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Miscellanea INGV

A new photographic dataset of the coseismic geological effects originated by the Mw5.9 Visso and Mw6.5 Norcia earthquakes (26th and 30th October 2016, Central Italy)

38

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A NEW PHOTOGRAPHIC DATASET OF THE COSEISMIC GEOLOGICAL EFFECTS ORIGINATED BY THE Mw5.9 VISSO AND Mw6.5 NORCIA EARTHQUAKES (26TH AND 30TH OCTOBER 2016, CENTRAL ITALY)

Emergeo Working Group*



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Immagine di frontespizio

Coseismic fault scarp on the western side of Mt. Vettore.

Normazione ortoeditoriale, Revisione testi e Impaginazione

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Introduction

This paper follows a previous issue of Miscellanea INGV [Emergeo Working Group, 2017] dedicated to the seismo-geological effects produced by the 24 August 2016 Amatrice earthquake. In this work, we present a collection of pictures showing the geological effects produced on either the natural or the built environment by the late October 2016 Visso and Norcia earthquakes in Central Italy. Two months after the beginning of the seismic sequence with the occurrence of the Mw6.0 Amatrice mainshock, on the 26 October a new earthquake with Mw5.9 occurred 25 km to the north, near the village of Visso. Finally, on the 30 October, the largest shock of the sequence with Mw6.5 struck the area between the two previous events, near Norcia. The October earthquakes occurred along the ~NW-striking, SW-dipping, ~30 km-long fault system known as the Mt. Vettore – Mt. Bove fault system (VBFS). Both the 26 October earthquake and, most significantly, the 30 October mainshock generated new and larger ruptures at the surface, often exceeding those originated by the August event. After the three mainshocks a total of almost 30 kilometers of surface faulting were mapped between the villages of Cupi to the north and Arquata del Tronto to the south. The coseismic ruptures were observed along several fault planes belonging to the VBFS, both on sinthetic and on antithetic splays. Figure 1 shows the map of the most prominent surface ruptures observed in the field, along with the location of the main shocks of the seismic sequence.

Following the October events, the Emergeo Working Group surveyed a ~500 km^2 large area, collecting more than 7000 observations of surface coseismic effects such as fractures, ruptures, landslides, and other secondary effects related to shaking (e.g. mud volcanism, liquefaction, clast extrusions, soil remobilization, etc.). Most of the coseismic geological effects were collected through field survey along with additional observations achieved by means of helicopter flights and helikite (helium balloon). About 15000 photographs were shot during the survey.

This atlas presents a wide selection of photos (about one hundred pictures) of coseismic ground effects observed over an area extending ~30 km by ~10 km in the NW-SE and in the NE-SW directions, respectively. Each picture reports information on the type of effect, the site of observation, and the geographical coordinates (decimal degrees). Figure 2 shows the general location map of the photographs.

Further information on the 2016-2017 Central Italy seismic sequence and on the associated coseismic effects can be retrieved in: Chiaraluce et al. [2017], Pucci et al. [2017], and Civico et al. [2017]. A collection of earthquake-induced effects, for both the Visso and Norcia events (with a specific focus on landslides), is presented also by Gruppo di Lavoro CERI [2016a and b].

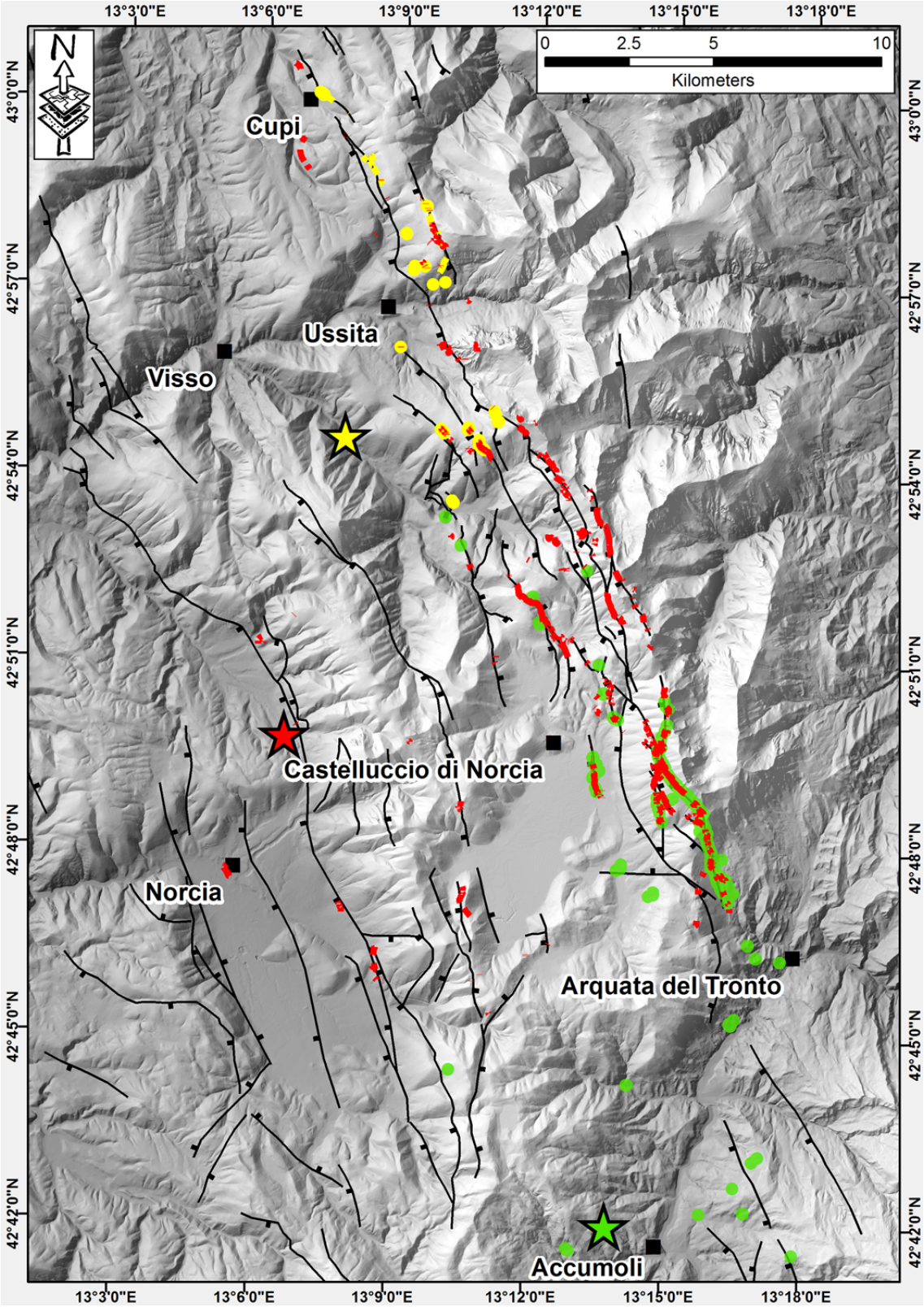


Figure 1. Location of the mainshocks and of the geological observations of coseismic effects produced during the 2016 seismic sequence in Central Italy. Stars indicate the epicenters of the three mainshocks: i) green, August 24th Mw6.0 Amatrice earthquake; ii) yellow, October 26th Mw5.9 Visso earthquake; iii) red, October 30th Mw6.5 Norcia earthquake. Color dots and lines indicate the associated coseismic effects. Main normal faults in the area are shown with black solid lines. The coseismic geological effects originated by the Amatrice earthquake are widely illustrated in Emergeo Working Group [2017].

