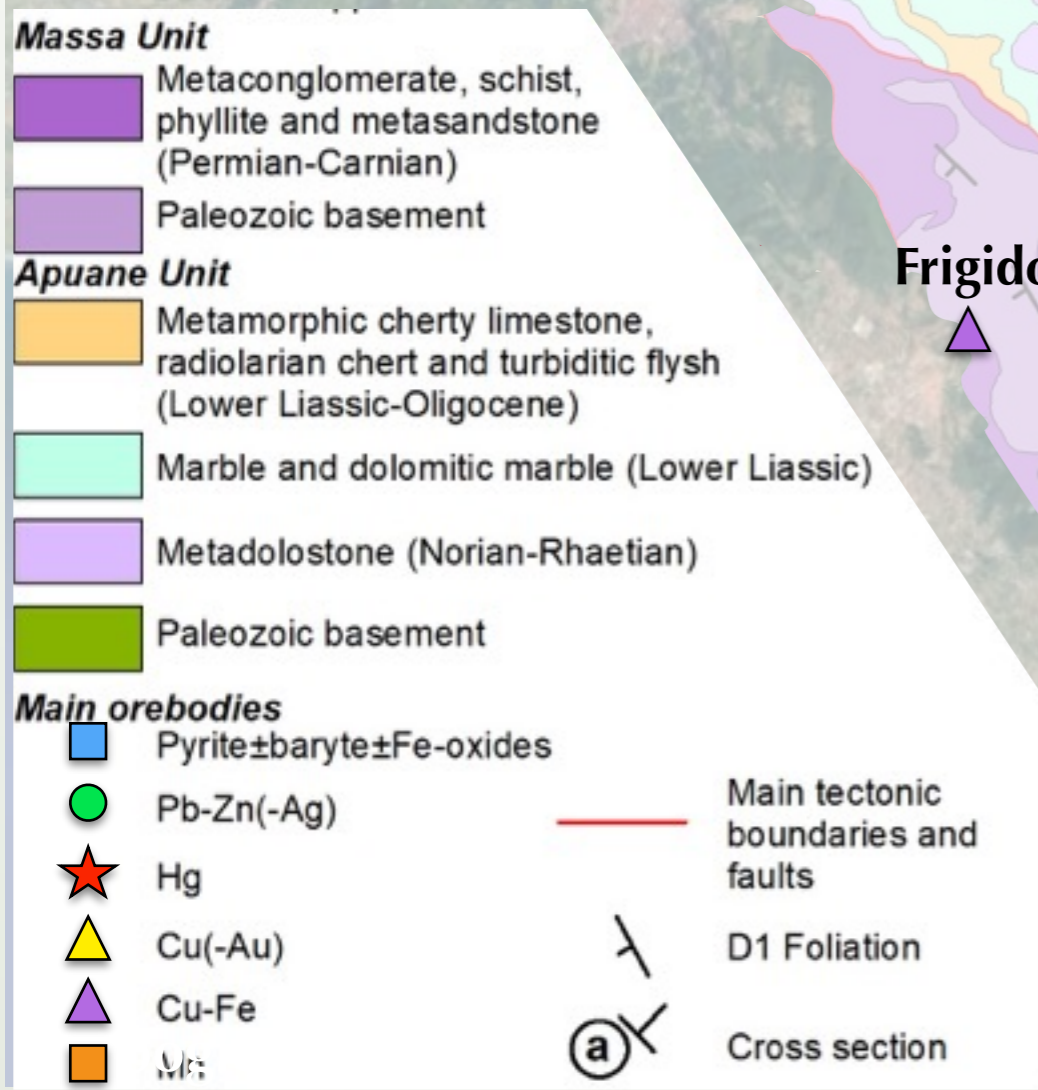


Buca della Vena

(a)

Alpi Apuane ores

Molli, 2004 modified from Carmignani & Kligfield, 1990



Buca della Vena



**Quartz, "Il Bimbo"; 21x10 cm
Photo: A. Dini**

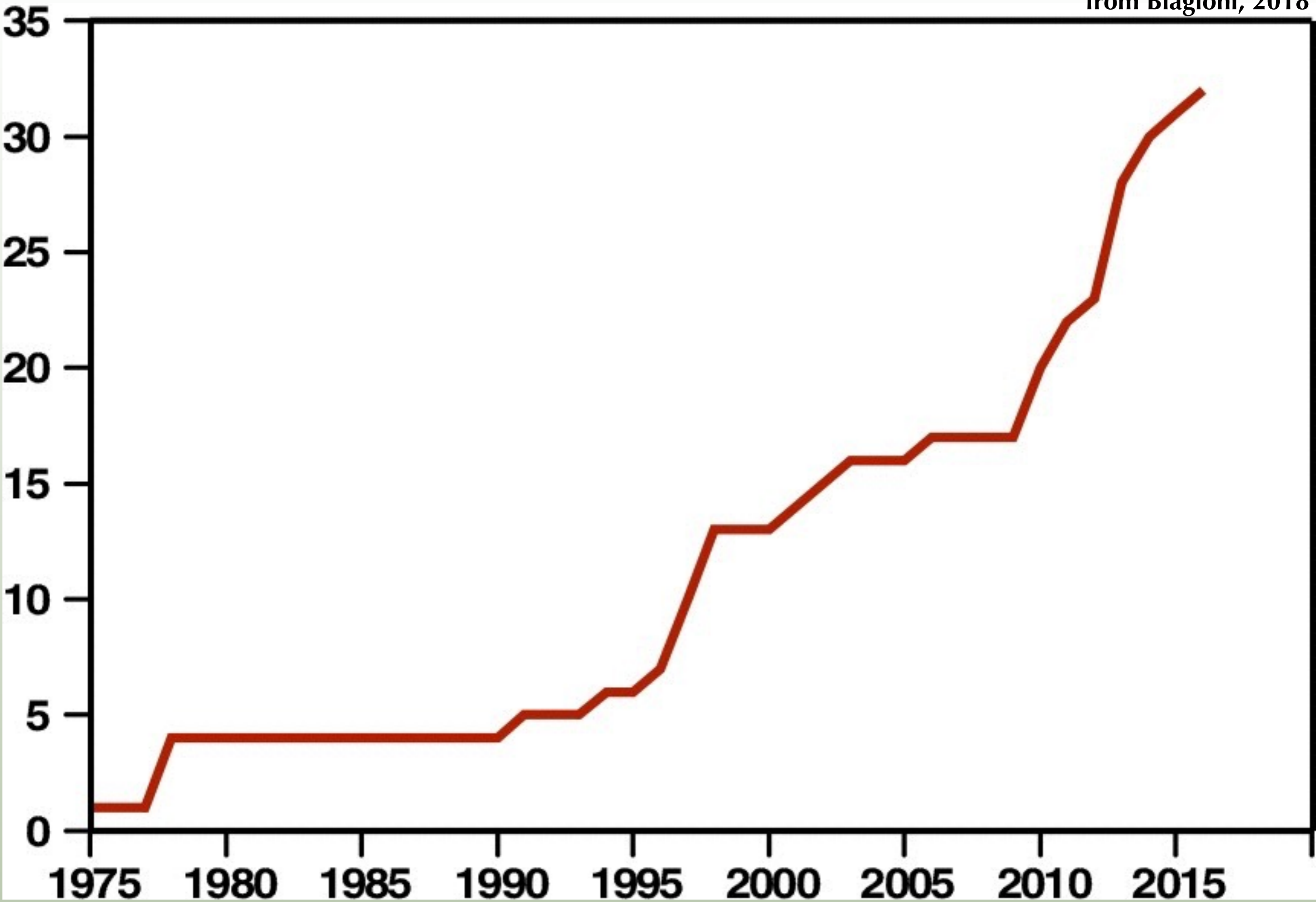


Boulangerite ($\text{Pb}_5\text{Sb}_4\text{S}_{11}$), ~25x15 cm

Photo: M. Lorenzoni

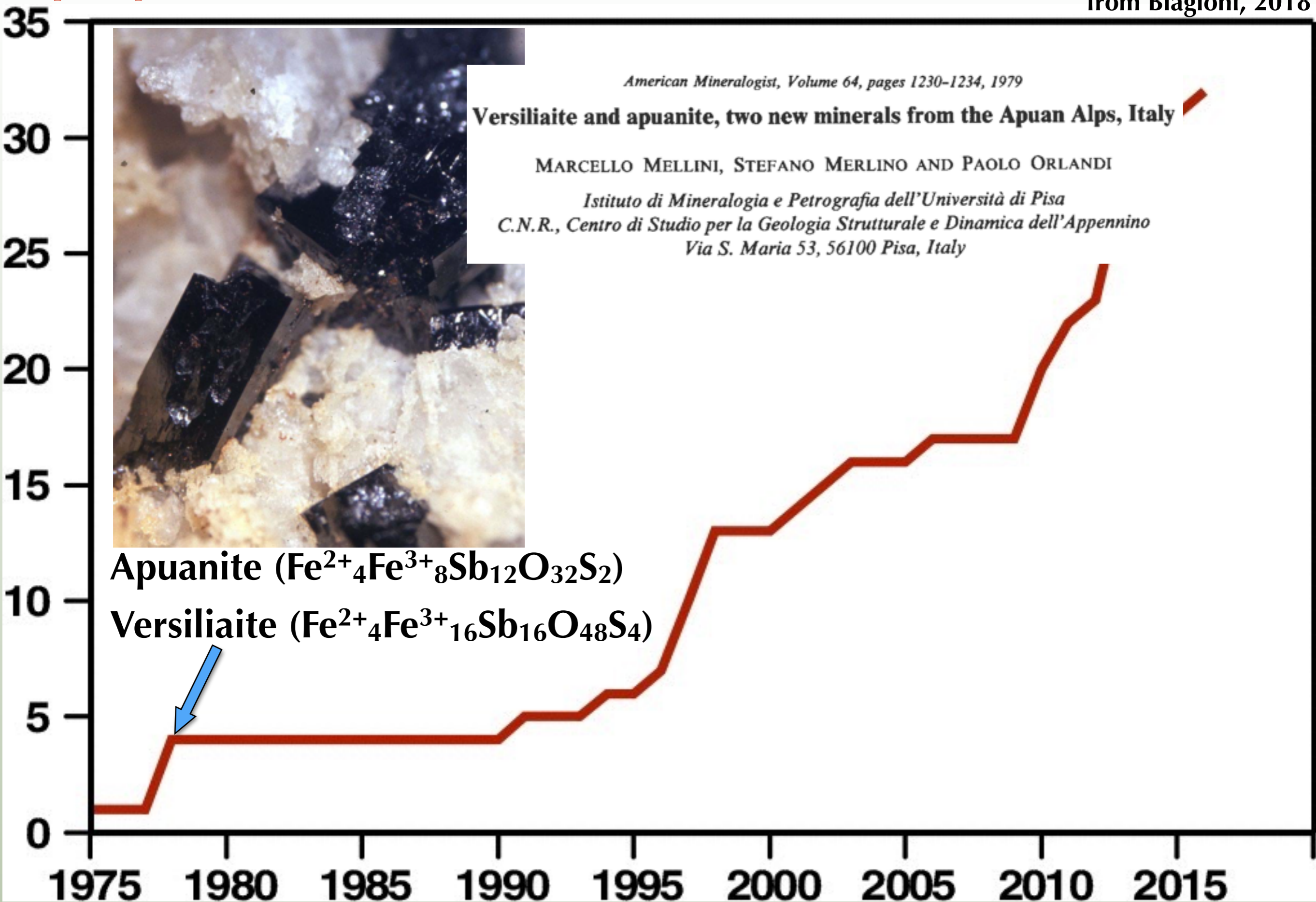
Alpi Apuane new minerals

from Biagioni, 2018



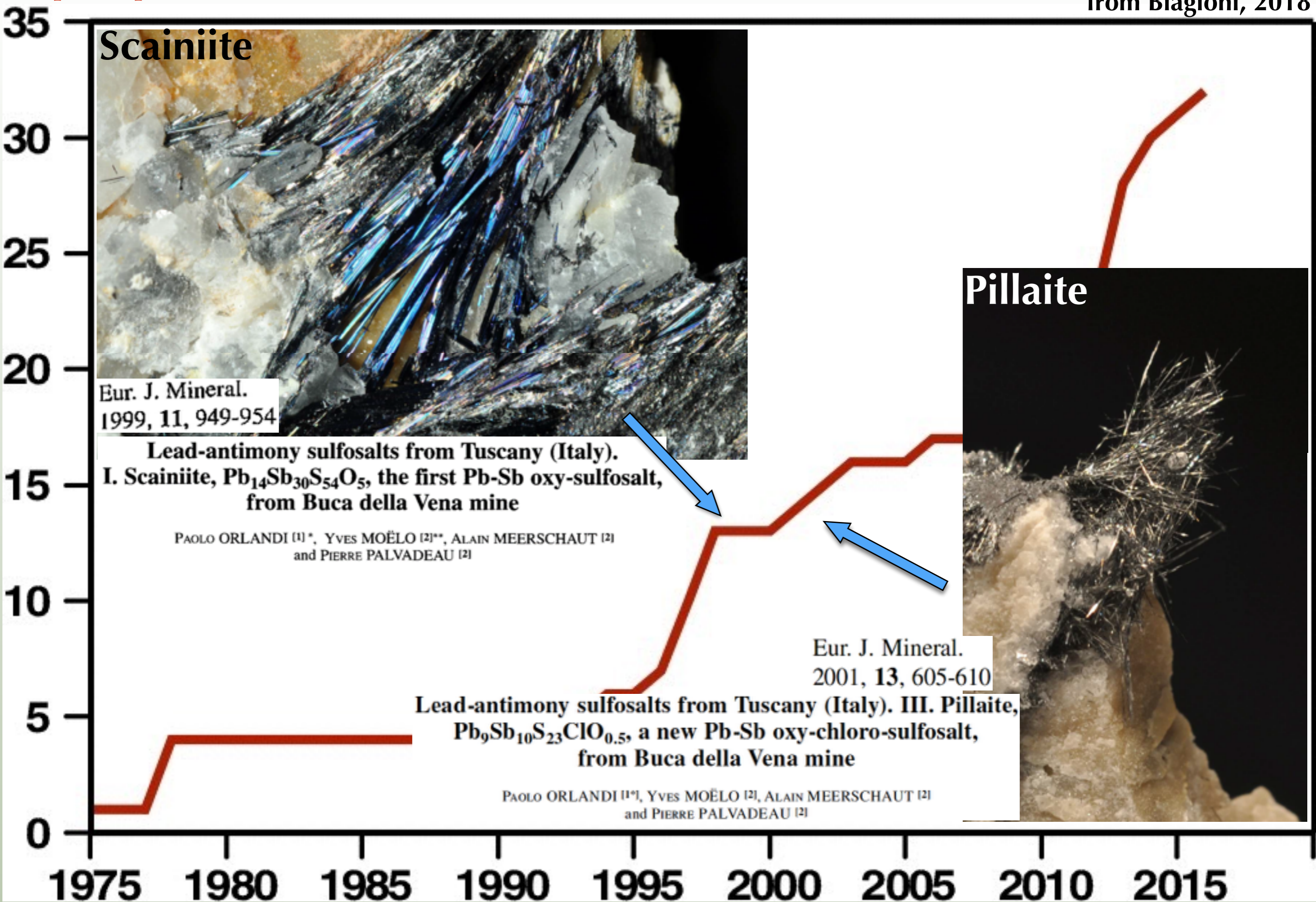
Alpi Apuane new minerals

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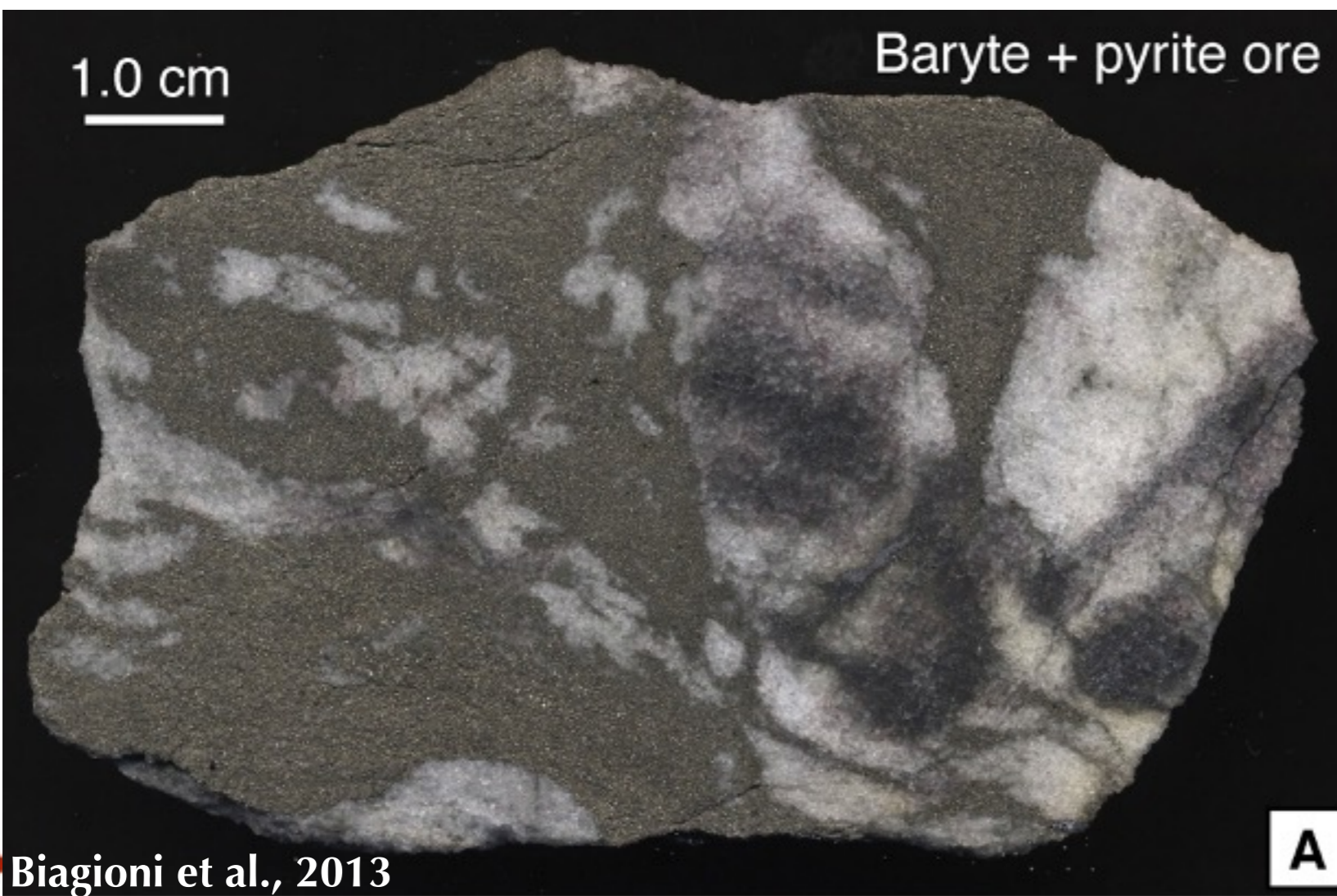
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Mineralogical Magazine, February 2014, Vol. 78(1), pp. 101–117

