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Mapping the geology of the 2016 Central Italy earthquake fault (Mt. Vettore - Mt. Bove fault, Sibillini Mts.): geological details on the Cupi - Ussita and Mt. Bove - Mt. Porche segments and overall pattern of coseismic surface faulting.

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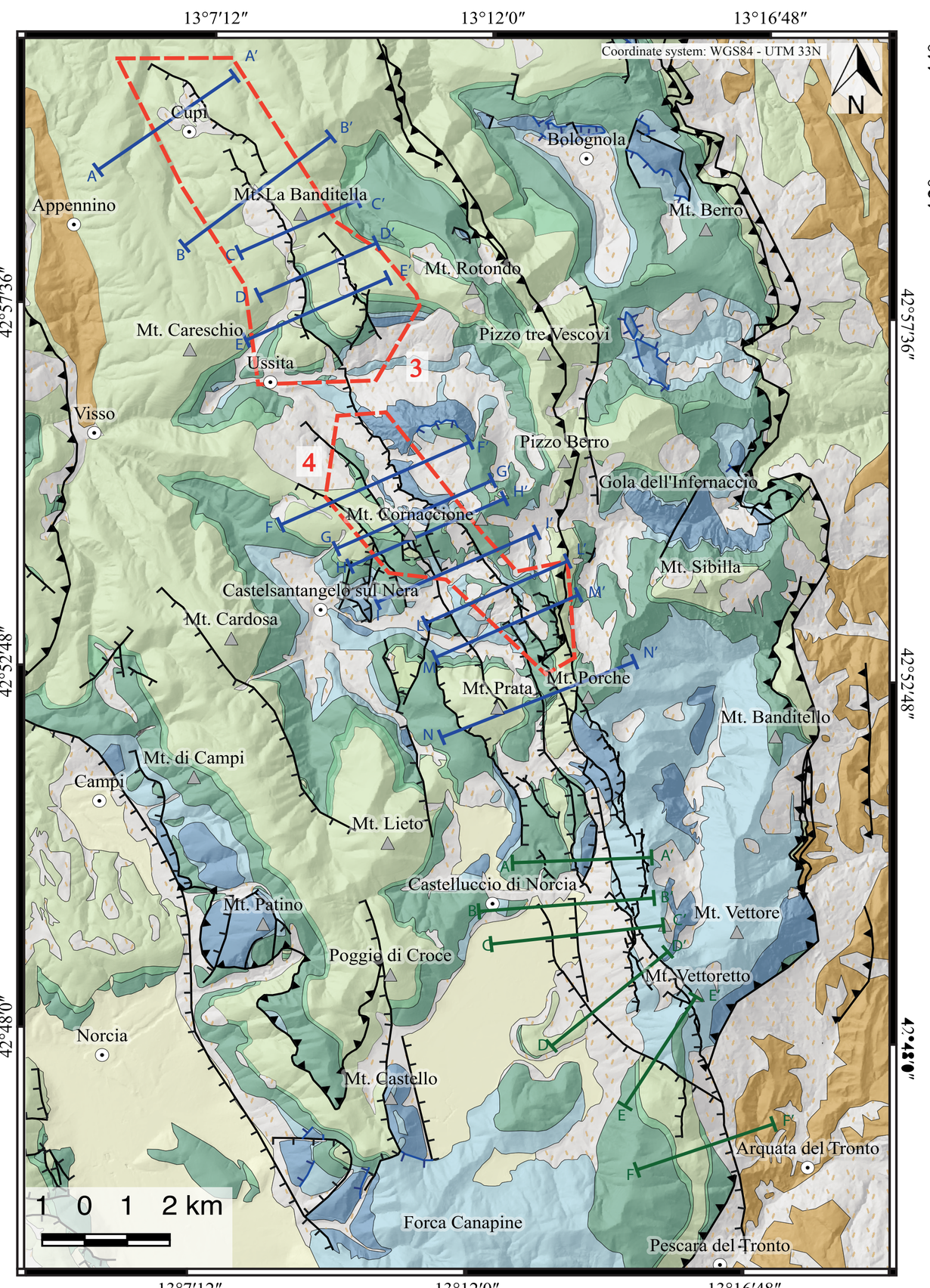
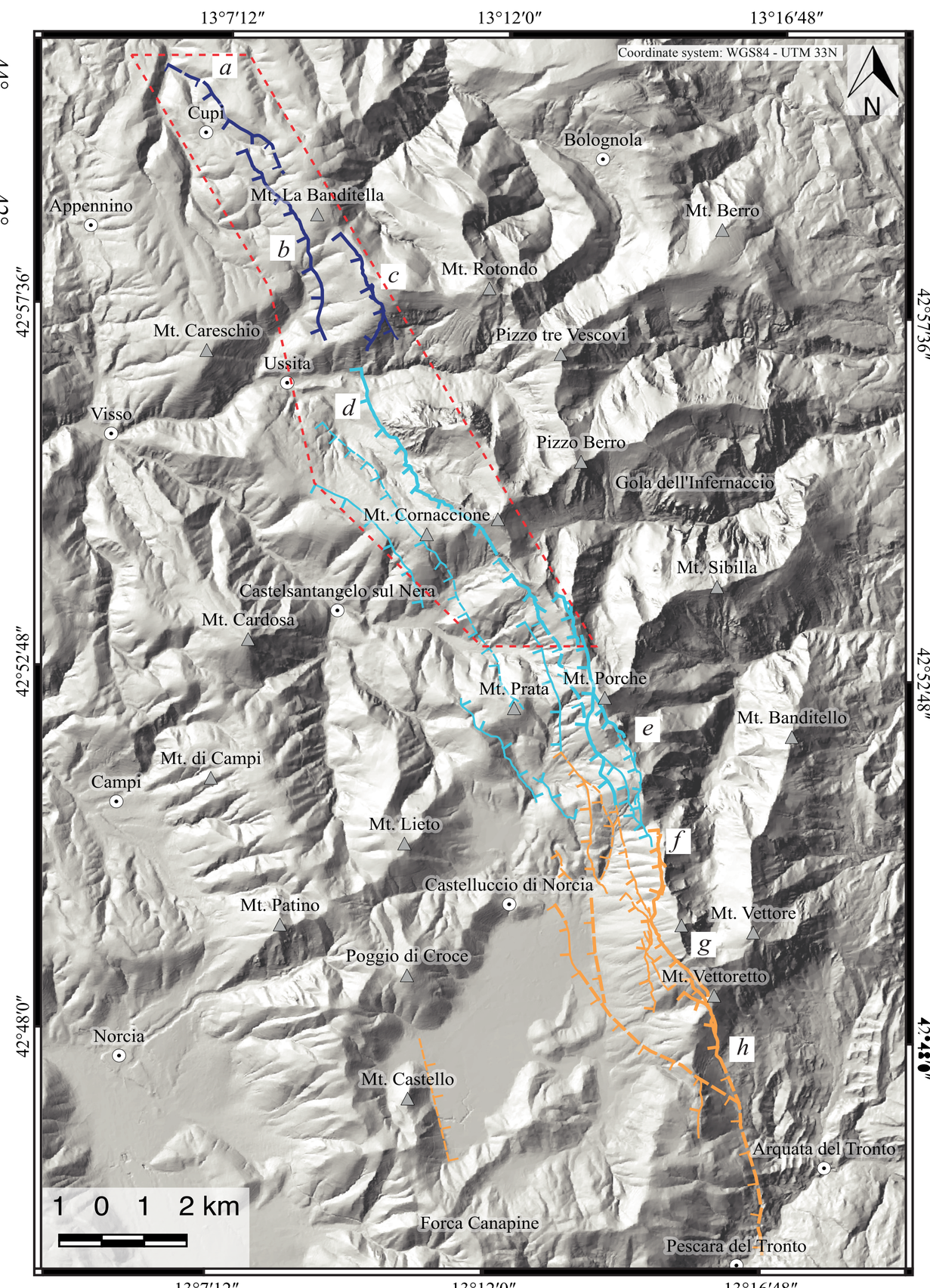
1. Geological Map of Mts. Sibillini Area




