



MISCELLANEA INGV

A photo and video collection on the
surface faulting: the Mw 7.8
Kahramanmaraş (Turkey) earthquake
of February 6, 2023



ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

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A photo and video collection on the surface faulting: the Mw 7.8 Kahramanmaraş (Turkey) earthquake of February 6, 2023

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Cover Surface faulting near the village of Kisik (Karaağaç, Pazarcık District, Kahramanmaraş Province, Turkey) | In copertina Fagliazione superficiale nei pressi del villaggio di Kisik (Karaağaç, Distretto di Pazarcık, Provincia di Kahramanmaraş, Turchia)

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Introduction

On February 6, 2023, two large earthquakes struck southeastern Türkiye near the Syrian border. The first one (the Kahramanmaraş earthquake) reached a magnitude Mw 7.8 rupturing the southern segment of the predominantly southwest-trending East Anatolian Fault Zone (EAFZ). Just nine hours later, another devastating earthquake (Mw 7.6, the Elbistan earthquake) occurred about 90 kilometers away, along the east-west striking Northern Strand of the EAFZ, specifically the Sürgü–Misis Fault system (Figure 1). These earthquakes caused catastrophic damage across southeastern Turkey and northwestern Syria, resulting in over 50,000 fatalities and tens of thousands of injuries. The most affected Turkish provinces included Kahramanmaraş, Gaziantep, Hatay, Adıyaman, Diyarbakır, and others [AFAD, 2023; USGS, 2023; Kürçer et al., 2023].

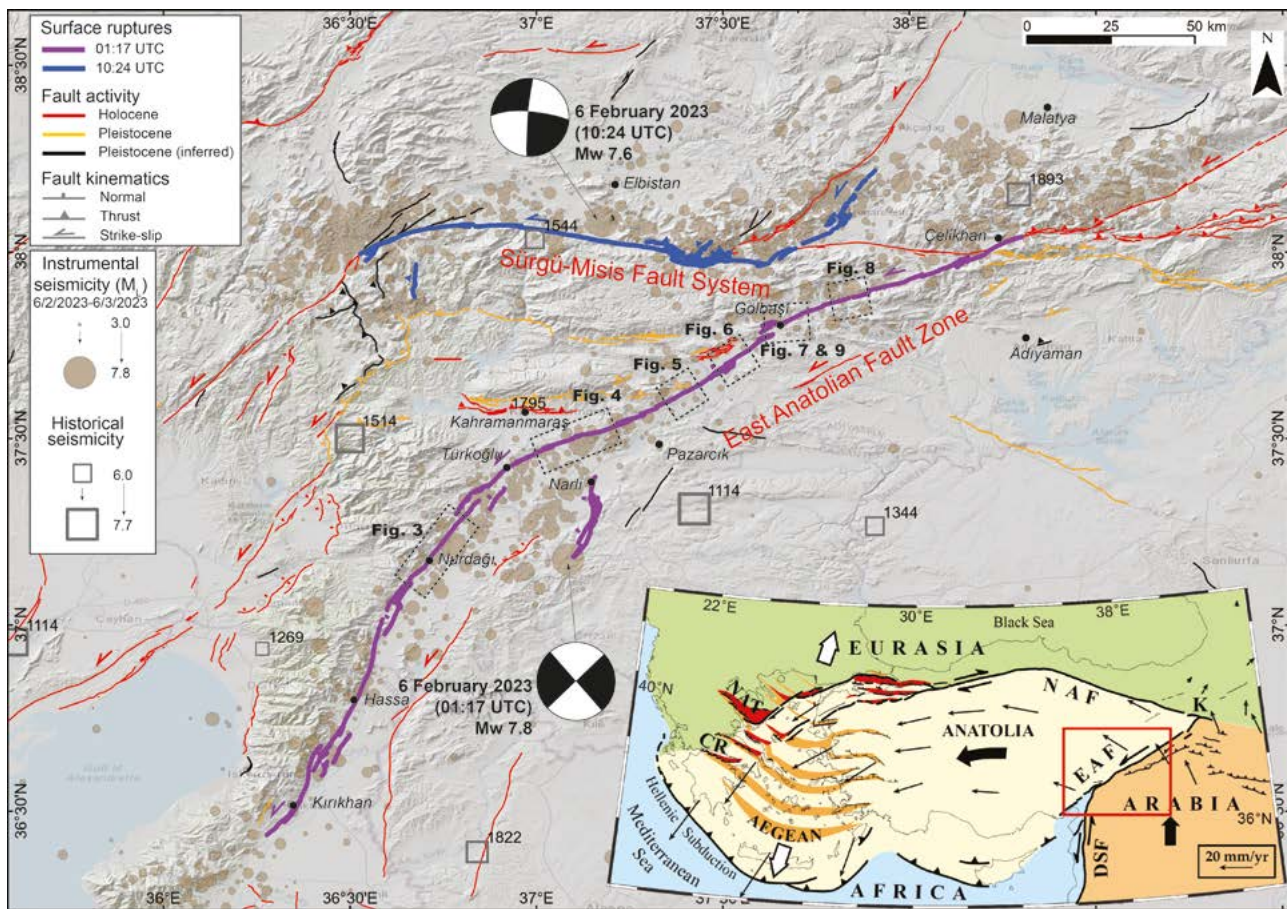


Figure 1 Simplified tectonic map of the 2023 seismic sequence area. Active faults from Emre et al. [2018]. Purple and blue lines refer to the Mw7.8 and 7.6 causative faults, respectively. Focal mechanisms and instrumental seismicity from Koeri. Historical earthquake from Stucchi et al. [2024]. Black dashed boxes locate the areas of photo acquisition. Shaded relief from the 30-m DEM ASTER V003 (NASA/METI/AIST/Japan Spacesystems and U.S./Japan ASTER Science Team, 2019). (Modified from Pucci et al. [2025]).

In response to these disasters, the Italian Department of Civil Protection (DPC) organised, in collaboration with the Turkish Disaster and Emergency Management Authority (AFAD), an Italian scientific geological mission to Turkey in May 6-13, 2023. The team, composed of experts from the DPC's Competence Centers (EMERGEO Working Group of INGV – Istituto Nazionale di Geofisica e Vulcanologia; ISPRA - Istituto Superiore per la Protezione e la Ricerca

Ambientale; INOGS – Istituto Nazionale di Oceanografia e di Geofisica Sperimentale), carried out a field survey in the areas affected by the Mw 7.8 Kahramanmaraş earthquake. The primary target was to collect data on the primary coseismic surface faulting in order to measure the displacement along strike and then reconstruct the near-fault slip distribution [Pucci et al., 2025]; moreover, the variety of deformation styles recognised in the field and other primary and secondary coseismic surface geological effects prompted us to document through photographs and videos, also employing a drone, the main structural features of the rupture. This kind of documentation, although collected in selected spot areas, is crucial not only for a better understanding of seismic source dynamics but also for supporting the reconstruction phase, with special attention to problems due to surface faulting in urbanised areas.

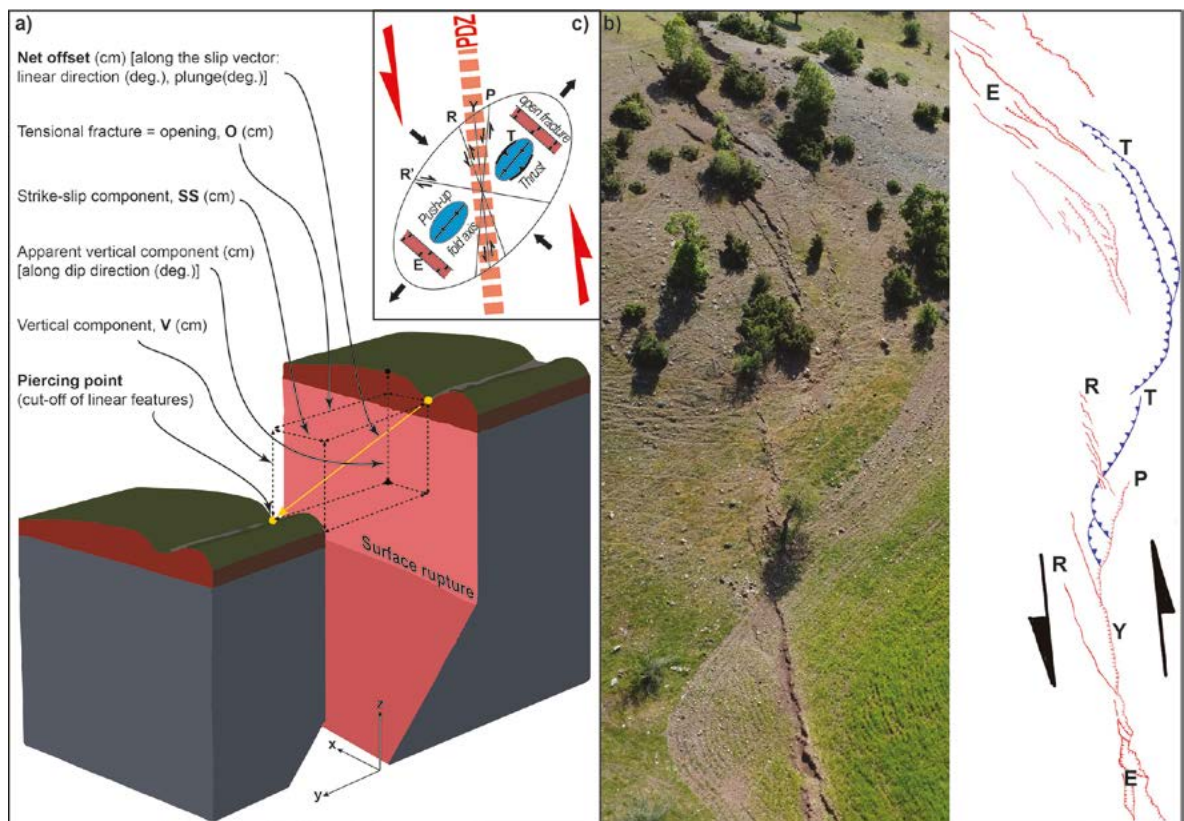


Figure 2 (a) Block diagram of the measured offset components; (b) example of differences between the theoretical typology of the structure composing the mole-track (see text for details) and the coseismic ruptures observed in the field in the Kisik area. Blue lines are reverse faults and red lines are strike-slip and normal faults; (c) theoretical typology of ruptures from infinitesimal plain strain (PDZ-Principal Displacement Zone, R and R'-Riedel, E-extensional fracture, T-thrust, Y-shear and P-shears; folded mound, push-up). Note that the large coseismic deformation tends to rotate the fracture pattern, diverting from the theoretical angle (c) with the fault trend (Modified from Pucci et al. [2025]).

In this collection, preliminarily we include a drone-recorded video of the Kisik, Kartal, and Harmanlı areas, providing a panoramic view of the coseismic rupture's structural pattern at a local scale. Moreover, we show the photos documenting the arrangement of the coseismic surface rupture extensively described in Pucci et al. [2025], affecting the districts of Islahiye, Nurdağı (Figure 3), Dulkadiroğlu (Figure 4), Pazarcık (Figure 5) and Gölbaşı (Figure 6, 7 and 8) districts, through the Gaziantep, Kahramanmaraş and Adıyaman provinces.

Finally, for the area of Gölbaşı (Figure 9), we present pictures of the impressive liquefaction effects responsible for further devastation inside the town. Note that some photos in close proximity are not shown on the location maps to improve readability. Nevertheless, accurate geolocation is guaranteed by the geographical coordinates included with each photo.

In this paper, we present a selection of 125 pictures from over 4,000 photographs taken during the field survey carried out from 6 to 12 May 2023 along the central sector of the EAFS. Here the team surveyed a sector approximately 180 km long over more than 380 km of coseismic surface rupture produced during the Kahramanmaraş earthquake, characterised by predominantly left-lateral strike-slip displacements up to 6 metres and extensive liquefaction phenomena.

It is important to note that, during the surface faulting processes, the finite coseismic deformation tends to rotate the early structures (from the theoretical angle with the general fault trend) and forms mixed-mode fractures (hybrid fractures), which displace according to both shear and extensional components due to near surface failure (Figure 2).

Then, inside of a defined fault kinematics, we may observe a combination of coseismic structures, from compressional to extensional and pure strike-slip, that only after a careful mapping (Figure 2a) are able to depict the effective kinematics of a fault. For these reasons, we can observe compressive structures in a mainly trans-tensile context, or vice versa, that together (Figure 2b) define the strike-slip Principal Displacement Zone (PDZ; Figure 2c).