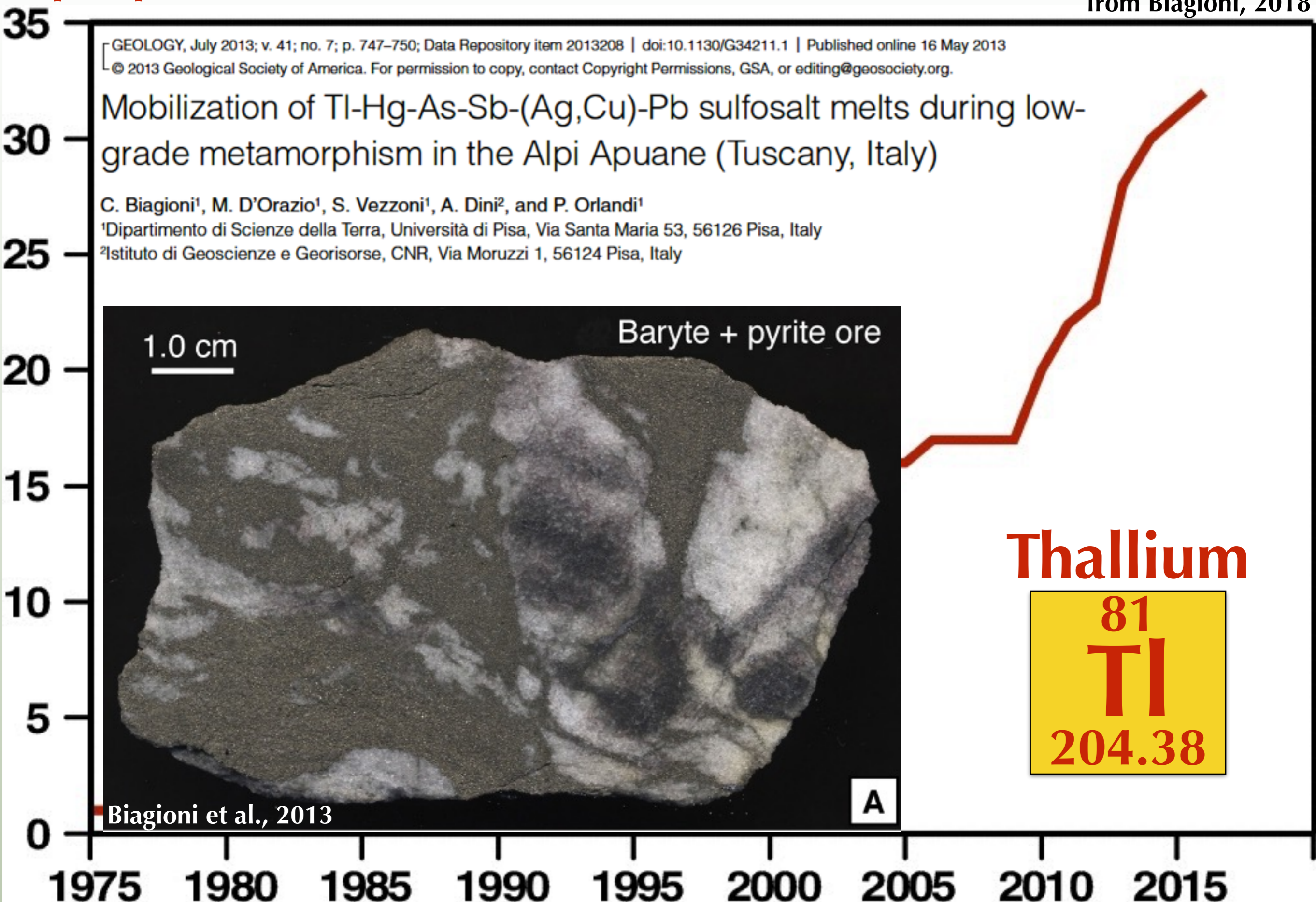
Mercury-arsenic sulfosalts from the Apuan Alps (Tuscany, Italy). II. Arsiccioite, $\text{AgHg}_2\text{TlAs}_2\text{S}_6$, a new mineral from the Monte Arsiccio mine: occurrence, crystal structure and crystal chemistry of the routhierite isotypic series

C. BIAGIONI^{1,*}, E. BONACCORSI¹, Y. MOËLO², P. ORLANDI^{1,3}, L. BINDI⁴, M. D'ORAZIO¹ AND S. VEZZONI¹



Alpi Apuane new minerals

from Biagioni, 2018

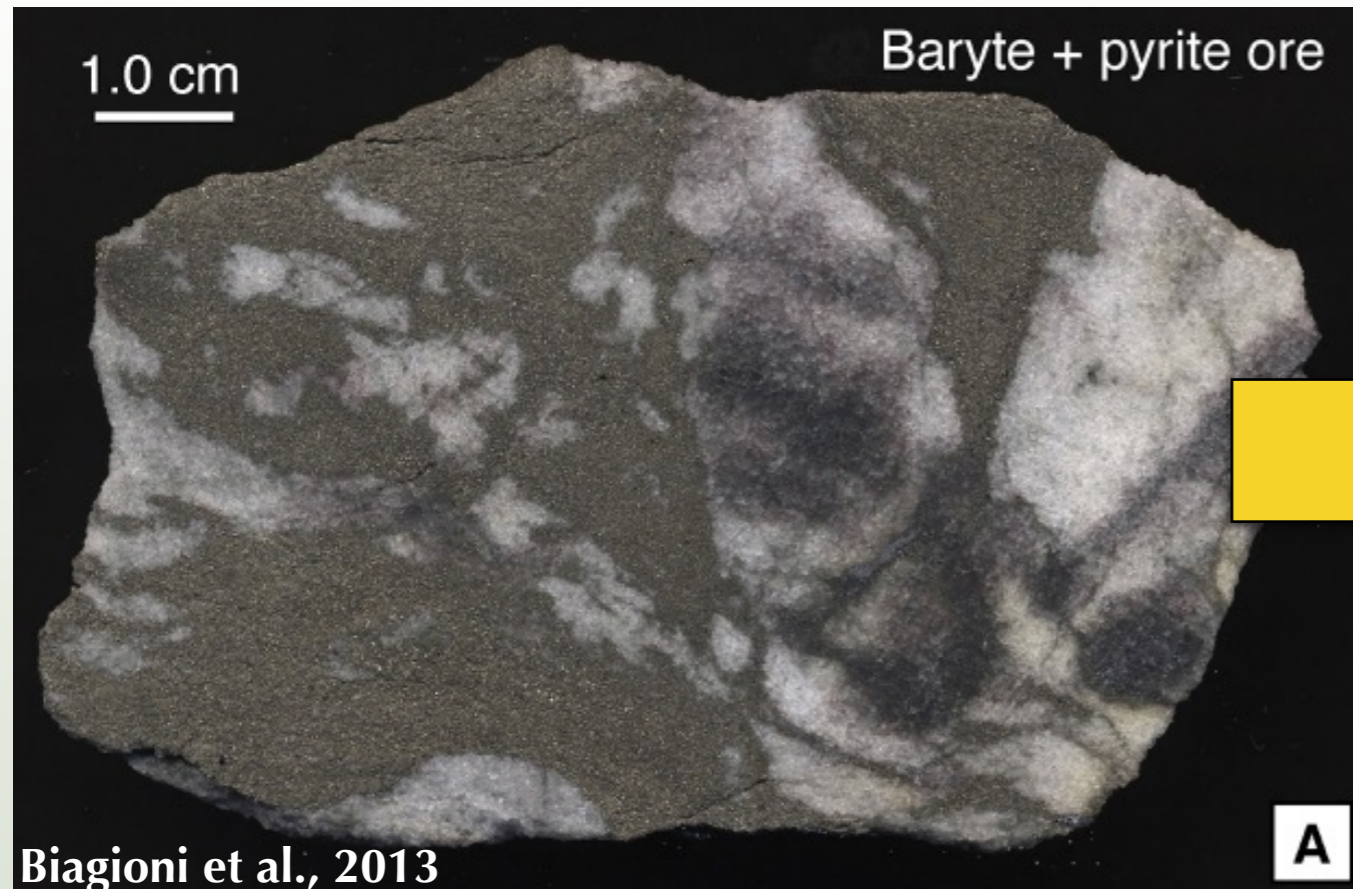


Alpi Apuane new discoveries

VALDICASTELLO LA SOSTANZA E' ALTAMENTE TOSSICA

La Nazione, 4-10-2014

E' scoppiato l'allarme "tallio"
Vietato usare acqua dei rubinetti



Biagioni et al., 2013



Mine Water Environ

DOI 10.1007/s10230-017-0485-x

Thallium and Other Potentially Toxic Elements in the Baccatoio Stream Catchment (Northern Tuscany, Italy) Receiving Drainages from Abandoned Mines

Martina Perotti¹ · Riccardo Petrini¹ · Massimo D'Orazio¹ · Lisa Ghezzi¹ · Roberto Giannecchini¹ · Simone Vezzi¹

Science of the Total Environment 548–549 (2016) 33–42

Human exposure to thallium through tap water: A study from Valdicastello Carducci and Pietrasanta (northern Tuscany, Italy)

Beatrice Campanella^{a,b}, Massimo Onor^a, Alessandro D'Ulivo^a, Roberto Giannecchini^c, Massimo D'Orazio^c, Riccardo Petrini^c, Emilia Bramanti^{a,*}

Journal of Geochemical Exploration 197 (2019) 84–92

Groundwater and potentially toxic elements in a dismissed mining area: Thallium contamination of drinking spring water in the Apuan Alps (Tuscany, Italy)

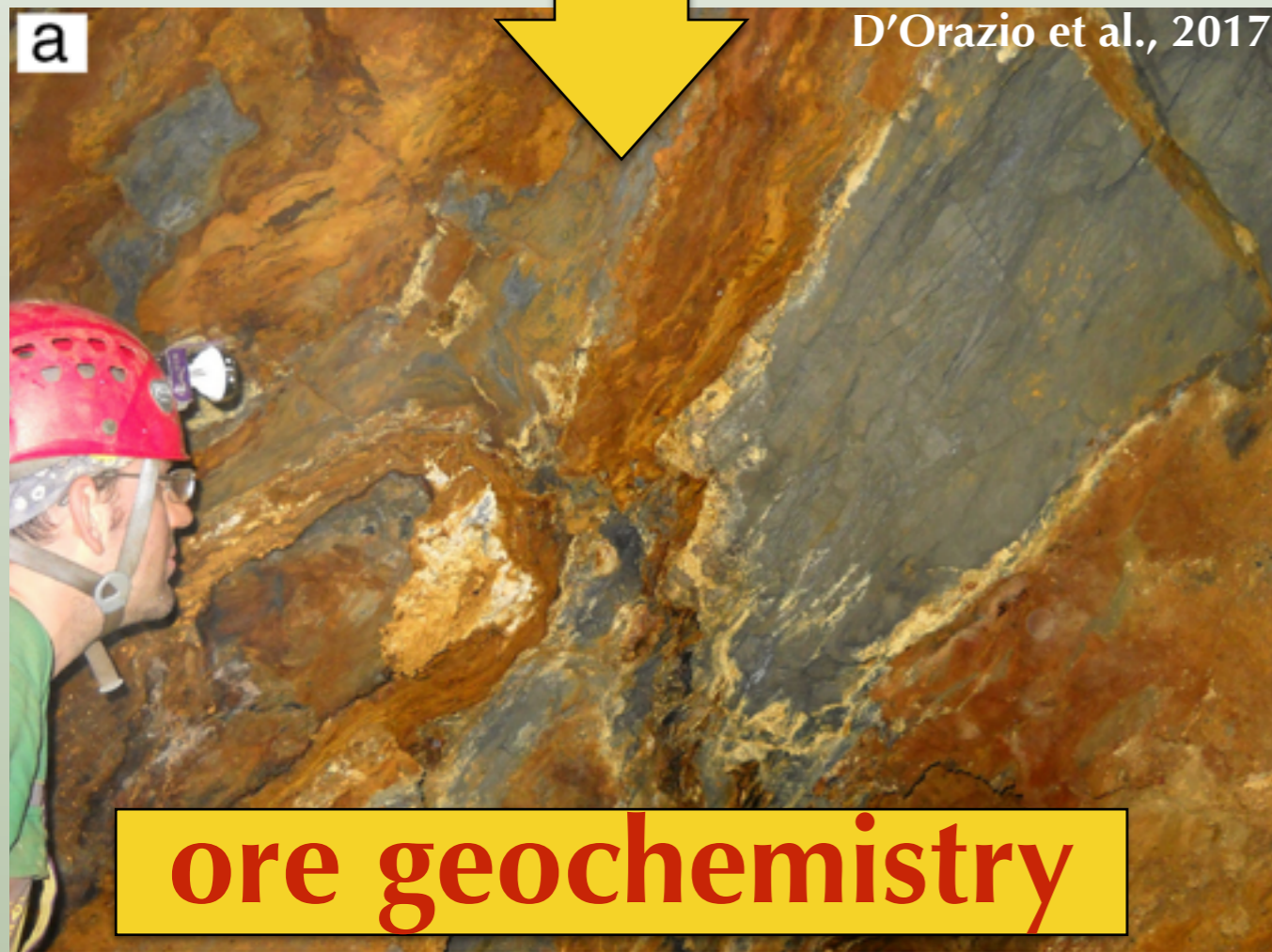
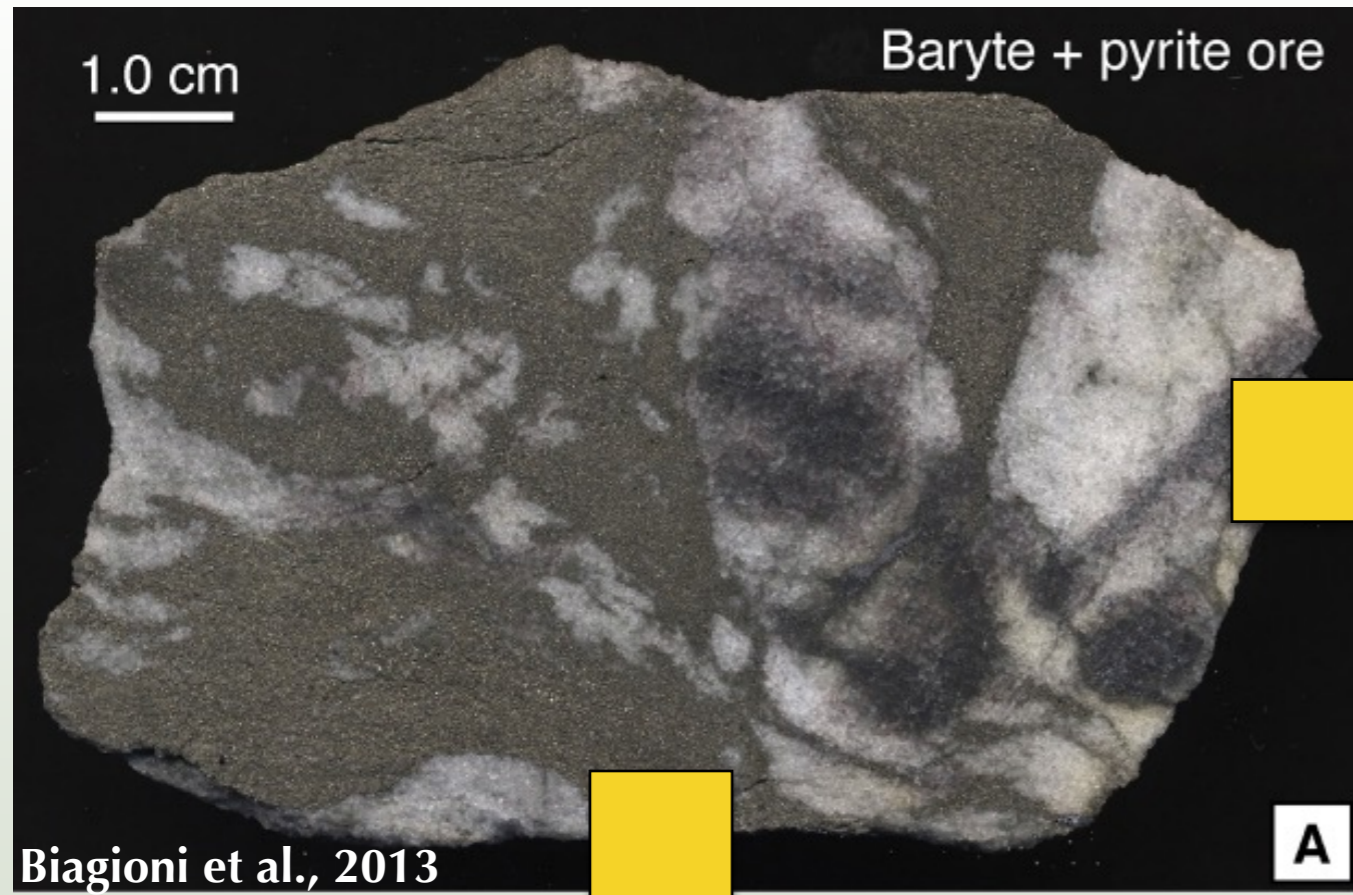
Lisa Ghezzi^{a,*}, Massimo D'Orazio^a, Marco Doveri^b, Matteo Lelli^b, Riccardo Petrini^a, Roberto Giannecchini^a

Alpi Apuane new discoveries

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Vietato usare acqua dei rubinetti



As, Sb, Hg, Tl, Pb, Bi...