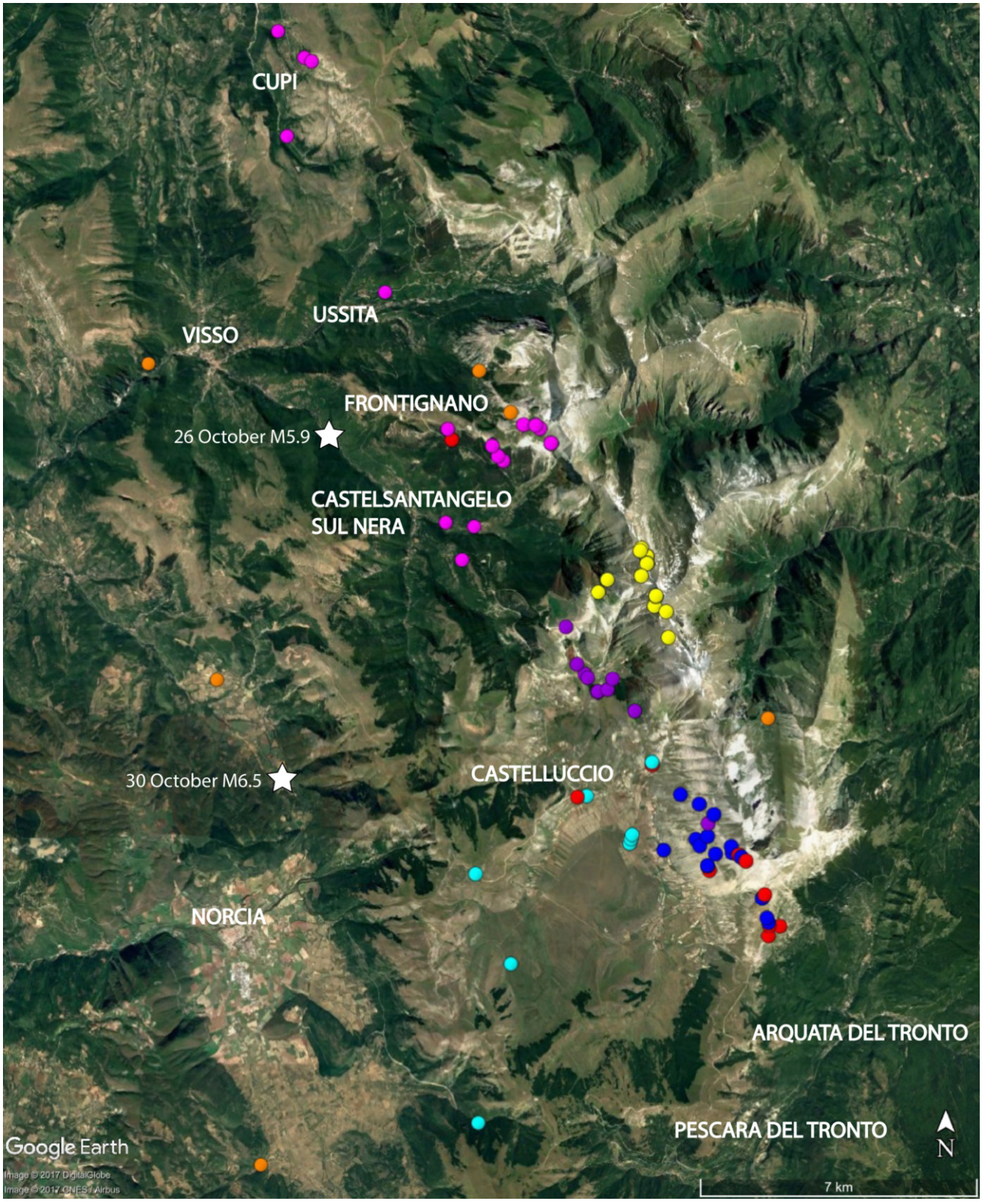
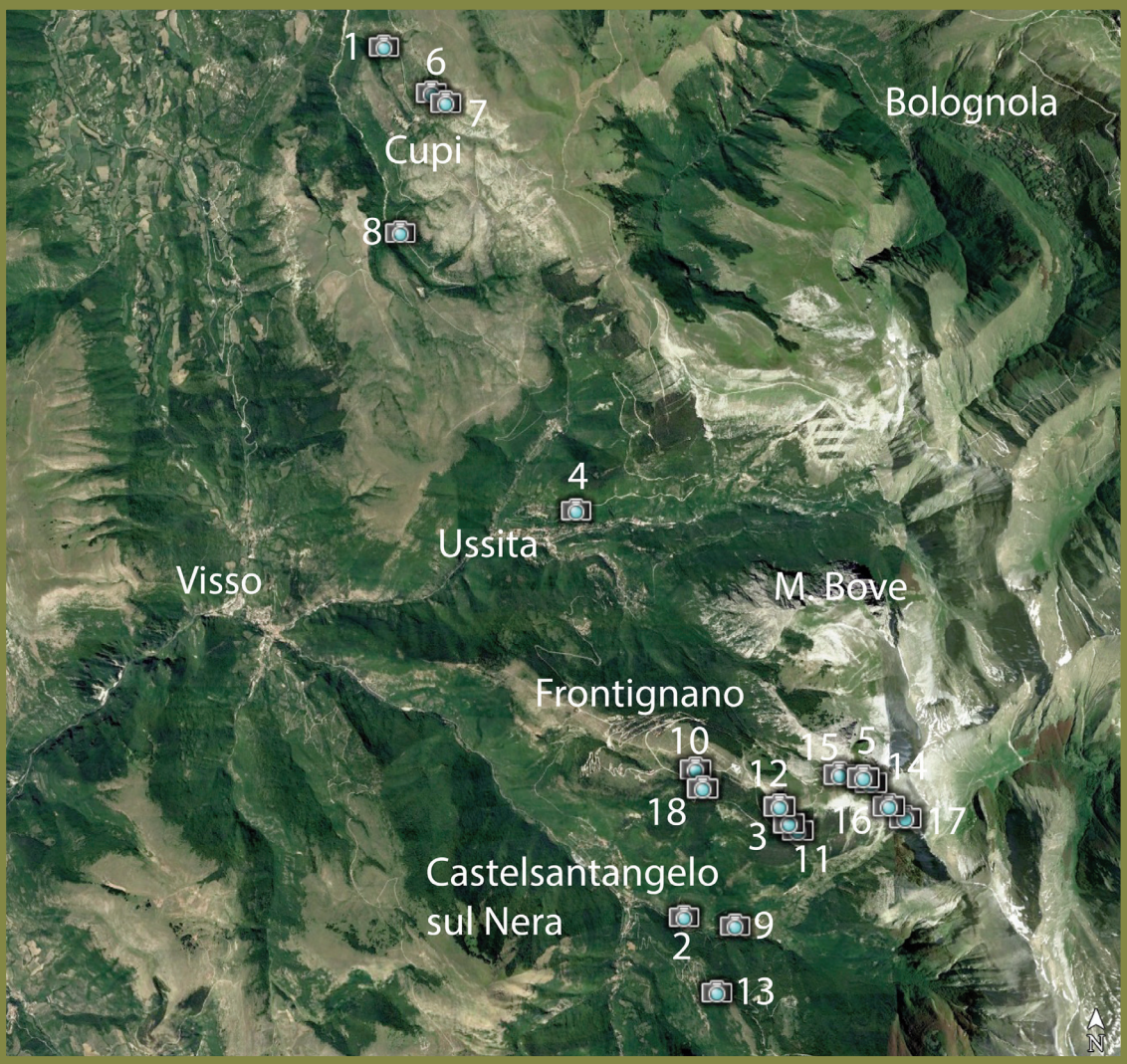


Figure 2. Location of the pictures shown in the photo gallery. Colors reflect the groups of photographs presented: Mt. Bove and north of Visso, magenta; Mt. Porche, yellow; Landslides, dark orange; Castelluccio Plain, cyan; Mt. Vettore - Mt. Vettoretto, blue; Antithetic faults, dark violet; 24 August *vs* 30 October effects, red. White stars mark the epicenters of the October earthquakes. Pictures of the group "Mud volcanism" are located outside the map.

Mt. Bove and north of Visso



Detailed location map of the photographs of the area "Mt. Bove and north of Visso".



Photo 1. Detach of slope debris (foreground) and freshly exposed free face on the bedrock fault plane (brownish strip at the center of the photo). These features, near the village of Cupi (MC), mark the northernmost limit of the coseismic ruptures originated by the 26th October earthquake, and in general by the whole seismic sequence of Central Italy.
43.00207 N 13.11948 E



Photo 2. Close-up of a fresh fault surface activated during the 26th October earthquake. The brown strip (indicated by a red arrow) represents the coseismic slip. The deformation observed at the surface following this event is comparable to that produced by the Amatrice earthquake ~20 km farther south.
42.89260 N 13.16372 E



Photo 3. Particular of a bedrock fault plane with a freshly exposed free face experiencing slip during the Visso earthquake. The moss alignment indicates the interface between colluvium and fault surface prior to the shock.
42.90724 N 13.18054 E



Photo 4. Widely extended crack in the asphalted road near Ussita (MC); the spoon shape of the crack led to suppose an active landslide process (i.e. see also the evident bending of the tree vegetation on the right). The operator in the picture attends to the fracture measuring.
42.94714 N 13.14392 E



Photo 5. Details of the activated fault on the western slope of Mt. Bove. The slip observed at this site is likely cumulated during the 26 and 30 October seismic events.
42.91373 N 13.19210 E



Photo 6. Free face on the bedrock fault plane near Cupi (MC). Both the Visso and the Norcia events likely produced vertical displacement at this site, although the relative effects are not distinguishable.
43.00205 N 13.11781 E



Photo 7. The evidence of displacement is testified by the brownish, ~12 cm-high strip along the slope of Costa Tranquilla close to the village of Cupi (MC). Also in this case the observed displacement was likely produced by both the events of October 2016.
43.00065 N 13.12041 E



Photo 8. Large longitudinal fracture along the paved road to Cupi; the detail in the inset shows a vertical offset of ~30 cm.
42.98404 N 13.11197 E



Photo 9. Enlarged image of the Mt. Bove southwestern flank as it appeared to the first surveyors the day after the Mw6.5 Norcia earthquake. It is evident a significant scarp on the mountain front. The shape of the scarp suggests a contribution of gravity to the slope instability.
42.89162 N 13.17294 E



Photo 10. Set of fractures on the unpaved mountain road near Frontignano (MC). The system of sub-parallel fractures crosses the road with no evidence of gravity phenomena, and is consistent with the strike of the Frontignano fault.
42.91372 N 13.16467 E



Photo 11. Free face in slope debris, with vertical slip of about 30 cm (view from the north). The slip observed in this image was mainly originated by the 30 October seismic event on the Mt. Cornacchione fault (partially activated during the 26 October event too).
42.90623 N 13.18220 E



Photo 12. Detail of the fault rupture mobilized during the 30 October earthquake along the road to the Frontignano skilift. Vertical slip exceeds 10 cm.
42.90950 N 13.17872 E



Photo 13. This coseismic landslide, that affected also the road near the village of Gualdo (MC), was already activated following the Amatrice earthquake, as testified by the ruptured patches of new asphalt along the fracture.
42.88361 N 13.16915 E