2. Structural Map of Mt. Vettore - Mt. Bove Fault System



LEGEND

- Stratigraphy:
- Slope Deposits: slope, landslide and alluvial deposits (Holocene)
- Fluvio - lacustrine deposits (Middle/Upper Pleistocene - Holocene)
- Laga Formation, Schlier, marne con cerrogna, Bisciaro (Aquitanian - Messinian)
- Scaglia Cinerea, scaglia variegata, Scaglia Rossa, Scaglia Bianca, (Upper Albian p.p. - Aquitanian p.p.)
- Marne a Fucoidi (Lower Aptian - Upper Albian)
- Maiolica Fm. (Upper Tithonian - Lower Aptian p.p.)
- Jurassic complete succession (Calcari Diasprigni, Calcari e Marne a Posidonia, Rosso Ammonitico, marne del Serrone, Corniola) and condensed successions (Bugarone group) (Carixian p.p. - Lower Tithonian)
- Calcare Massiccio (Hettangian - Carixian)

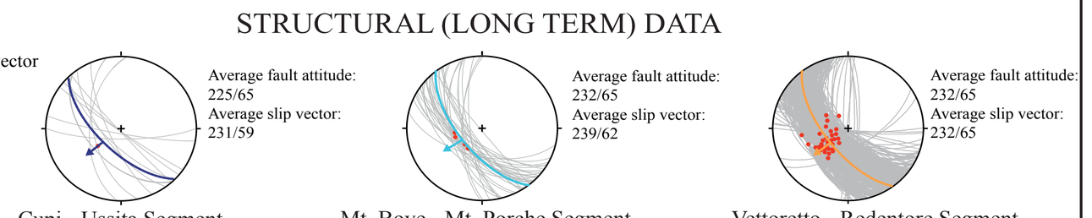
- Tectonics:
- Fault
- Normal fault
- Jurassic fault
- Thrust
- Survey areas boundary
- 3 Cupi - Ussita
- 4 Mt. Bove - Mt. Porche
- Section trace (this work)
- Section trace (Brozzetti et al. 2019)

Surface faulting survey area

Mt. Vettore Mt. Bove Fault System (length: 30 km):

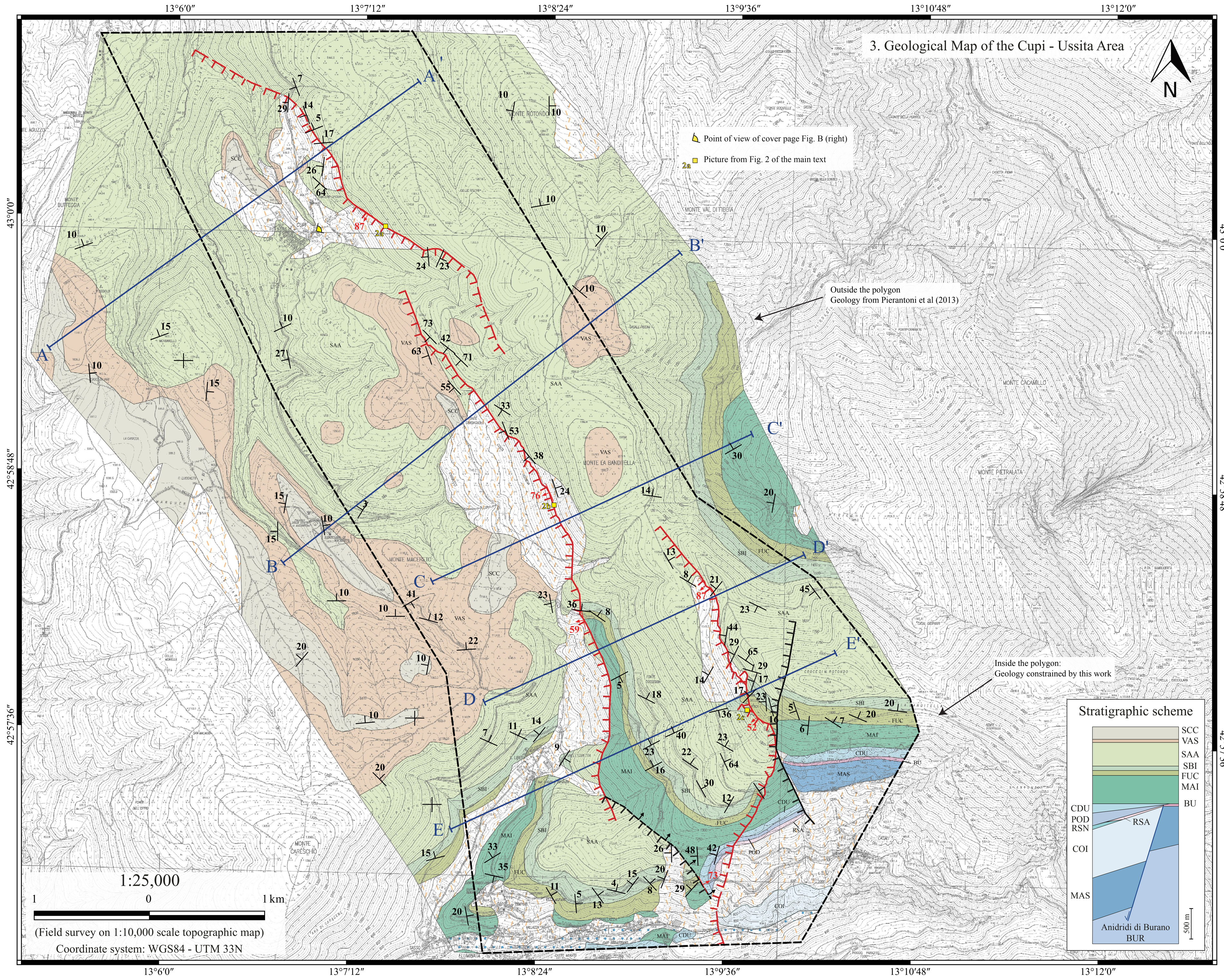
	Main Outcropping	Main Buried/Uncertain	Secondary Outcropping	Secondary Buried/Uncertain
- **Cupi-Ussita Segment (9 km)** *a: Cupi section (4 km); b: Mt. Banditella section (5 km); c: Mt. Rotondo section (3 km).*				
- **Mt. Bove-Mt. Porche Segment (12 km)** *d: Mt. Bove section (10 km); e: Mt Porche section (4 km).*				
- **Vettoretto-Redentore Segment (10 km)** *f: Quarto.S.Lorenzo section (2.5 km); g: Redentore section (2 km); h: Vettoretto section (2 km).*				