Miner Deposita (2017) 52:687–707
DOI 10.1007/s00126-016-0697-1

Thallium-rich pyrite ores from the Apuan Alps, Tuscany, Italy: constraints for their origin and environmental concerns

Massimo D'Orazio¹ · Cristian Biagioni¹ · Andrea Dini² · Simone Vezzoni¹

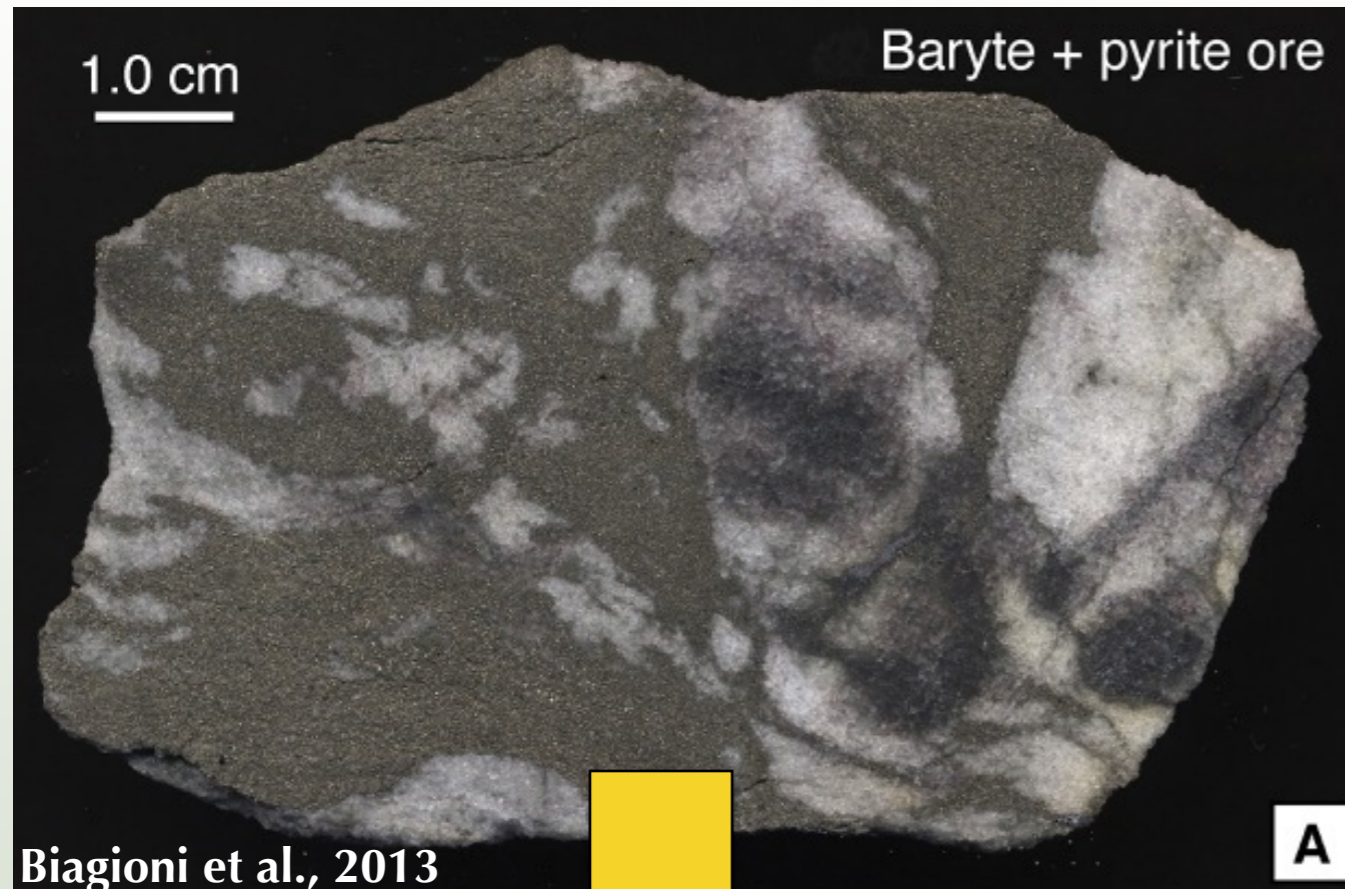
Ore Geology Reviews 102 (2018) 59–105

Textural and trace element evolution of pyrite during greenschist facies metamorphic recrystallization in the southern Apuan Alps (Tuscany, Italy): Influence on the formation of Tl-rich sulfosalt melt

Luke L. George^a, Cristian Biagioni^{a,*}, Massimo D'Orazio^a, Nigel J. Cook^b

Alpi Apuane new discoveries

Permian magmatism



JOURNAL OF MAPS
2018, VOL. 14, NO. 2, 357–367

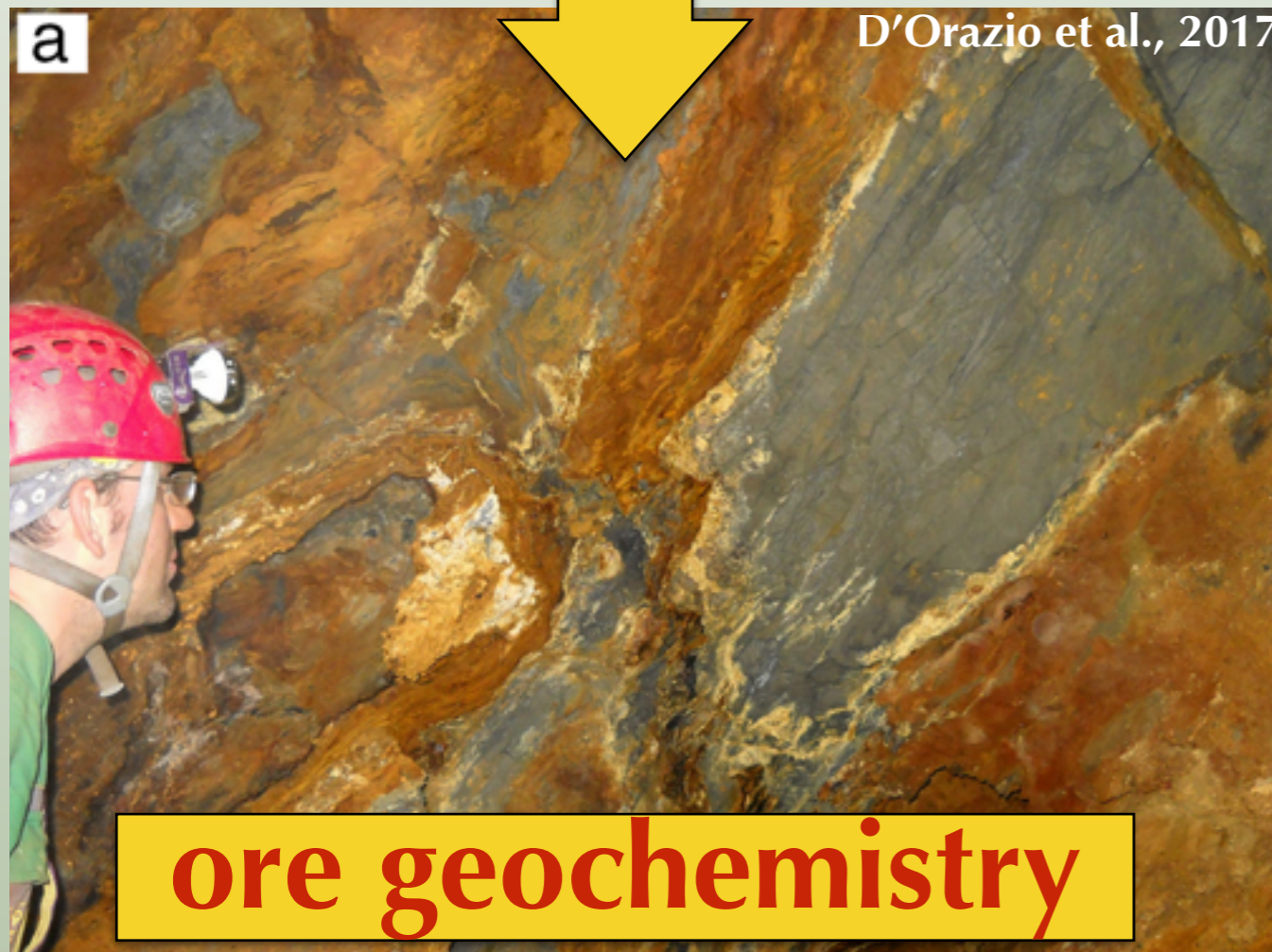
Geology and tectonic setting of the Fornovolasco area, Alpi Apuane (Tuscany, Italy)

Diego Pieruccioni ^a, Yuri Galanti ^b, Cristian Biagioni ^b and Giancarlo Molli ^b

Lithos 318–319 (2018) 104–123

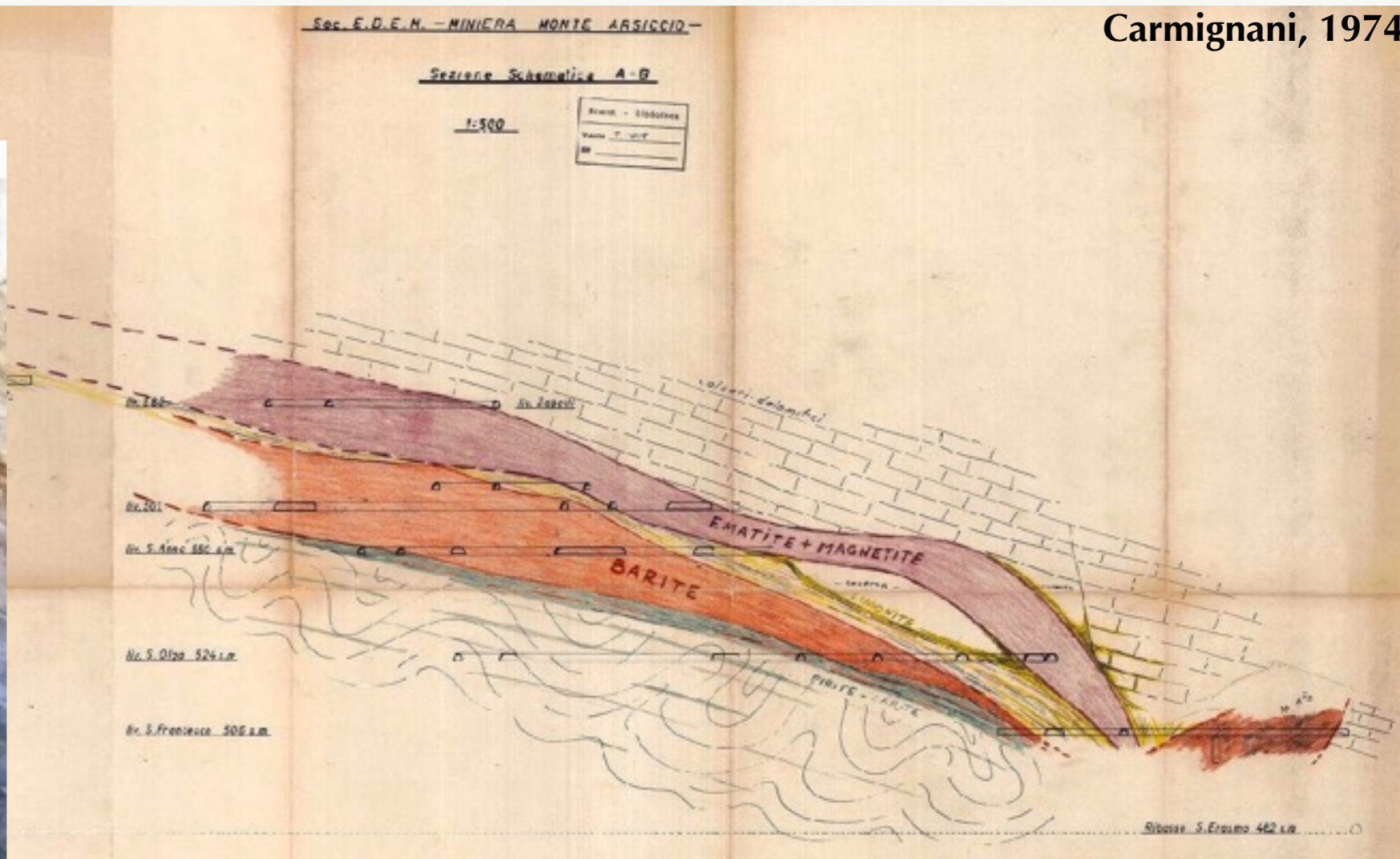
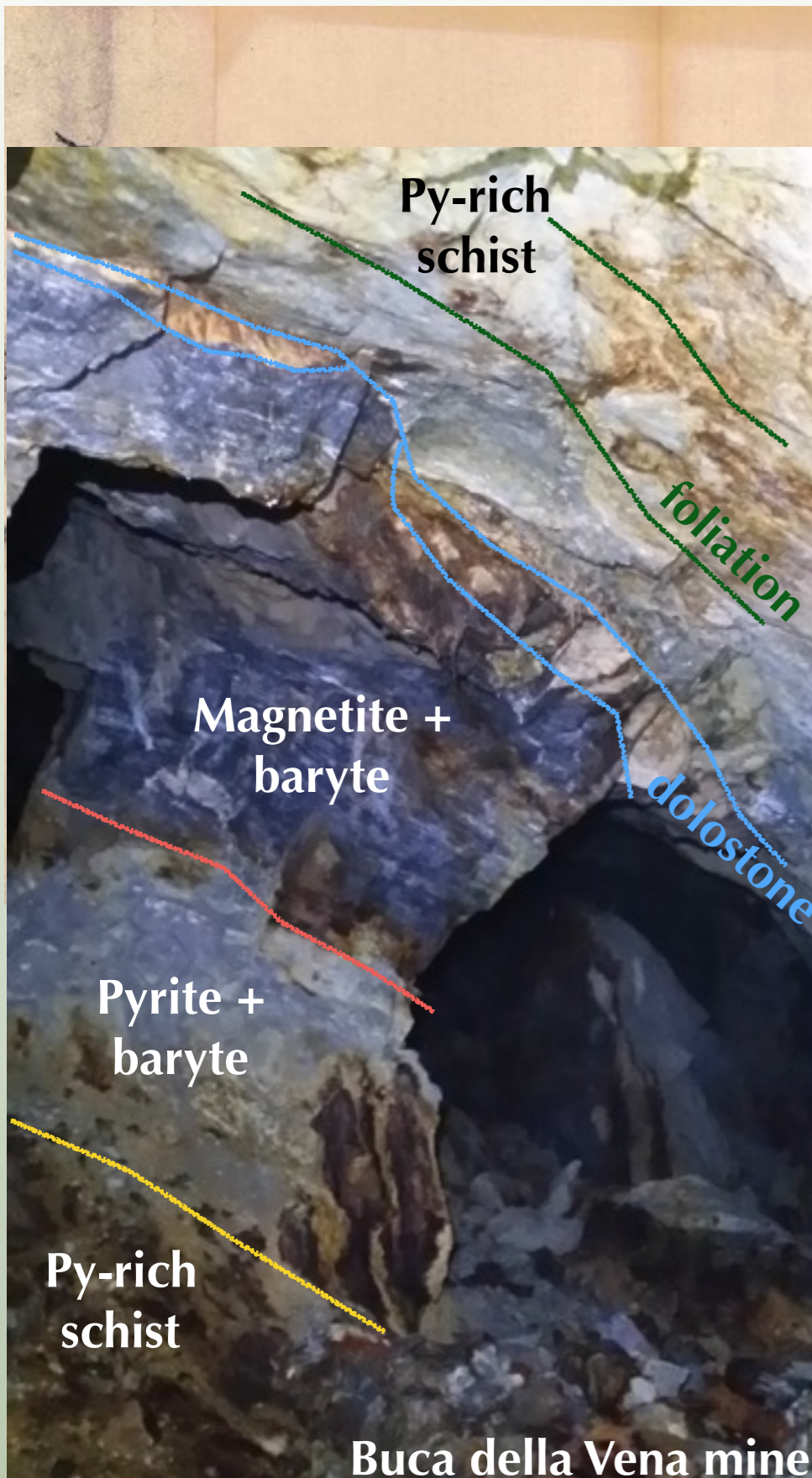
Evidence of Permian magmatism in the Alpi Apuane metamorphic complex (Northern Apennines, Italy): New hints for the geological evolution of the basement of the Adria plate

Simone Vezzoni ^a, Cristian Biagioni ^{a,*}, Massimo D'Orazio ^a, Diego Pieruccioni ^a, Yuri Galanti ^a, Maurizio Petrelli ^{b,c}, Giancarlo Molli ^a



Baryte, pyrite, and Fe-oxides orebodies

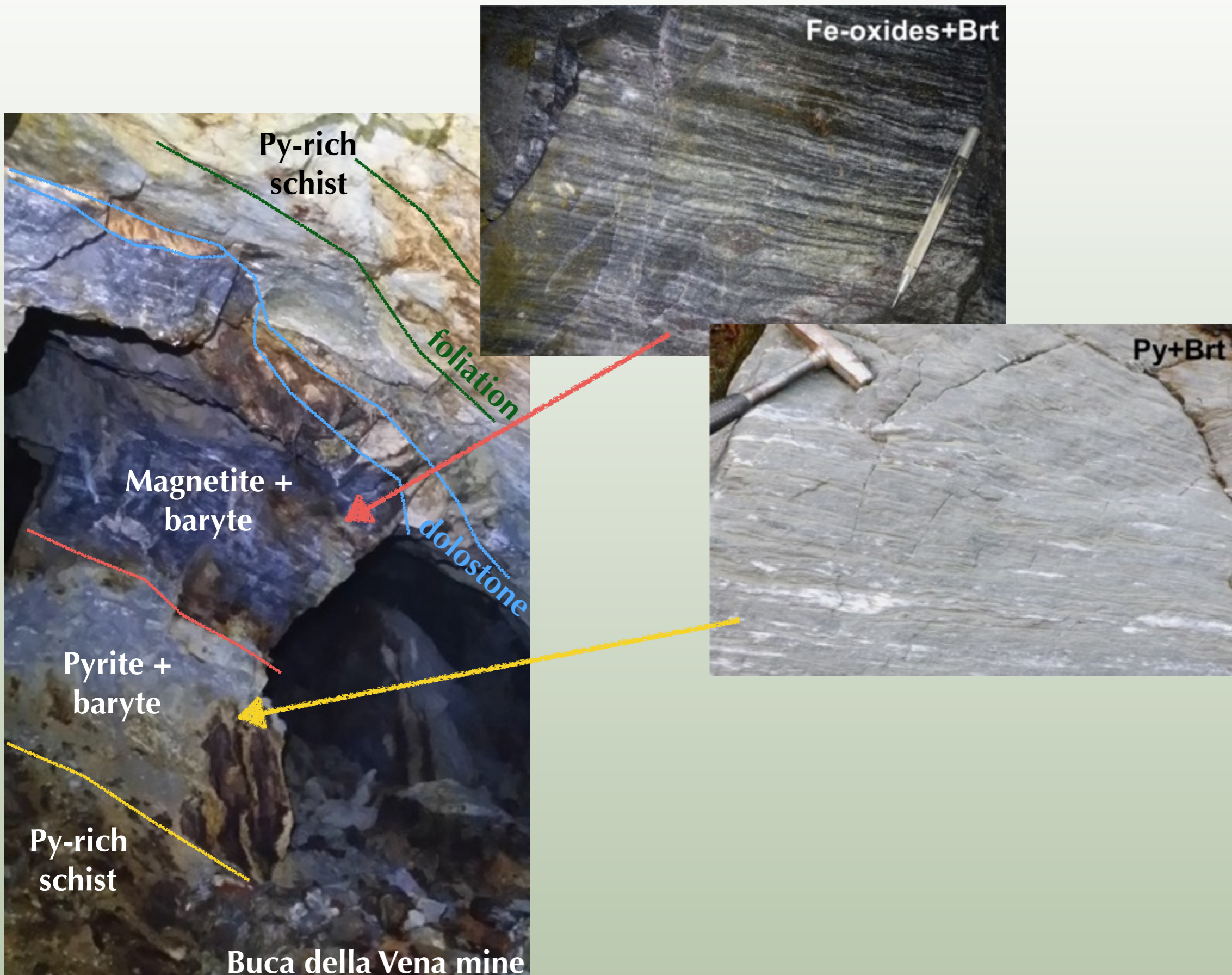
Main features: 1. stratiform;