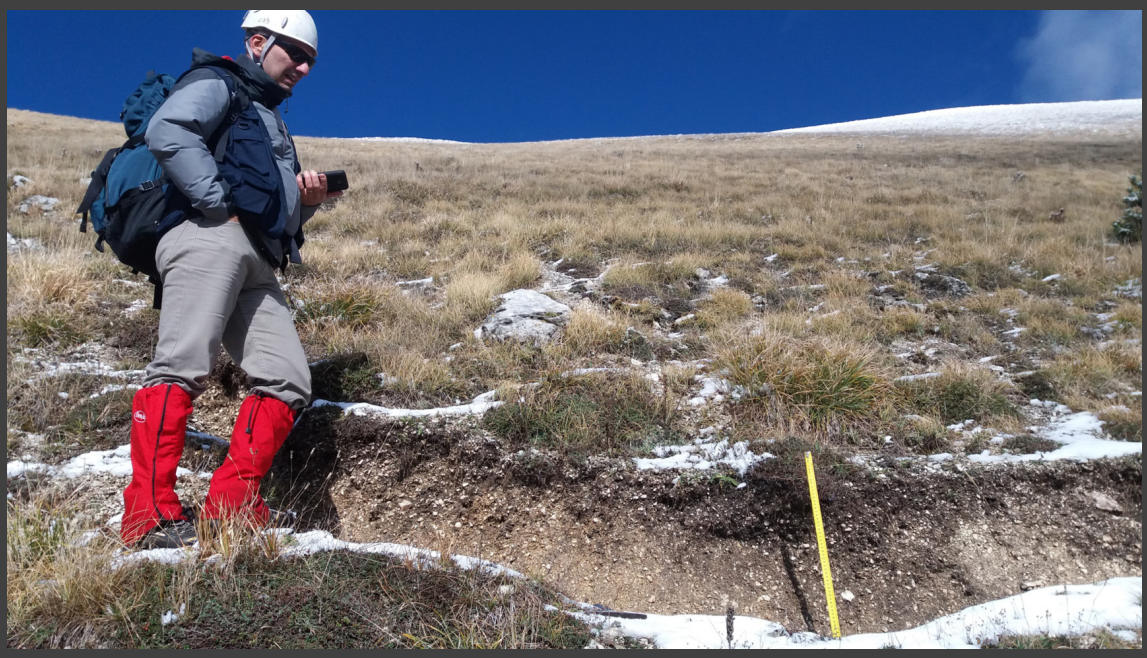


Photo 14. Western slope of Mt. Bove: the ~50 cm vertical slip observed here originated during the Norcia earthquake. The operator is measuring the main fault parameters (i.e strike, dip, and amount of vertical and horizontal offset) by means of a smartphone implemented with a software for collecting structural field data.
42.91308 N 13.19347 E



Photo 15. The first snow fallen on the Mt. Bove flanks enhances the trace of the coseismic ruptures (marked by red arrows), evident as a dark waving line on the mountain slope.
42.91397 N 13.18840 E



Photo 16. The fault cuts the gravel road along the west flank of Mt. Bove; the displacement measured at this location (about 70 cm) was accomplished also through gravity phenomena. 42.90989 N 13.19697 E



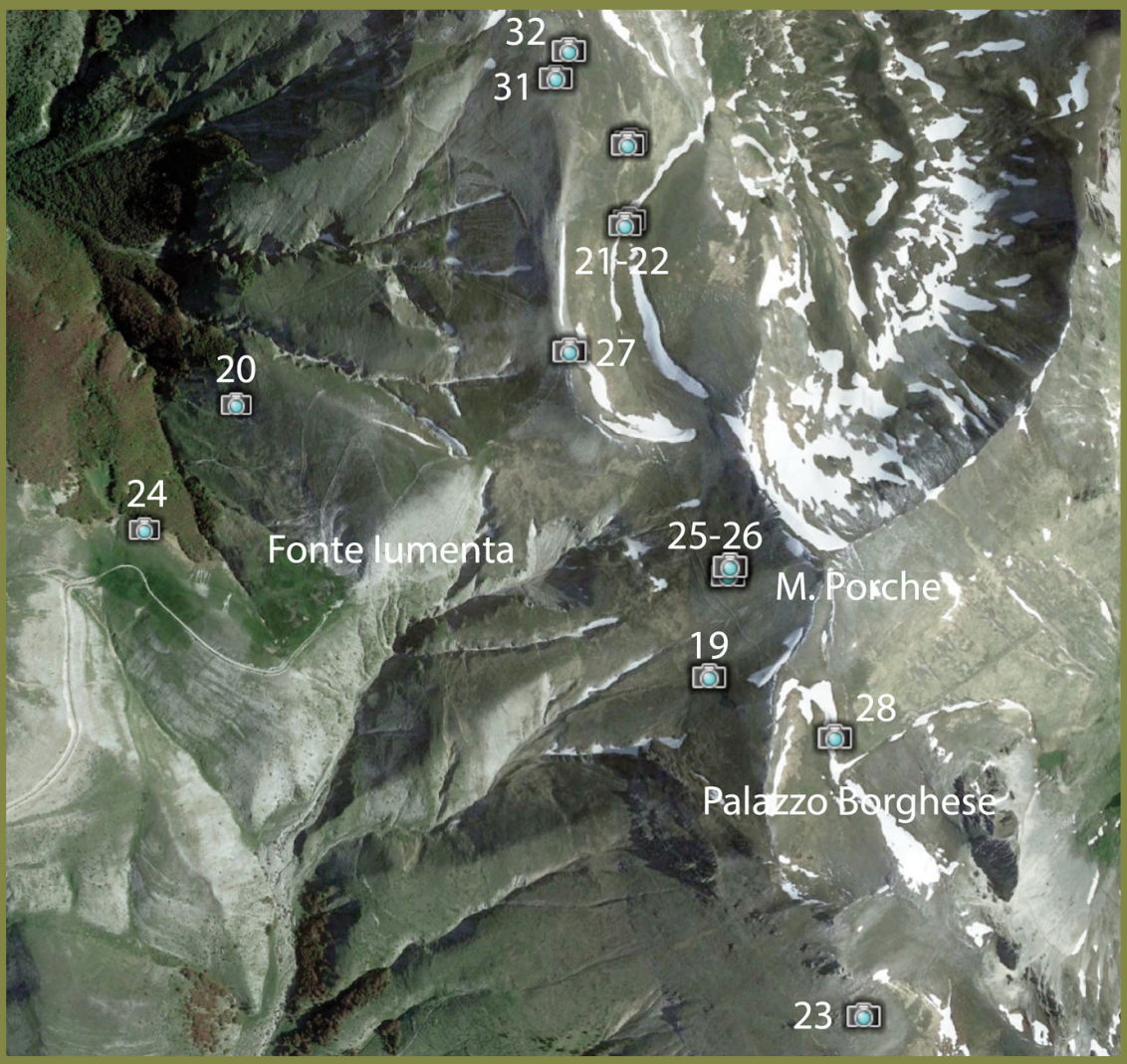
Photo 17. Details of the fault scarp of photo n. 16; at this site the fault cut unconsolidated terrains and produced a displacement through both slip and gravity effects. The yellow metersticks are positioned to indicate the vertical and horizontal offsets.
42.90977 N 13.19703 E





Photo 18. Set of joined fractures crossing the dirt road to the Frontignano skilift as their appeared the day after the Norcia event. Maximum horizontal opening is 18 cm (top). The yellow meterstick (bottom) shows that the opening of the fracture affects at least the first meter below the ground surface.
42.91131 N 13.16591 E

Mt. Porche



Detailed location map of the photographs of the area "Mt. Porche".

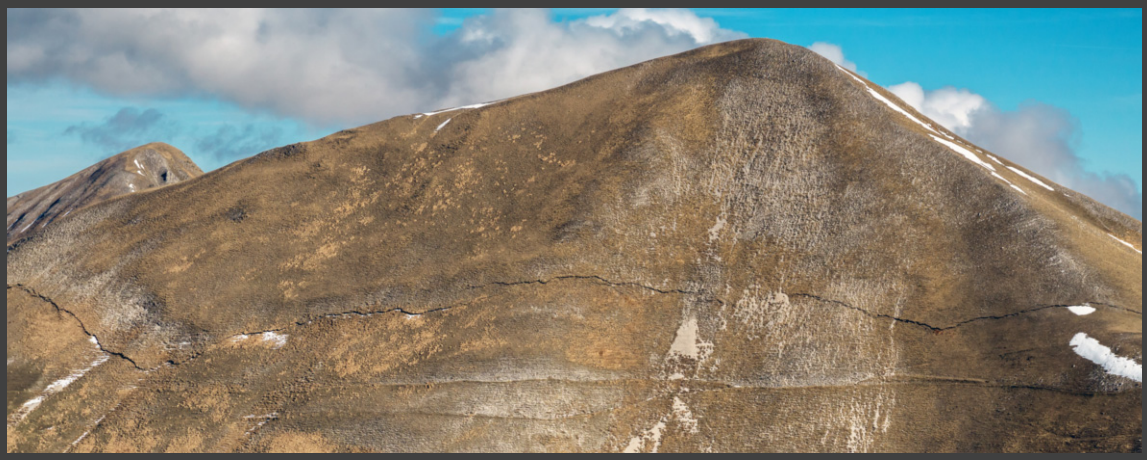


Photo 19. The main coseismic rupture on the southwestern face of Mt. Porche. This fracture discontinuously propagates towards the south, affecting the northwestern flank of Mt. Vettore (field of view towards N).
42.87291 N 13.22871 E



Photo 20. Panoramic view of the fracture (red arrows) that wends along the western face of Mt. Porche (field of view approximately towards E); the trekking path to Mt. Porche is in the foreground.
42.87891 N 13.21482 E