STRUCTURAL (LONG TERM) DATA

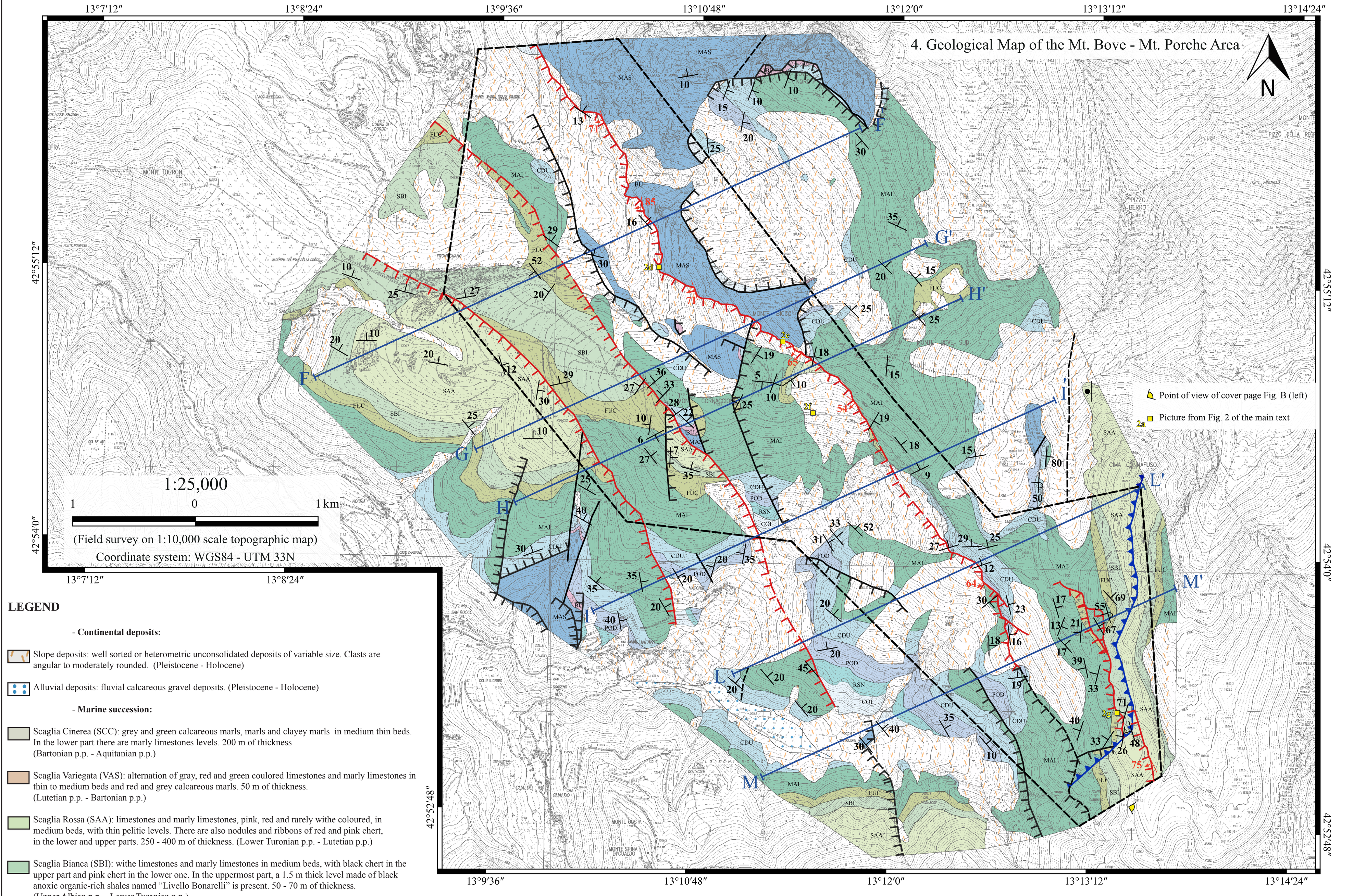


Cupi - Ussita Segment — Mt. Bove - Mt. Porche Segment — Vettoretto - Redentore Segment

3. Geological Map of the Cupi - Ussita Area



4. Geological Map of the Mt. Bove - Mt. Porche Area



LEGEND

- **Continental deposits:**

Slope deposits: well sorted or heterometric unconsolidated deposits of variable size. Clasts are angular to moderately rounded. (Pleistocene - Holocene)

Alluvial deposits: fluvial calcareous gravel deposits. (Pleistocene - Holocene)

- **Marine succession:**

Scaglia Cinerea (SCC): grey and green calcareous marls, marls and clayey marls in medium thin beds. In the lower part there are marly limestones levels. 200 m of thickness (Bartonian p.p. - Aquitanian p.p.)

Scaglia Variegata (VAS): alternation of gray, red and green coulored limestones and marly limestones in thin to medium beds and red and grey calcareous marls. 50 m of thickness. (Lutetian p.p. - Bartonian p.p.)

Scaglia Rossa (SAA): limestones and marly limestones, pink, red and rarely withe coloured, in medium beds, with thin pelitic levels. There are also nodules and ribbons of red and pink chert, in the lower and upper parts. 250 - 400 m of thickness. (Lower Turonian p.p. - Lutetian p.p.)

Scaglia Bianca (SBI): withe limestones and marly limestones in medium beds, with black chert in the upper part and pink chert in the lower one. In the uppermost part, a 1.5 m thick level made of black anoxic organic-rich shales named "Livello Bonarelli" is present. 50 - 70 m of thickness. (Upper Albian p.p. - Lower Turonian p.p.)

