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## Geological map of the San Donato – Costa Thrust Zone, Belluno Thrust System, eastern Southern Alps (northern Italy)

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### ABSTRACT

We present a 1:7500 scale geological map of part of the footwall of the south verging Belluno Thrust of the seismically active eastern Southern Alps of northern Italy. We report a previously unknown thrust zone, the “San Donato-Costa Thrust Zone”, that cuts across the local Meso-Cenozoic stratigraphic succession. 1:2500 and 1:5000 geological mapping, in combination with the revision and improvement of the local lithostratigraphy and detailed structural analysis, provided new insights into the thrust geometry and the setting of the greater area it deforms. We show that the recorded deformation style (e.g. folding vs. faulting) exhibits notable variations within the affected Meso-Cenozoic stratigraphic succession, with shortening accommodated by fold trains and several subparallel thrust splays with variable amounts of stratigraphic offset cumulated during repeated faulting. Our results contribute to a better definition of folding and faulting within the Mesozoic carbonate multilayer system of the eastern Southern Alps.

### ARTICLE HISTORY

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### KEYWORDS

Geological mapping; thrust zone architecture; Meso-Cenozoic stratigraphy of the European Southern Alps; eastern Southern Alps; Belluno Thrust

## 1. Introduction

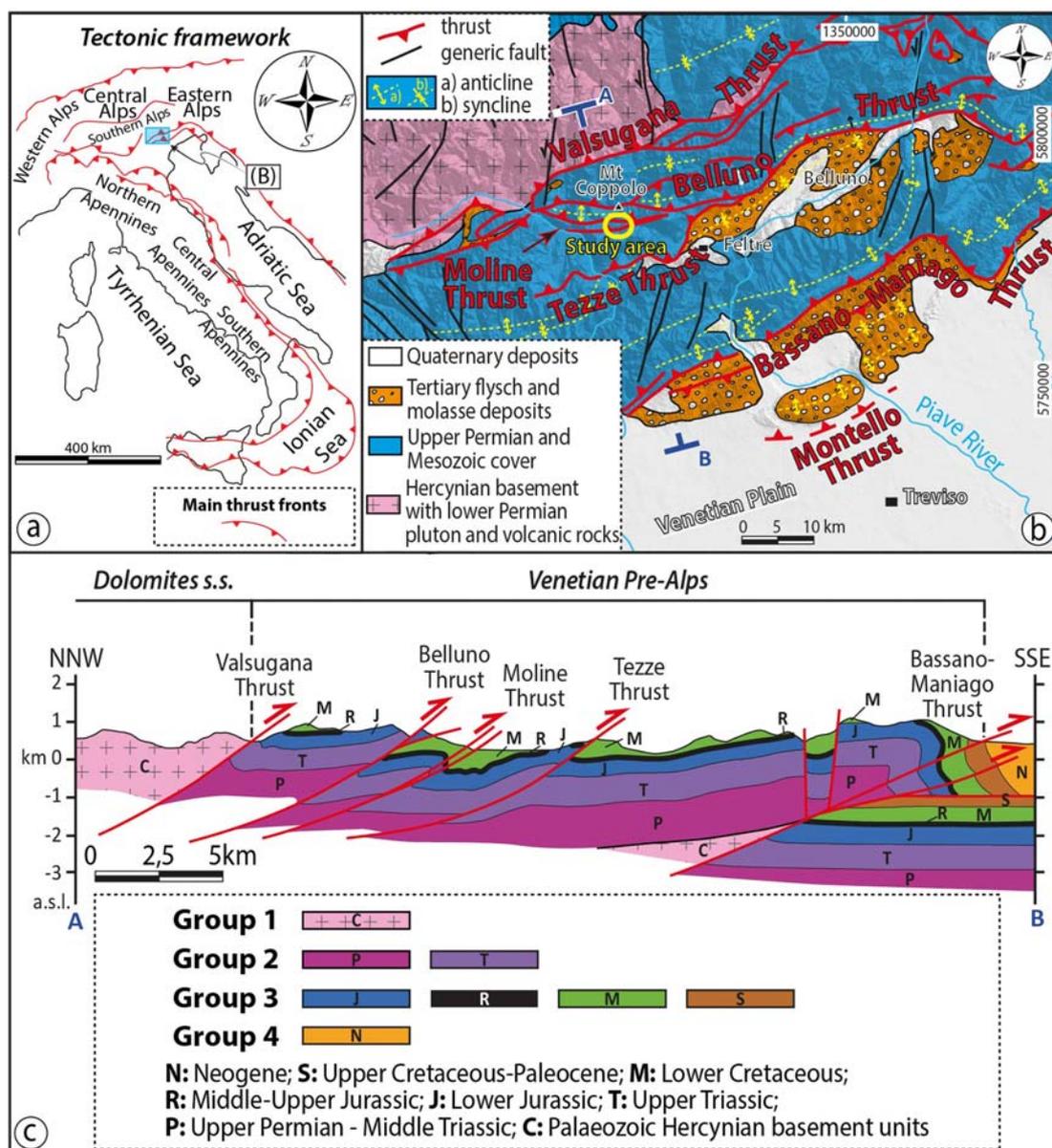
Geological maps are a key element of any scientific and applied geological study by reporting detailed and disparate information and making it readily available to public administrators and scientific communities. In this perspective, our geological mapping effort was conceived and planned to map and characterise the key geological features of an interesting tectonic area of the eastern Southern Alps (hereafter ESA) of northern Italy. The ESA are part of the Neogene south-verging fold-and-thrust belt of the European Alps (Castellarin et al., 2006; Doglioni, 1990; Schmid et al., 2004). They are a seismically active orogen characterised by medium to large magnitude earthquakes ( $M > 6$ ) (e.g. Anderlini et al., 2020; Anselmi et al., 2011; Serpelloni et al., 2016). Despite their seismogenic potential, large areas of the ESA, such as the chosen study area, are surprisingly under-investigated from a cartographic point of view, with the only existing official geological map being the 1:100000 sheet nr. 22 ‘Feltre’ of the ‘Carta Geologica d’Italia’ series (Braga et al., 1971), which dates back to 1971. This consideration, coupled with an ongoing research project aiming at the field characterisation of potentially seismic sources within the stratigraphic succession of this area, led to our geological mapping, specifically aiming at integrating the general geological knowledge of the area with an original and detailed structural characterisation. Our