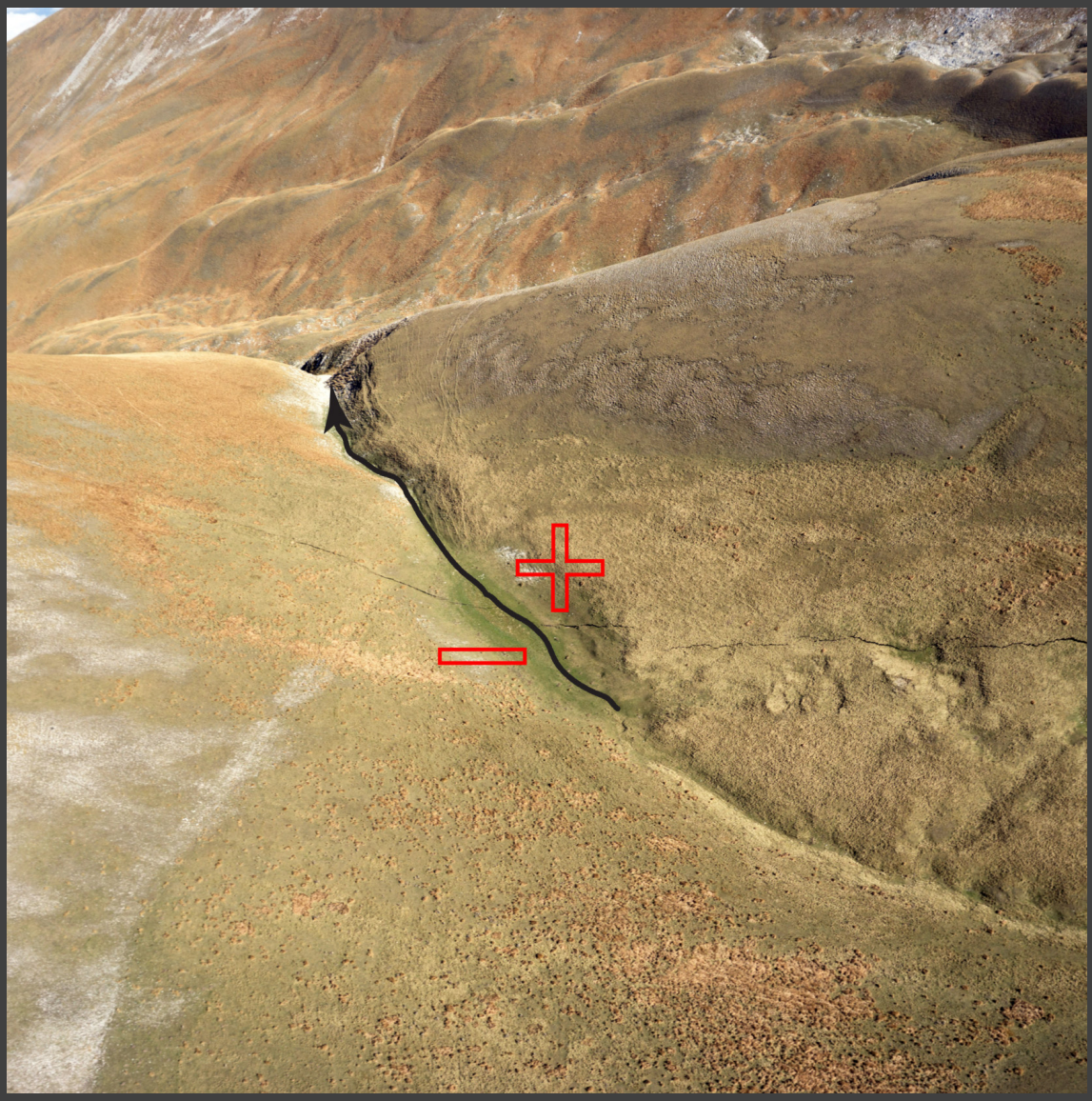


Photo 21. View of the main rupture extending from the northern slope of Mt. Porche toward north (visual angle towards NE). The coseismic scarp dams the natural flow of the ephemeral stream (indicated by the black solid line) toward the gulch in the background. Red symbols show the relative sense of slip across the scarp (plus, uplift; minus, subsidence).
42.88173 N 13.22668 E



Photo 22. The extensional stress experienced by rocks and soils during the earthquake caused different behaviours according to the different characteristics of the involved material. Here, between Mt. Porche and Scoglio della Volpe, instead of a single longitudinal rupture, several subparallel shorter fractures were created with a trend oblique with respect to the general structural trend.
This kind of geometry is called "en échelon" (field of view approximately towards N).
42.88248 N 13.22644 E



Photo 23. The main coseismic rupture runs just below the crest of Palazzo Borghese (helicopter view approximately towards E).
42.86581 N 13.23313 E



Photo 24. Few centimeters of snow cover the western side of Mt. Porche, making the fracture evident especially from afar (visual angle approximately towards ESE). The close-up shows two INGV field operators at work in field mapping along the coseismic rupture.
42.87603 N 13.21197 E



Photo 25. Detail of a fracture near the top of Mt. Porche (average displacement 40 cm, visual angle approximately towards SSE). Snow made the field work more difficult to the personnel that with incoming winter and temperature increasingly colder, is obliged to rush the survey before even the deeper fractures were concealed.
42.87505 N 13.22901 E



Photo 26. Detail of the fracture on the western face of Mt. Porche. Soil and debris are displaced for several decimeters (field of view approximately towards E).
42.87513 N 13.22895 E



Photo 27. Panoramic view of the fracture on the western flank of Mt. Porche (visual angle approximately towards E). The coseismic fault rupture, which is part of the main Mt.Vettore - Mt. Bove faults system, is clearly visible at least up to Sasso Borghese Pass.
42.87972 N 13.22472 E



Photo 28. Fractures are often characterized by a considerable continuity. In this picture the fracture displacing the western side of Mt. Porche continues towards south and affects the eastern face (visual angle approximately towards ESE).
42.87166 N 13.23223 E



Photo 29. Detail of the main fracture along the slope that heads northward from the top of Mt. Porche. Soil is displaced for about 30-40 cm (field of view approximately towards N).
42.88421 N 13.22645 E



Photo 30. Sometimes the displacement across the seismic ruptures may be not so evident because of the grass. Anyway, a trained eye can still recognize morphological anomalies like this counterslope scarplet formed by the rupture near Scoglio della Volpe (visual angle approximately towards N). White symbols show the relative sense of movement across the scarp.
42.88413 N 13.22646 E

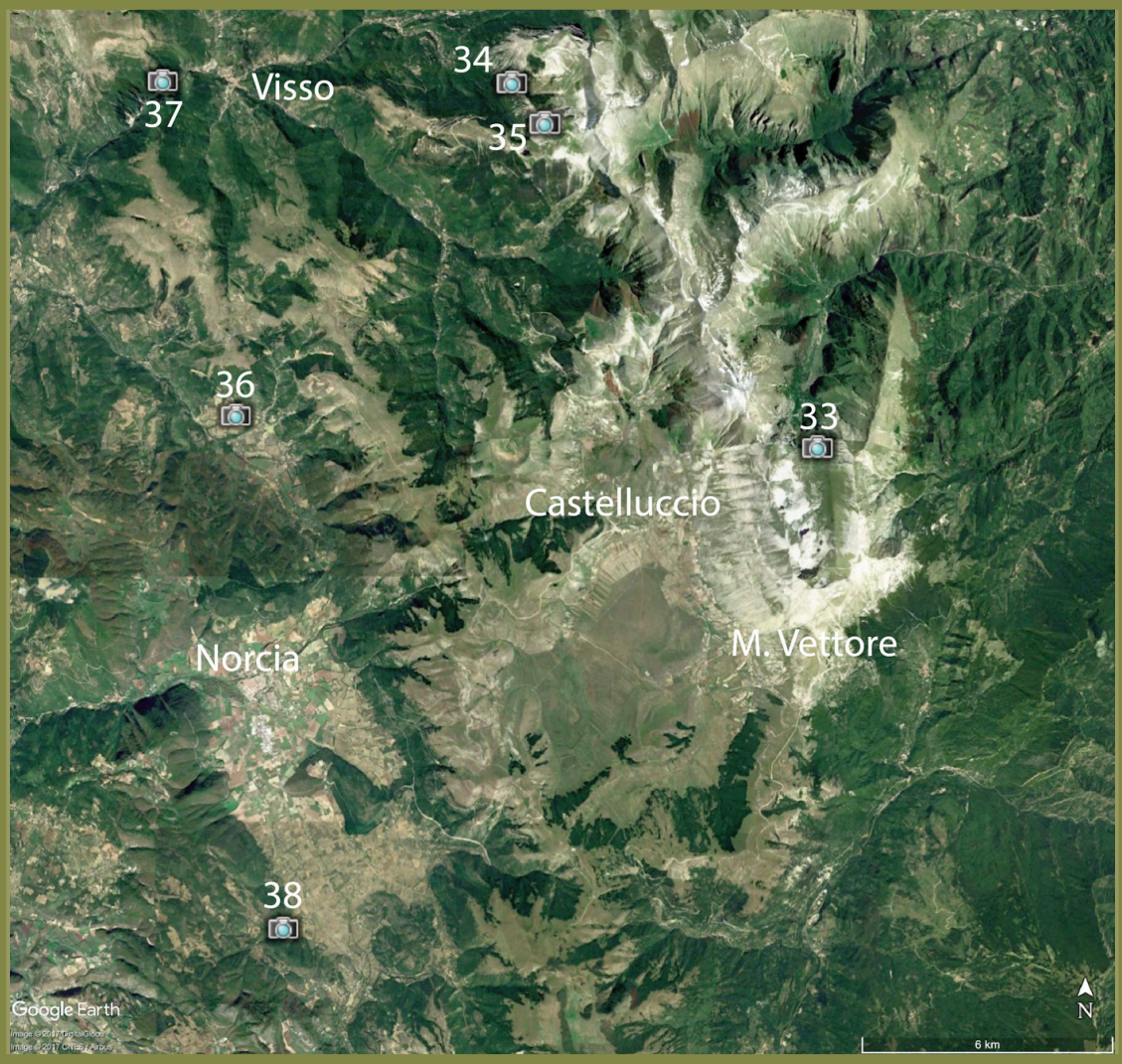


Photo 31. Detail of the fracture at the top of Cima Valleinfante (NW of Mt. Porche). Here the soil is upthrown for about 30 cm against the maximum gradient direction of the slope, thus causing a local reversal of the topography (visual angle approximately towards NNE).
42.88538 N 13.22430 E



Photo 32. Panoramic view of the fracture affecting the western side of Mt. Porche (field of view towards ESE).
42.88593 N 13.22466 E

Landslides



Detailed location map of the photographs of the group "Landslides".