Keywords Earthquake; Surface faulting; Coseismic rupture; Kahramanmaraş

A drone view on the coseismic ruptures of the Mw 7.8 Kahramanmaraş (Turkey) earthquake of February 6, 2023



Nurdağı

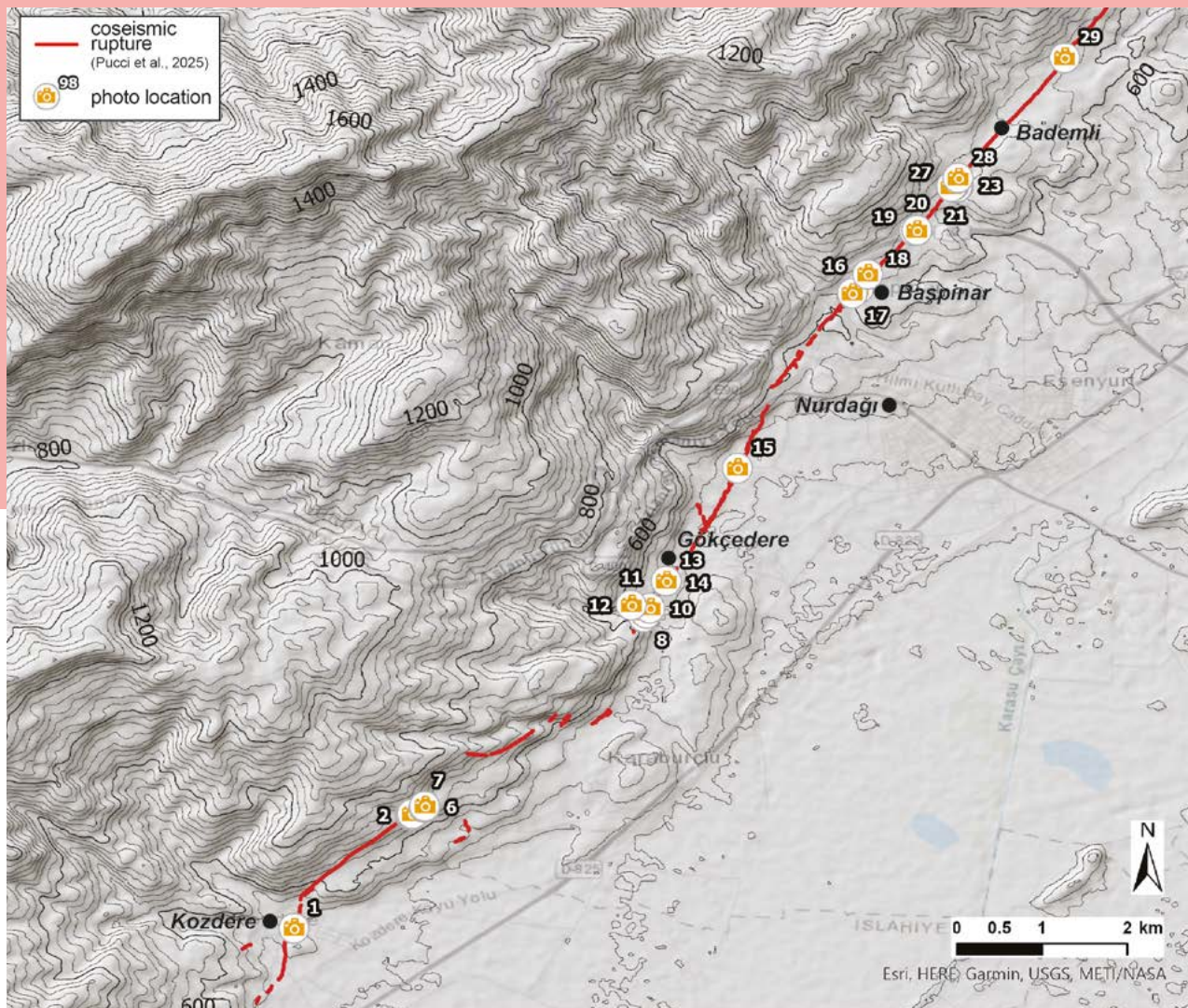


Figure 3 Location map of the photos documenting the features of surface faulting in the Islahiye and Nurdağı districts (Gaziantep province).



Photo 1 (37.127789°N, 36.667270°E) – The fault trace runs through the village of Kozdere (Islahiye district, Gaziantep province), offsetting roads with more than one meter of displacement. Although repairs restored most of the infrastructure affected by the faulting, its surface traces were still documented throughout the village. Here, a clear example of a tar road displaced by distributed deformation, which as a whole exhibits a purely left-lateral net offset of 90 cm.



Photo 2 (37.139741°N, 36.679528°E) – Features of a typical coseismic rupture pattern: en-echelon right-stepping transtensional Riedel shears (with 50 cm of opening component) and a left-stepping push-up (person on it), exhibiting a 70 cm offset.



Photo 3 (37.139790°N, 36.679613°E) – Metric-scale transpressive (push-ups) and transtensive (Riedel shears) structures alternate, forming a rupture mole-track. Transtensional features display openings of up to 40 cm, while push-up structures reach heights of up to 30 cm.



Photo 4 (37.139790°N, 36.679613°E) – Coseismic surface rupture highlighted by a mole-track with a pressure ridge, approximately 8 m in length, showing up to 70 cm of vertical component of the deformation.

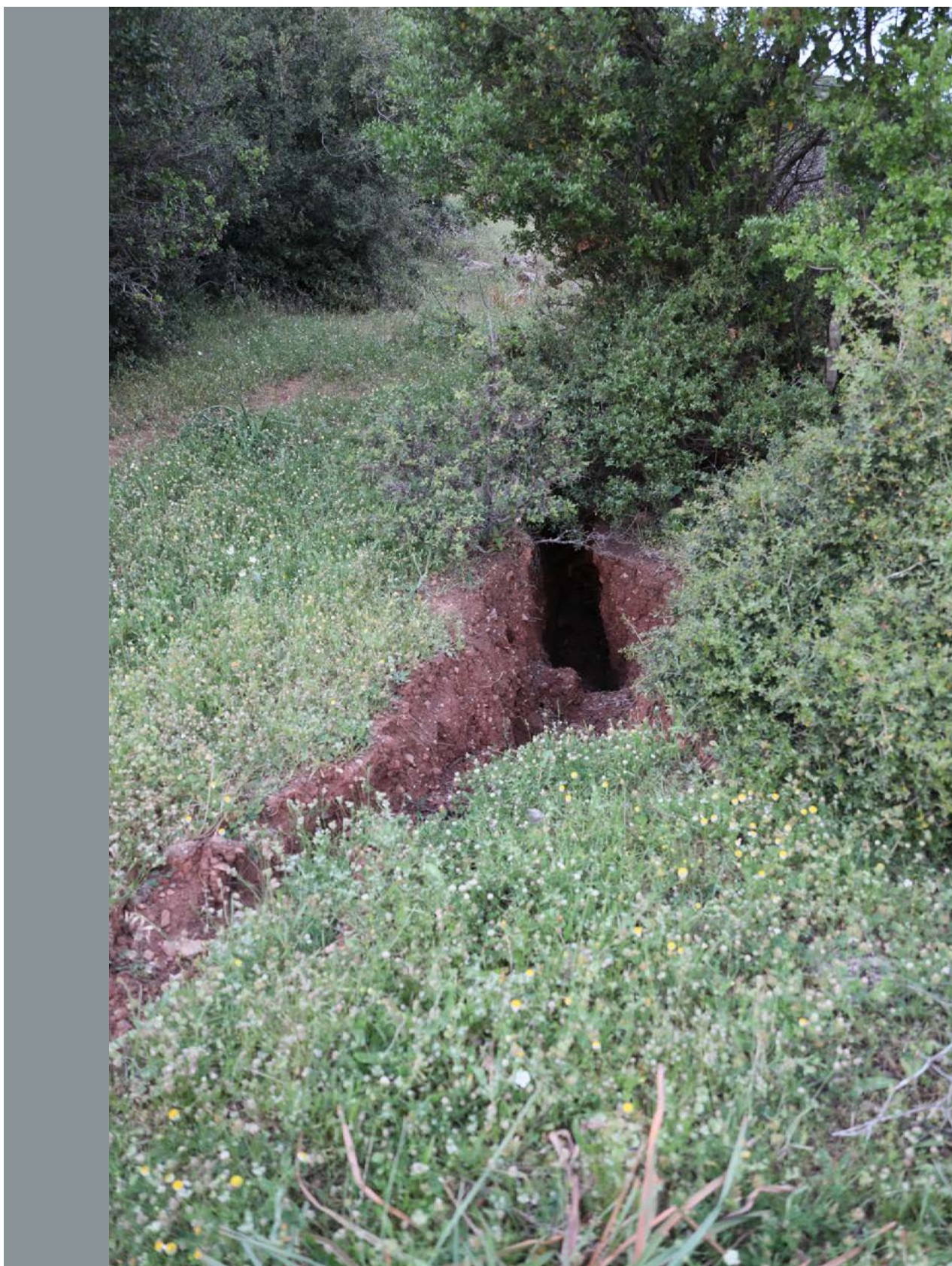


Photo 5 (37.140573°N, 36.680943°E) – The coseismic surface rupture, expressed as a mole-track, is characterised by transtensional structures, producing grabens up to 70 cm wide and about 10 m long.



Photo 6 (37.140567°N, 36.681057°E) – The mole-track pattern is characterised by transtensional fractures with up to 60 cm of opening component, resulting in a trench up to 2 meters deep, frequently infilled by gravitational collapse of the two walls.



Photo 7 (37.140567°N, 36.681057°E) – In this site, the coseismic surface rupture is composed by major Riedel elements, expressing a dominant transtensional component with a maximum vertical offset of 50 cm, and a limited opening component.



Photo 8 (37.160682°N, 36.704166°E) – The mole-track pattern is here characterised by decametric en-echelon extensional elements, producing a vertical offset of up to 110 cm and a trench up to 130 cm wide and 2 meters deep.



Photo 9 (37.160984°N, 36.704419°E) – The coseismic surface rupture is expressed by decametric-scale en-echelon elements. Here, a set of tensional openings, up to 50 cm each, affects a ca. 5 m-wide push-up responding to the ground flexure. The cumulative opening of the mole-track is ca. 130 cm.



Photo 10 (37.161528°N, 36.704793°E) – At this site, the earthquake rupture features an en-echelon right-stepping push-up, 50 cm in height, showing a net width of 5 m.

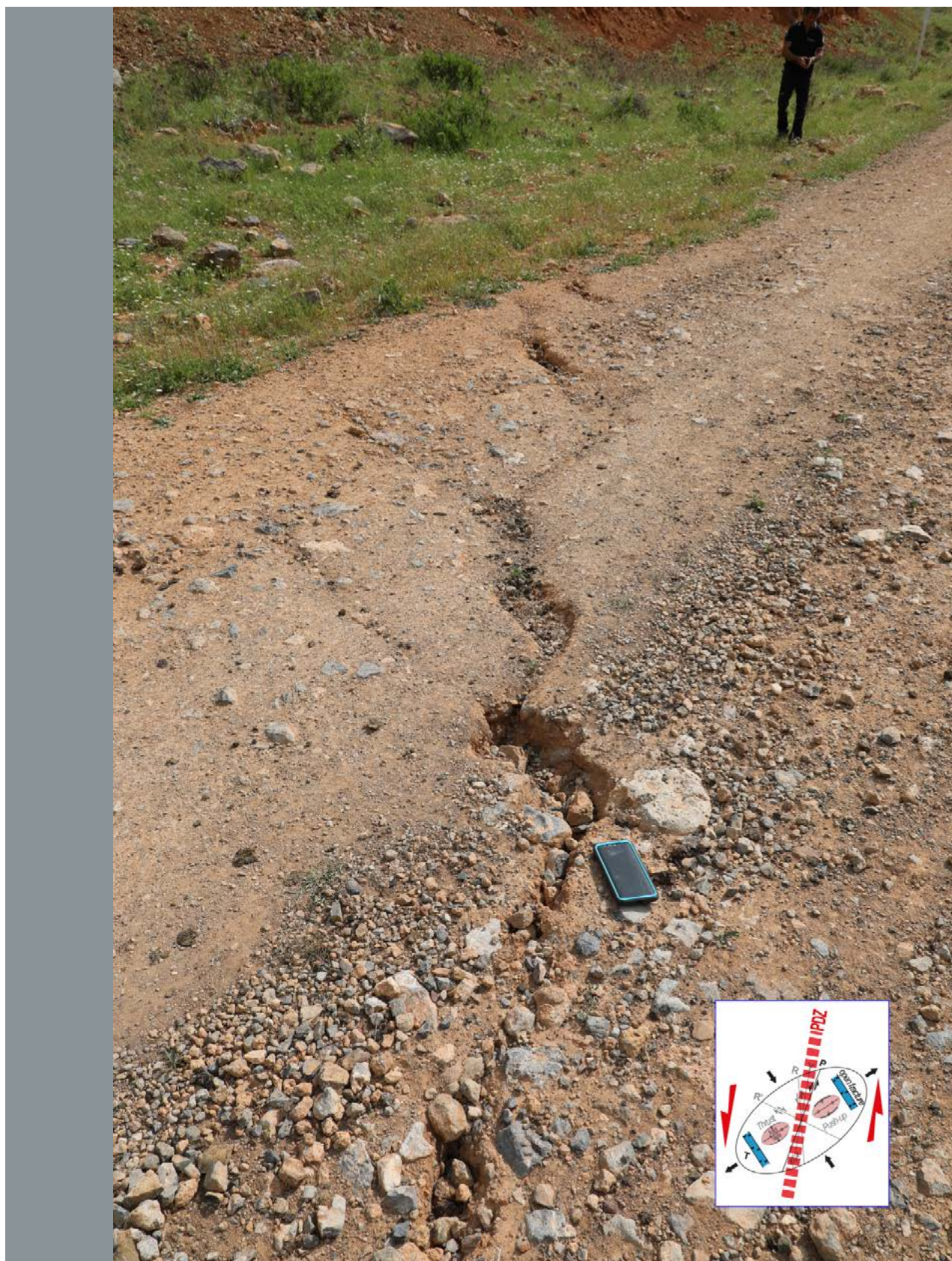


Photo 11 (37.161863°N, 36.702838°E) – Coseismic rupture with dominant right-lateral en-echelon tension cracks (2–3 m long; opening 10 cm) linked by left-stepping strike-slip elements. This pattern characterizes transtensional zones, such as releasing step-overs. The inset shows theoretical rupture typology from infinitesimal plane strain (symbols in Figure 2); non-observed typologies are opacified.