ultimate goal was to produce a modern cartographic tool to be used as input to further regional, structural, and eventually, seismological studies.

We mapped an area of about 7 km<sup>2</sup> at the 1:2500 and 1:5000 scale close to the village of Lamon in the Belluno Province, shown on the [Main Map](#) at the 1:7500 scale. Our results permitted the definition and formalisation of a new, thus far unreported, kilometric thrust, the San Donato-Costa Thrust Zone (hereafter SCTZ). From a geological perspective, the area and the SCTZ belong to the footwall of the Belluno Thrust ([Figure 1](#)), one of the most frontal and significant thrusts of the ESA. The map, together with detailed outcrop studies, biostratigraphy considerations and facies and structural analysis, remarkably improves the understanding of the evolution of the Belluno Thrust by adding on to the work of [Doglioni and Carminati \(2008\)](#) and [Selli \(1998\)](#). In a broader picture, our work offers a leap into the details of the thrusting deformation affecting the multilayer sedimentary succession of the ESA.

## 2. Geological setting

The ESA are the south-verging retro-belt of the eastern Alpine orogen, mainly formed during Cenozoic convergence between the European and Adria plates ([Doglioni & Carminati, 2008](#)). The ESA are therefore the result of a long and complex geological evolution



**Figure 1.** (a) Schematic tectonic framework of Italy. (b) Geo-structural map of the eastern Southern Alps in the Belluno Thrust area (redrawn and modified after Doglioni, 1990 and Vignaroli et al., 2020). The study area is shown; (c) Geological cross-section of the eastern Southern Alps (redrawn and modified after Selli, 1998; Bosellini et al., 2003; Doglioni & Carminati, 2008). Its trace is shown in (b).