Marne a Fucoidi (FUC): marls, shaly marls, marly limestone grey, green and red coulored with organic-rich clay levels. In the upper part, marly limeston prevails and green chert is present. 50 - 80 m of thickness. (Lower Aptian - Upper Albian)

Maiolica (MAI): white mudstones in thin-medium beds with gray or white chert in the lower part and black chert in the upper part. 150 - 450 m of thickness. (Upper Tithonian - Lower Aptian)

- **Complete Jurassic succession:**

Calcari Diasprigni (CDU): the lower part is made up of thinly bedded green, red and gray siliceous mudstones with green, red or gray chert and marly levels. Clastic and bioclastic limestones are also present. The upper part is named "Calcari ad Aptici", and is composed of grey, green and red cherty limestones in medium - thin beds with aptychi. 150 m of thickness. (Upper Bajocian - Lower Titonian)

Calcari e Marne a Posidonia (POD): whitish - brown limestones and marly limestones in medium beds, sometimes nodular. Posidonia filaments are abundant. Clastic and bioclastic limestones are present and chert increases upward. 200 m of thickness. (Upper Toarcian p.p. - Lower Bajocian)

Rosso Ammonitico (RSA): pink and red nodular limestones and marly limestones in medium to thin beds alternating with red marls and shaly marls. The unit can be partially or totally replaced by the "Marne del Serrone" Formation. 40 m of thickness. (Toarciano p.p.)

Marne del Serrone (RSN): green and grey marly limestones of various thickness, marls and shaly marls and clastic limestones in medium beds. Variable thickess, from a few to 150 m. (Pleinsbachian p.p. - Toarcian p.p.)

Corniola (COI): grey and brown limestones in thin to thick beds. Gray and white nodules or ribbons of chert are present. Olistoliths of Calcare Massiccio are present. The upper part can be replaced by the "Marne del Serrone" Formation. Thickness of 500 m or more. (Lower Sinemurian p.p. Lower Toarcian p.p.)

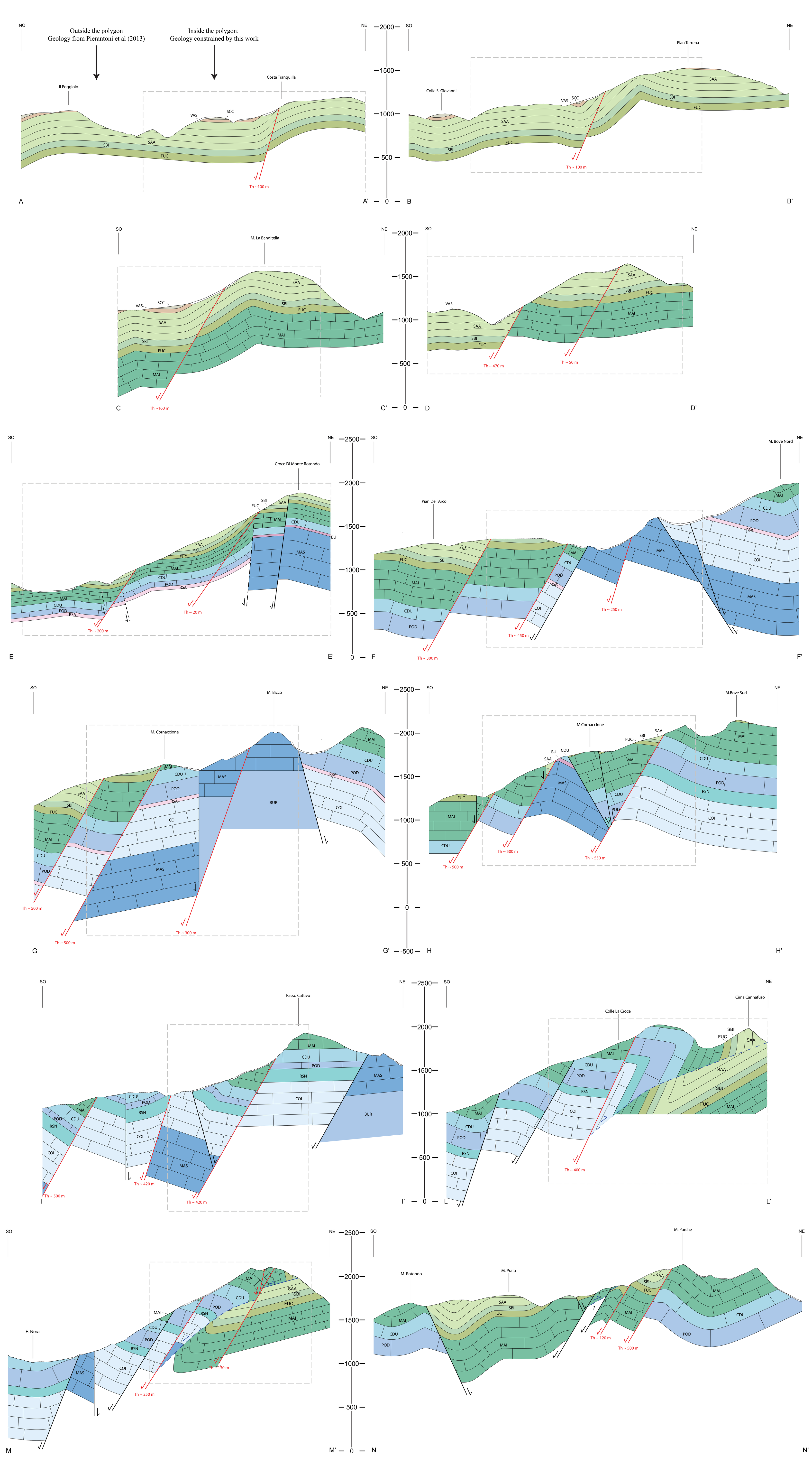
- **Condensed Jurassic succession**

Bugarone group (BU): nodular and locally dolomitized grey, brown or pink mudstones in medium beds. Marls are present in the middle part. There are ammonites, crinoids and brachiopods. 40 m of thickness. (Carixian p.p. - Lower Titonian)