Photo 12 (37.161863°N, 36.702838°E) – Detail of the previous structural pattern (photo 11). The left-lateral strike-slip kinematics of the left-stepping en-echelon arrangement of the strike-slip elements determine a tensional opening between the two elements (few-cm wide, with no vertical component). In the box a sketch map of the typology of rupture.



Photo 13 (37.164370°N, 36.706508°E) – Transtensional earthquake rupture crossing Gökçedere (Nurdağı/Gaziantep). In the cemetery, decametric en-echelon segments dislocate the pavement. Total displacement shows a ~130 cm left-lateral offset (using tree line reference) and a 40 cm vertical offset (east-facing viewpoint).



Photo 14 (37.164370°N, 36.706508°E) – Detail of the previous photo 13 (viewed from the north). The coseismic surface rupture is characterised by two en-echelon, decameter-scale transtensional branches with a large opening component and a meter-scale interposed gravity graben.

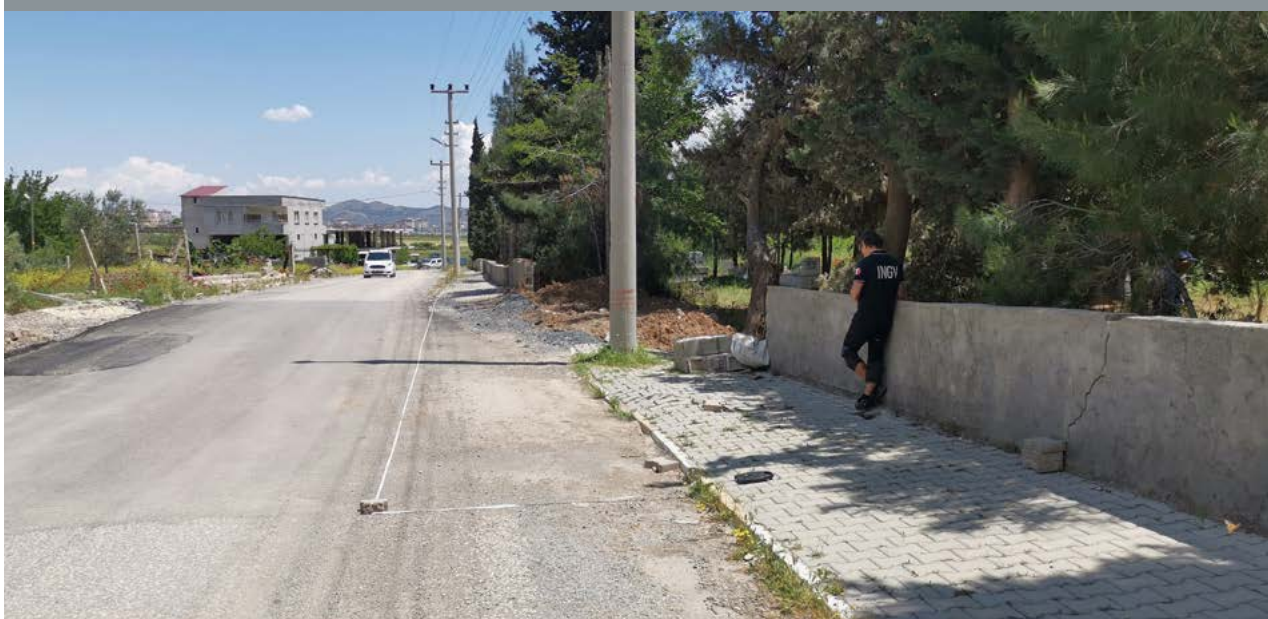


Photo 15 (37.176261°N, 36.713990°E) – The coseismic displacement affected a road (just repaired) in the town of Nurdağı: the cumulative left lateral offset is 210 cm, estimated by projecting on the fault trace the dislocated road side.



Photo 16 (37.195202°N, 36.726757°E) – Panoramic view (from northwest) showing the coseismic surface rupture near the village of Başpınar (Nurdağı district/Gaziantep province).



Photo 17 (37.194690°N, 36.726102°E) – Detail of the previous photo 16: here, the rupture features a prevailing transtensional movement with an opening of up to 110 cm.



Photo 18 (37.196710°N, 36.727732°E) – Surface coseismic rupture characterized by a left-lateral offset of 300 cm of a paved road in the village of Başpınar.



Photo 19 (37.201277°N, 36.732665°E) – Here, the coseismic rupture shows a metric-scale push-up ridge with smaller flexural cracks affecting the fold hinge.



Photo 20 (37.201277°N 36.732665°) – Detail of the previous photo 19: the push-up generated between the en-echelon right-stepping transtensional Riedel shears.



Photo 21 (37.205771°N, 36.737026°E) – Panoramic view (from southwest) of the coseismic surface rupture running on a wheat field near the village of Bademli (Nurdağı district/Gaziantep province), (see also photographs from 22 to 28).



Photo 22 (37.205811°N, 36.737076°E) – Panoramic view (from northeast) of the same site shown in photo 21.



Photo 23 (37.206023°N, 36.737299°E) – 420 cm of cumulative left-lateral offset of a dirt road.
The gentle bend is due to early repairs necessary to reconnect the dislocated road sections.



Photo 24 (37.205886°N, 36.737132°E) – A closer view of the olive grove from photo 23. The coseismic fault rupture at the surface displaces a fence line and the rows of olive trees with approximately 380 cm of aggregated left-lateral motion.



Photo 25 (37.206083°N, 36.736885°E) – Drone view (from southeast) of the coseismic rupture shown in photos 23 and 24: note on the left (grassy area) the compound scarp north of the fault trace.



Photo 26 (37.206252°N, 36.736804°E) – Drone view (from southwest) of the dirt road displaced by the coseismic rupture in photograph 23: the left-lateral component of movement of the fault is clearly visible also in the fields paralleling the road.

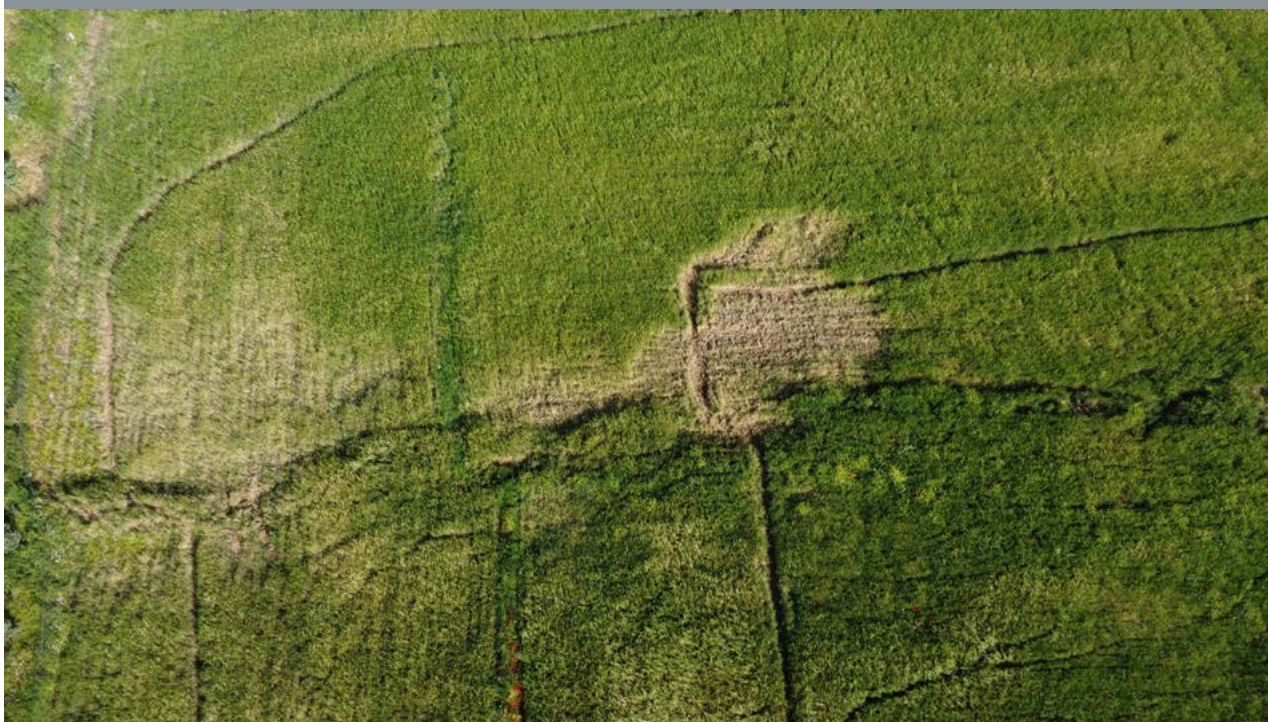


Photo 27 (37.205923°N, 36.736528°E) – Drone view (from northwest) of the surface rupture (see photos 21–22). Displaced ditches evidence a 300–380 cm left-lateral offset. Despite low vegetation, the rupture trace and offset partitioning across fault splays remain clearly discernible.



Photo 28 (37.206844°N, 36.737263°E) – Drone view (from northeast) of the coseismic rupture of photo 24. Note the left-lateral displacement (ca. 310 cm) of the field boundaries.



Photo 29 (37.219515°N 36.748460°E) – Detail of the coseismic rupture associated with a transtensive kinematics resulting in dominant right-stepping Riedels, with vertical offset component of up to 60 cm, linked by lateral ramps.

Kahramanmaraş

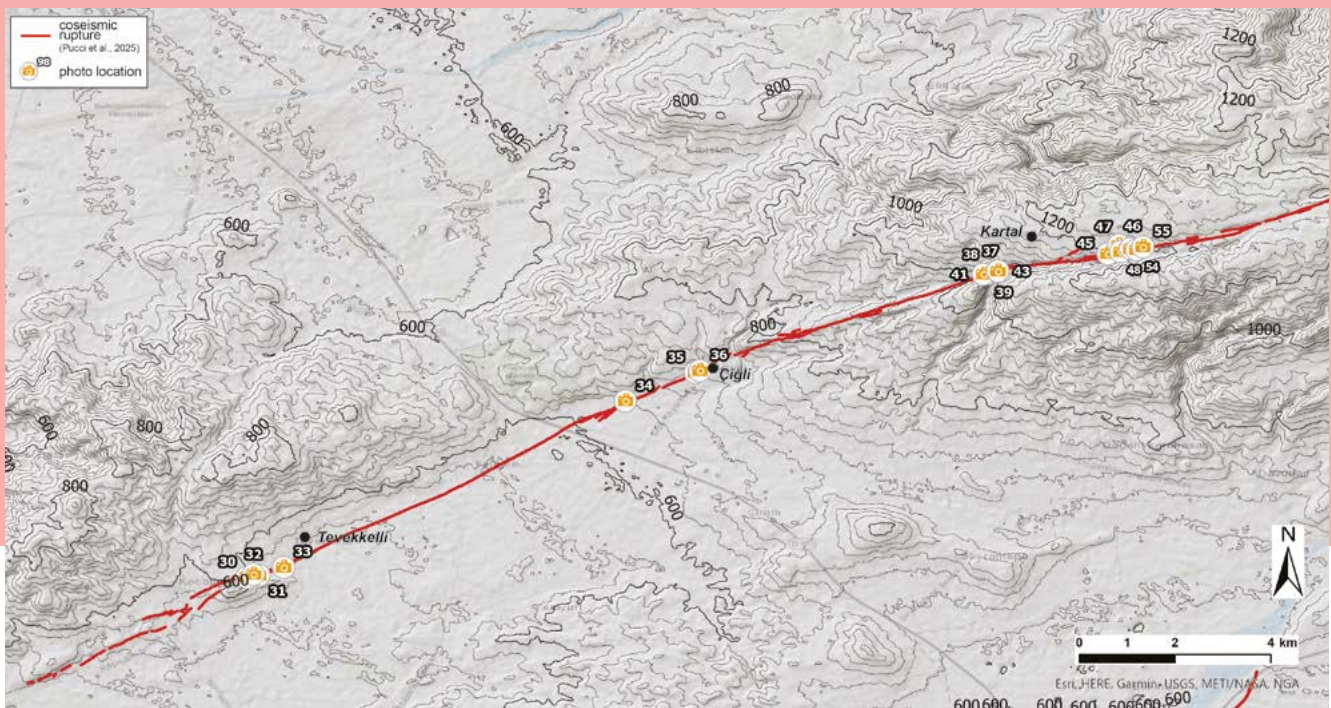


Figure 4 Location map of the photos documenting the features of surface faulting in the Dulkadiroğlu district (Kahramanmaraş province).



Photo 30 (37.452119°N, 36.982894°E) – Drone view (from southwest) of the fault trace near the village of Tevekkelli. The linear coseismic rupture displaces ridge crests, hill flanks, and gullies, creating shutter ridges and deflected drainage. Maximum left-lateral displacement measures ~340 cm.