linked to three principal tectonic phases: (i) Permo – Triassic rifting, associated with calcalkaline volcanism, controlled by N-S trending lithospheric lineaments in response to overall E-W stretching (Doglioni, 1987; Schaltegger & Brack, 2007; Winterer & Bosellini, 1981); (ii) renewed Triassic – Jurassic rifting still in response to E-W stretching, forming N-S trending structural highs with intervening deep basins (e.g. Bosellini et al., 1981; Masetti et al., 2012; Picotti & Cobianchi, 2017; Santantonio & Carminati, 2011); (iii) Cenozoic shortening and continental collision between the Adriatic and European plates, characterised by a strong variability of the direction and sense of the principal tectonic transport (e.g. Eocene WSW ‘Dinaric Trend’ – upper Miocene SE ‘Valsugana Trend’) (Carminati et al., 2004; Castellarin et al.,

2006; Castellarin & Cantelli, 2000; Doglioni, 1987; Doglioni & Bosellini, 1987; D’Ambrogio & Doglioni, 2008; Schmid et al., 2004; Viola et al., 2001). The ESA can be divided into two main realms separated by the regional-scale Valsugana Thrust: the Dolomites s.s. to the north and the Venetian Pre-Alps to the south (Figure 1(c)). The study area is located within the Venetian Pre-Alps, which mainly formed during the late Palaeogene and Neogene compressional phase of the Alpine orogeny (Castellarin et al., 2006; D’Alberto et al., 1995).

Structurally, the Venetian Pre-Alps form an E-W-trending fold-and-thrust belt (Figure 1(b) and (c)) with a main tectonic transport towards the south. From north to south, there are six main thrusts shaping this part of the belt: the Valsugana Thrust, the Belluno

Thrust, the Moline Thrust, the Tezze Thrust, the Basano-Maniago Thrust, and the Montello Thrust (Figure 1(b) and (c)), which, in map view, form an anastomosed pattern of structures converging toward the Valsugana Thrust to the west (Figure 1(b)) (Doglioni, 1990, 1992; Doglioni & Carminati, 2008). The age of thrusting generally decreases moving to the south, toward the Venetian Plain (Figure 1(b)) (Castellarin et al., 2006; Doglioni & Carminati, 2008), with the southernmost frontal Montello Thrust interpreted to be seismically active (Anselmi et al., 2011; Benedetti et al., 2000; Carminati et al., 2007). The Cenozoic cumulative total shortening for the ESA has been estimated to c. 30 km (e.g. Castellarin et al., 2006; Castellarin & Cantelli, 2000; Doglioni, 1990).

The mapped area pertains to the footwall of the Belluno Thrust, which is a WSW-ESE-trending c. 20 km long structure (Figure 1(b)) that dips c. 30° to the north (Figure 1(c)). It accommodated a total shortening of c. 6–8 km (D'Ambrogio & Doglioni, 2008; Selli, 1998). Multiple phases of thrust reactivation, with evidence of coseismic rupturing, have recently been inferred on the basis of meso- to microstructural analyses and have been related to the thrust long-lasting propagation history (Vignaroli et al., 2020). The hanging wall of the thrust is characterised by a regional-scale anticline deforming Jurassic and Lower Cretaceous sedimentary units with a sub-vertical forelimb and a c. 20° north-dipping back-limb (Figure 2(b)). The footwall to the Belluno Thrust in the study area is described in detail below.