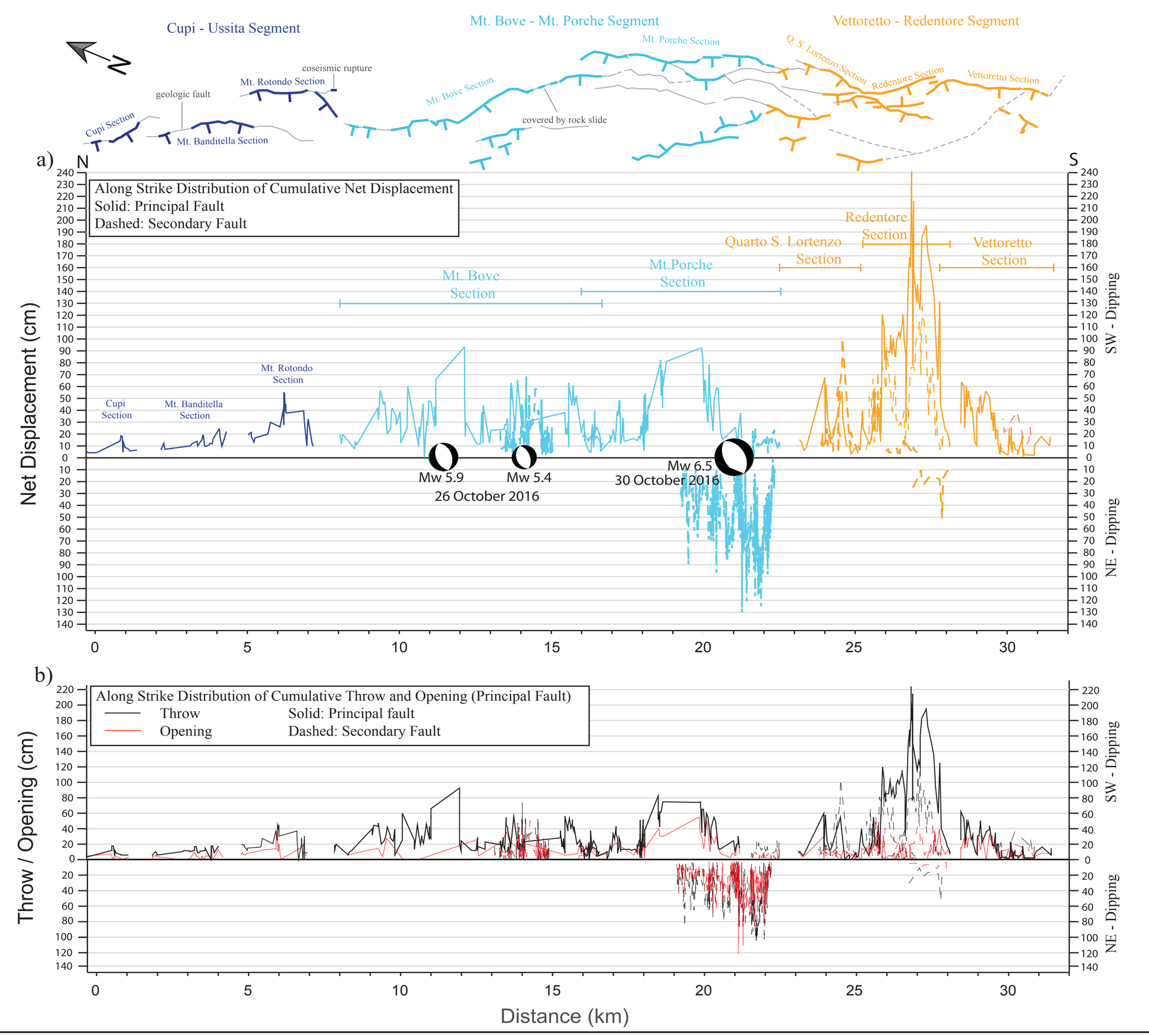
Calcare Massiccio (MAS): white, or more rarely gray or brown grainstones, packstones and sometimes wackstones, massive or coarsely bedded with cyclothemic features. Ooid and bioclastic grainstones are present in the uppermost part. Maximum 700 m of thickness. (Hettangian - Carixian)

- Reactivated normal fault
- Uncertain/buried reactivated normal fault
- Not reactived normal fault
- Uncertain/buried not reactivated normal fault
- Rotated fault
- Fault
- Thrust
- Section traces
- Bedding
- Horizontal bedding
- Overturned bedding
- Vertical bedding
- Fault attitude

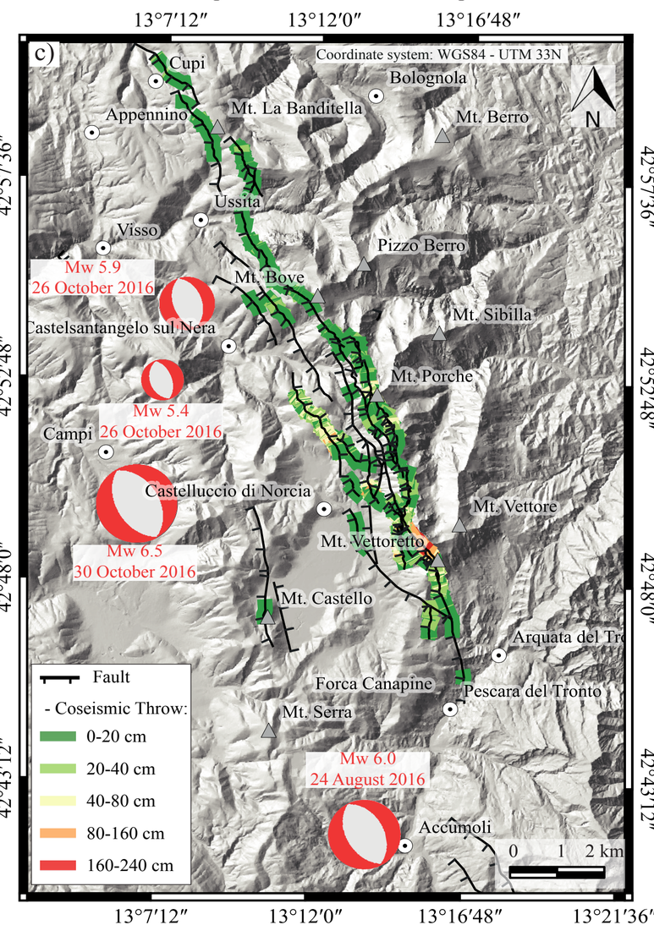
5. Geological Sections (Scale 1:25,000)