Photo 31 (37.452509°N, 36.985112°E) – Drone view (from northeast) of the coseismic escarpment. The narrow fault zone shows few en-echelon arrangements of Riedel shears, absence of opening components and up to 250 cm of apparent vertical offset due to lateral juxtaposition of slopes.



Photo 32 (37.452677°N, 36.984166°E) – Detail of the coseismic rupture viewed from northeast.
Note the left-lateral deflection of the gully (~320 cm) at the right bottom corner.



Photo 33 (37.453997°N 36.989798°E) – Some hundreds of meters northeast of the previous photos, the coseismic rupture enters a plain: here, the left step of two fault strands produced a spectacular pull-apart (picture's bottom left), resembling a negative flower structure.



Photo 34 (37.485160°N, 37.053903°E) – Coseismic left-lateral deflection of ~400 cm affecting an artificial waterway near the Çiğli village.



Photo 35 (37.490467°N, 37.066978°E) – Retaining wall in the Çiğli village affected by coseismic surface faulting displaying a pure left-lateral offset of 260 cm.



Photo 36 (37.490882°N, 37.067873°E) – At this site (view from the northeast) the coseismic rupture trace runs parallel to the house wall uplifting the house with respect to the paved outdoor, no clear significant damage can be reported.



Photo 37 (37.509495°N, 37.121345 °E) – Panoramic view (from north) of the coseismic rupture southwest of the village of Kartal. Here, the coseismic surface rupture branches in multiple parallel strands, with partitioning of the left-lateral displacement (see also photographs 38, 39, 40).



Photo 38 (37.509495°N, 37.121345 °E) – Previous photo close up: note the left-lateral displacement of the tree alignments along the hill slope and the coseismic rupture with evident vertical offset component (see also photographs 37, 39, 41).



Photo 39 (37.509500°N, 37.123718°E) – Detail of the previous photo: here the coseismic rupture features a left-lateral offset of 350 m with up to 250 cm of vertical offset. Note also the en-echelon arrangement of the individual elements.



Photo 40 (37.508917°N 37.121052°E) – Drone view (from west) of the same rupture section of photographs 37-38-39. Note the en-echelon arrangement of the parallel, right stepping coseismic rupture strands defining a deformation zone width of up to 25 m.



Photo 41 (37.509380°N, 37.123407°E) – Mole-track expression of the rupture due to the dominant presence of push-ups, resulting from the transpressional kinematics of the hosting strand.



Photo 42 (37.509417°N, 37.509417°E) – Left-lateral offset of ~430 cm measured by means of the tree line dislocation.



Photo 43 (37.509487°N, 37.123761°E) – Drone azimuthal view of the previous photo. The olive tree field boundary was reworked by the owner to recover the left-lateral displacement.



Photo 44 (37.512861°N, 37.145044°E) – Drone view (from northeast) of the coseismic rupture east of the Kartal village. Note that the rupture trace parallels the drainage incision and flanks an elongated pressure ridge, probably representing the long-term expression of transpressional kinematics.



Photo 45 (37.512746°N, 37.144398°E) – Detail of the previous photo. The horizontally dislocated (~330 cm) limit of the green and brown cultivated fields highlights the left-lateral component of movement.

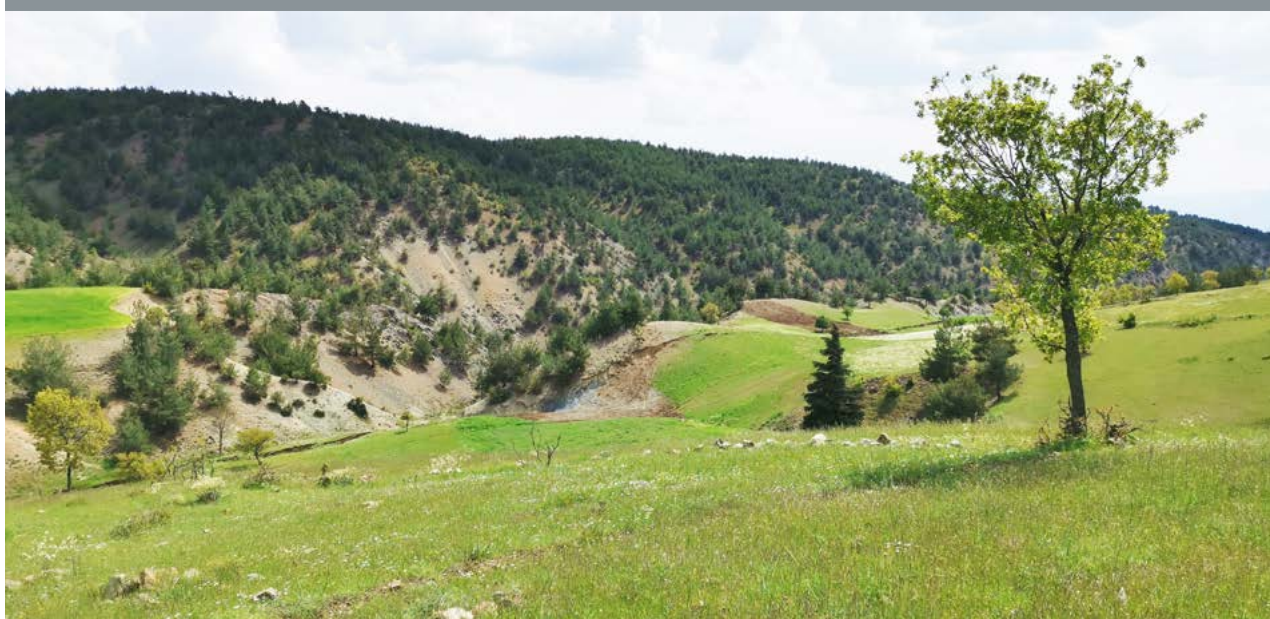


Photo 46 (37.514374°N, 37.146404°E) – View (from the northeast) of the coseismic rupture of photo 44 deforming different morphological elements of the environment.

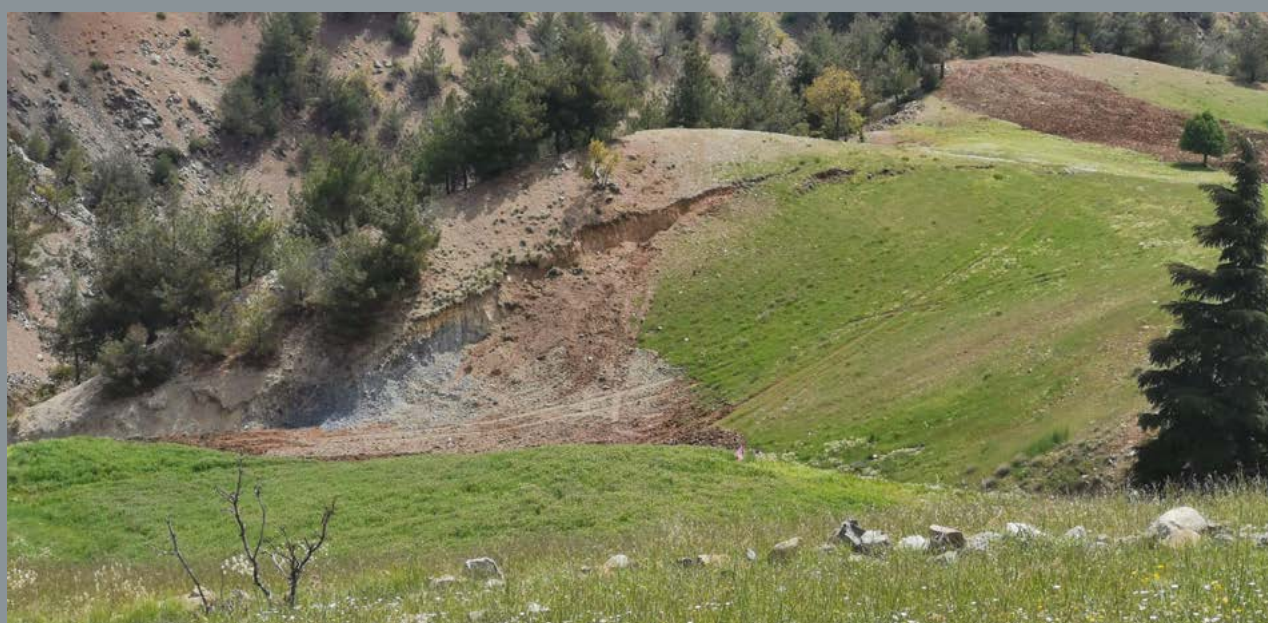


Photo 47 (37.514374°N 37.146404°E) – Detail of the previous photo. The vertical component is mostly apparent, and results from the left-lateral displacement that juxtaposes an oblique slope.



Photo 48 (37.513147°N, 37.146798°E) – View of the coseismic rupture running at the base of the pressure ridge. The arrangement is consistent with quasi-pure left-lateral kinematics. Note the dip-slip component at the pull-apart basins, locally caused by small extensional bends.

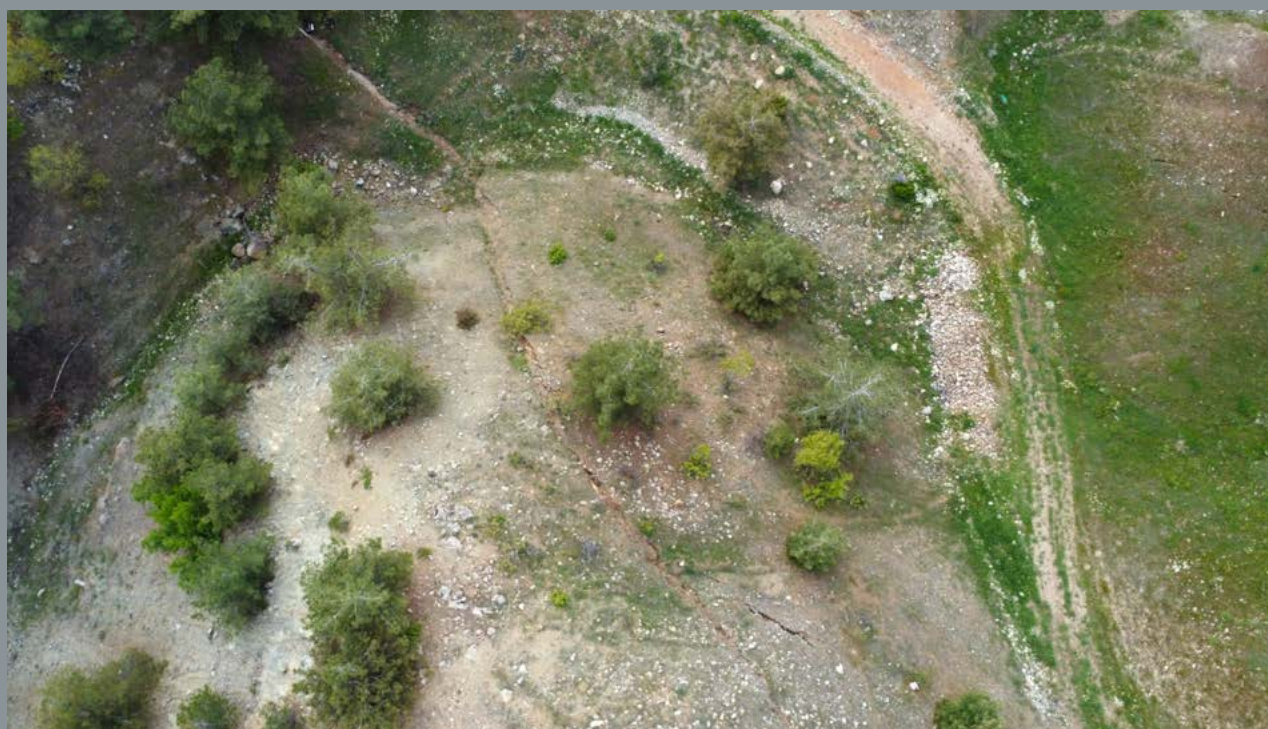


Photo 49 (37.513719°N, 37.149131°E) – Drone view (from east) of the coseismic rupture crosscutting a small valley, deflecting and damming the stream talweg (see also photo 50).



Photo 50 (37.513710°N, 37.148678°E) – Detail of the previous photo (view from west).
Note the flip of the coseismic free face due to the left-lateral slip component along differently oriented valley flanks.



Photo 51 (37.513745°N, 37.148705°E) – The coseismic free face marked by an impressive clear-cut plane (view from north).



Photo 52 (37.513708°N, 37.148664°E) – Particular of the fault plane in photo 51. The slickenlines are locally well preserved; the ruler is aligned with the strike of the striae.



Photo 53 (37.513708° N, 37.148664° E) – Detail of the previous photo.
The ruler indicates the apparent vertical displacement of more than 90 cm.



Photo 54 (37.514044°N, 37.150936°E) – Panoramic view (from east) of the area in photo 49.
Note the pressure ridge affected by secondary parallel rupture strands.



Photo 55 (37.513502°N, 37.149821°E) – Panoramic view (from east) of the left-stepping pressure ridges flanked by the coseismic ruptures. Note that the coseismic offset of more than 300 cm of the whitish stone wall.