The stratigraphy of the Venetian Pre-Alps (Figure 1(c)) pertains to the geological framework of the eastern margin of the Trento Plateau, which resulted from the Triassic-Jurassic E-W lithospheric stretching described above (D'Alberto et al., 1995). It is the expression of a polyphasic tectonic evolution and can be subdivided into four groups (Figure 1(c)). The first group is represented by the Palaeozoic Hercynian igneous and metamorphic basement (Figure 1(c)), which is not exposed in the study area. The second group, unconformably resting on the Palaeozoic basement, is represented by a >3 km thick Permo-Triassic succession made of siliciclastic and carbonate-dolomitic sedimentary units, capped by Lower Jurassic shallow water carbonates (Figure 1(c)) (Bosellini et al., 1981; Masetti et al., 1998; Trevisani, 1991). The third group is formed by pelagic sedimentary units, spanning in age from the Lower Jurassic to the Palaeocene (Figure 1(c)), and marking the drowning of the benthic factory of the aforementioned shallow water carbonates. This Lower Jurassic-Palaeocene succession, which is indeed well exposed in the study area, is formed by a cherty succession made of pelagites and hemipelagites (Figure 1(b) and (c)). The uppermost group is represented by lower Eocene to Miocene terrigenous and bioclastic

rocks (Figure 1(b) and (c)) (D'Alberto et al., 1995; Stefani et al., 2007).