Photo 33. A steep rocky face made by weathered and fractured material is often at the base of landslide/earthquake-induced phenomena. This photo shows a rockfall along a face of Mt. Vettore (field of view towards WNW).
42.84709 N 13.26552 E



Photo 34. A rock avalanche on a face of Mt. Bove (view from helicopter; visual angle approximately towards NE).
42.92731 N 13.17452 E



Photo 35. Rockfall along a track on the western flank of Mt. Bove (visual angle towards N). Darker areas mark the craters originated on the downslope path by the bouncing of the largest boulders. 42.91694 N 13.18443 E



Photo 36. Rock boulders fallen from the hills near Campi (PG), north of Norcia (visual angle approximately towards NE). The traces left by the boulders rolling downslope are clearly visible. 42.85491 N 13.08917 E



Photo 37. A landslide dams the River Nera near Visso. The phenomenon blocked the stream channel and caused local flooding.
42.93034 N 13.06660 E

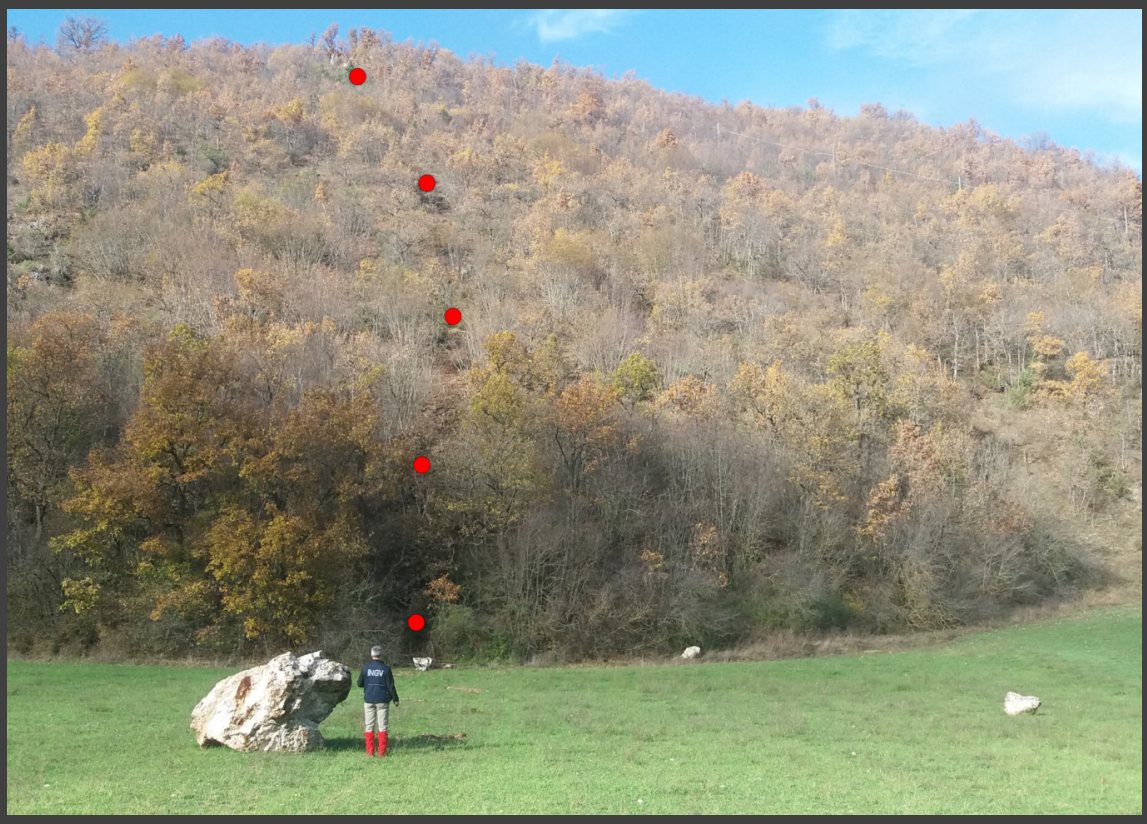


Photo 38. Often earthquakes can shake large boulders even down gentle slopes. In this photo a rock of several tons has fallen from a hilly area near Ocricchio. The path followed by the boulder is clearly traceable amid the vegetation.
42.73923 N 13.10423 E

Mud volcanism



Detailed location map of the photographs of the group "Mud volcanism".



Photo 39. Mud volcanism (or sedimentary volcanism) is a natural phenomenon originated by geologic processes involving sediments, water and gas; it is usually connected to deposits of organic material, natural gas, and hydrocarbon trapped in impermeable clay lenses. In response to the earthquake shaking mud deposits can be squeezed upwards by compressive forces and erupted at the ground surface. This picture testifies the most remarkable effect of mud emission observed after the 30th October Norcia earthquake. It occurred nearby Santa Vittoria in Matenano (FM), a village located about 38 km from the epicenter. The emission of muddy sediments continued for several days at this site. See detailed report on this particular phenomenon at this link.
43.03888 N 13.47725 E



Photo 40. View from the north-east of the mud deposit at Santa Vittoria in Matenano. The thickness of the flow deposit locally exceeded 40 cm. It was estimated that the volume of mud emitted was about 75 m^3.
43.03974 N 13.47785 E



Photo 41. Panoramic view of the main site of mud emission at Santa Vittoria in Matenano. GPS surveys allowed to estimate that in the first three days after the earthquake the area covered by the mud was about 1000 m^2, and that the maximum distance traveled by the flow was ~100 metres. 43.04029 N 13.47764 E

Castelluccio plain



Detailed location map of the photographs of the area "Castelluccio plain".



Photo 42. The three splays of the Mt. Vettore fault; the lower one runs along the Castelluccio Plain (black arrows in the foreground), the middle one (blue arrows) starts at 1600 m asl and reaches the upper one (red arrows) at 2100 m asl. Compare with photo n. 12 of Emergeo Working Group [2017]. 42.81831 N 13.22295 E



Photo 43. Top: the ~700 m-long coseismic rupture observed along the south-western flank of Colli Alti e Bassi at the northern tip of the Castelluccio Plain. Bottom: the same stretch of fault as it appeared from the helicopter. Red symbols show the relative sense of slip across the fault plane. 42.83588 N 13.22916 E



Photo 44. Longitudinal fracture system, with consistent vertical displacement, along the dirt road from Campi to Castelluccio di Norcia (PG).
42.81151 N 13.17390 E



Photo 45. Coseismic fractures with offset in the Forca Canapine tunnel along the SS685 Road connecting Norcia (PG) to Arquata del Tronto (AP).
42.75209 N 13.17488 E



Photo 46. Photo taken from helicopter of a sinkhole, a depression or hole in the ground caused by collapse of the surface layer due to karst. In this case the seismic shaking broadened the pre-existing hole. Maximum width of the sinkhole ~2.5 m.
42.78936 N 13.18509 E



Photo 47. Piano Grande di Castelluccio normal fault, basal fault splay of the Mt. Vettore master fault. At this site the vertical offset is about 15 cm.
42.81845 N 13.22316 E

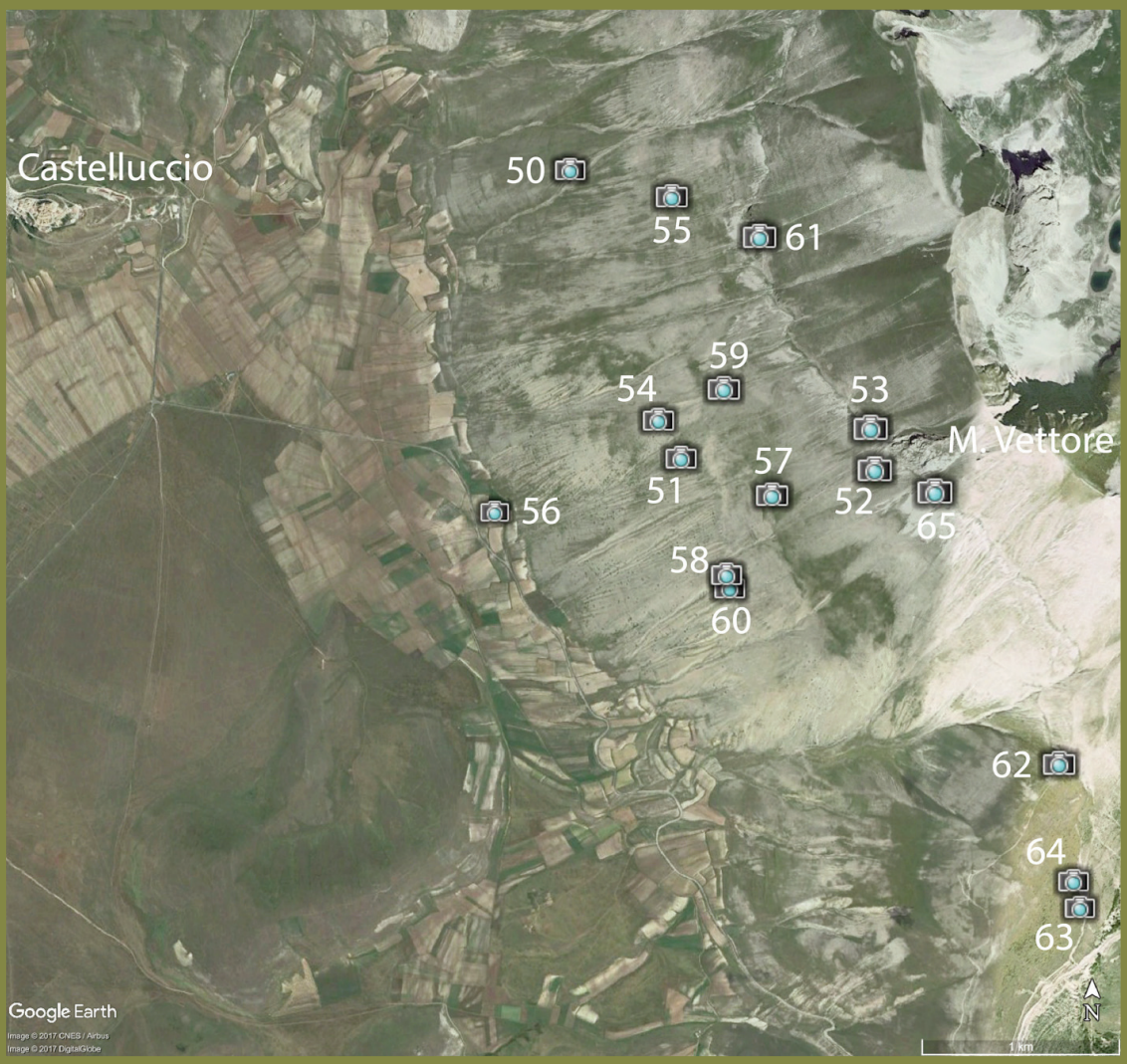


Photo 48. The helicopter and the helikite aerostat used to collect aerial photos; the fractures intersecting the paved road of the Castelluccio Plain belong to the lower splay of the Mt. Vettore fault (see pictures n. 42 and n. 47).
42.81935 N 13.22320 E



Photo 49. The devastated village of Castelluccio di Norcia emerges from the foggy plain.
42.82860 N 13.20900 E

Mt. Vettore - Mt. Vettoretto



Detailed location map of the photographs of the area "Mt. Vettore - Mt. Vettoretto".