Kisik

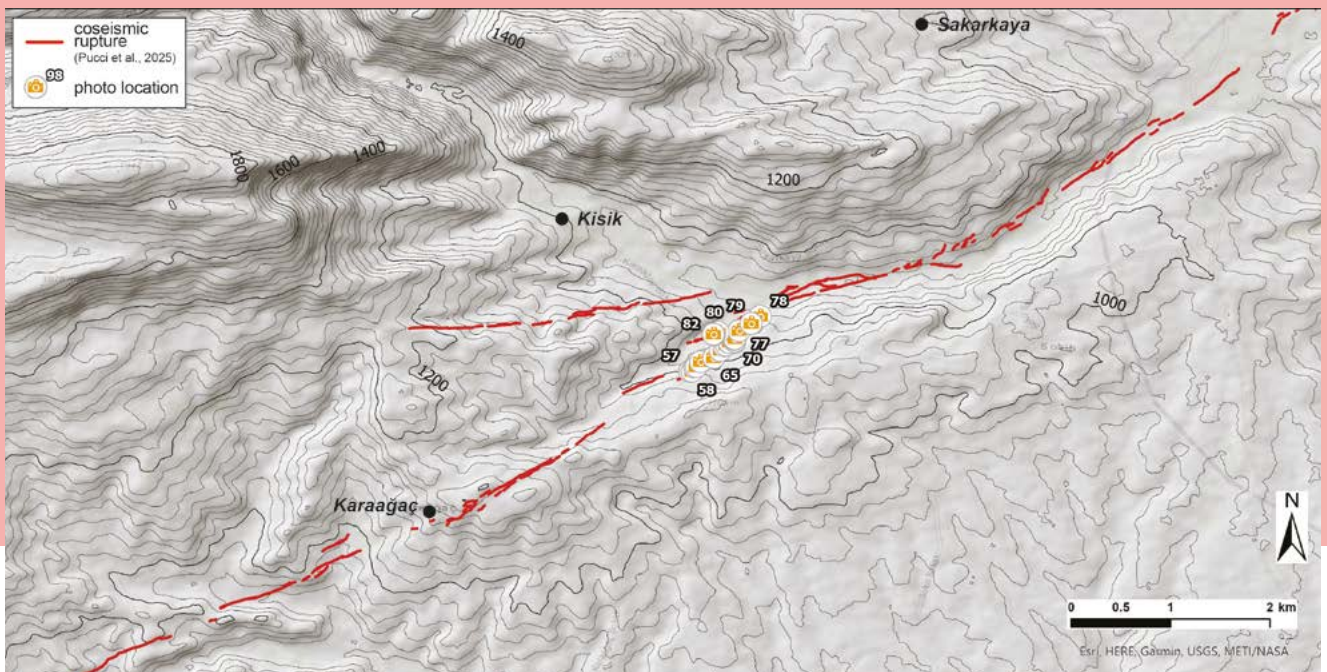


Figure 5 Location map of the photos documenting the features of surface faulting in the Kisik area (Karaağaç, Pazarcık district, Kahramanmaraş province).



Photo 56 (37.616031°N, 37.383909°E) – Drone view (from northeast) of the surface rupture characterized by decameter-scale pull-apart basins due to right-stepping Riedels.



Photo 57 (37.615527°N, 37.383265°E) – The apparent vertical offset component of up to 210 cm is given by the lateral dislocation of the oblique slope.

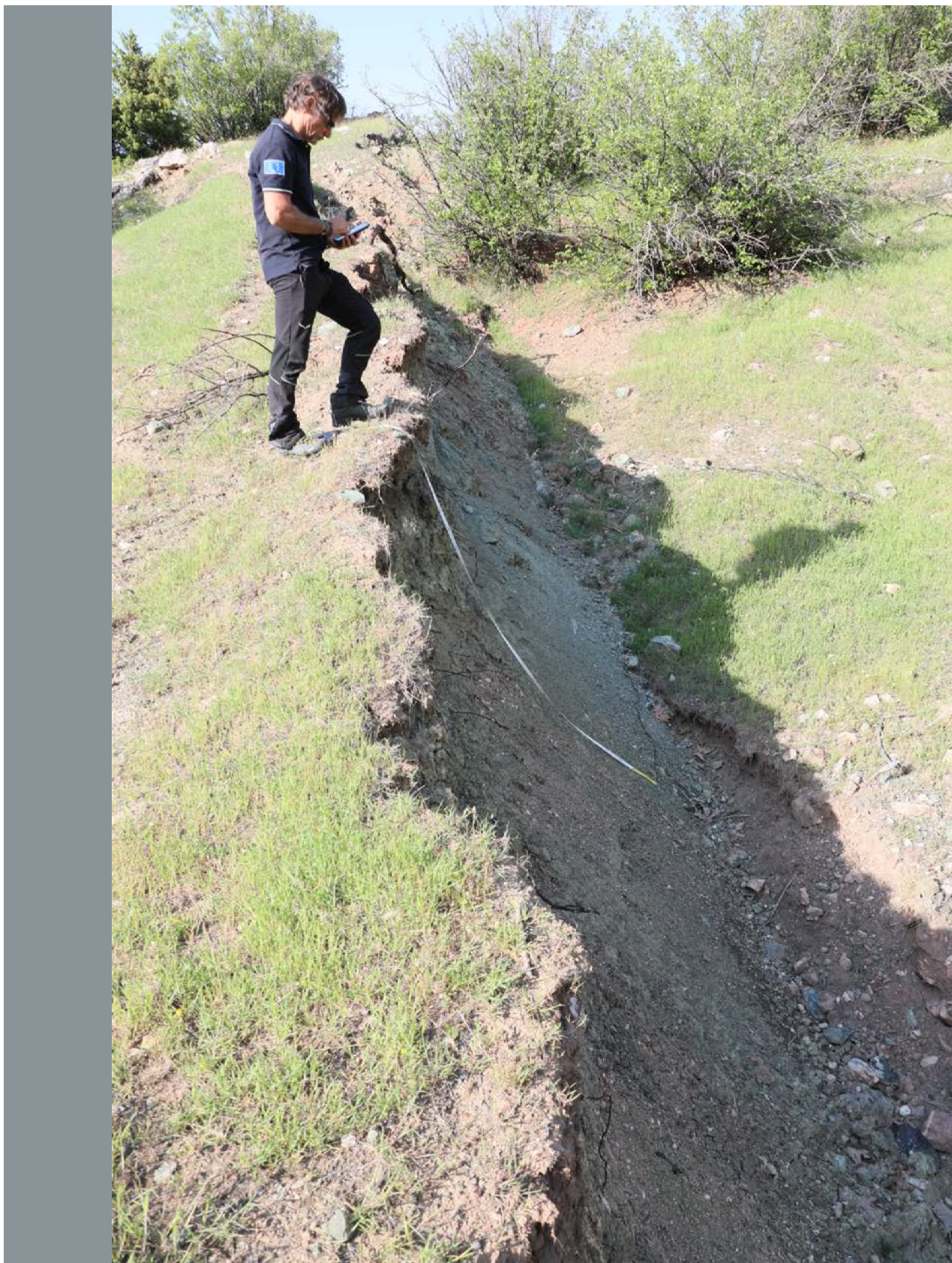


Photo 58 ($37.615554^{\circ}\text{N}$, $37.383393^{\circ}\text{E}$) – Different view of photo 57. The sharp left-lateral offset of 370 cm is responsible for the large apparent vertical offset, with no opening component.



Photo 59 (37.615834°N, 37.383714°E) – View of a coseismic graben due to a pull-apart characterised by a width of 7 m and apparent vertical offset reducing uphill.



Photo 60 (37.615957°N, 37.383808°E) – Drone view (from northeast) of the surface rupture characterized by left-lateral displacement of 300 cm and right-stepping strands.



Photo 61 (37.615917°N, 37.383838°E) – Detail of the mole-track. Alternating decametric transpressional (counterslope dip slip at the back) and transtensional structures (front).



Photo 62 (37.616531°N, 37.384623°E) – Drone view (from northeast). 8.5 m-wide right step of the coseismic surface rupture through en-echelon parallel strands.



Photo 63 (37.616457°N, 37.384436°E) – Particular of the parallel strands (view from northeast) shown in the previous photo. Please note the small-scale arrangement of right-stepping Riedels and left-stepping compressional turf rolls.



Photo 64 (37.616343°N, 37.384361°E) – Detail of a coseismic mole-track (view from northeast) where the right-stepping Riedels present an opening component of 30 cm.



Photo 65 (37.616735°N, 37.385413°E) – Azimuthal drone view of the coseismic rupture. A 370 cm offset of the transtensional Riedel (right) forms a meters-wide graben; conversely, a right bend in the rupture trace produces a mole-track dominated by push-ups (left).



Photo 66 (37.617402°N, 37.386010°E) – Typical extensional-dominated transtension defining a negative flower structure composed of right-stepping en-echelon grabens.



Photo 67 (37.618305°N 37.387104°E) – Panoramic view (NE to SW) of coseismic ruptures (photos 62–66). Note the counterslope downthrowing and along-strike variability, featuring (bottom to top): pure strike-slip Y-shears, push-ups, and en-echelon Riedel shears with tensional grabens. Inset: theoretical rupture typology from infinitesimal plane strain (symbols/sketch in Figure 2); non-observed typologies are opacified.



Photo 68 (37.617806°N, 37.386329°E) – Drone view of the narrow coseismic rupture pattern along a straight Y-shears. Note the left-lateral displacement of the field's border.



Photo 69 (37.617865°N, 37.386536°E) – Locally, the coseismic rupture (view from southwest) is characterised by a simple and narrow clear-cut paralleling the average trend of the displacement zone (Y-shear).

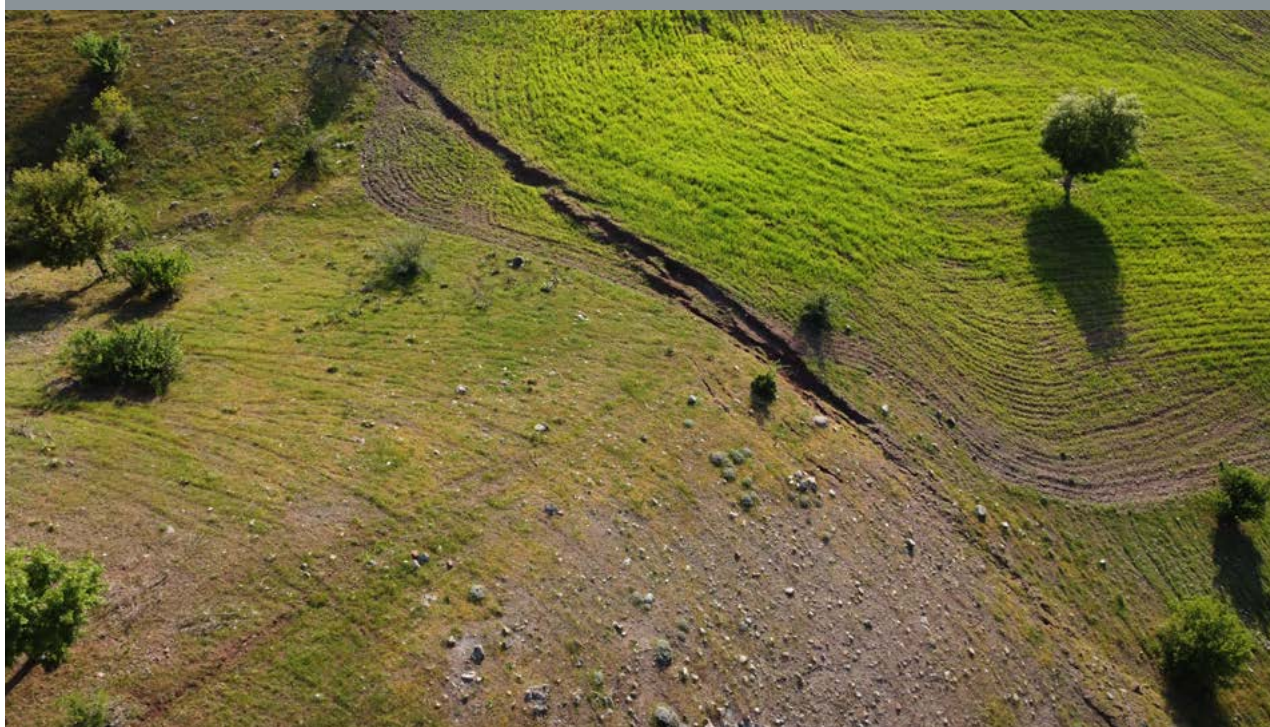


Photo 70 (37.618113°N, 37.387282°E) – Drone view (from east) of the Y-shear. The rupture pattern presents small complexities here characterised by narrow branching into parallel strands enclosing short Riedel shears.



Photo 71 (37.618105°N, 37.386790°E) – Particular of the individual right-stepping en-echelon elements (lower right corner) and view (from southwest) of a right bend of the rupture trace.