6. Coseismic Surface Parameters



Displacement Distribution Map



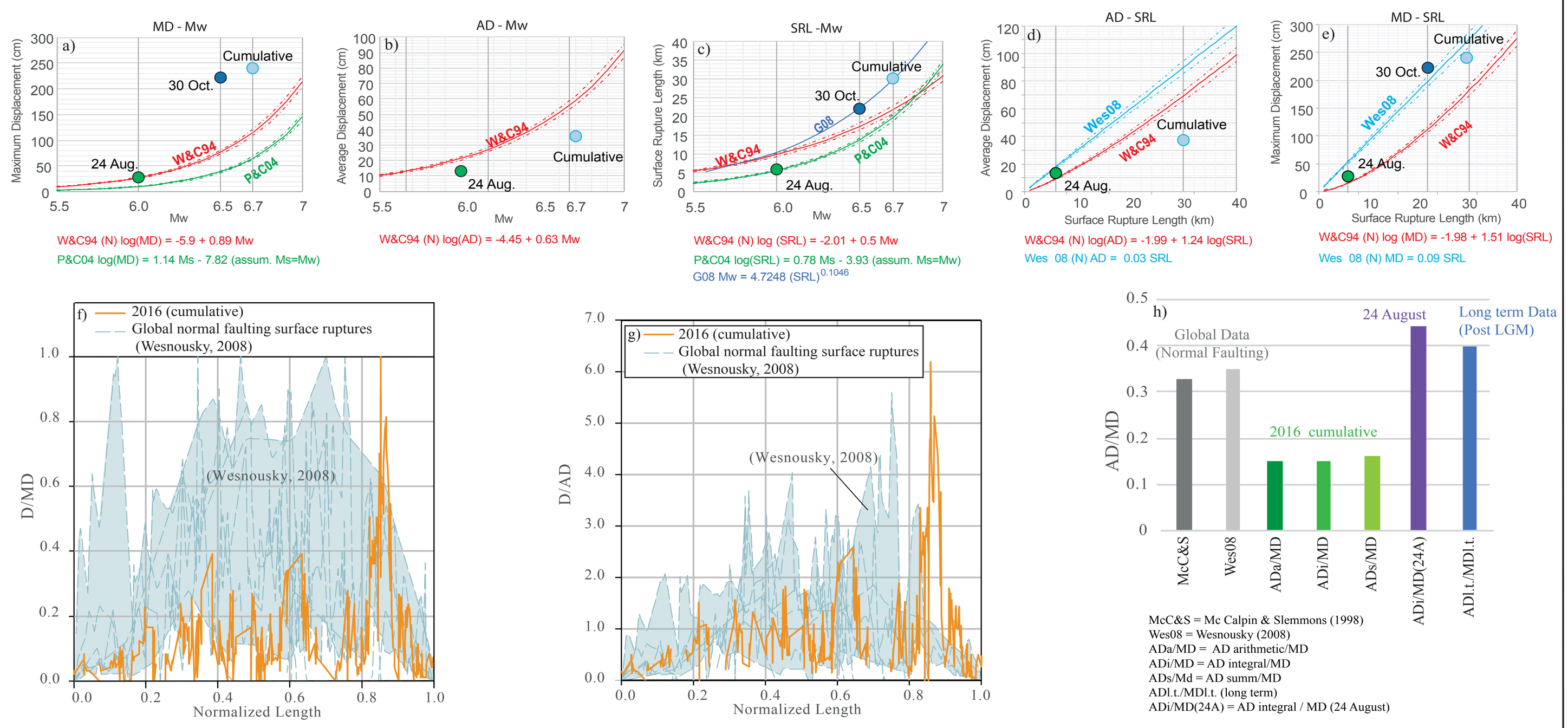
(a) Along-strike distribution of the net coseismic displacement (D) measured after the October 30, M 6.5 shock (cumulative D of the August 24 and October 26 and 30 earthquakes; modified from Brozzetti et al., 2019). Each fault segment, represented by lines of different colour, shows a peak of displacement. The Vettoretto - Redentore segment has a very localized high displacement zone.
(b) Along-strike distribution of the cumulative throw (black line) and opening (horizontal aperture measured perpendicular to rupture strike; red lines). The coseismic parameters are listed in the following table. AD integral is the average D obtained by integrating the D distribution over the entire length of the surface rupture. AD arithmetic is the arithmetic mean of all the measured D values.

COSEISMIC PARAMETERS

	Cumulative (Mw 6.7)	30 October (Mw 6.5)	24 August (Mw 6.0)
SRL	30 km (<32 km)	≥ 22 km	5.8 km
MD	240 cm	222 cm	28.5 cm
AD integral	36 cm		12.7 cm
AD arithmetic	37 cm		

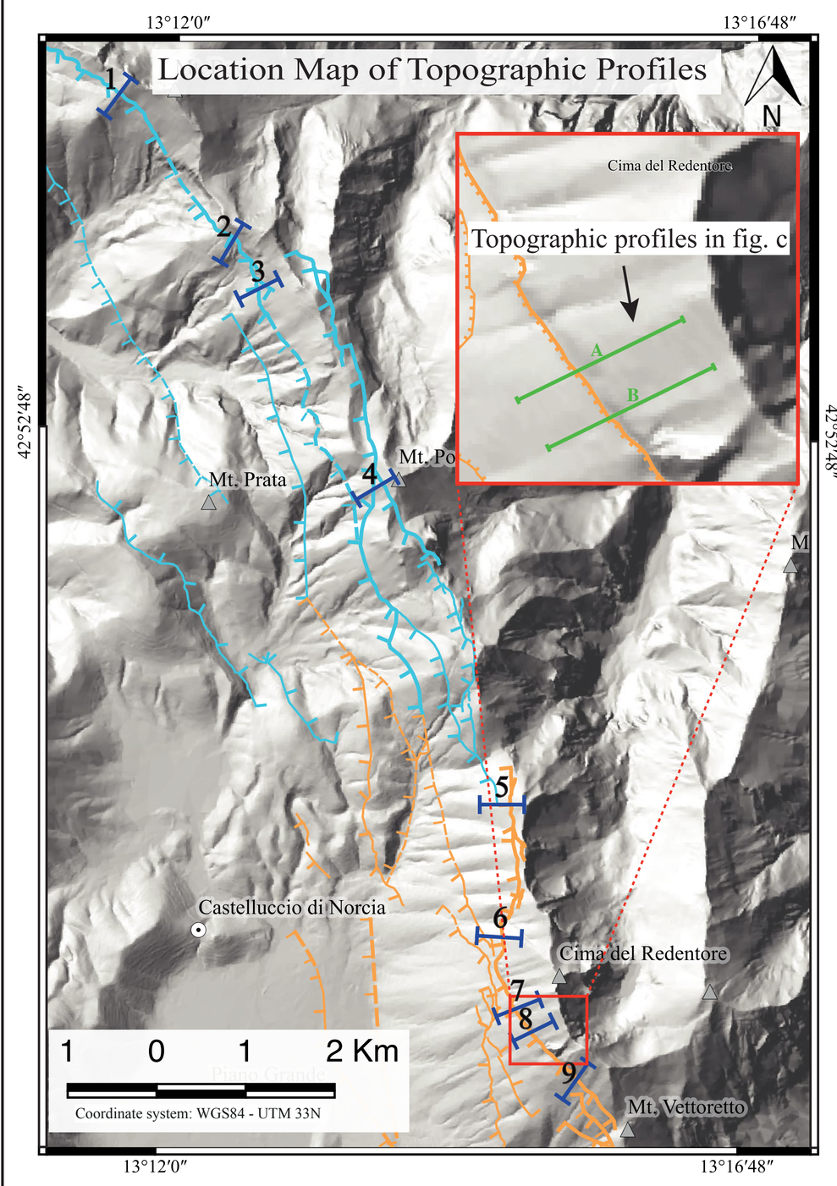
SRL = Surface Rupture Length
MD = Maximum Displacement
AD = Average Displacement