Photo 50. Helicopter image of the Mt. Vettore western slope in the Castelluccio area, shot after the 30 October earthquake. The so called "Cordone del Vettore" fault, i.e. the upper trace visible in the image, experienced movement also during the 24 August Amatrice earthquake. The middle splay (center of the photo), visible here as a discontinuous scarp in the terrain and vegetation mantle, ruptured principally during the 30 October Norcia earthquake (lower splay not visible in the photo). 42.82978 N 13.23773 E



Photo 51. Aerial view of the middle splay along the Mt. Vettore western flank. Here the continuity of the fault is fully appreciable as well as the vertical offset.
42.81818 N 13.24362 E



Photo 52. Aerial view of the Cordone del Vettore fault: the fresh activated fault surface is visible as a light brown strip on the right (fault trace cutting rock and terrain) and as a white strip on the left, both freezing the amount of slip produced by the 30 October earthquake.
42.81752 N 13.25253 E



Photo 53. Panoramic view of the coseismic free face on the "Cordone del Vettore" fault: the contact between the grey and the whitish strips indicates the upper boundary of the fault patch that slipped during the Amatrice earthquake first, and during the Norcia earthquake afterwards. In this section we measured the largest vertical displacements on the coseismic ruptures associated with the Norcia earthquake. The picture gives an impressive feeling of what could happen during an on-going strong earthquake and its effects on the morphology and landscape.
42.81896 N 13.25218 E



Photo 54. The way the mountain comes into shape: orogenesis (older) and repetitive dip-slip earthquakes (younger and present-day) concurred to the rise of Mt. Vettore massif and created its current – and ever evolving – morphology. The whole process includes a series of phenomena, among which slip on faults takes a fundamental role. The photo depicts a section of the fault surface that, as a single component of the process, gives its contribution to shaping the mountain.
42.81966 N 13.24241 E



Photo 55. Mt. Vettore aerial view (picture taken from NW). The snow filling works as a highlighter for the free surfaces generated by the slip of the 30 October earthquake.
42.82804 N 13.24298 E

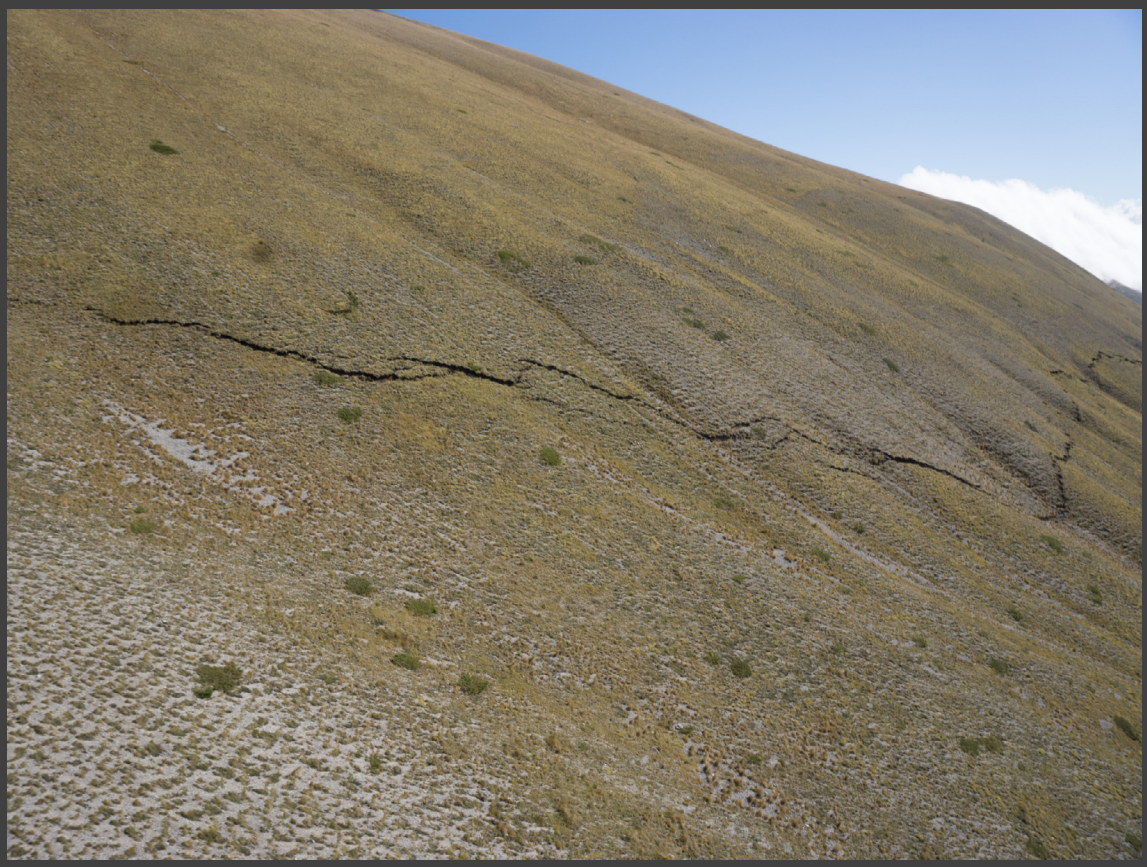


Photo 56. Detail of the middle splay of the Mt. Vettore fault (see also pictures n. 50 and n. 51), front view.
42.81616 N 13.23337 E



Photo 57. Side view of the Mt. Vettore fault middle splay from south, where the fault cuts through unconsolidated terrain. The Castelluccio village and the Piano Grande di Castelluccio lie in the background.
42.81668 N 13.24806 E



Photo 58. Close-up of the middle Mt. Vettore fault; the vertical slip in this fault patch is about 100 centimeters.
42.81362 N 13.24608 E



Photo 59. The fog and the autumn colors mitigate the image of distress that commonly goes along with the earthquake occurrence. The data collection, one of the main activity of the field survey, requires time, accuracy and sometimes physical skills; here the survey included a 1000 m climb in a mountain environment.
42.82069 N 13.24561 E



Photo 60. Etching on fault surface due to the reciprocal slip of rough free surfaces. These traces are precious indicators of the sense and amount of the slip.
42.81349 N 13.24613 E



Photo 61. The two free fault surfaces visible here created in their reciprocal movement a canyon, resulting from the action of slip combined with gravity effects. Extreme weather conditions can be characteristic of field survey in mountain environment even in mid-season periods.
42.82600 N 13.24706 E



Photo 62. Aerial view of the main fault scarp cutting the western flank of Mt. Vettoretto near the summit.
42.80663 N 13.26262 E



Photo 63. This picture shot from the helikite shows a ~50 m-long stretch of the main rupture at the hangingwall of the bedrock fault plane on the eastern flank of Mt. Vettoretto (compare photo n. 64 in Emergeo Working Group [2017]).
42.80022 N 13.26561 E



Photo 64. Helikite picture showing the development of the ruptures within a gully along the eastern side of Mt. Vettoretto. Right stepping, en-échelon arrangement of fractures is clearly visible at this site.
42.80148 N 13.26487 E