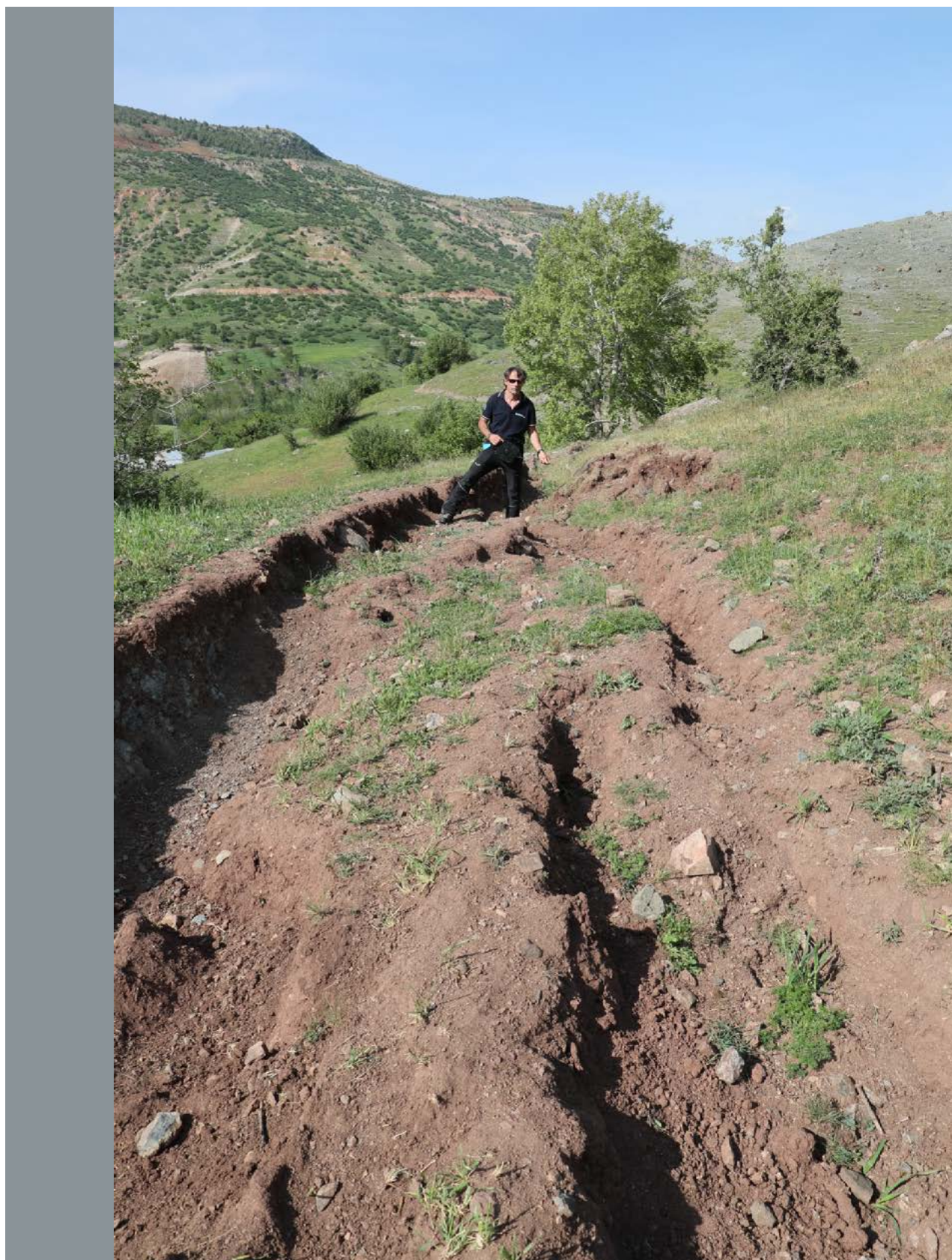


Photo 72 (37.618116°N, 37.386815°E) – Detail of a large gravity-graben (due to loose deposits collapse at the opening transtensional Riedels): ~17 m long, up to 2.3 m wide, with a mean apparent vertical offset of 40 cm.



Photo 73 (37.618230°N, 37.387288°E) – Azimuthal view of the fault trace characterised by dominant en-echelon right-stepping grabens of a left lateral transtensional fault. In the box: a) the theoretical typology of ruptures from infinitesimal plain strain. The ruptures not visible in the photo are made opaque (See Figure 2 for the symbol explanation); b) sketch map of the typology of ruptures.

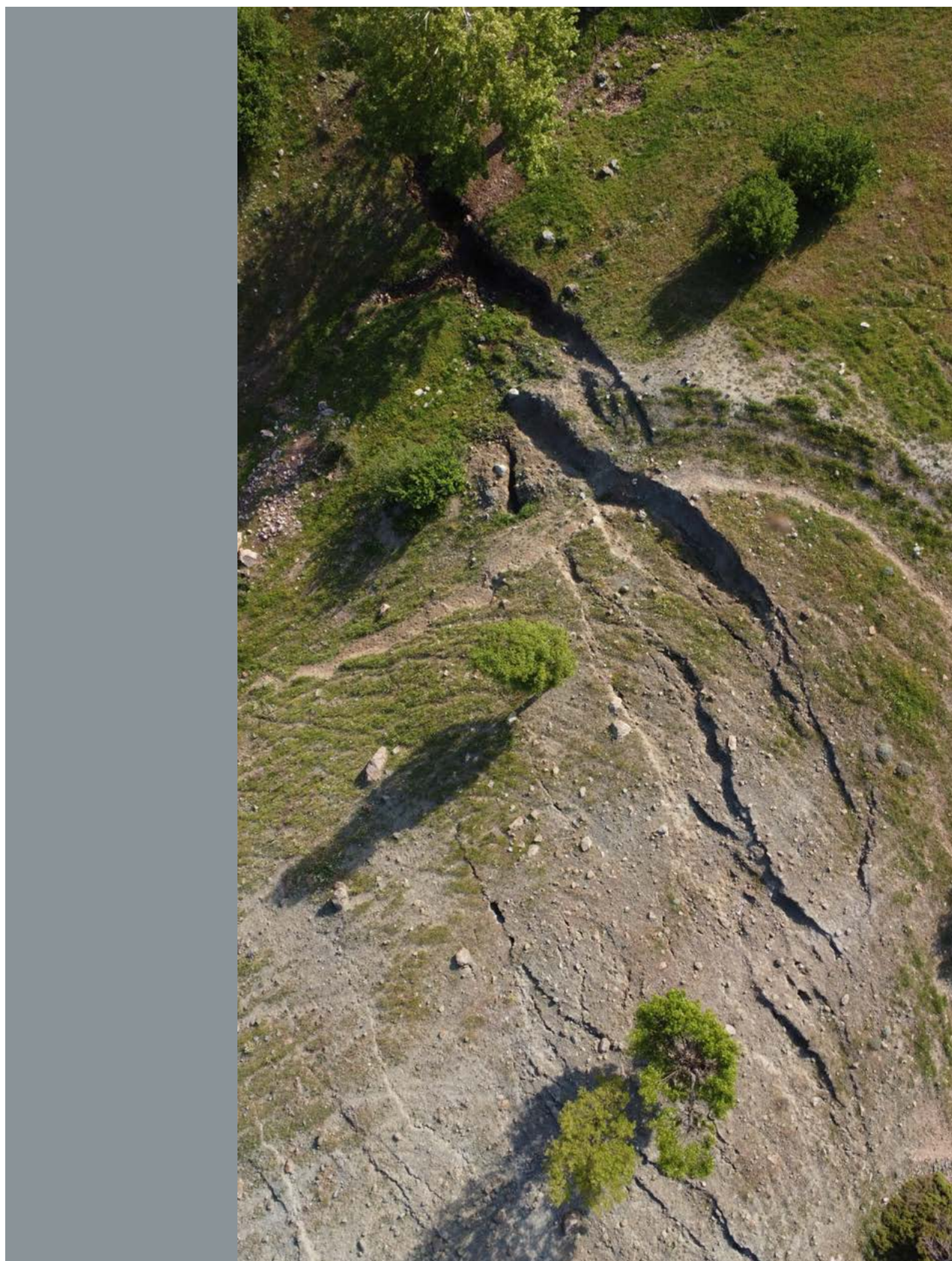


Photo 74 (37.618716°N, 37.387383°E) – Detail of the previous photo: the tree in the left upper corner is shown in the next photo.



Photo 75 (37.618392°N, 37.387276°E) – View (from south) of the site shown in photos 73 and 74. The coseismic rupture offset and dammed the stream thalweg, where the 120 cm apparent vertical offset produced a pond.



Photo 76 (37.618451°N, 37.387307°E) – Close-up of the previous photo. The thalweg cut-off was used as a piercing point to measure a net left-lateral offset of 300 cm, with a true vertical component of 50 cm.



Photo 77 (37.619174°N, 37.387709°E) – Azimuthal view of the coseismic rupture crossing a farm and causing its complete collapse.



Photo 78 (37.620463°N, 37.389613°E) – Drone view (from northeast) of the coseismic rupture.
Note the collapsed farm shown in the previous photo.



Photo 79 (37.619827°N, 37.388798°E) – Detail of the coseismic dislocation shown in the previous photo. At this site, a net left-lateral offset of 320 cm was recorded, the important apparent vertical offset together with the coseismic graben induced a stream piracy, forming a natural pool.



Photo 80 (37.619048°N, 37.385829°E) – Drone view (from SE) of parallel rupture strands (~300 cm left-lateral displacement). The decametric deformation zone comprises a ground flexure (faint thrust component, on the right), a left-lateral strike-slip zone with alternating grabens and push-ups (on the left), and connecting en-echelon right-stepping Riedel shears. The assemblage forms a gentle positive flower structure. Inset: a) theoretical rupture typology from infinitesimal plane strain (non-observed typologies opacified; see Figure 2 for symbols); b) rupture typology sketch map.

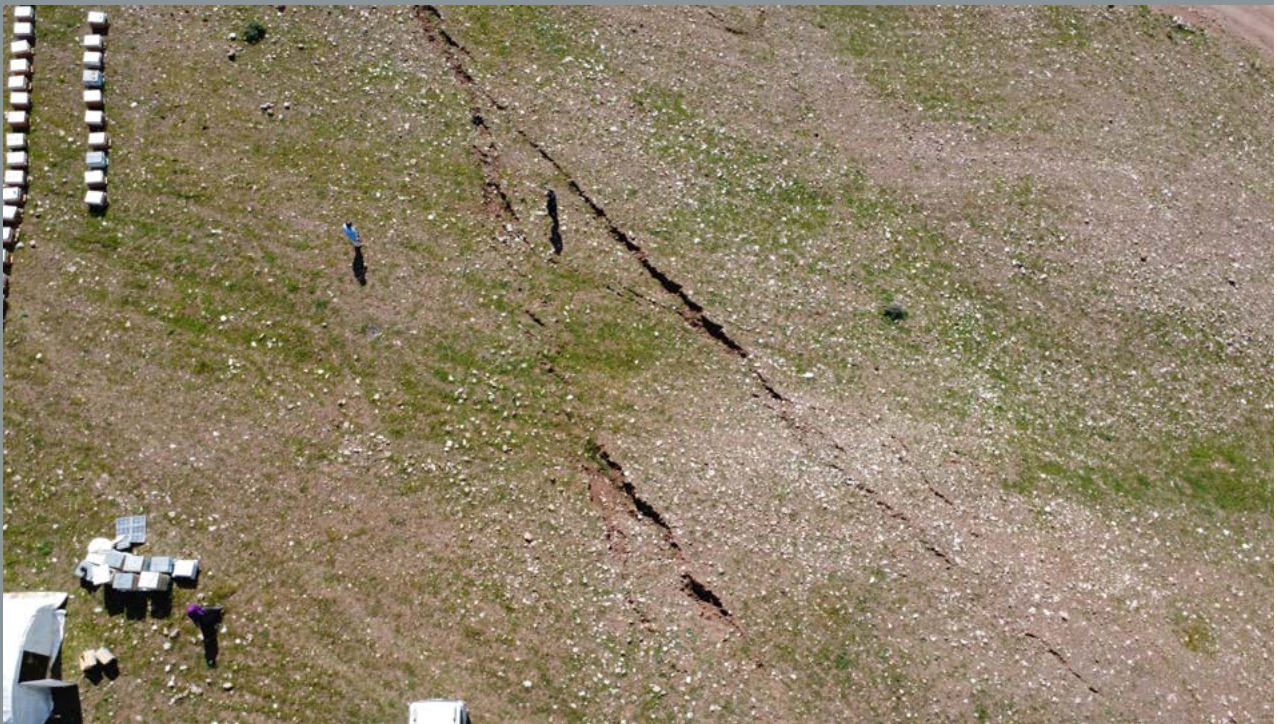


Photo 81 (37.618793°N, 37.385469°E) – Detail (azimuthal view) of the oblique en-echelon right-stepping Riedel shears connecting to the left-lateral strike-slip. Usually, the junctions express increasing features with transtensional character.



Photo 82 (37.618856°N, 37.385382°E) – Particular of the oblique en-echelon Riedel shear in the previous photo.