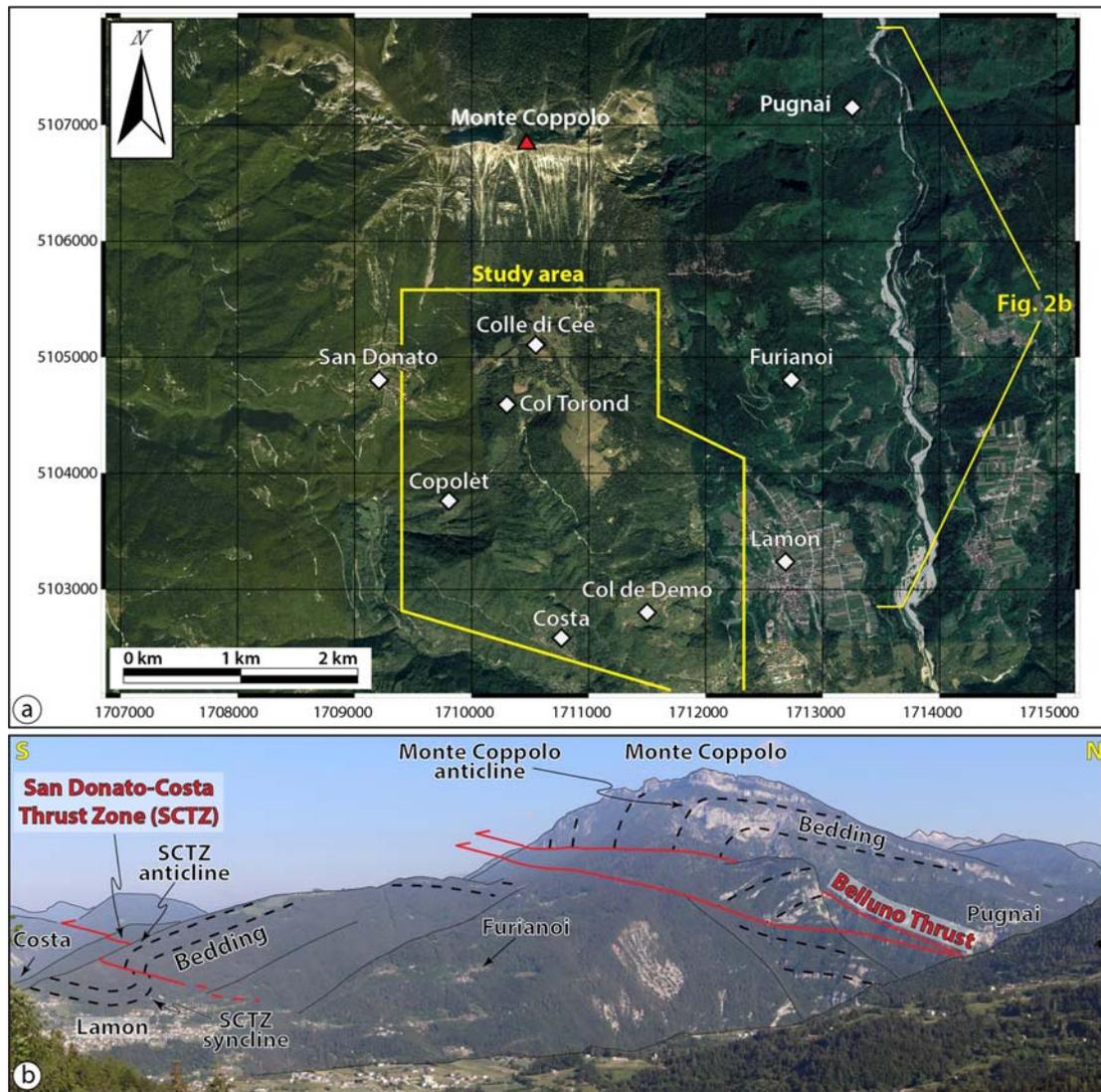
### 3. Methods

Geological mapping was carried out with the 'Carta Tecnica Regionale' (CTR, available online at <https://idt2.regione.veneto.it/idt/downloader/download>) of the Veneto Region as topographic base at the 1:2500 and 1:5000 scales, depending on the necessary detail to elucidate the structural and sedimentological features under study. The spatial reference of the Cartesian grid used for the georeferentiation of the map is based on the metric system 'Monte Mario /Italy Zone 1', EPSG: 3003.

Geological mapping was specifically aimed at the understanding of the structural and stratigraphic framework of the study area based on: (i) the definition of the local stratigraphy and stratigraphic relationships (lateral thickness and facies variations), by either following the lithological contacts in the field or crossing them along N-S transects at high angle to the strike of the SCTZ; (ii) the mapping of main structural elements, analysed and classified in terms of their spatial distribution, orientation, geometry and kinematics.

Furthermore, field analysis and the biostratigraphic characterisation of representative samples focused on the classification of the planktonic fauna, aiming to define: (i) the polarity (normal or overturned) of the investigated succession affected by deformation; (ii) the actual stratigraphic unit; (iii) the stratigraphic throw along the main mapped faults. The stratigraphic and structural field study was accompanied by the collection of thirty hand specimens, representative of the main sedimentary units, that were analysed in thin section at the optical microscope to define the specific palaeontological content. The Dunham (1962) classification for carbonate rocks was used for microfacies classification.

As to the stratigraphy, in this work the Upper Cretaceous interval is described by introducing a more detailed differentiation compared to what is reported by Braga et al. (1971). In detail, according to the recent literature from surrounding areas (Barbieri & Grandesso, 2007; Costa et al., 1979; Picotti, 2003; Zanferrari et al., 2013), the 'Scaglia Variegata Alpina Fm' (VAA) was chosen for the portion of the succession sandwiched between the Maiolica Fm below and the Scaglia Rossa Fm above. The VAA can be easily identified in the field by lithofacies analysis, it being characterised by a remarkable and significant increase of the marly and clayey component compared to the overlying and underlying units. Additionally, the VAA was subdivided into two lithofacies, the 'Marne a Fucoidi lithofacies' (VAA1) and the 'Scaglia Bianca lithofacies' (VAA2), borrowing the



**Figure 2.** (a) Orthophoto of the study area (Google Satellite, 'QuickMapServices' for Qgis 3.8). The location of the panoramic view of Figure 2(b) is shown. The Cartesian grid and coordinates are based on the metric system 'Monte Mario/Italy Zone 1'; (b) panoramic view of the study area, with the SCTZ in the immediate footwall of the Belluno Thrust. The main villages and localities are shown.

formational names from the nomenclature of the Central Apennines stratigraphy (e.g. Cipriani & Bottini, 2019; Coccioni et al., 1987; Petti & Falorni, 2007a, 2007b). This was made possible by the stark sedimentological and biostratigraphical differences that are easily recognised in the field and at the microscope. The choice to use a higher stratigraphic resolution reflects the need to better constrain the throw of the investigated faults and the geometries of the analysed structures.