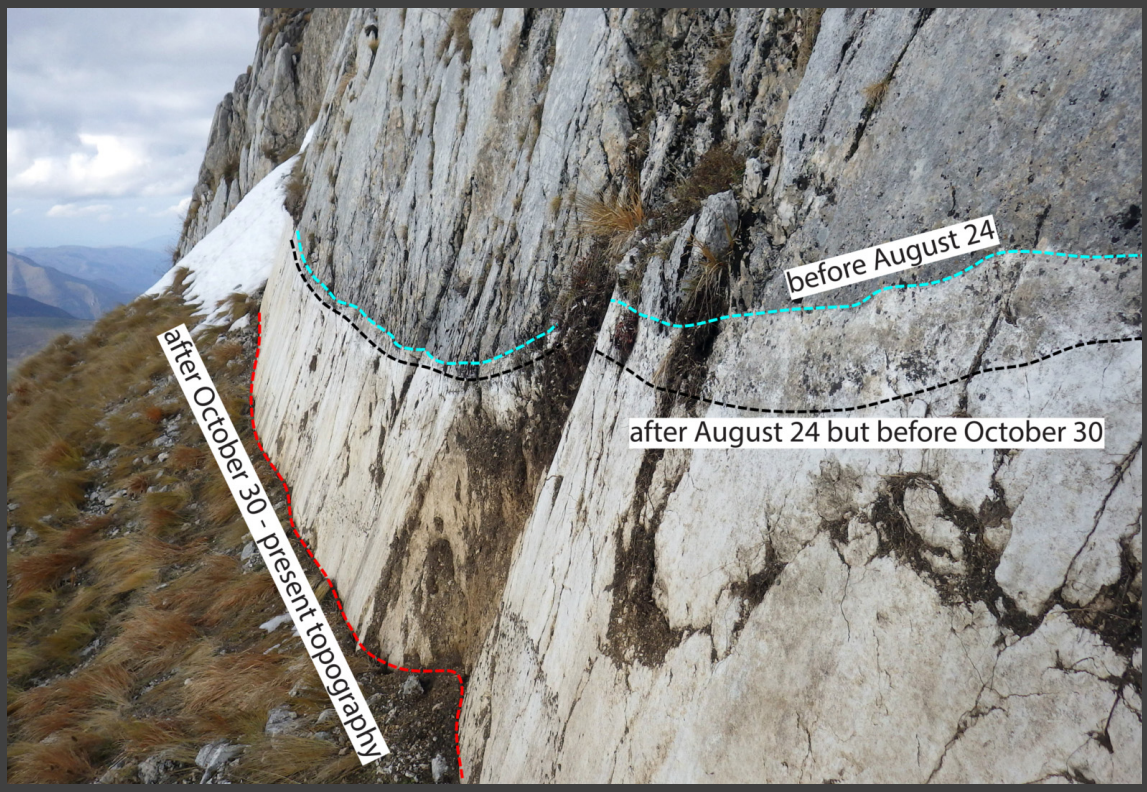
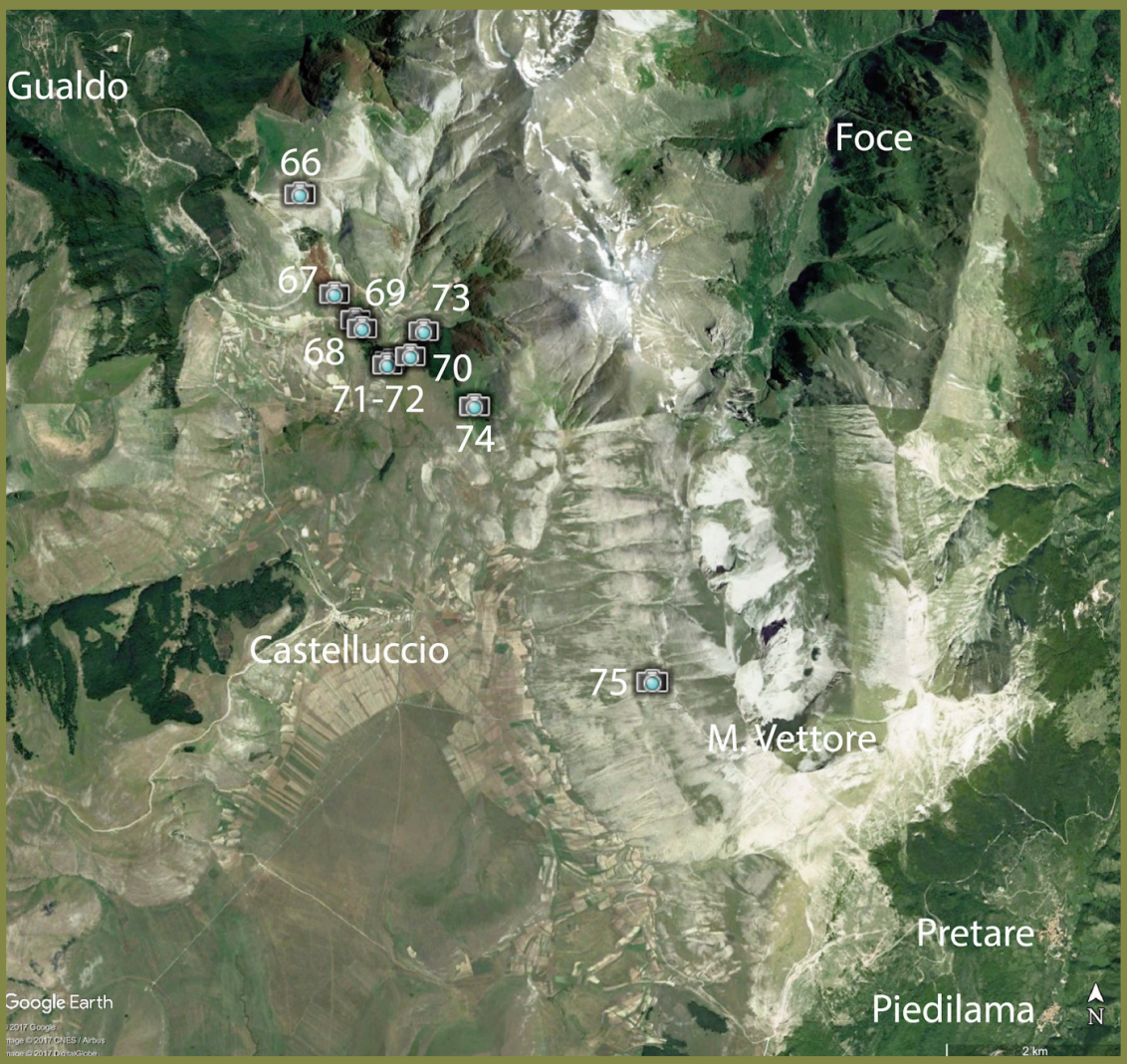


Photo 65. Details of the freshly exposed fault surface on the "Cordone del Vettore" fault (altitude ~2100 m asl). Normal fault scarps in rock are generally covered by a colluvium wedge that preserves the fault plane from oxidation and weathering. The earthquake slip exhumes the buried fault surface that can appear as a lichen- and vegetation-free plane with contrasting color.
42.81670 N 13.25510 E

Antithetic faults



Detailed location map of the photographs of the group "Antithetic faults".



Photo 66. Antithetic and synthetic fault sets are typical in extensional domains. In particular, an antithetic fault is a secondary normal fault whose sense of displacement is opposite to the associated master fault so that it dips in the opposite direction. In this picture (view from the unpaved road to Fonte della Iumenta toward the south) the Mt. Vettore fault (red dashed line) in the background is the master fault and dips toward the west. The ruptures in the foreground (yellow dashed line) mark the Mt. Prata normal fault, which is the most prominent antithetic fault in the area; it runs roughly parallel to the Mt. Vettore-Mt. Bove master fault, dips toward the east, and extends for about 4 kilometers between Spina di Gualdo and Capanna Ghezzi. Color symbols indicate the sense of displacement across each fault.
42.86807 N 13.20190 E



Photo 67. At this site the antithetic fault cuts and badly displaces the dirt road to Madonna della Cona and Forca di Gualdo (view from the north).
42.85938 N 13.20561 E

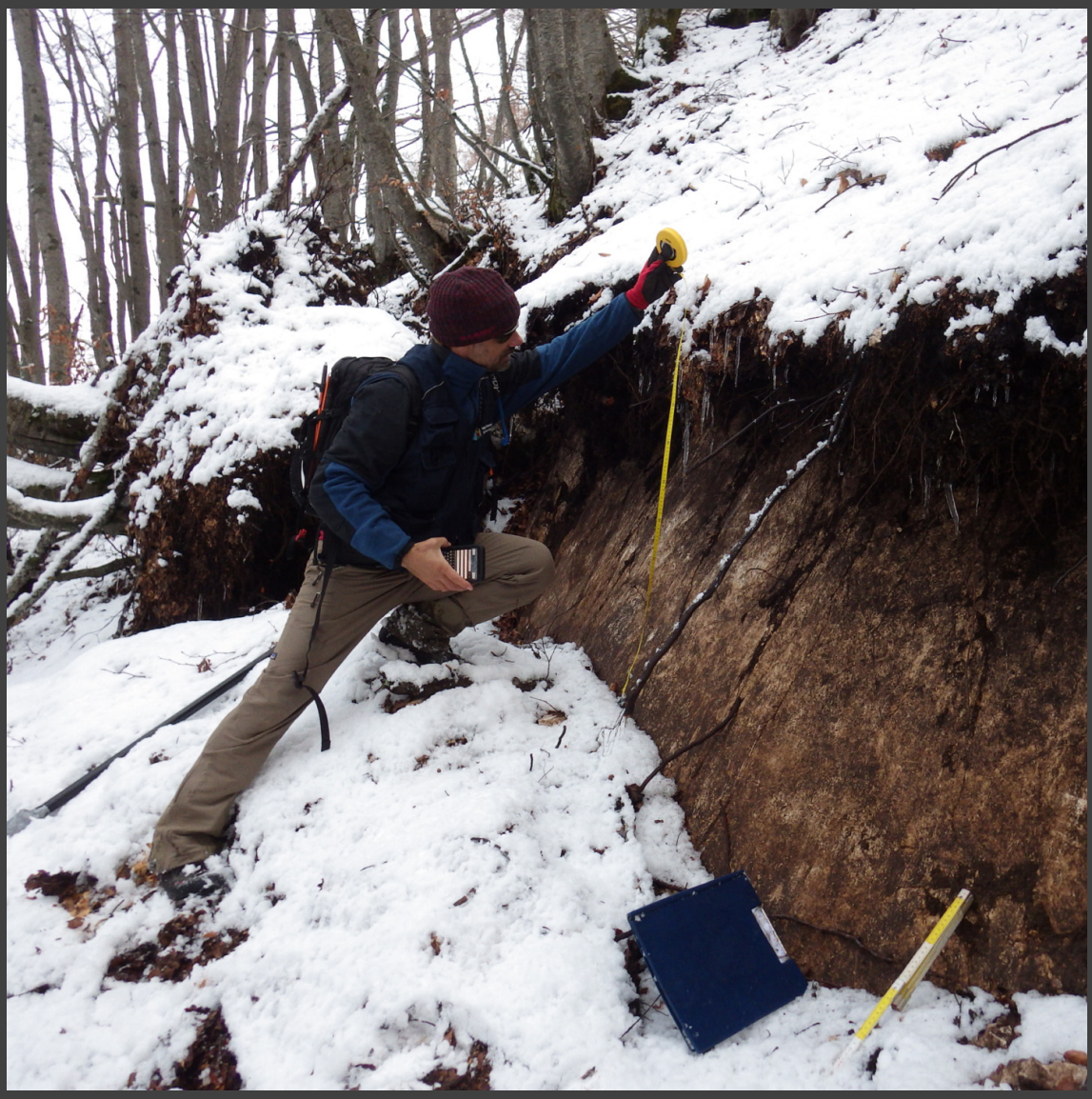


Photo 68. Up to 80-100 cm of vertical displacement have been observed along this section of the Mt. Prata antithetic fault on the eastern side of Colle Minio.
42.85625 N 13.20904 E