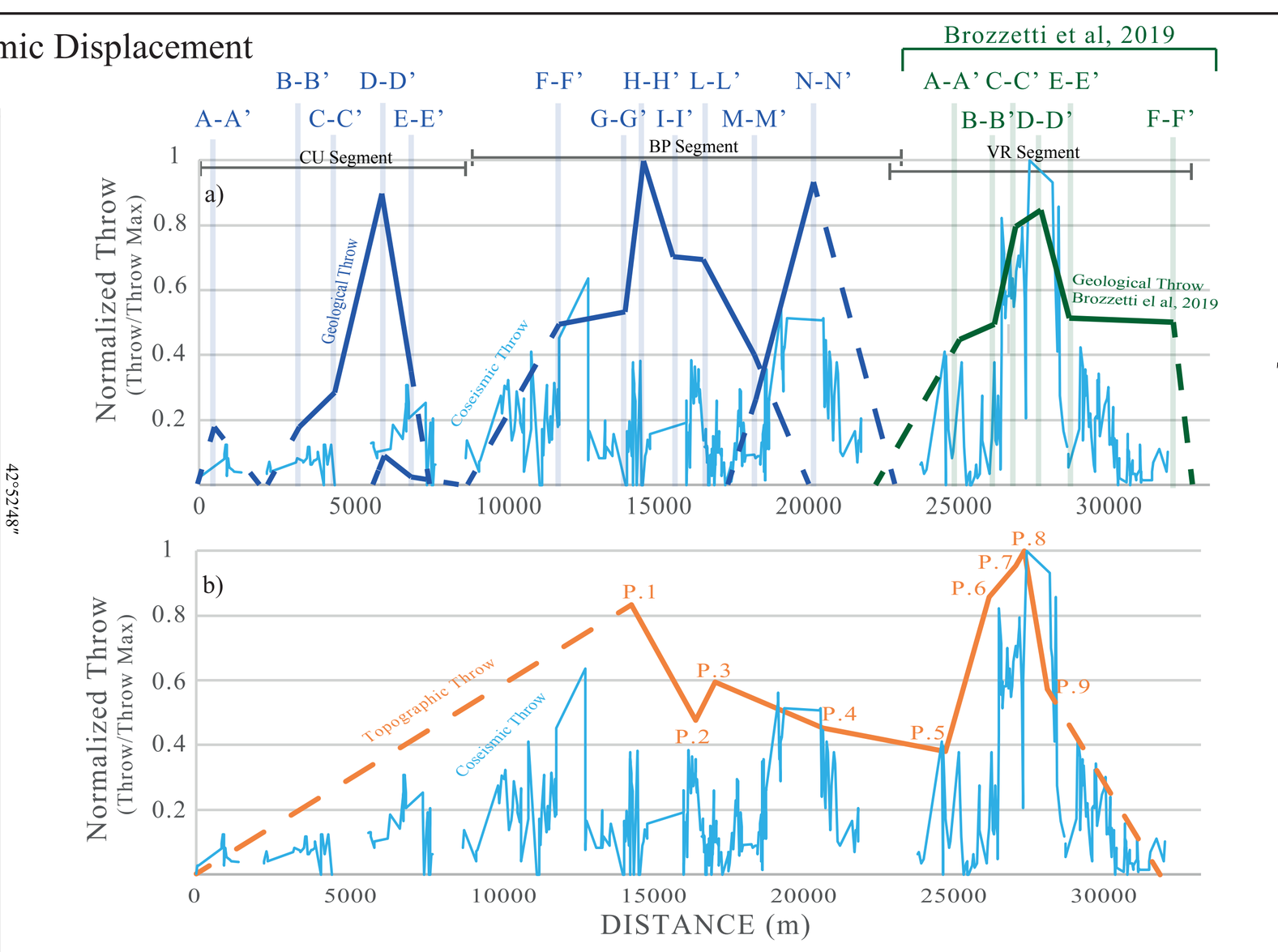
7. Comparison with Global Data



Coseismic parameters of the 2016 earthquakes compared with empirical relationships MD vs Mw (a), AD vs Mw (b), SRL vs Mw (c), AD vs SRL (d) and MD vs SRL (e) proposed in the literature for global normal faulting earthquakes. Key to abbreviations: W&C94 = Wells and Coppersmith (1994); Wes 08 = Wesnousky (2008); P&C04 = Pavlides and Caputo (2004); G08 = Galli et al. (2008).
The relations that best fit the 2016 data are those between SRL and Mw. Note that both integral and arithmetic AD are lower than the expected values, while MD is higher than the expected values. Low values of AD are likely caused by attenuation of the coseismic displacement toward the surface, due to the high segmentation of the fault system. High values of MD are possibly due to localized tectonic phenomena (e.g., back-tilting, see Frame 8) caused by volumetric accommodation of fault irregularities at shallow depths.
f) 2016 cumulative displacement profile, normalized by MD, compared with the envelope of normalized displacement profiles (light blue area) obtained from a set of global normal faulting earthquakes (dashed lines) surface ruptures (from Wesnousky, 2008). Note that the 2016 profile is at the lower edge of the global data, due to the anomalously high MD.
g) 2016 cumulative displacement profile, normalized by AD (integral), compared with the envelope of normalized displacement profiles (light blue area) obtained from a set of global normal faulting earthquakes (dashed lines) surface ruptures (from Wesnousky, 2008). Note that the 2016 profile is more consistent with global data compared to the D/MD profile.
h) Mt. Vettore – Mt. Bove D/MD values in comparison with global data obtained from compilations of normal faulting surface ruptures. ADsumm. is the integral mean of the displacement distribution obtained by summing the contribution of all the synthetic and antithetic distributed (secondary) faults. The long term values (ADl.t./MDl.t.) refer to the post-Late Glacial Maximum (post-LGM) displacement calculated on topographic profiles across fault scarps (see Frame 8).