Balkar

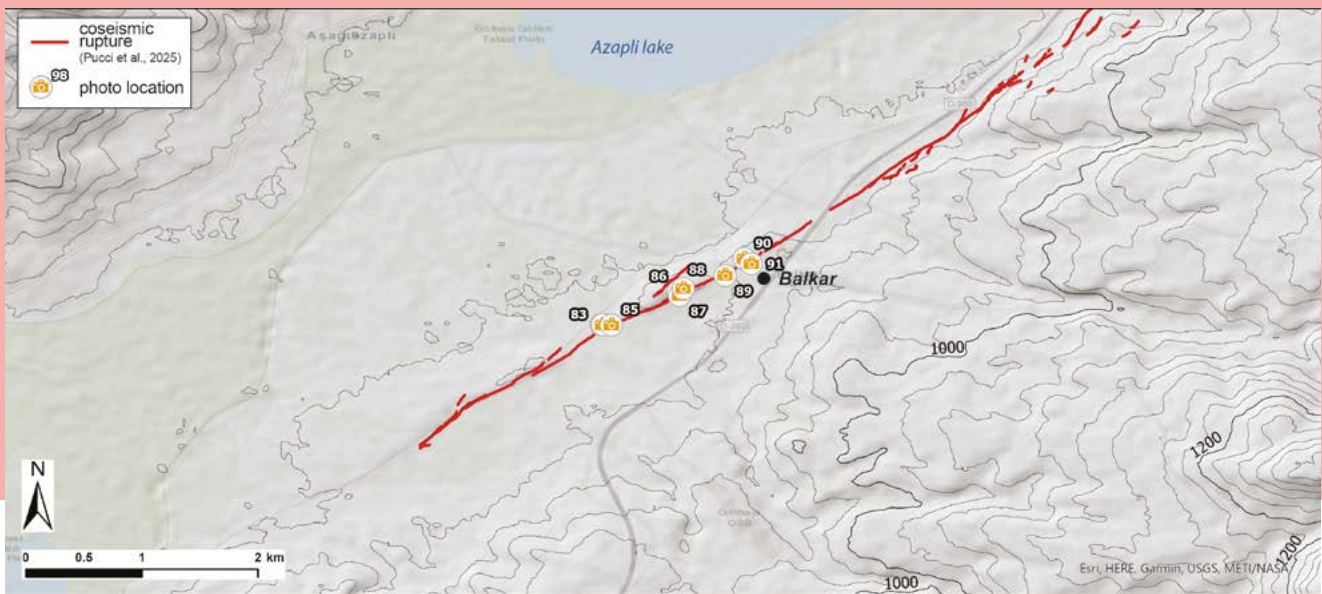


Figure 6 Location map of environmental effects documenting the features of surface faulting near the town of Balkar (Gölbaşı district, Adıyaman province).



Photo 83 (37.726267°N, 37.548959°E) – Panoramic view (from north) of the coseismic mole-track with widespread presence of the push-ups that testify to an increased transpressional kinematics.



Photo 84 (37.726257°N, 37.549059°E) – Detail of the mole-track.
The dominant push-ups are expressed as meters-wide turf rolls.



Photo 85 (37.726239°N, 37.549748°E) – Drystone wall displaced by the coseismic surface rupture (view from south). The left-lateral net slip is 390 cm; note that the offset is accommodated smoothly, with a bend, since the incoherent nature of the man-made feature.



Photo 86 (37.728819°N, 37.554887°E) – Fence dislocated by the left-lateral strike-slip fault (view from northwest).



Photo 87 (37.728526°N, 37.555025°E) – Same fence of the previous photo (view from southeast). Here, the coseismic net left-lateral horizontal slip at the surface is 360 cm, calculated by projecting the fence trend and taking into account the real general strike of the rupture (not orthogonal to the fence).



Photo 88 (37.729071°N, 37.555299°E) – Another parallel fence dislocated by the coseismic surface fault rupture (view from northwest). The left-lateral horizontal slip is 340 cm.



Photo 89 (37.730082°N, 37.558543°E) – Dirty road deformed at the surface by the coseismic fault rupture (view from southeast): here the left-lateral displacement is 400 cm.



Photo 90 (37.731386°N, 37.560029°E) – A road dislocated by the earthquake fault in the village of Balkar (view from northwest): most of the severely damaged buildings appear confined to the near-fault area.



Photo 91 (37.730973°N, 37.560585°E) – The same road as in the previous photo (view from southeast). The left-lateral offset is 360 cm.

Gölbaşı

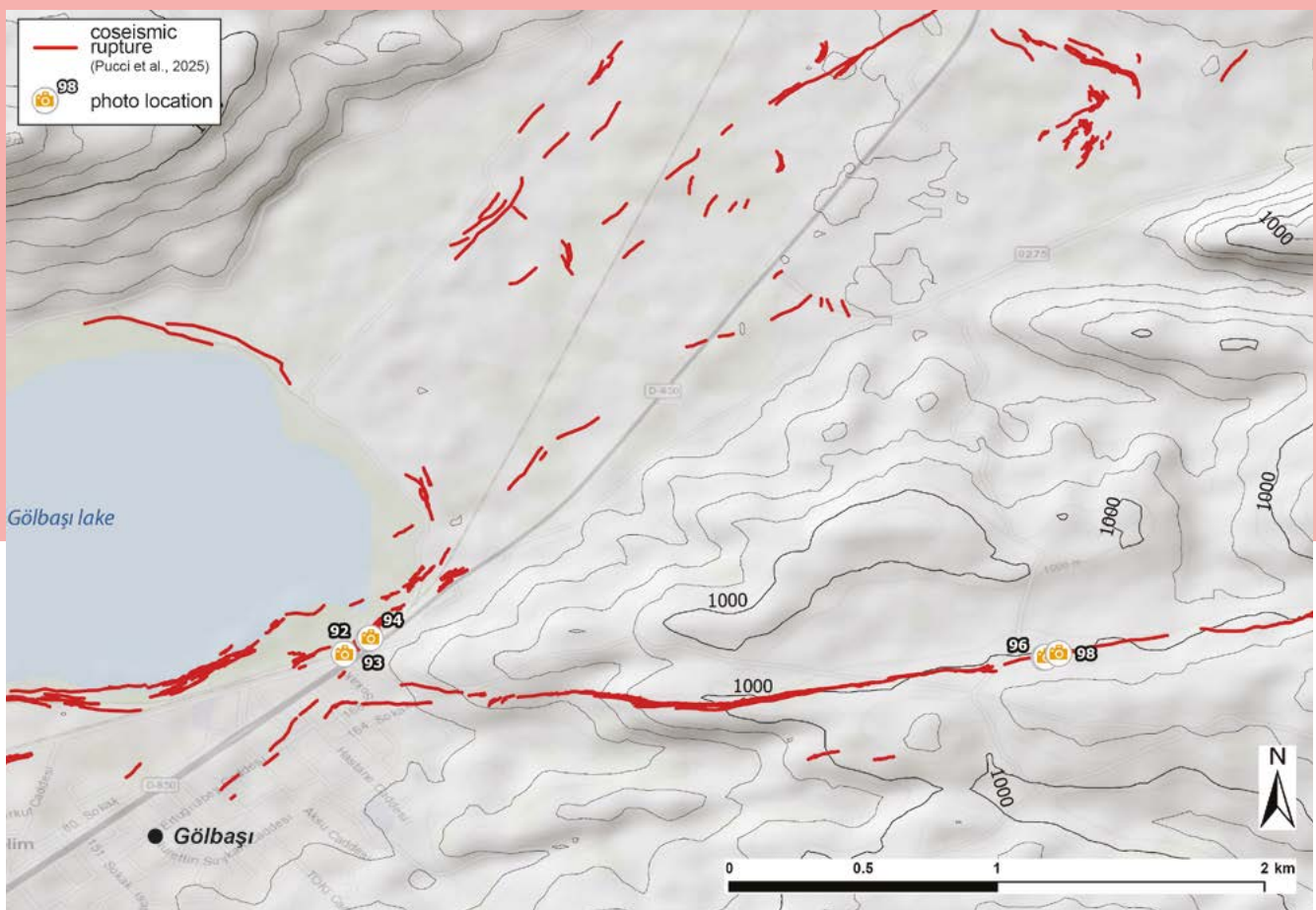


Figure 7 Location map of environmental effects documenting the features of surface faulting near the town of Gölbaşı (Adıyaman province).



Photo 92 (37.795348°N 37.659133°E) – Decametric-scale en-echelon Riedel shears affecting a paved sidewalk in the urban area (view from southwest). The deflected centerline recorded the coseismic kinematics and offset partitioning (note the front Riedel accommodating the vertical component).



Photo 93 (37.795853°N, 37.659954°E) – Railway deformation (NE view). Unlike the direct rupture intersection, this bending lacks lateral embankment or road displacement. Here, the tracks align with the compressional component between two stepping rupture sections; deformation results from plastic shortening transmitted through the rigid steel (see Pucci et al., 2025 for details).



Photo 94 (37.795885°N, 37.660012°E) – Railway deformation in Gölbaşı (view from southwest). In this case the bending was determined directly by the coseismic rupture crosscut (note the railway embankment dislocation).



Photo 95 (37.795370°N, 37.683104°E) – View (from east) of the coseismic rupture showing ~200 cm of left-lateral offset and up to 100 cm of vertical component.



Photo 96 (37.795242°N, 37.682638°E) – Particular of the vertical dislocation component of the rupture shown in the previous photo (view from west).



Photo 97 (37.795257°N, 37.682698°E) – Detail of the previous photo.
The clayey free face stores kinematics indicators (i.e. grooves).



Photo 98 (37.795373°N 37.683116°E) – Locally, the left bend of the rupture trend produced at the surface a significant extensional deformation, expressed by meter-wide grabens along the Riedel shears.

Harmanlı



Figure 8 Location map of environmental effects documenting the features of surface faulting near the Harmanlı village (Gölbaşı district, Adıyaman province).



Photo 99 (37.839273°N, 37.723895°E) – At this site, the coseismic rupture exhibits a relatively smaller displacement at the surface (~160 cm of left-lateral offset, with an average vertical component of 10-30 cm and a maximum opening of 40 cm).



Photo 100 (37.839629°N, 37.724545°E) – The rupture pattern consists of a set of multiple strands, with right-stepping en-echelon arrangement, composing a ~60 m-wide deformation zone, well outside the photo.



Photo 101 (37.840082°N, 37.727873°E) – The coseismic free-face in colluvial deposits shows a significant vertical offset (here ~90 cm) and no opening component. The deposits of free face tend to collapse hindering the transpressional kinematics and producing a false dip direction of the rupture plane.



Photo 102 (37.844537°N, 37.741737°E) – Drone view (from south) of the coseismic rupture at the base of a ridge, representing the long-term expression of the morphotectonic activity of the fault.



Photo 103 (37.844836°N, 37.740426°E) – Detail (view from east) of the previous photo. The coseismic rupture at the surface shows a vertical offset of 160 cm, associated with a local transtensional kinematics.

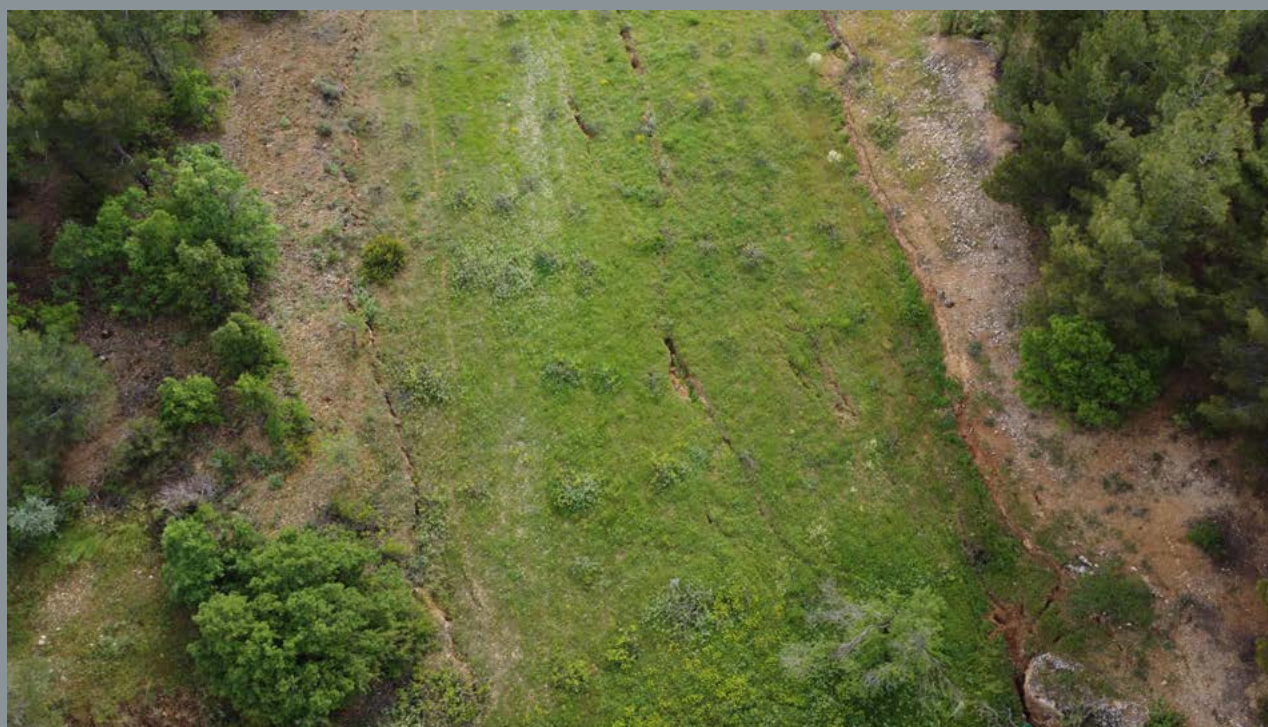


Photo 104 (37.844673°N, 37.740372°E) – Drone view (from northeast) of the same area. Here, the main transtensional rupture (on the right) and its antithetic structure generate a graben crossed by Riedel structures and tensional cracks defining a negative flower structure.