Photo 69. The coseismic scarp runs along the slope of Colle Minio. View from northwest.
42.85707 N 13.20818 E



Photo 70. Panoramic view from south-east of the Mt. Prata antithetic normal fault (highlighted by red arrows) along the eastern side of Colle Minio. In this section, the maximum vertical displacement is 60 cm. At the lower left corner of the picture, the rupture crosses and dams the course of the stream that drains the San Lorenzo basin toward the Pian Perduto basin (see photo 72).
42.85354 N 13.21535 E



Photo 71. View from the east of the antithetic fault at Colle Minio. The vertical displacement along this section of the fault is in the range 40-60 cm.
42.85307 N 13.21232 E



Photo 72. Here the rupture causes a local change of the hydrological setting of the area, as it hampers the surface flow of the small stream of the San Lorenzo basin toward the background. However, in the aftermath of the earthquake the flow kept going within the subsoil.
42.85287 N 13.21221 E



Photo 73. In the background a short section of the Colle Minio rupture is visible. The southern termination of this rupture is located at the Portella del Vao stream crossing (see photo 72). Then, the rupture steps to east along the northern side of Mt. Abuzzago in the foreground, where the vertical offset is 35 cm on average.
42.85600 N 13.21690 E

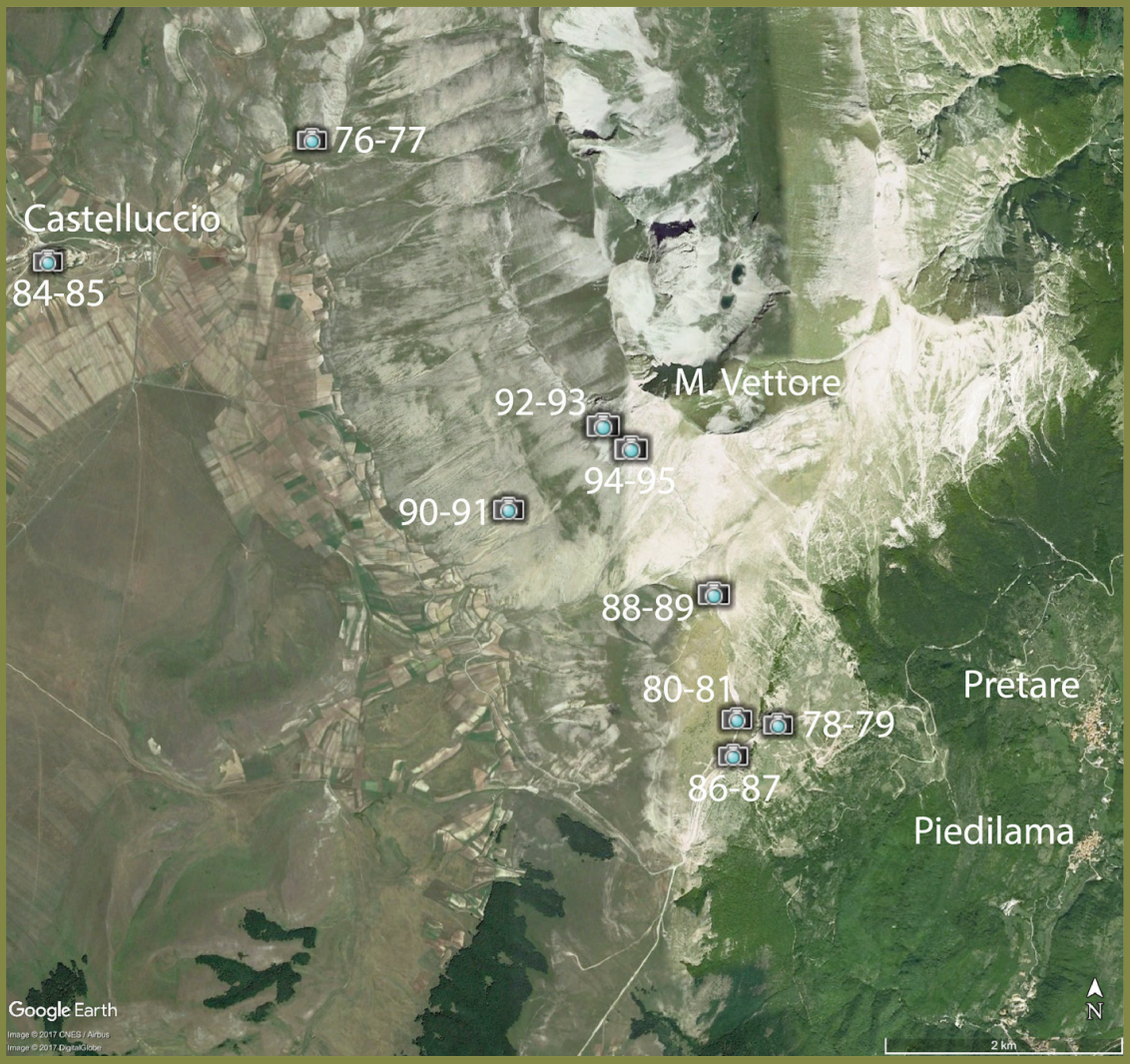


Photo 74. Helicopter view of the Mt. Prata antithetic fault in the Capanna Ghezzi area. Red arrows in the picture indicate the main ruptures associated with this fault. Close-up and detail in the upper left corner show that the rupture intercepts and severely damages the depot of the shepherd. 42.84876 N 13.22359 E



Photo 75. This antithetic rupture runs at an elevation of ~1900 m asl along the western flank of Mt. Vettore. The relative sense of displacement along strike produces a counterslope morphology. 42.82378 N 13.24561 E

24th August *vs* 30th October effects



Detailed location map of the photographs of the group "24th August *vs* 30th October effects". Pictures n. 82 and n. 83 are located outside the map.



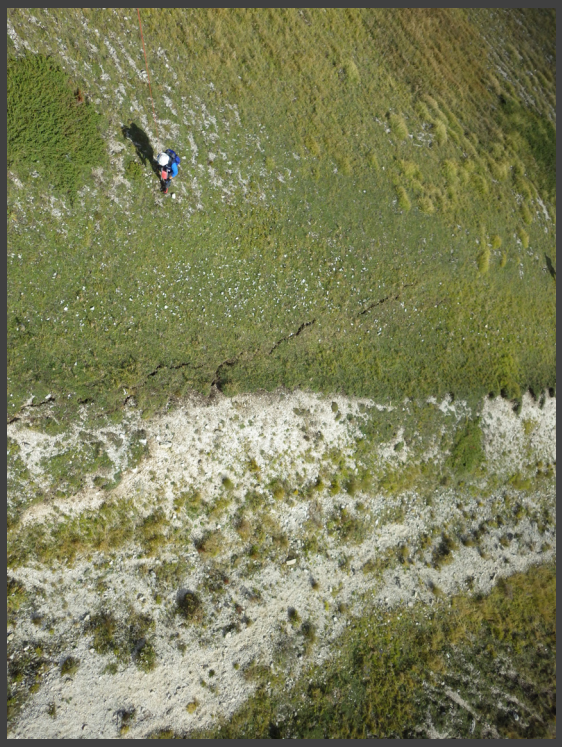


Photos 76 - 77. In this section we show a series of photographs that compare the different effects produced at the same locations by the Mw 6.0 Amatrice earthquake and by the Mw 6.5 Norcia earthquake. It should be stressed that the Norcia event was 5-6 times larger than the Amatrice event in terms of energy released. The above pictures show the fault plane at Colli Alti e Bassi with 1-2 cm of displacement (top) after the 24 August event (note that the white ribbon at the base was already existing before the Amatrice earthquake) and about 60 cm (bottom) after the 30 October shock. 42.83610 N 13.22952 E





Photos 78 - 79. (Top) The tarred road by this fracture at Forca di Presta was promptly paved after the Amatrice event, but the asphalt broke again (bottom) with the same fracture pattern following the Norcia event.
42.79878 N 13.26990 E





Photos 80 - 81. North of Forca di Presta along the eastern side of Mt. Vettoretto the main rupture cuts the left flank of a small incision (top). Notice the different continuity and the increasing displacement along the rupture after the 30 October event (bottom). Both photographs were taken with the helikite aerostat.
42.79940 N 13.26600 E





Photos 82 - 83. Effects produced by the Mw5.9 Visso earthquake (top) and by the Mw6.5 Norcia earthquake (bottom) along the dirt road to the Frontignano skilift.
42.91127 N 13.16597 E





Photos 84 - 85. Fracture with horizontal opening in a concrete floor in the village of Castelluccio. 42.82844 N 13.20604 E





Photos 86 - 87. Although this track of road was completely re-asphalted after the Amatrice earthquake, surface faulting broke up again with identical pattern and kinematics (photo 87, fracture on the right) and produced a new larger rupture (photo 87, fracture on the left) showing continuity with the rupture zone cutting the slope.
42.79689 N 13.26589 E





Photos 88 - 89. Coseismic reactivation along the western side of Mt. Vettoretto on the southern continuation of the Mt. Vettore - Mt. Bove fault system. The offset originated by the Mw6.5 earthquake is about five times larger at this location. Compare with picture n. 62 for location. 42.80741 N 13.26336 E





Photos 90 - 91. The middle splay along the Mt. Vettore - Mt. Bove fault system showed a discontinuous set of fractures with small vertical displacement (less than 10 cm) after the 24 August event, and a 3-4 km-long scarp with an average displacement of 70 cm after the 30 October event. 42.81250 N 13.24672 E





Photos 92 - 93. Free face with dextral oblique slip along the fault plane at the "Cordone del Vettore".
42.81714 N 13.25438 E





Photos 94 - 95. Maximum displacement along the upper splay of the Mt. Vettore - Mt. Bove fault system following the Amatrice event: 20-25 cm. Maximum displacement at the same place following the Norcia event: ~200 cm.
42.81583 N 13.25654 E

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