To define and characterise the structural evolution of the area, eleven structural stations were carefully studied, and c. 600 readings of key structural elements were collected therefrom. The six most representative cases are shown on the Main Map. Structural readings were collected to define and characterise the orientation and geometry of mesoscopic stratigraphic and structural features and the direction and sense of

tectonic transport accommodated along the mapped splays of the SCTZ. We collected data of planar (bedding, slip surfaces, fault planes, S-C fabric, axial planes) and linear (slickenlines, fold axes) structures. Slickenline and slickenside orientations were measured to determine the direction and sense of tectonic transport of the SCTZ. Fold axes and axial planes, integrated with the description of the fold geometry, were also systematically collected to complete our structural database.

All planar data were recorded according to the dip direction/dip angle convention, whereas linear measurements according to the trend/plunge convention. Data were processed, plotted, and analysed using the *Stereonet* software (version 11.0.7). To optimise data visualisation, poles to planes were computed and contoured by Bingham analysis (Fisher et al., 1987). The tangent lineation plot (Twiss et al., 1991;

Wallace, 1951) of slickenlines on poles to fault planes was used to constrain the sense of movement of the footwall blocks.

## 4. Data and results

### 4.1. The study area

The study area belongs to the southern foothills of the Monte Coppolo (2069 m a.s.l.) (Figures 1(b) and 2). The local topography is characterised by a steep relief that commonly exceeds 1000 m of altitude a.s.l. (Figure 2). The area is located between the village of Lamon and locality Costa in the southeast, and the San Donato village in the northwest (Figure 2(a), 'Regional Structural Setting' panel in Main Map). It is located within the immediate footwall of the Belluno Thrust, which is well exposed along the dirt road connecting the Furiano and Pugnai localities (Figure 2), where the Upper Triassic-Lower Jurassic core of the Monte Coppolo anticline is exposed (Figure 2(b)).

### 4.2. Lithostratigraphy

In the following section, we describe the stratigraphic succession cropping out in the study area, providing specific information on the sedimentological and stratigraphic features that are useful to recognise the units in the field.

**Rosso Ammonitico Veronese Fm** (upper Tithonian *p.p.* – Bajocian *p.p.*). The unit is generally subdivided into three members (Barbieri & Grandesso, 2007) but only the uppermost crops out in the study area. As a whole, the unit is composed of white to reddish, well bedded to massive limestone and marly limestone, at times exhibiting a nodular structure. The member outcropping in the mapped area consists of massive to well bedded, nodular, reddish, red and grey limestone (Figure 3(b)). Nodules and lists of red and orange chert locally occur, associated with millimetre to centimetric marly laminated beds. The palaeontological content is dominated by *Saccocoma* sp., radiolarians, ammonites and aptychi. The texture is that of a wackestone-packstone. The disappearance of *Saccocoma* sp. and the increase of calcareous content mark the transition to the overlying formation. The outcropping thickness is about 20 m.