Carmignani, 1974

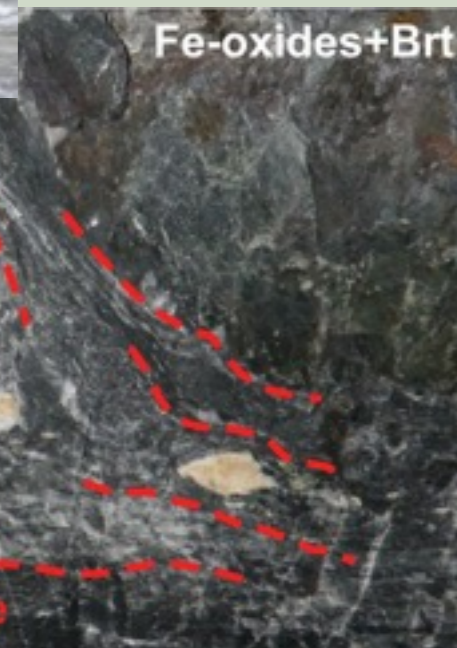
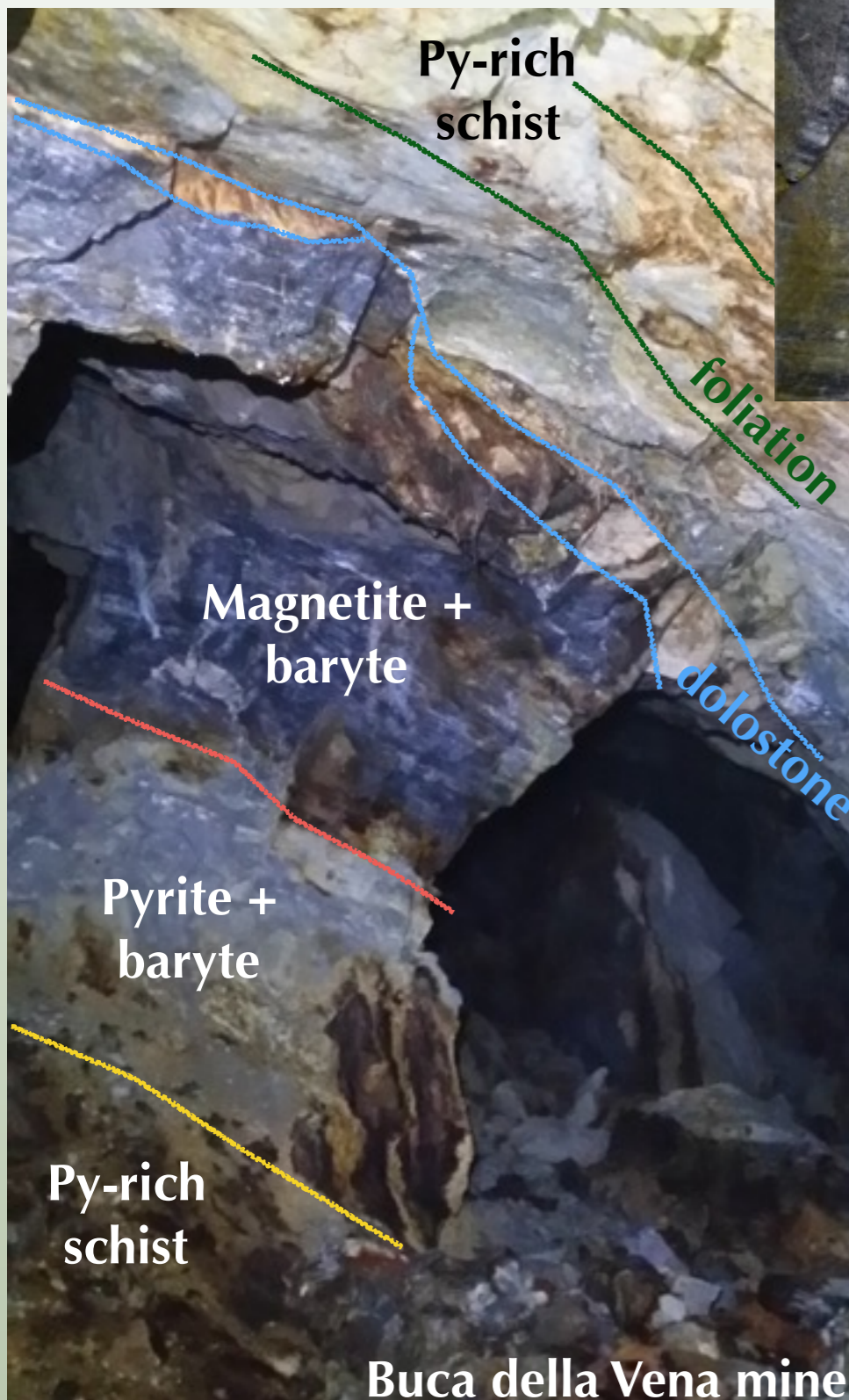
Baryte, pyrite, and Fe-oxides orebodies

Main features: 1. stratiform; 2. zoned;



Baryte, pyrite, and Fe-oxides orebodies

Main features: 1. stratiform; 2. zoned; 3. with metacarbonate lenses.



Baryte, pyrite, and Fe-oxides orebodies

Genetic models:

Metamorphic, epigenetic

e.g., Carmignani et al., 1972; 1975; 1976

- **Origin:**
Hydrothermal(-metasomatic)
related to the intrusion of an early-orogenic Apenninic plutonic body
- **Age:**
Miocene
- **Evidences:**
 1. Ore bodies location;
 2. No lithostratigraphic control;
 3. Ore zoning (“hot point”).

Pre-metamorphic, syngenetic

e.g., Cortecci et al., 1985; Ciarapica et al., 1985; Orberger et al., 1986; Benvenuti et al., 1986; Cortecci et al., 1992; Costagliola et al., 1998

- **Origin:**
Sedimentary(-hydrothermal?) proto-ore partly remobilized during the metamorphism
- **Age:**
Silurian-Devonian or Middle-Upper Triassic
- **Evidences:**
 1. Lithostratigraphic control;
 2. Ore bodies morphology;
 3. Ore texture;
 4. S, C e O isotopic composition.

Baryte, pyrite, and Fe-oxides orebodies

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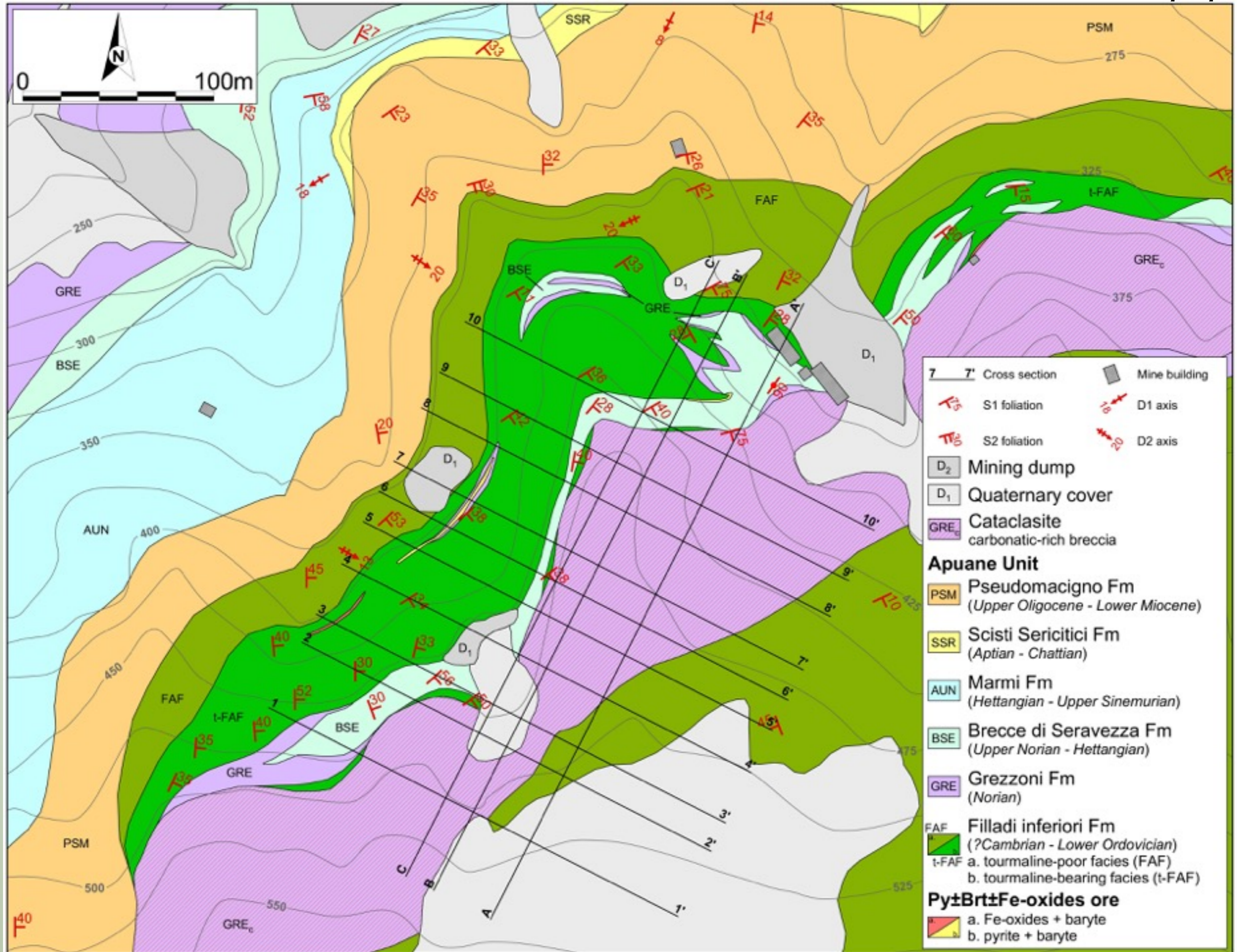
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Buca della Vena geological map

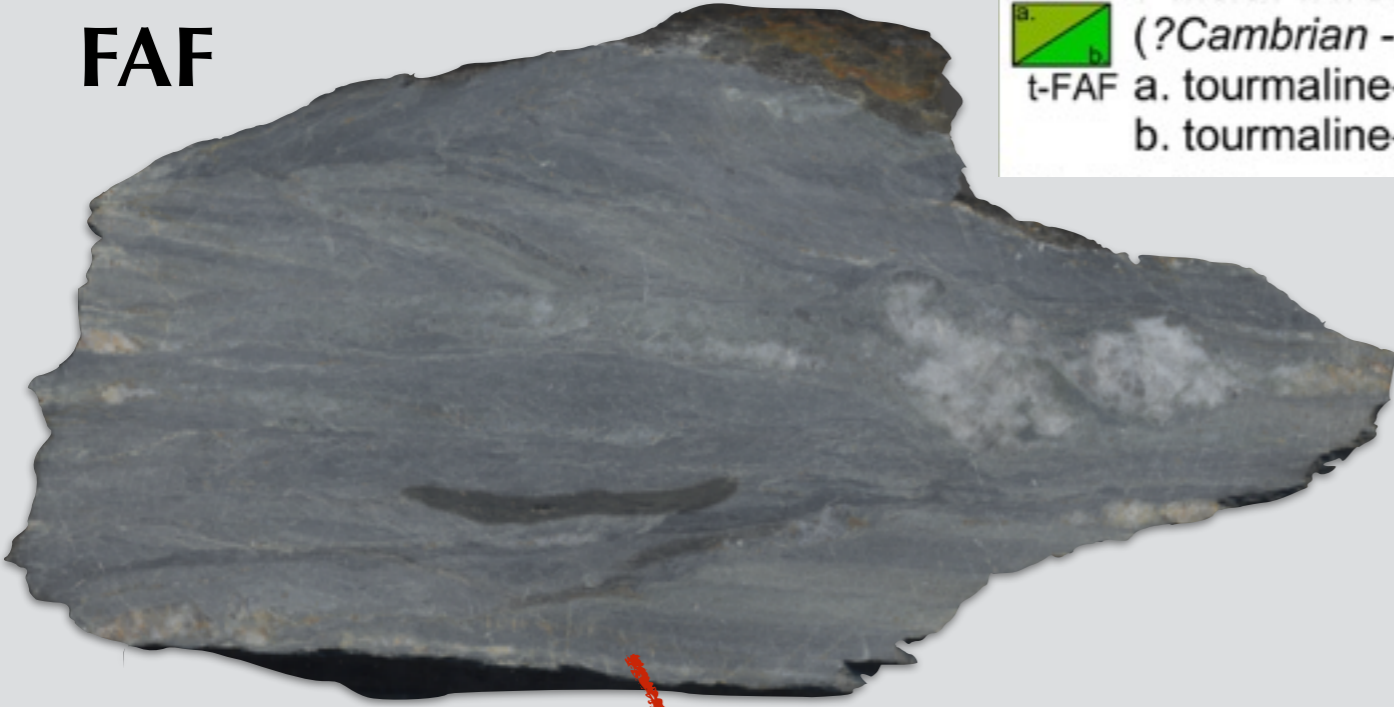
Vezzoni et al., *in prep.*



Buca della Vena geological map

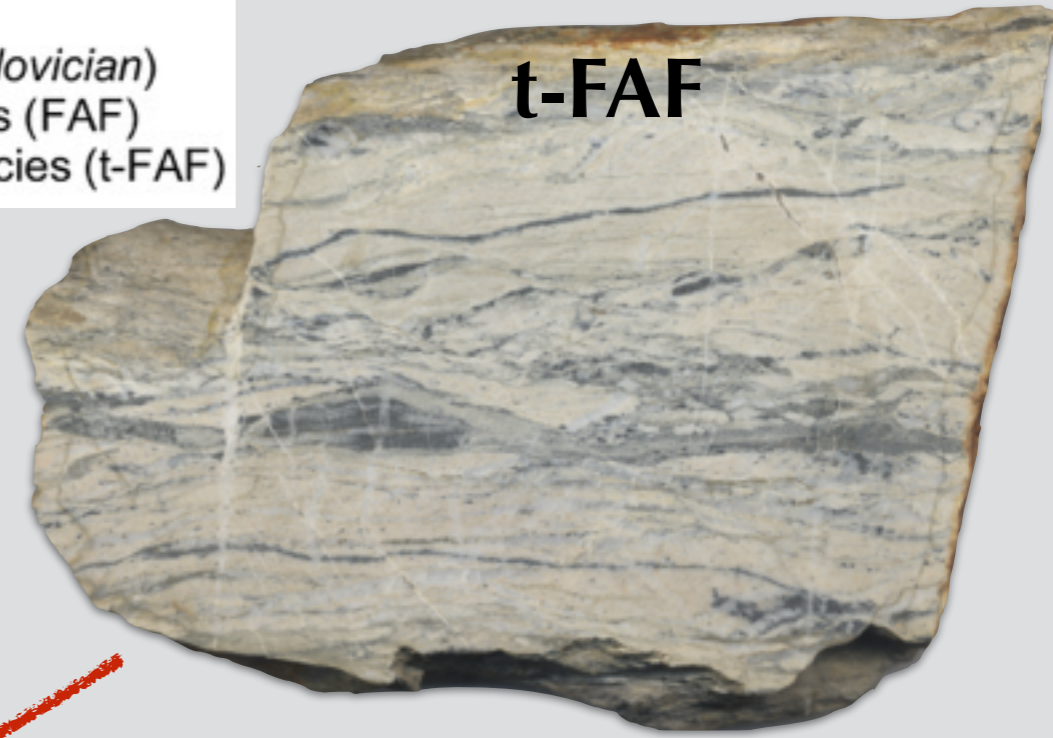
Vezzoni et al., *in prep.*

FAF

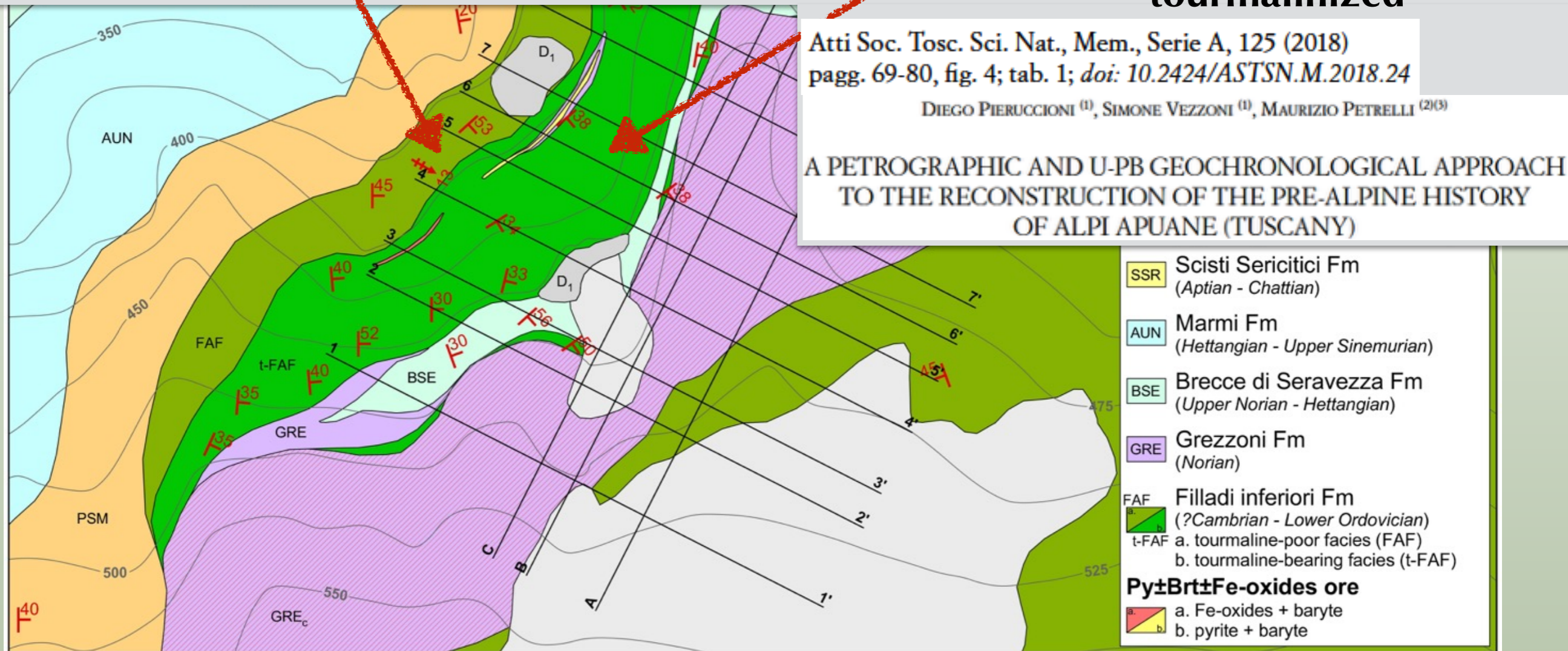


FAF Filladi inferiori Fm
 (?Cambrian - Lower Ordovician)
 t-FAF a. tourmaline-poor facies (FAF)
 b. tourmaline-bearing facies (t-FAF)