Photo 105 (37.844622°N, 37.739922°E) - Detail (view from west) of the main transtensional coseismic free-face: the average vertical offset is 70 cm.



Photo 106 (37.844488°N, 37.739743°E) – Another drone view (from south) of the main transensional rupture (top) bounding the graben. On the left is visible a free face on the limestones exposed in the footwall. In the box: a) the theoretical typology of ruptures from infinitesimal plain strain. The ruptures not visible in the photo are made opaque (See Figure 2 for the symbol explanation); b) sketch map of the typology of ruptures.



Photo 107 (37.844530°N, 37.739502°E) – Detail of the free face (from east) shown in the previous photo: here the horizontal offset is 240 cm and the apparent vertical offset 120 cm.



Photo 108 (37.844503°N 37.739303°E) – The coseismic rupture (at front) runs inside transversal valley and dislocates the opposite slope in the background (view from east). Note the fault's long-term expressions: the contact of different lithologies and the control on the hanging saddle.



Photo 109 (37.844453°N, 37.737365°E) – Drone view (looking west from the valley axis) of the area shown in photographs 103-107: note the grassy triangle that identifies the graben formed by the negative flower structure.



Photo 110 (37.844465°N, 37.737251°E) – Detail of the coseismic rupture running along the saddle shown in photograph 108: note the left-lateral displacement on the dirt road (offset 230 cm) and the tectonic contact between different lithologies.

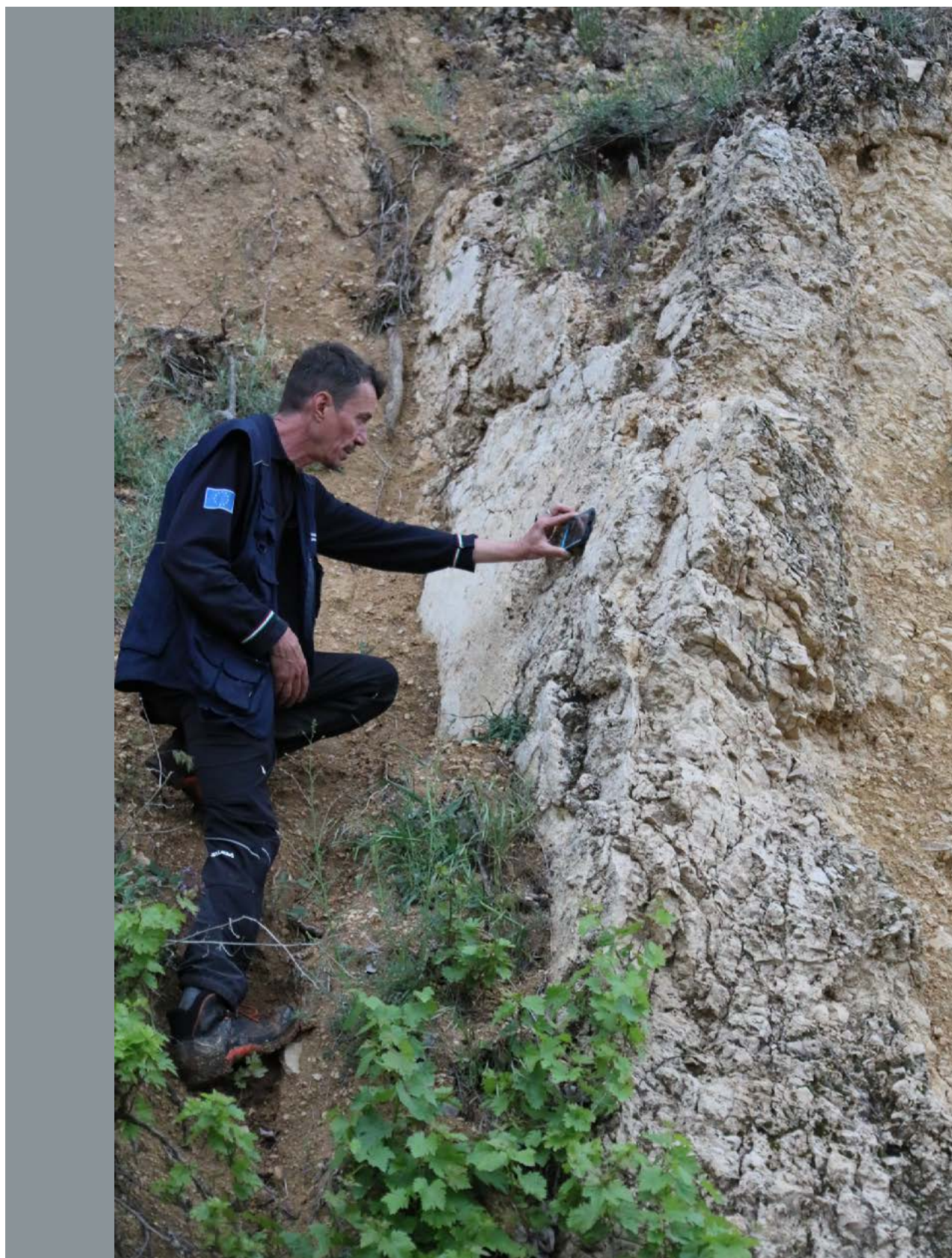


Photo 111 (37.844283°N, 37.736895°E) – Detail of the limestones slickenside affected by coseismic slip (same surface rupture shown in photo 110) and of the contact with the colluvial deposits.



Photo 112 (37.844167°N, 37.736518°E) – The coseismic rupture dislocates a waste landfill: here the left-lateral horizontal offset is 230 cm and the apparent vertical offset 40 cm.

Liquefaction effects

The February 6, 2023, Mw 7.8 Kahramanmaraş earthquake also produced widespread liquefaction phenomena in the areas prone to these secondary coseismic geological effects, typically occurring in fluvial dominated environments like basins, lakes or coastal plains featuring water-saturated infills. Although our field survey was primarily devoted to analysing the coseismic features of the surface faulting along the causative fault, the severity and extent of the liquefaction phenomena encountered in the Gölbaşı district - especially in the eastern sector of the basin along the lake located at the northernmost tip of the investigated area - caught our attention. So we visited the urban area of Gölbaşı, where the liquefaction-induced damage to buildings was particularly severe. Here, in addition to heavy structural damage caused by the ground motion, buildings and other man-made features suffered the shaking effects of a widespread differential ground settlement. Numerous buildings subsided into the ground by at least one-story (approximately 3–4 meters), in some cases while maintaining vertical alignment. Differential settlements caused many structures to tilt significantly, often in a consistent direction, suggesting localised variations in subsoil response. Notably, severely affected buildings were often situated adjacent to others which suffered only shaking-related damage, highlighting the high spatial variability of the liquefaction effects. Differences in design and depth of foundations, as well as variations in local subsurface conditions, likely played a significant role in this contrasting behaviour. In some cases, buildings sank, dragging parked vehicles beneath balcony overhangs; this makes evident the intensity and extent of the liquefaction phenomena in this area. In the following, we report a photo gallery showing a few examples of liquefaction-induced damage effects observed in the town of Gölbaşı.

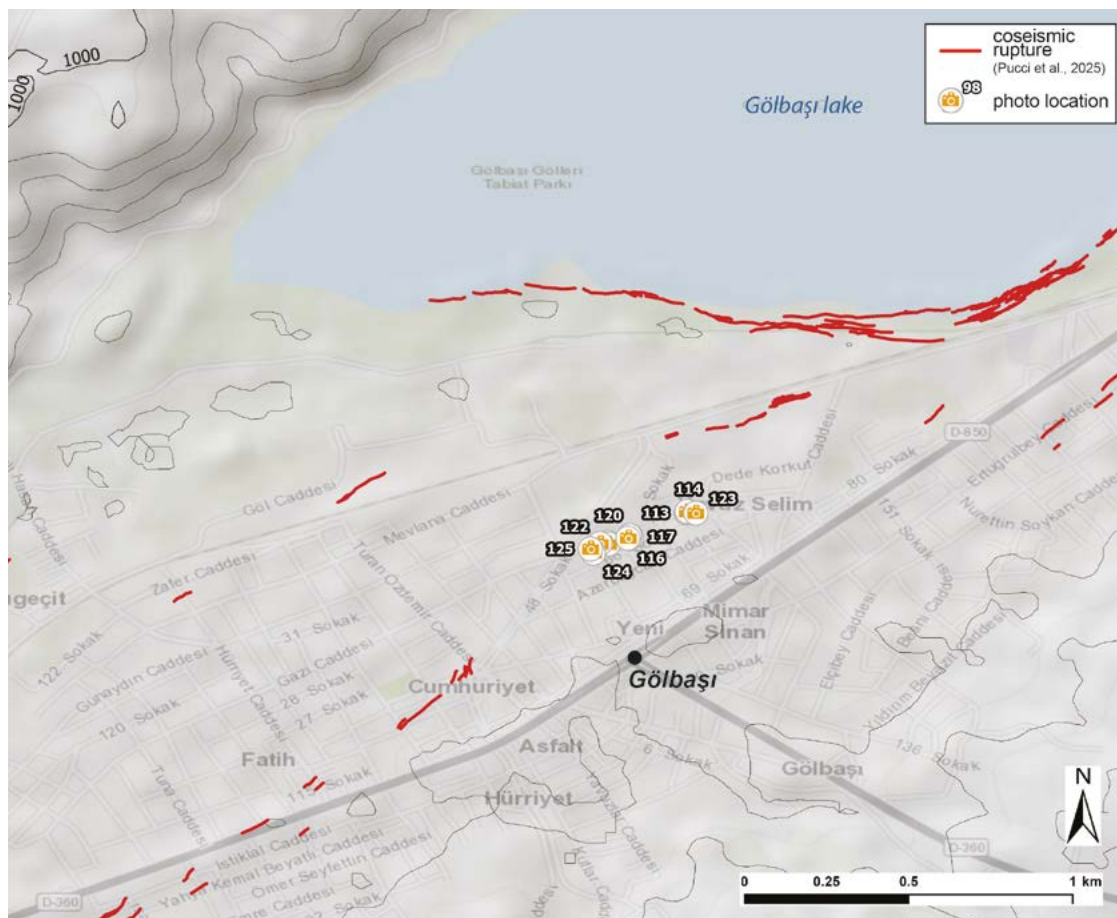


Figure 9 Location map of main liquefaction effects in the town of Gölbaşı.



Photo 113 (37.788744°N, 37.645260°E) – Panoramic view of a street in Gölbaşı: phenomena of soil liquefaction induced differential settlement in numerous edifices, resulting in their tilting and partial sinking.



Photo 114 (37.788786°N, 37.645323°E) – Detail of the previous photo showing the differential settlement caused by liquefaction effects under the structure's load, resulting in severe tilting of the building.



Photo 115 (37.788778°N, 37.645286°E) – Particular of the previous building: apart from the impressive tilt, a detailed inspection revealed structural damage such as cracking of load-bearing elements, floor and wall distortion, and misaligned openings and utilities. The building is obviously unsafe for use and has to be demolished.



Photo 116 (37.788045°N, 37.643711°E) – Panoramic view of a street in Gölbaşı: due to massive soil liquefaction, some buildings sank by one floor (approximately 3–4 meters) into the sand, destroying cars parked beneath balconies or cantilevered extensions



Photo 117 (37.788094°N, 37.643755°E) – Particular of the previous photo: note that the building maintained an apparent verticality.



Photo 118 (37.787945°N, 37.643129°E) – The vertical subsidence of the building by 3–4 meters has almost completely eliminated one floor, bringing the balconies down to the ground level. As a consequence, the cars parked beneath them were dragged down and finally truncated. Note, in the centre, the entrance to the building.



Photo 119 (37.787897°N, 37.643133°E) – Particular of the previous photo; on the left, the entrance to the building.



Photo 120 (37.788119°N, 37.643705°E) – Detail of a car truncated by the balcony's overhang structure.



Photo 121 (37.788056°N, 37.643670°E) – Another view of the building shown in photographs 154-157: in the foreground, the corner balcony, whereas on the right (bottom), the doors previously situated at the ground floor. The vertical subsidence is ca. 3–4 meters.



Photo 122 (37.787901°N, 37.642906°E) – Examples of different liquefaction effects on adjacent edifices: near the building shown in the previous photos, note the white edifice on the right side impressively tilted and wrenched from the foundation. Conversely, the smaller house in the foreground, with only two floors, appears to have suffered no damage, likely due to the lighter load of the building and its shallower foundation.



Photo 123 (37.788739°N, 37.645517°E) – Example of spatially variable soil liquefaction occurring beneath non-uniform structural loads: note the building sank ca. 2 meters into the ground, while the entrance porch and surrounding wall, being much lighter, did not exhibit significant settlement.



Photo 124 (37.787646°N, 37.642723°E) – Panoramic view of a street in Gölbaşı affected by severe and widespread soil liquefaction. All the buildings need to be demolished.



Photo 125 (37.787761°N, 37.642641°E) – Detail of a building affected by sinking and tilting. Note also the impressive non-structural damage to partition walls and plaster cladding pillars.

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