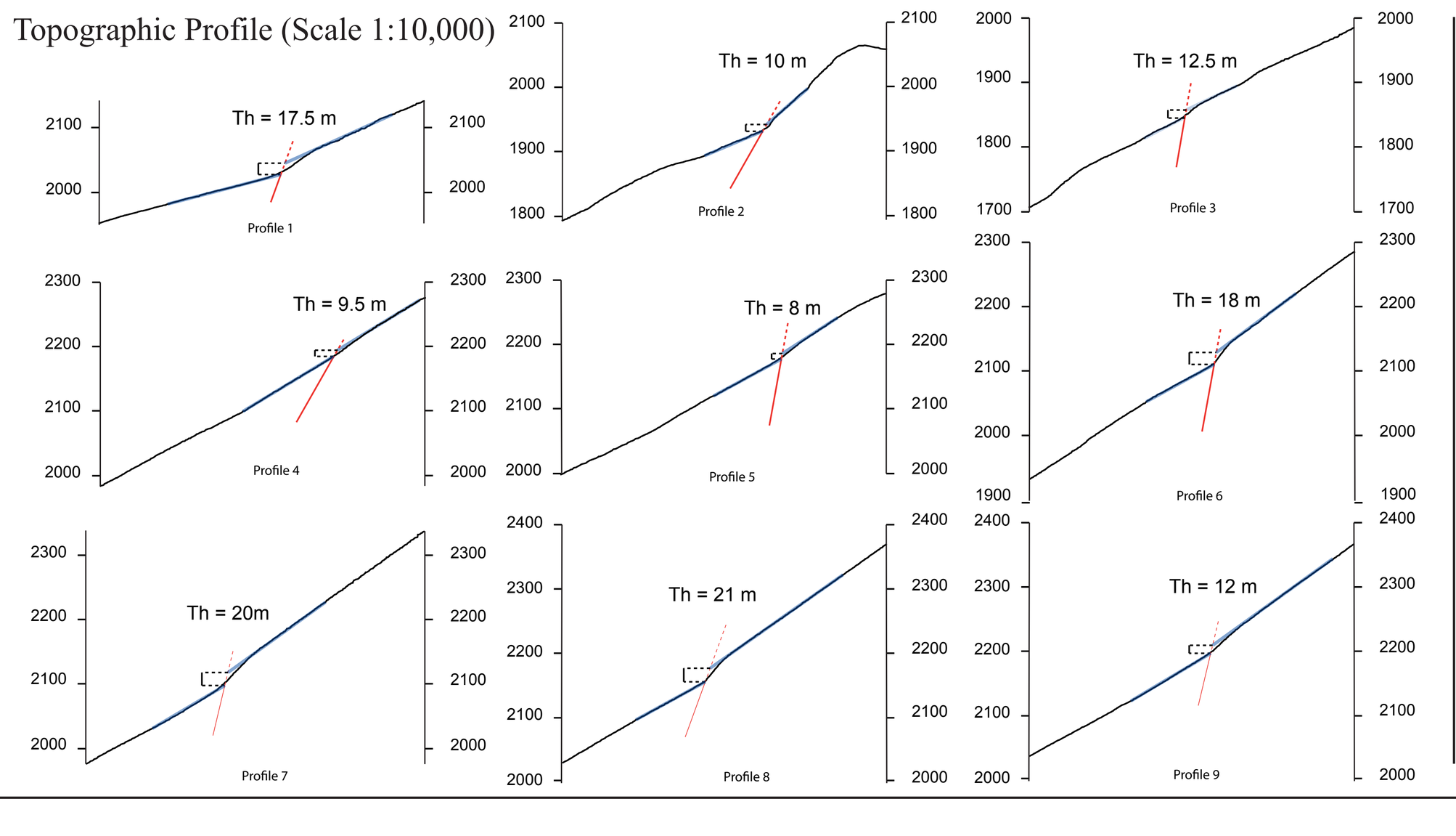
8. Comparison of Geologic, Topographic and Coseismic Displacement

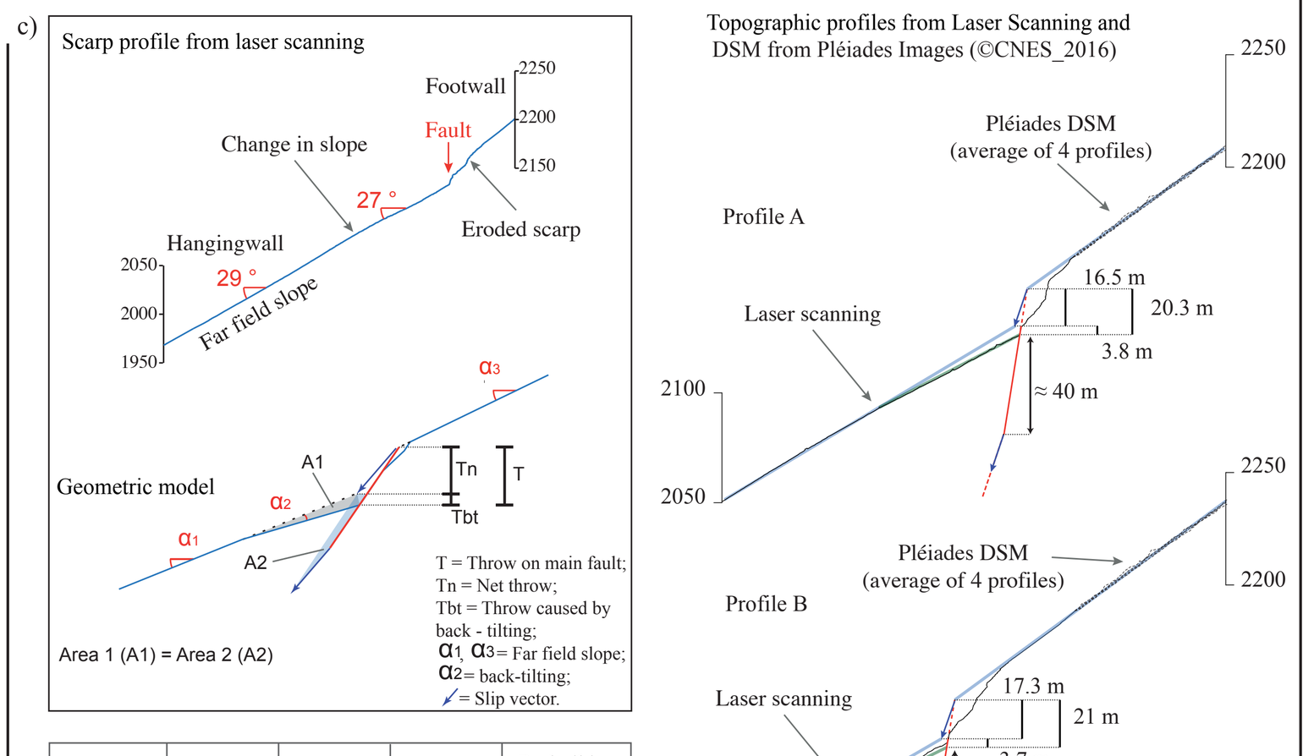




Vertical component of 2016 cumulative coseismic displacement (throw) compared with geologic (a) and topographic (b) throws. The throw values were normalized to the maximum throw in order to make coseismic, topographic and geologic data comparable. Topographic throw is interpreted to be the throw accumulated after the Late Glacial Maximum (post - LGM; e.g., Roberts and Michetti, 2004).
Topographic profiles are realized from a 50 cm - resolution Digital Surface Model (DSM) obtained from Pléiades Images (©CNES_2016) (from CEOS Seismic Hazard Pilot group, IPGP, France). Topographic throw was calculated by measuring the vertical offset of the far - field topographic slope across the fault scarp.
The geologic throw along the Cupi - Ussita and Mt. Bove - Mt. Porche segments was calculated from geologic sections in Frame 5. The geologic throw along the Vettoretto - Redentore segment is from Brozzetti et al. (2019).
c) Quantification of post - LGM back-tilting in the zone of MD by means of topographic profiles from Laser scanning (solid line, hanging wall and basal fault scarp) and Pléiades DSM (dotted lines, footwall) (location of topographic profiles in the inset of the map).

Topographic Profile (Scale 1:10,000)





	T (m)	Tn (m)	Tbt (m)	Back-tilting (%)
A	20.3	16.5	3.5	≈18.5
B	22.5	19.0	3.5	≈17.5
			MEAN	≈18