t-FAF



tourmalinized



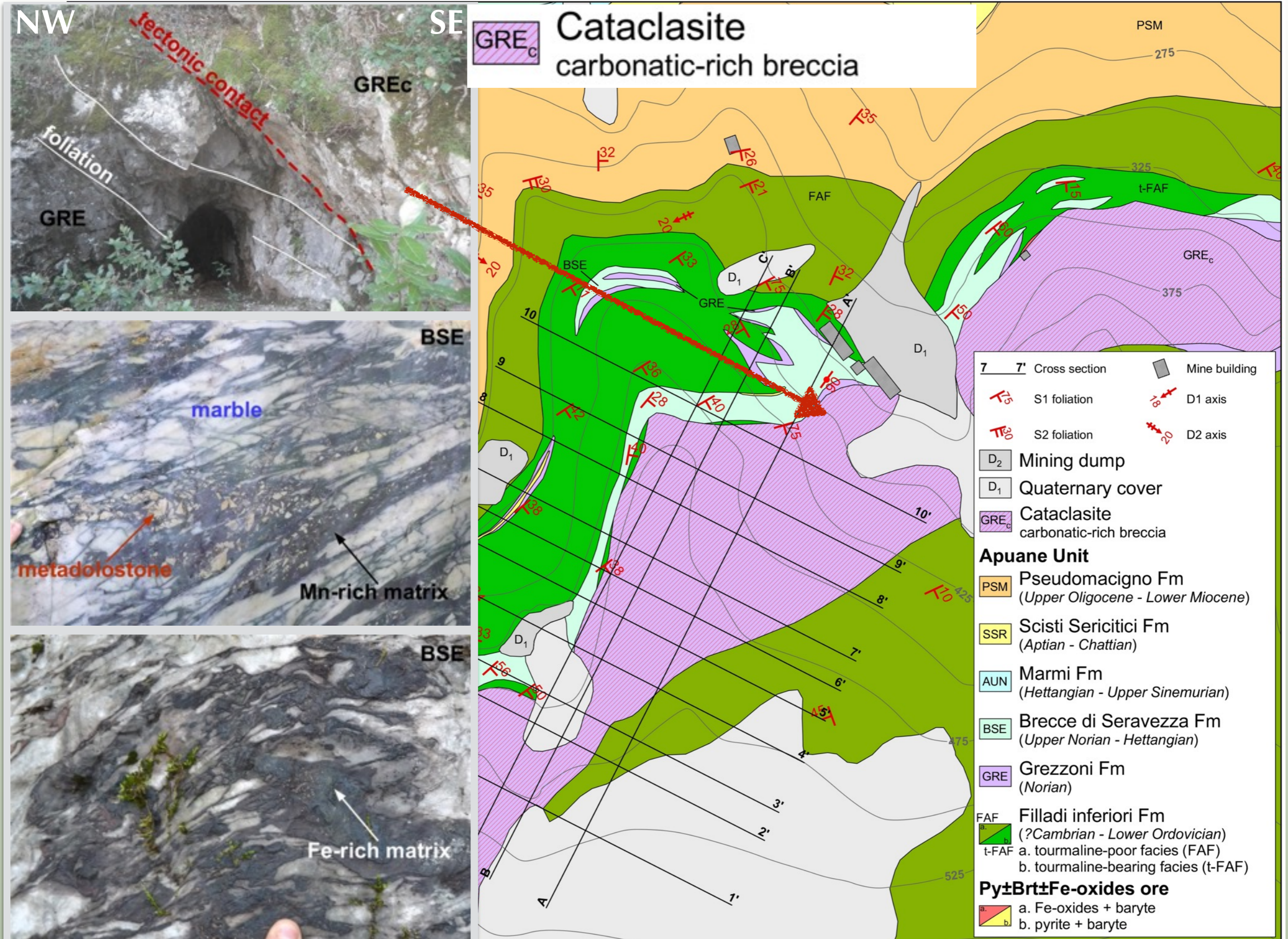
Atti Soc. Tosc. Sci. Nat., Mem., Serie A, 125 (2018)
 pagg. 69-80, fig. 4; tab. 1; doi: 10.2424/ASTSN.M.2018.24

DIEGO PIERUCCIONI ⁽¹⁾, SIMONE VEZZONI ⁽¹⁾, MAURIZIO PETRELLI ⁽²⁾⁽³⁾

A PETROGRAPHIC AND U-PB GEOCHRONOLOGICAL APPROACH
 TO THE RECONSTRUCTION OF THE PRE-ALPINE HISTORY
 OF ALPI APUANE (TUSCANY)

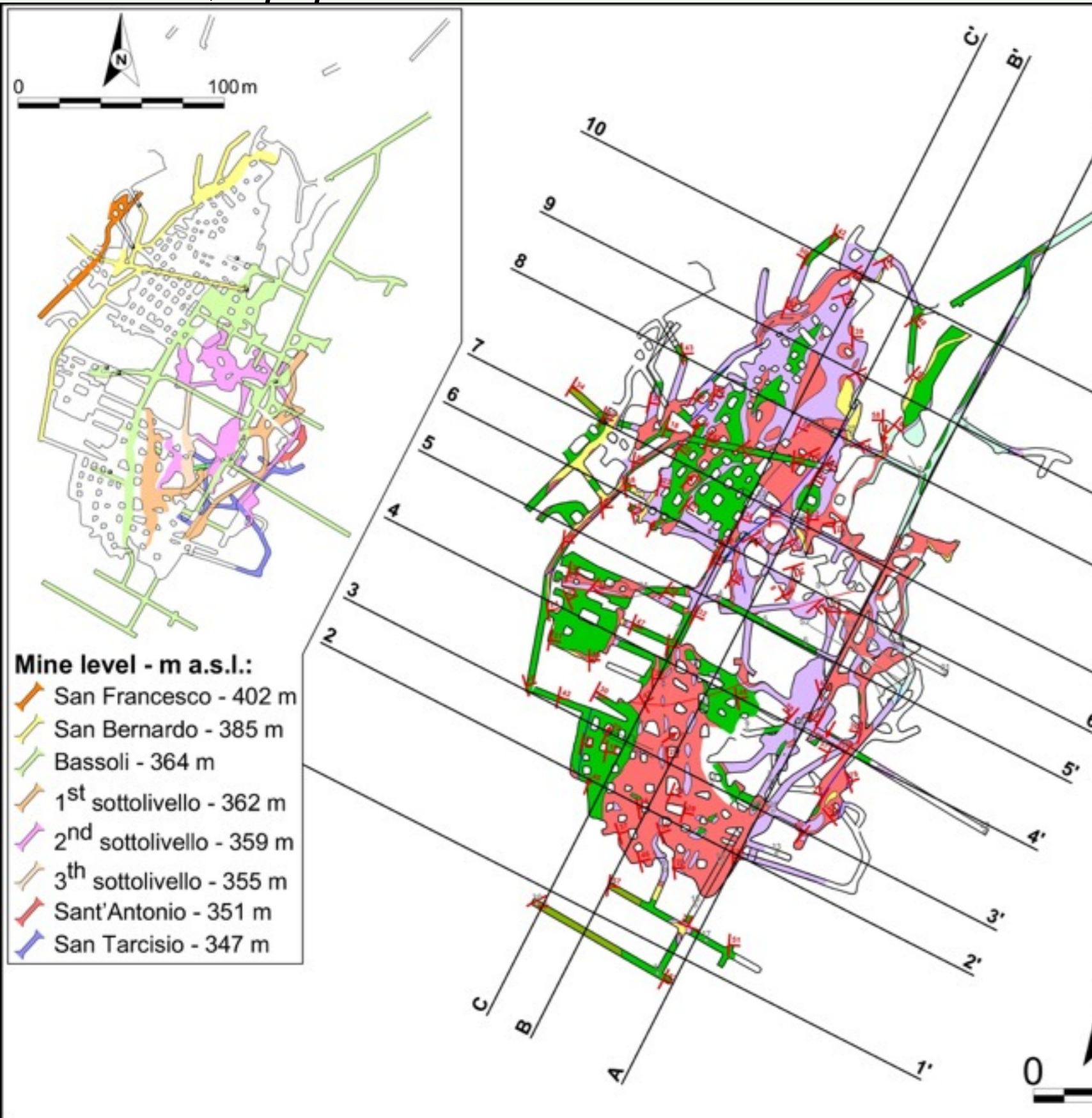
Buca della Vena geological map

Vezzoni et al., *in prep.*

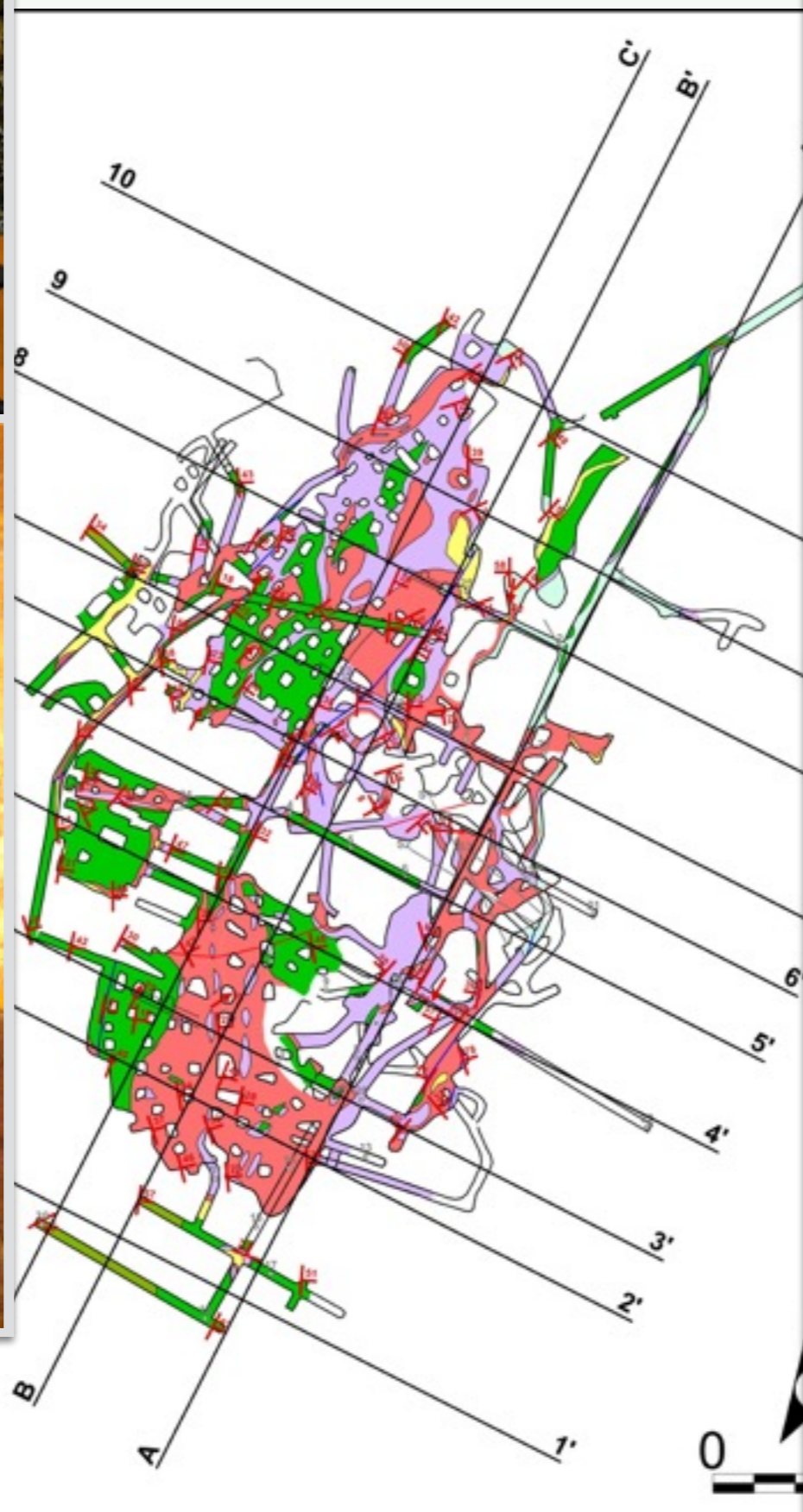
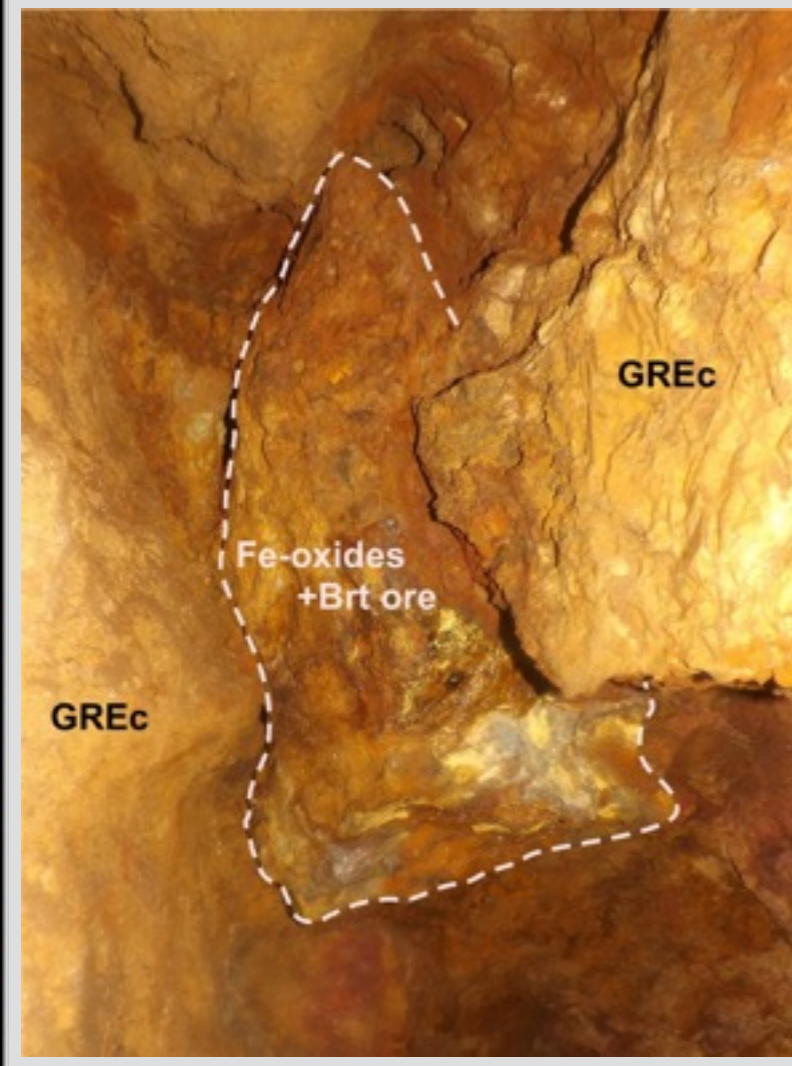
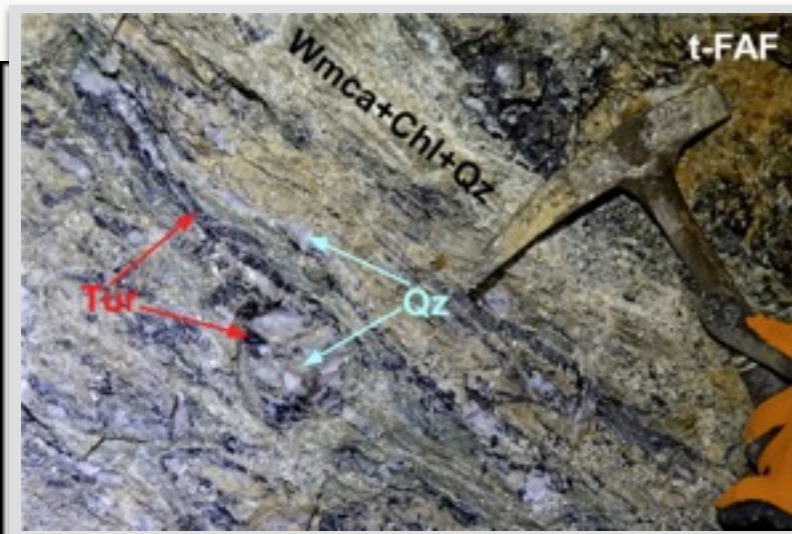


Buca della Vena geological map

Vezzoni et al., *in prep.*

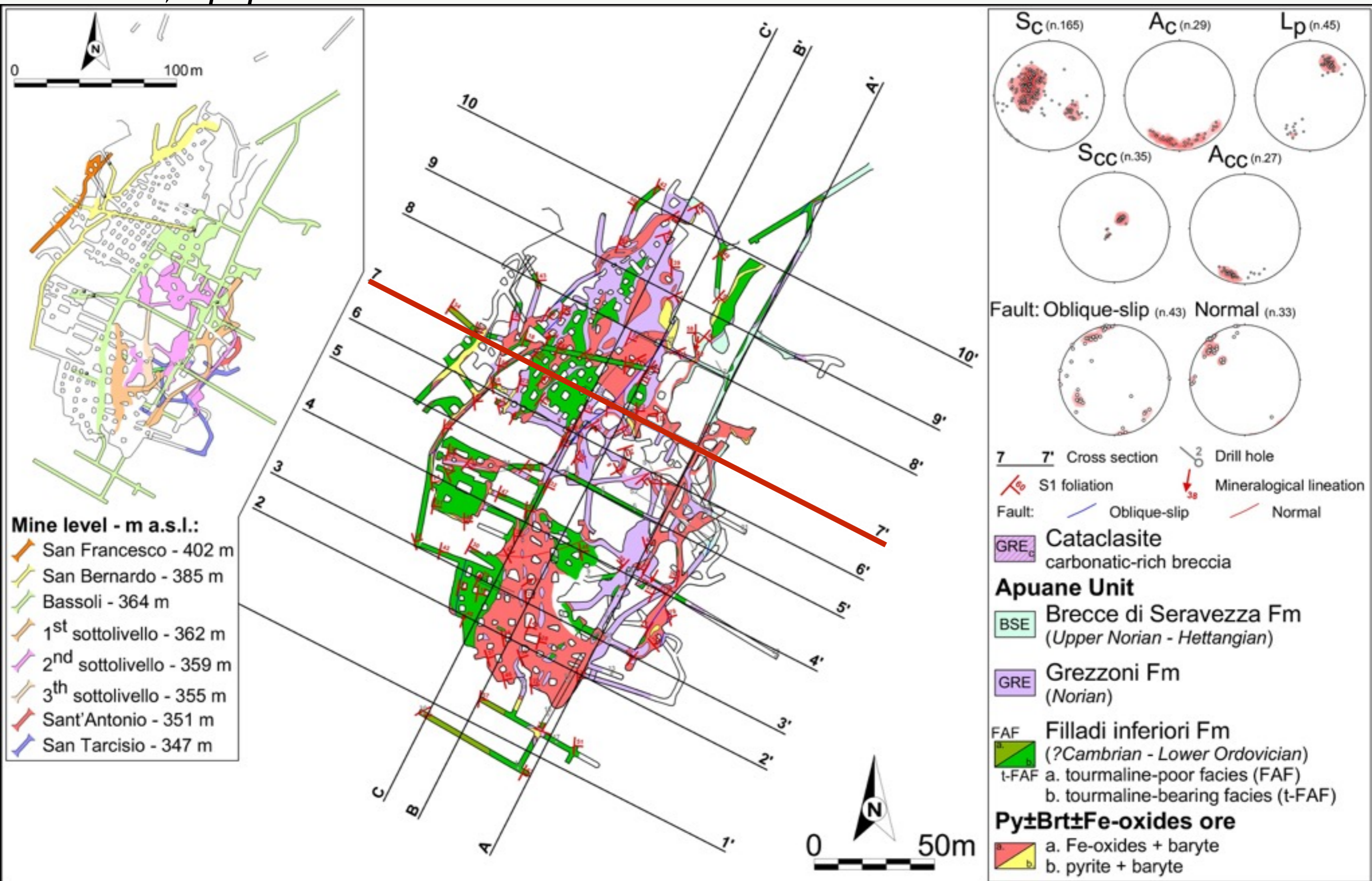


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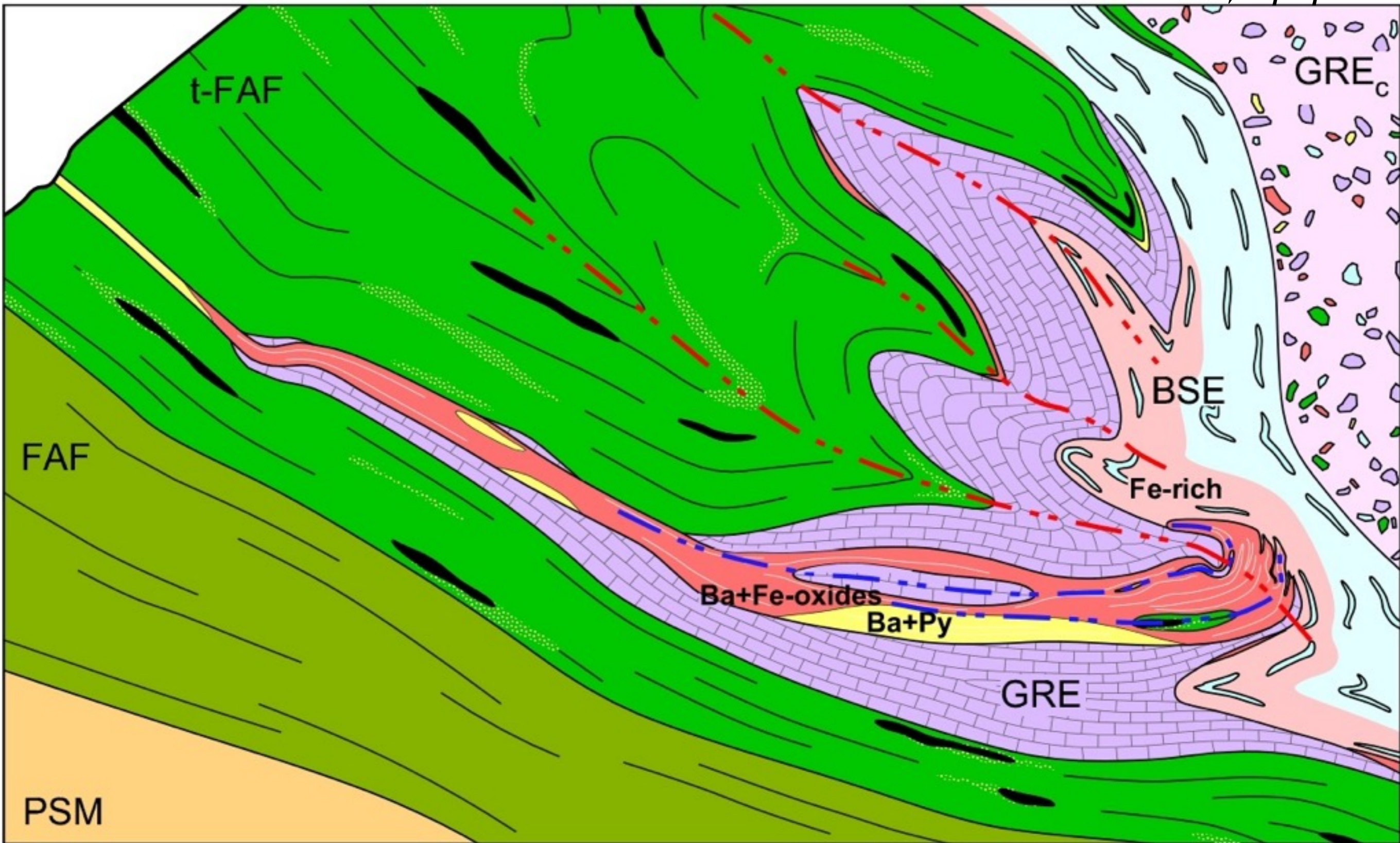
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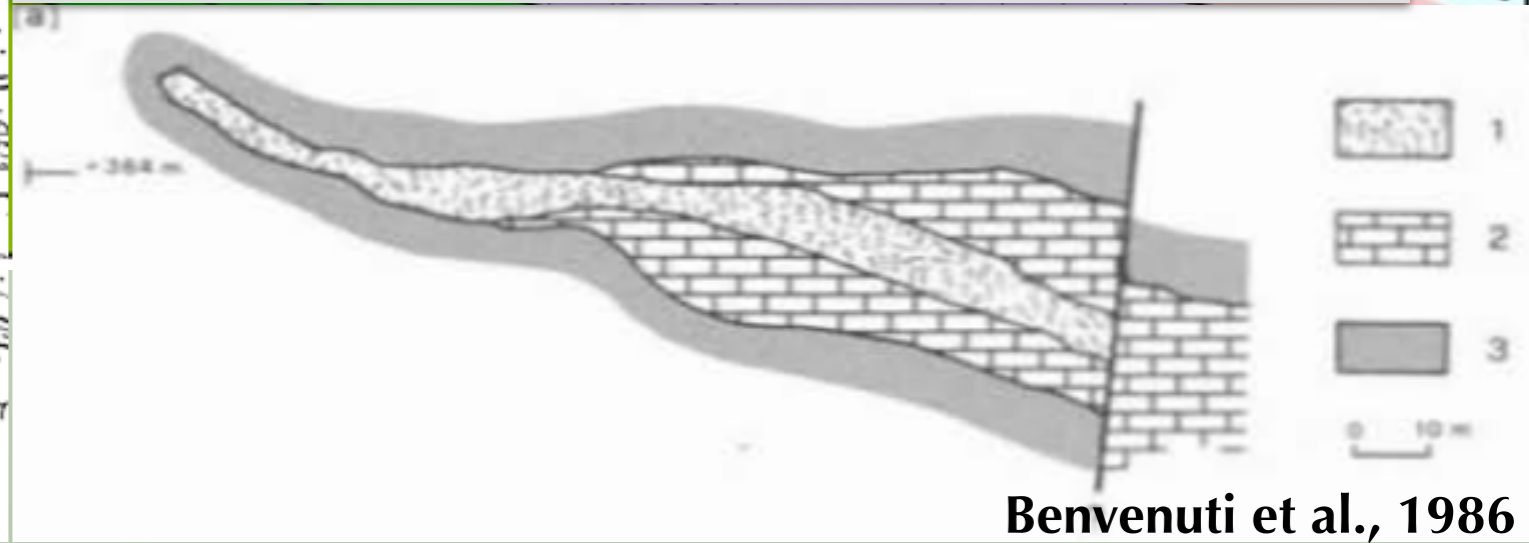
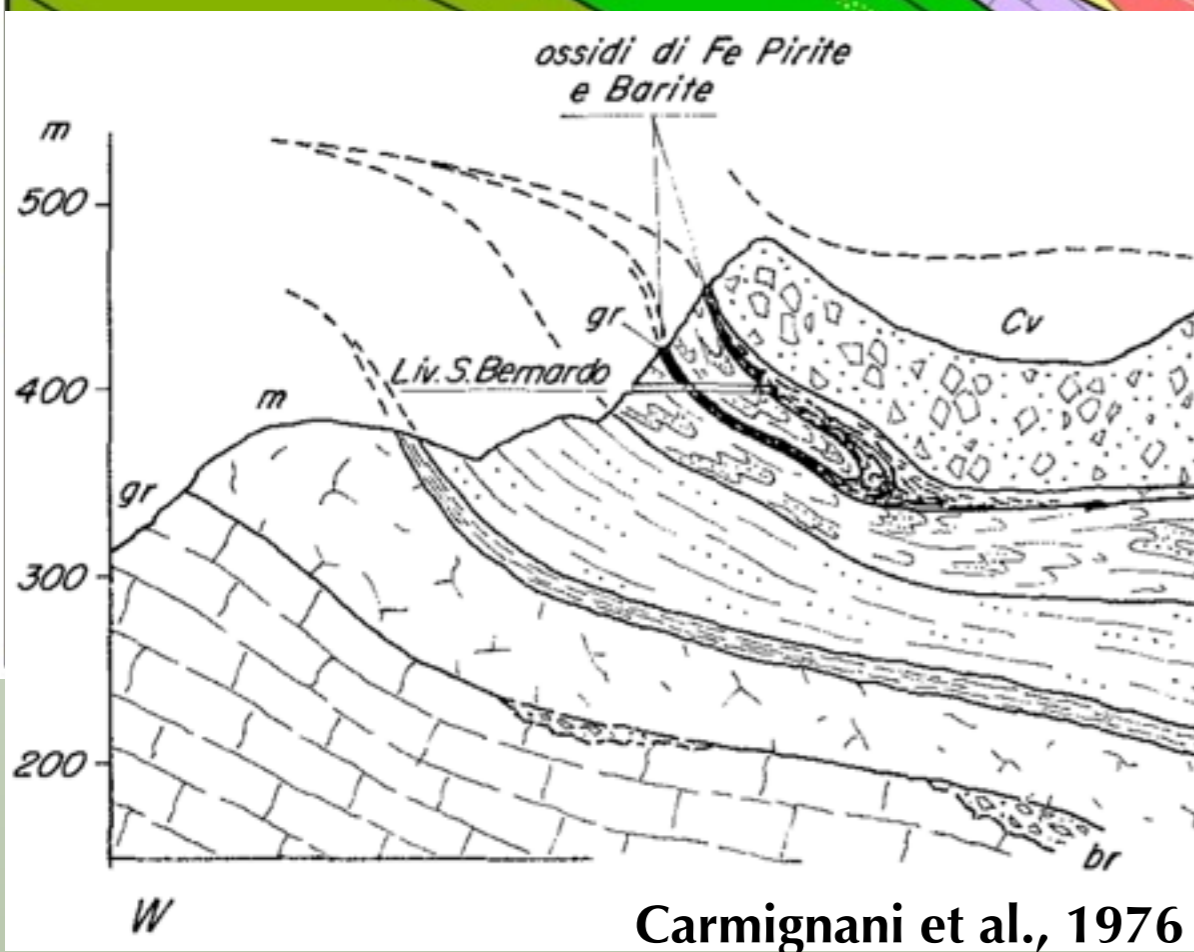
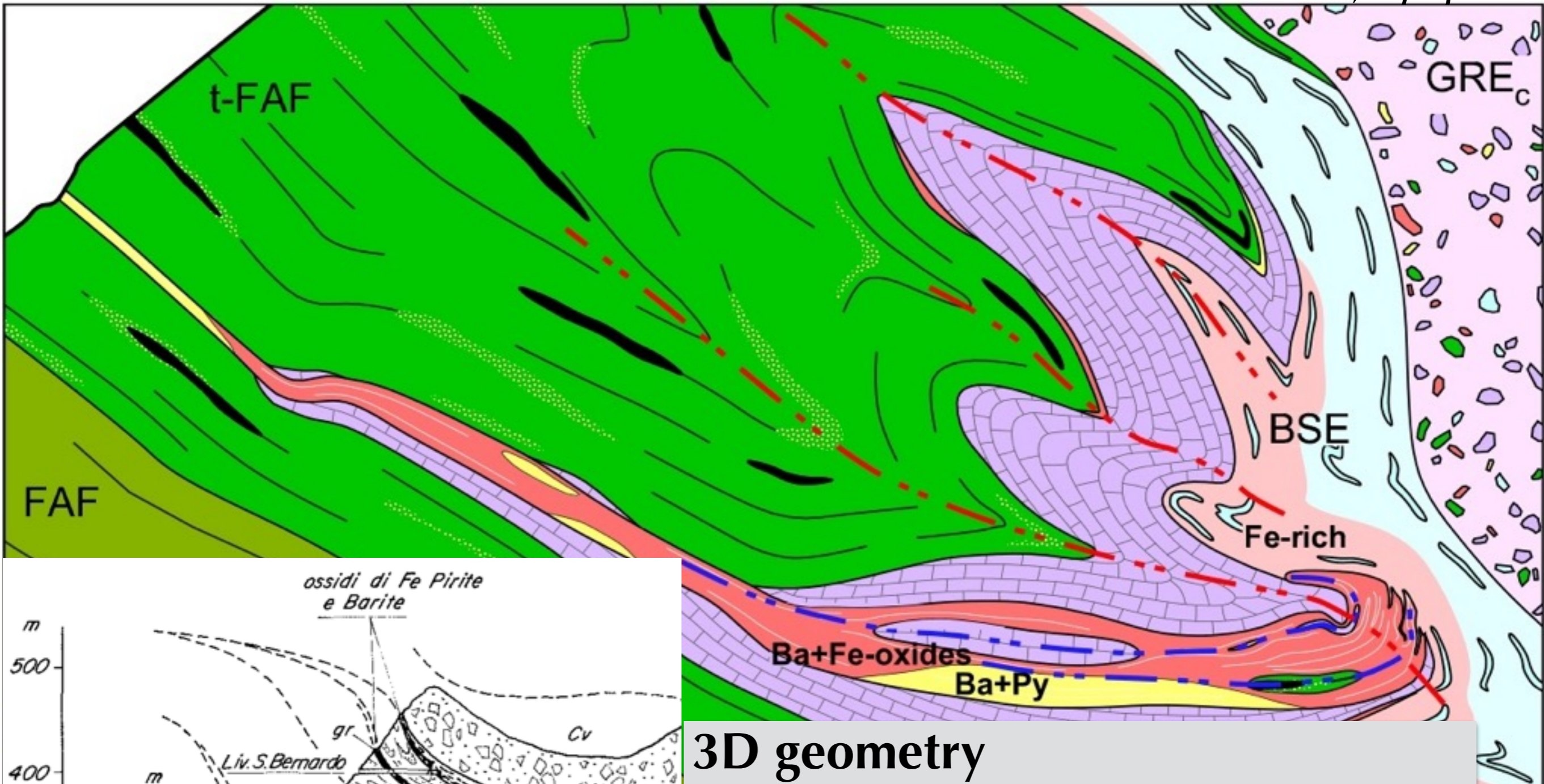
Buca della Vena geological section

Vezzoni et al., *in prep.*



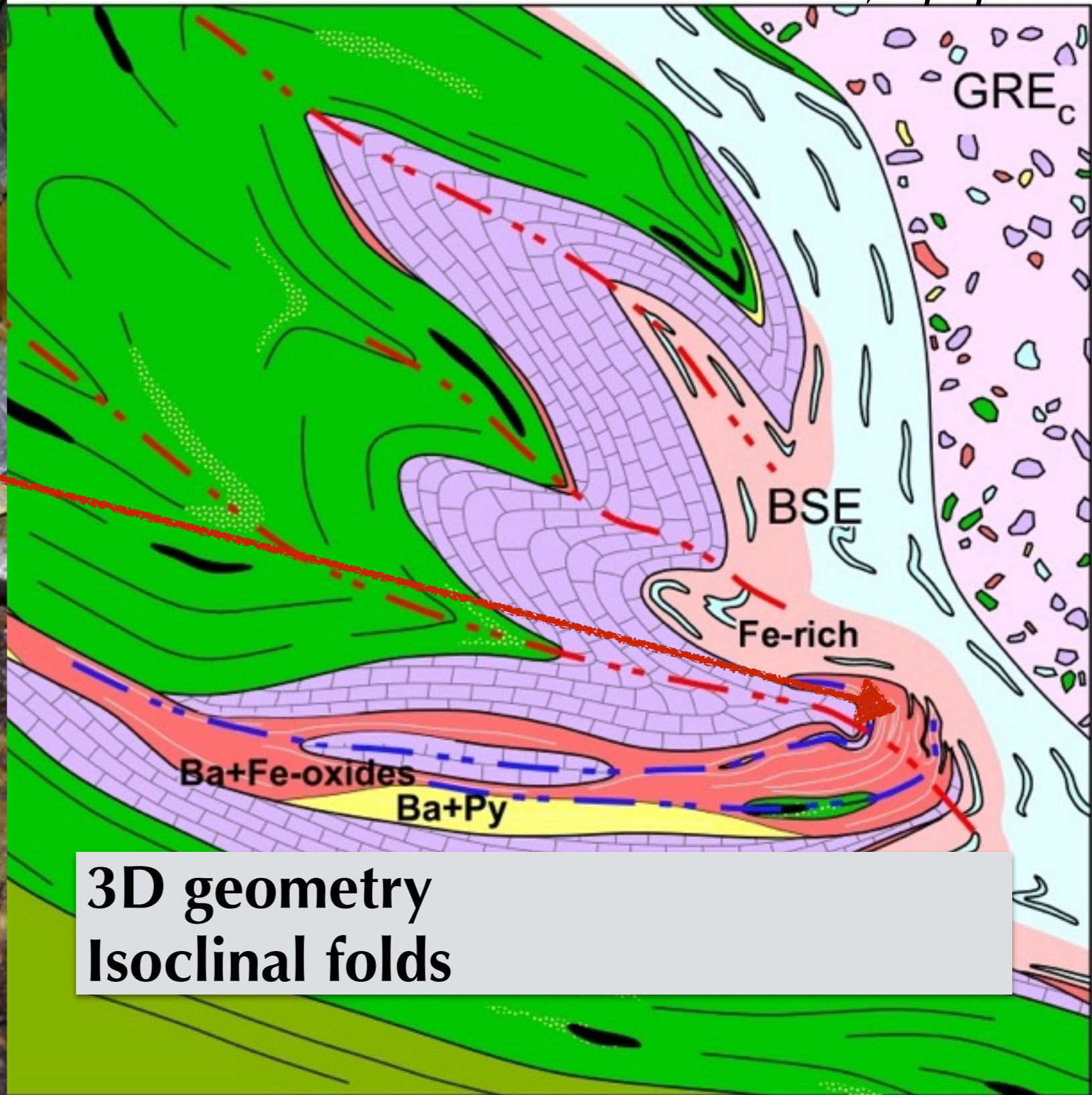
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Buca della Vena geological section

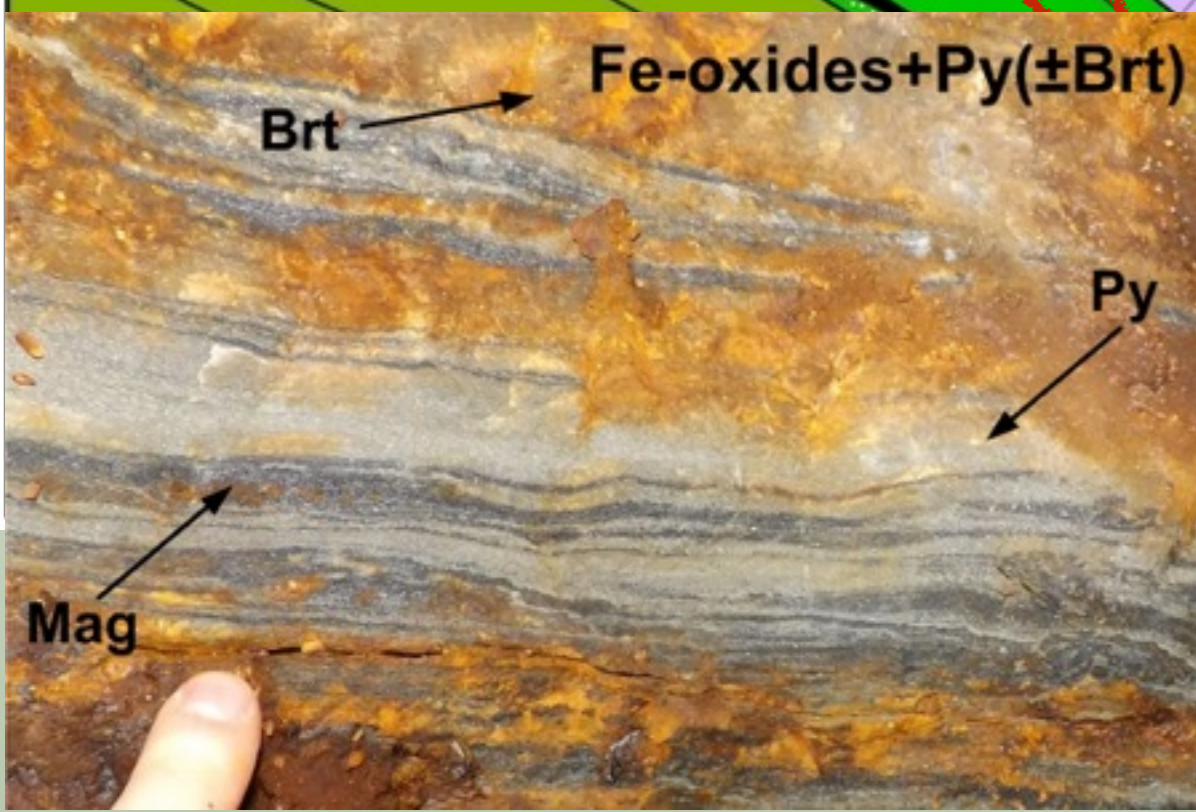
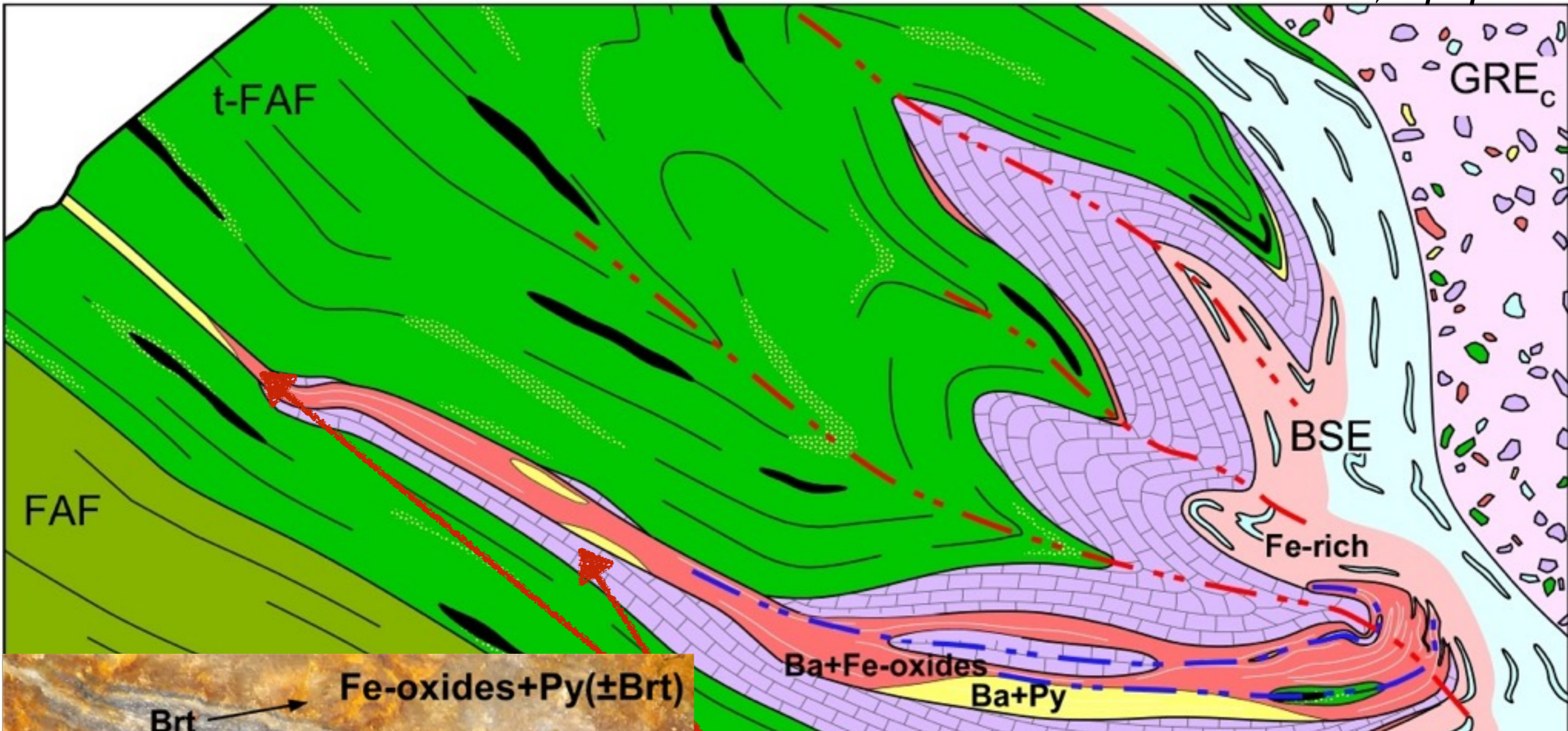
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**3D geometry
Isoclinal folds**

Buca della Vena geological section

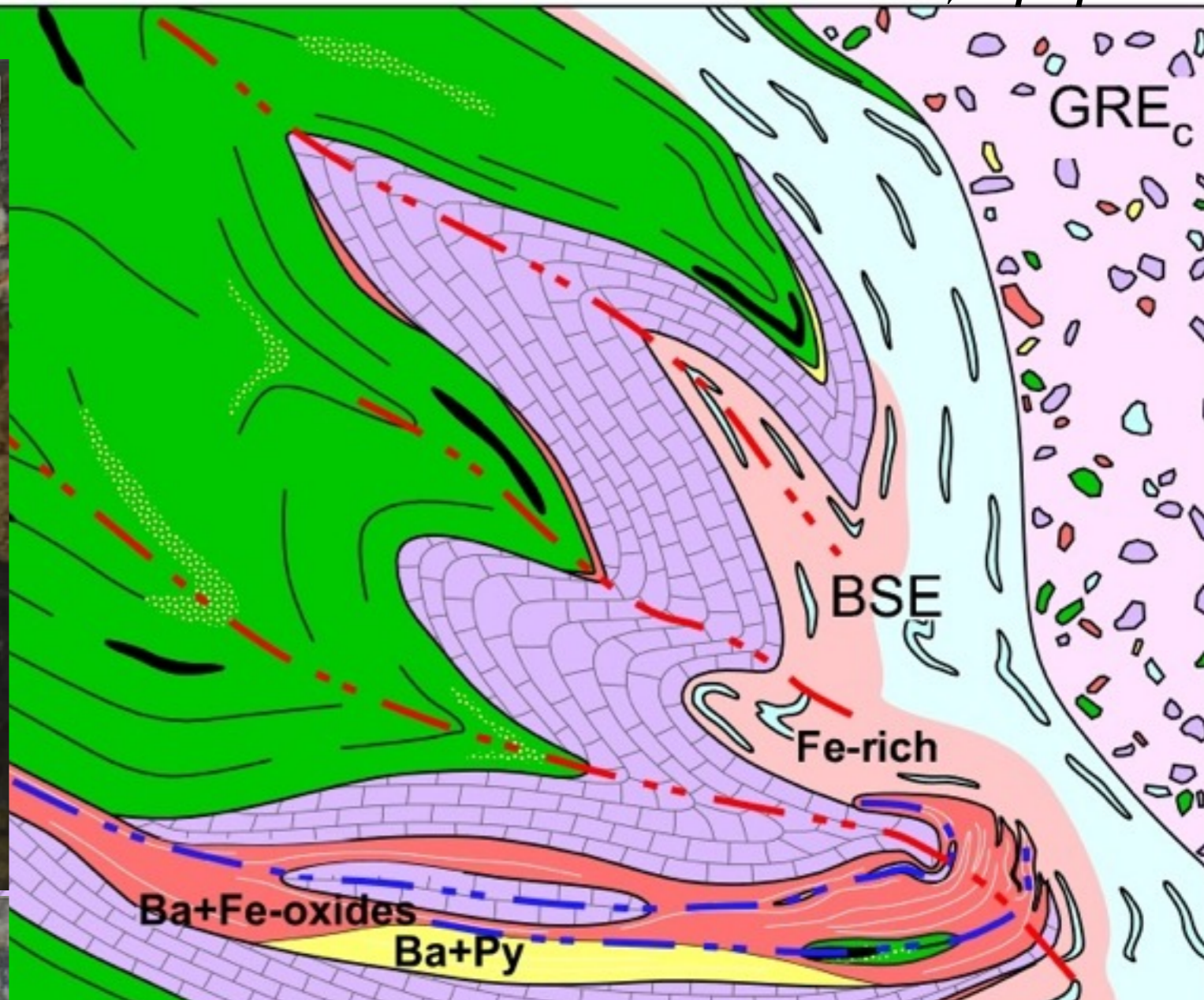
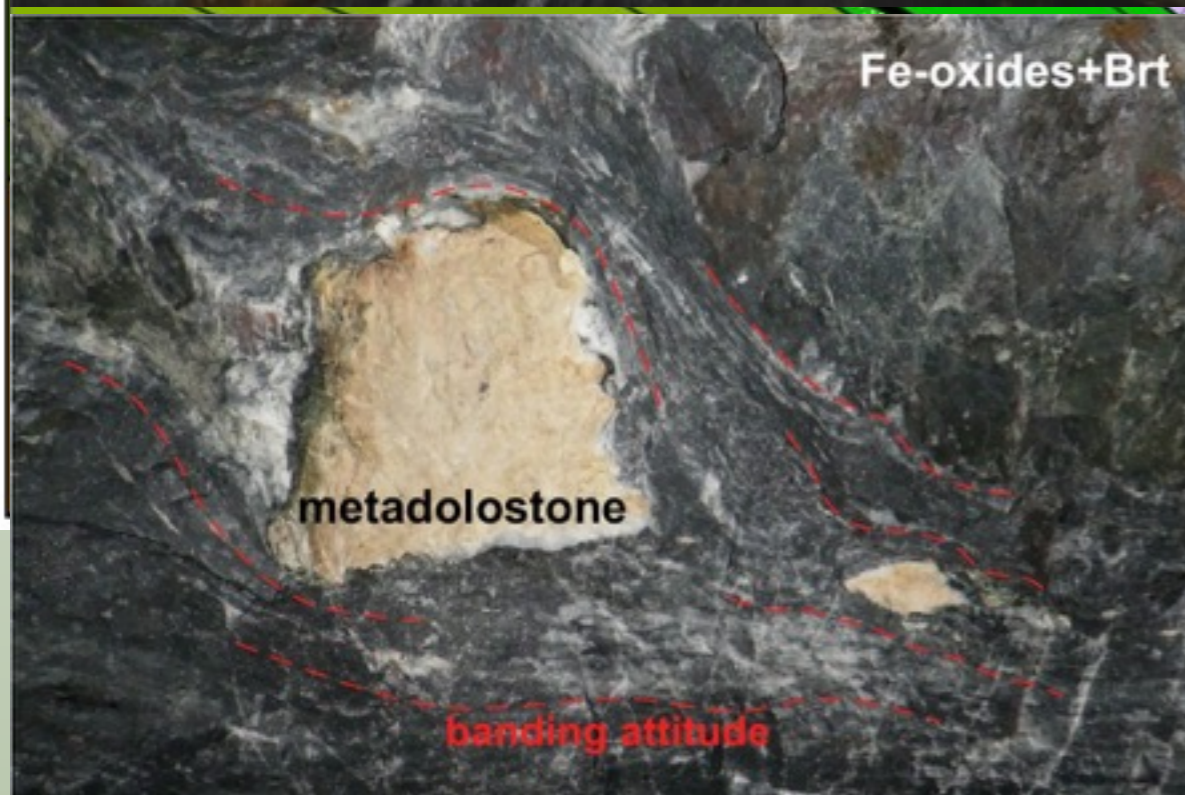
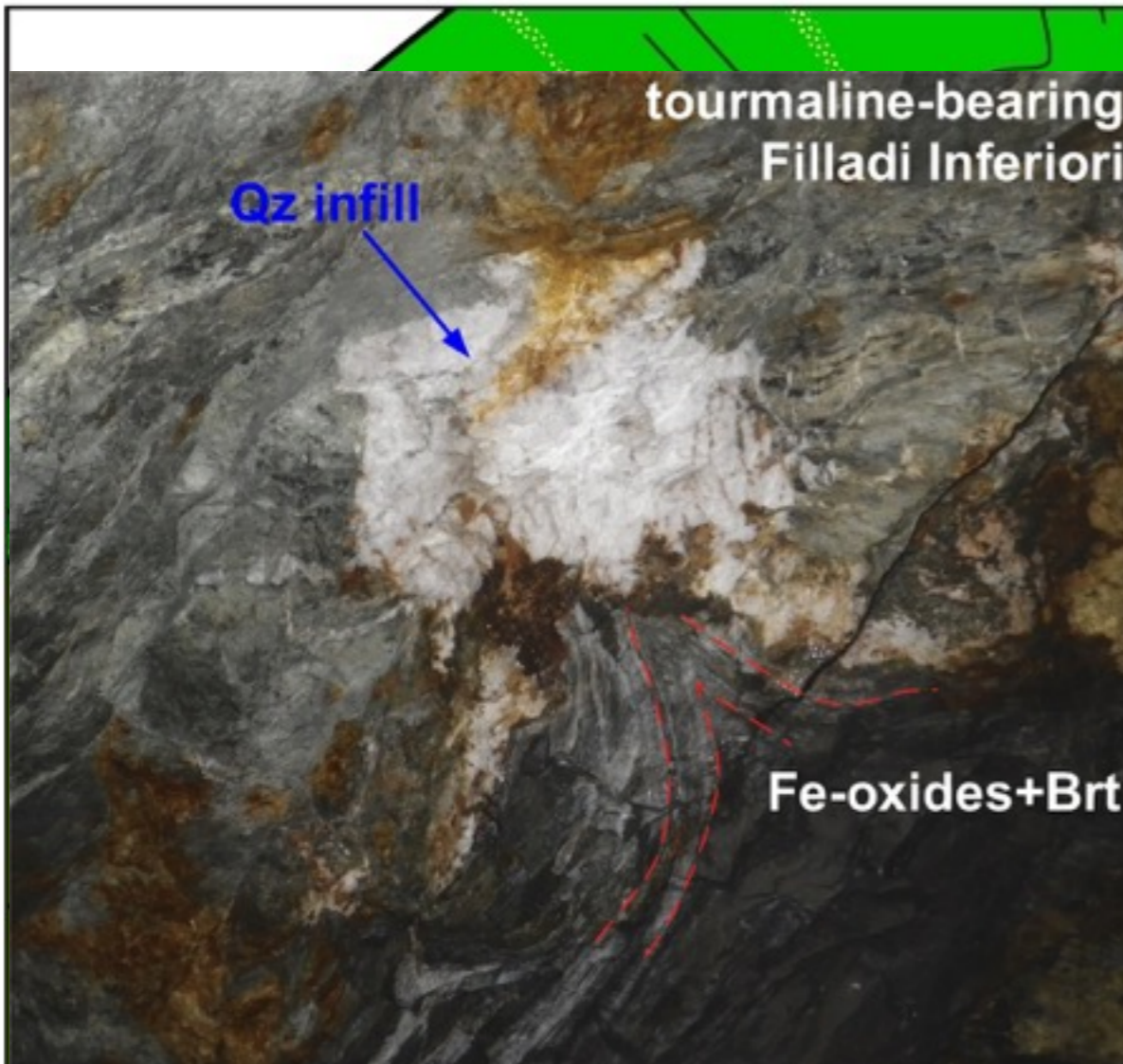
Vezzoni et al., *in prep.*



3D geometry
Isoclinal folds
Absence of ore zoning
Carbonate boudins

Buca della Vena geological section

Vezzoni et al., *in prep.*



3D geometry
Isoclinal folds
Absence of ore zoning
Carbonate boudins
Rheology ores vs. carbonate/schist
No metasomatism

Alpi Apuane Tl-district

baryte/pyrite and baryte/Fe-oxides (area%) ~ 1

Data from image analysis (Vezzoni et al., *in prep.*) and XRF (D'Orazio et al., 2017)

Ore type:	V (m³)	d (t/m³)	Tonnage (t)
baryte + pyrite	11000	4.75	53000
baryte + Fe-oxides	52000	4.85	252000
Buca della Vena mine			305000

Alpi Apuane Tl-district

Ore deposits:	BDV	M. Arsiccio	Pollone	CDR	Fornovolasco	AA district
	Massive pyrite					
Mined ore (t)						
Reserves (t)						
Tl-grade ($\mu\text{g/g}$)	-	77 ¹	-	675 ¹	871 ¹	
Tl-mined ore (t)						
Tl-reserves (t)						
	Mixed baryte + pyrite					
Mined ore (t)						
Reserves (t)						
Tl-grade ($\mu\text{g/g}$)	103 ¹	185 ¹	180 ¹	-	-	
Tl-mined ore (t)						
Tl-reserves (t)						
	Mixed baryte + Fe-oxides					
Mined ore (t)						
Reserves (t)						
	Fe-oxides/hydroxides					
Mined ore (t)						
Reserves (t)						

¹ D'Orazio et al., 2017

Alpi Apuane Tl-district

Ore deposits:	BDV	M. Arsiccio	Pollone	CDR	Fornovolasco	AA district
	Massive pyrite					
Mined ore (t)	-					
Reserves (t)	-					
Tl-grade (µg/g)	-	77 ¹	-	675 ¹	871 ¹	
Tl-mined ore (t)	-					
Tl-reserves (t)	-					
	Mixed baryte + pyrite					
Mined ore (t)	-					
Reserves (t)	53000 ²					
Tl-grade (µg/g)	103 ¹	185 ¹	180 ¹	-	-	
Tl-mined ore (t)	-					
Tl-reserves (t)	5.5					
	Mixed baryte + Fe-oxides					
Mined ore (t)	149000 ²					
Reserves (t)	103000 ²					
	Fe-oxides/hydroxides					
Mined ore (t)	-					
Reserves (t)	-					

¹ D'Orazio et al., 2017

² Vezzoni et al., *in prep.*

Alpi Apuane Tl-district

Ore deposits:	BDV	M. Arsiccio	Pollone	CDR	Fornovolasco	AA district
	Massive pyrite					
Mined ore (t)	-	29600	-	36000	-	65600
Reserves (t)	-	-	-	48780 ³	30000 ⁴	78780
Tl-grade (µg/g) ¹	-	77 ¹	-	675 ¹	871 ¹	
Tl-mined ore (t)	-	2.5	-	24.5	-	27.0
Tl-reserves (t)	-	-	-	33.0	26.0	59.0
	Mixed baryte + pyrite					
Mined ore (t)	-	340000	174000	-	-	514000
Reserves (t)	53000 ²	110000 ⁵	-	-	-	163000
Tl-grade (µg/g) ¹	103 ¹	185 ¹	180 ¹	-	-	
Tl-mined ore (t)	-	63	31.5	-	-	94.5
Tl-reserves (t)	5.5	20.5	-	-	-	26.0
	Mixed baryte + Fe-oxides					
Mined ore (t)	149000 ²	250000	-	-	-	399000
Reserves (t)	103000 ²	90000 ⁵	-	-	-	193000
	Fe-oxides/hydroxides					
Mined ore (t)	-	76500	-	14500	-	91000
Reserves (t)	-	-	-	96000 ³	-	96000

¹ D'Orazio et al., 2017

² Vezzoni et al., *in prep.*

³ Galli, 1956

⁴ Cortese, 1923

⁵ Ercole Martina, 1969

Data from "Relazione sul Servizio Minerario ..."

AA district - Tl > 206.5 t (Reserves 85 t)

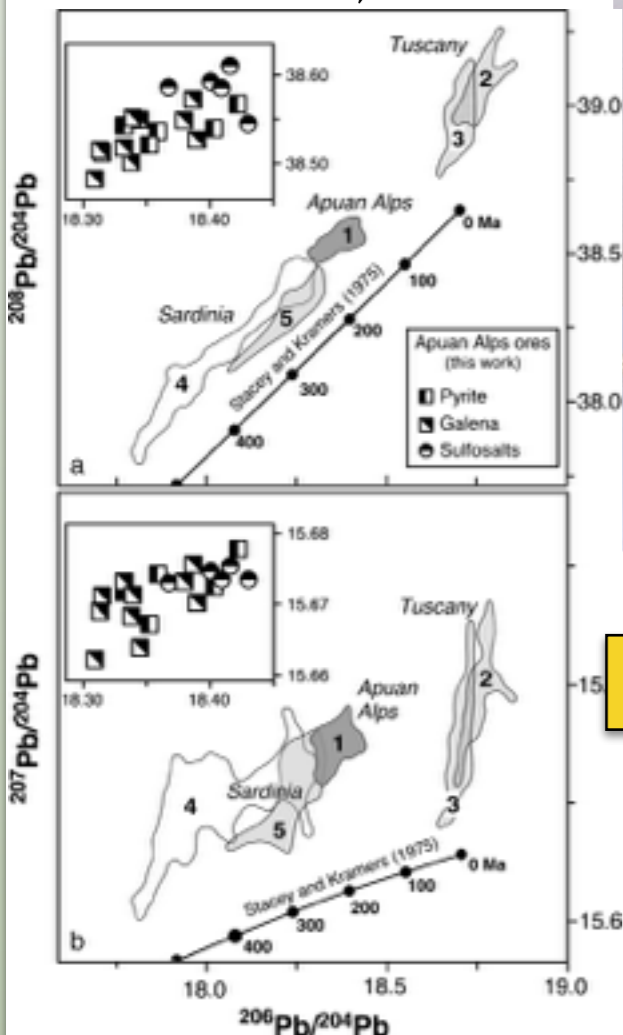
Conclusion

Buca della Vena is an exceptional geosite

1. The actual ore setting was acquired during Alpine tectono-metamorphic event
2. The proto-ore suffered partial exhumation and supergene alteration (Upper Trias-Lower Jurassic)
3. The field geology integrated with petrography, geochemistry, isotopic data point to an hydrothermal proto-ore related to the Permian magmatism

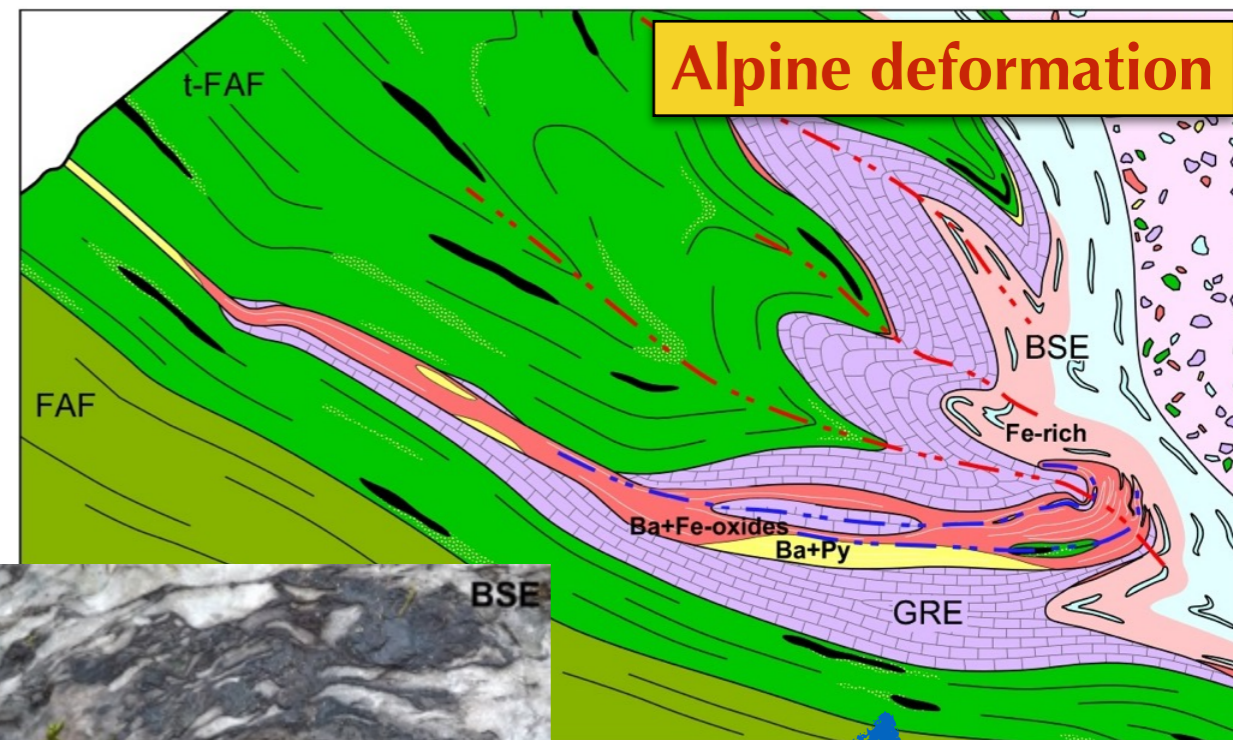
⇒ AA is a world-class Tl-district

D'Orazio et al., 2017



+As, Sb, Hg, Tl, Bi...

Hydrothermal system



Supergene alteration

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⇒ AA is a world-class TI-district

Distribution of pre-Mesozoic Units

Franke, 1989; Martínez-Catalán, 1990; Neubauer, 2014; Ribeiro & Sanderson, 1996; von Raumer et al. 2002, 2013

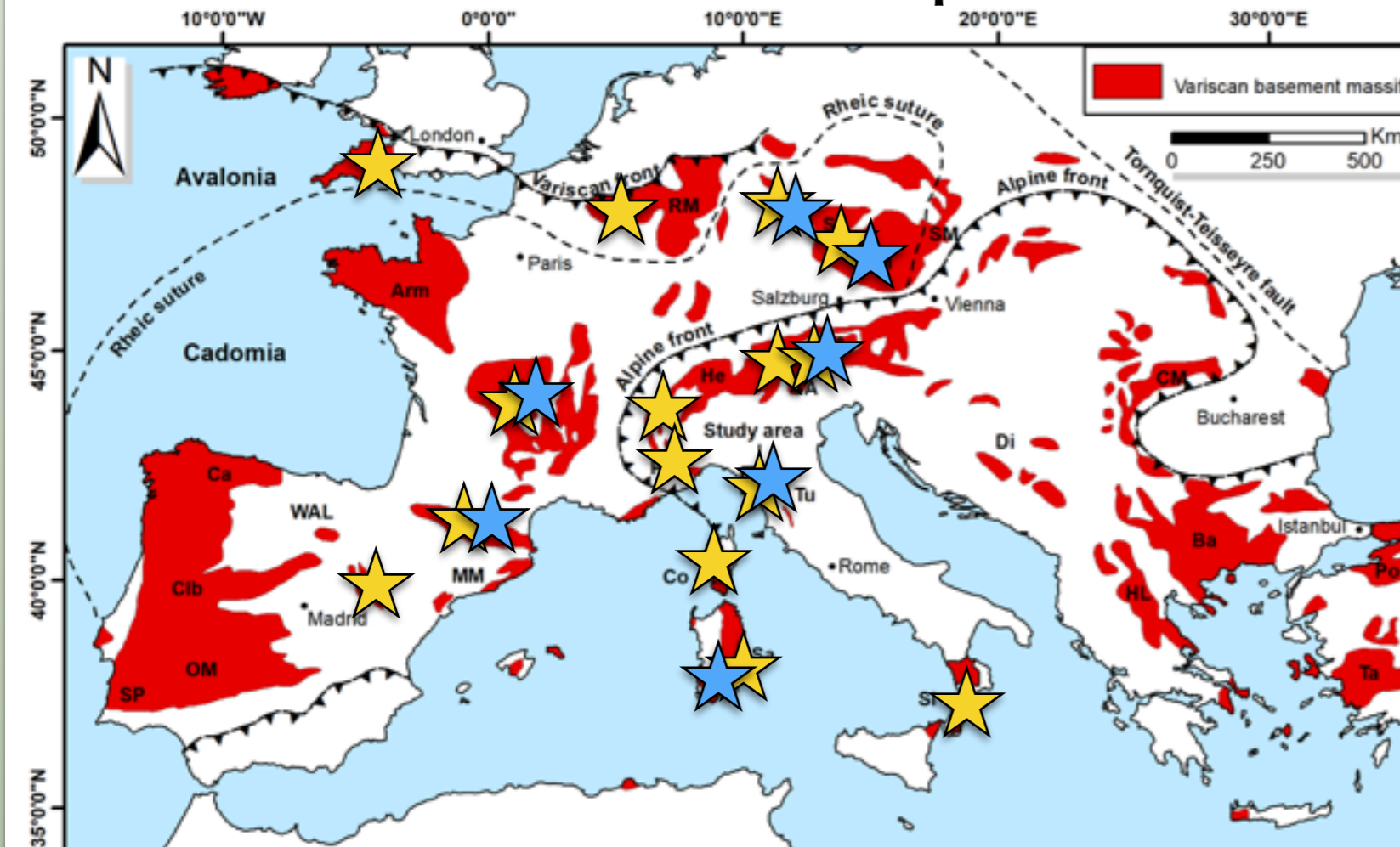
Permian events

★ Magmatism

e.g., Buzzi et al., 2008; Cabanis et al., 1990; Cassinis et al., 2008; Dallagiovanne et al., 2009; Deroin & Bonin, 2003; Finger et al., 2003; Forster et al., 1999; Gaggero et al., 2007; Lago et al., 2004; Marignac & Cuney, 1999; McCann et al., 2006; Ronca et al., 1999; Traversa et al., 2003; Visonà et al., 2007; ...

★ Ores

e.g., Ackerman et al., 2017; Boni et al., 2015; Cabral et al., 2017; Cugerone et al., 2018; De Capitani et al., 1999; Harlaux et al., 2018; Kopp et al., 2012; Marignac & Cuney, 1999; Melcher & Onuk, 2019; Nadoll et al., 2019; Ostendorf et al., 2019; ...



Conclusion

Field-based studies are crucial to constrain original setting, genesis and fate of orebodies

Relevant implications e.g., natural vs anthropic environmental pollution

Ore deposits are “geological gyms” for students



Buca della Vena: la Via del Ferro delle Alpi Apuane



XI
Giornata Nazionale
delle Miniere

Sabato 25 maggio 2019

Buca della Vena (Cardoso, LU) è uno dei più importanti geositi minerari delle Alpi Apuane, sia da un punto di vista storico che scientifico.

L'escursione, in mezzo a boschi e scorci panoramici sulle Alpi Apuane, guiderà alla scoperta delle passate attività minerarie con l'occasione di “toccare con mano” le mineralizzazioni qui coltivate.

Ritrovo - Piazza Europa,
Pontestazzemese ore 9:00
Difficoltà - media
Rientro previsto - ore 15:00

Prenotazione obbligatoria entro
mercoledì 22 maggio
costo assicurazione CAI - 8 euro

Nome, Cognome, data di nascita ed
eventuale iscrizione al CAI
dovranno essere inviati tramite
mail a:

Simone.Vezzoni@igg.cnr.it

Pranzo al sacco presso
Osservatorio Astronomico
“Alpi Apuane” (Stazzema)



foto L. Tinagli





https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en

METHODOLOGY FOR ESTABLISHING THE EU LIST OF CRITICAL RAW MATERIALS

• Guidelines •



Raw materials