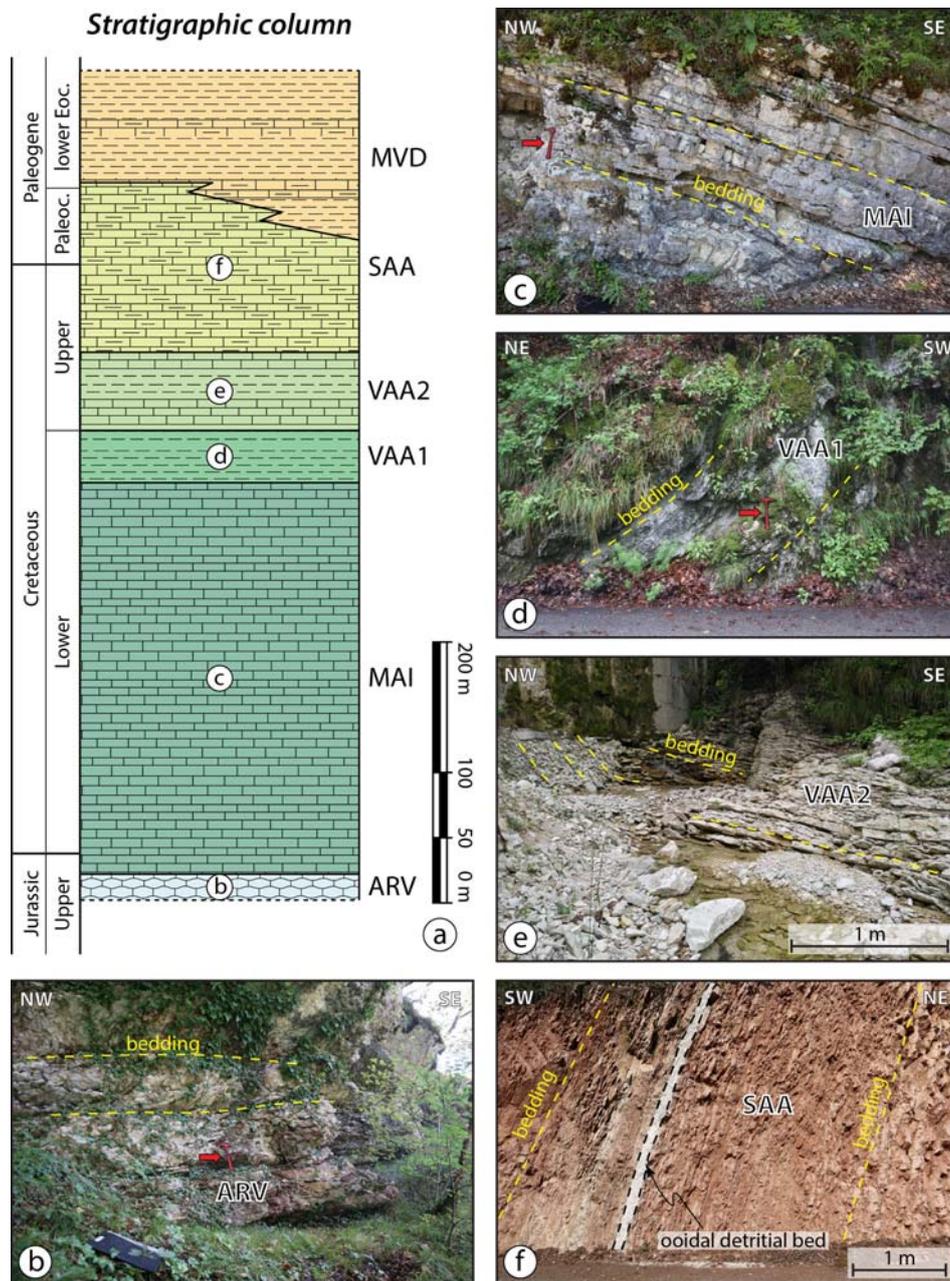
**Maiolica Fm** (lower Aptian – upper Tithonian *p.p.*). This unit is formed by well bedded to massive, (Figure 3(c)) white to grey mudstone. Black, grey, and locally dark-red chert occurs extensively. To the top, the chert content decreases concomitant with an increase of marly layers, typically black in colour. Calpionellids, radiolarians (in the lower part of the unit, Figure 4(a)), aptychi and rare ammonites represent the palaeontological content. Locally, the stratification is interrupted by massive bodies of shallow water

carbonate material. The texture is that of a mudstone – wackestone (Figure 4(a)). The passage to the overlying unit is marked by a strong increase of the marly content. The thickness is more than 300 m.

**Scaglia Variegata Alpina Fm** (lower Turonian *p.p.* – lower Aptian). The unit consists of well bedded limestone, marly limestone and marl (Figure 3(d) and (e)). The total thickness varies from 60 to 100 m. The unit is subdivided into two lithofacies:

- VAA1 – marly lithofacies (upper Albian – lower Aptian). It is formed by thinly bedded polychrome marly limestone, marl and shale (Figure 3(d)). An up to 1m thick black shale horizon, representing the Ocean Anoxic Event (OAE) 1a 'Selli Level' (e.g. Coccioni et al., 1987; Erba, 2004; Erba et al., 1999) occurs close to the base of the informal member. Locally, centimetric beds made of shallow water carbonate material occur. Planktonic foraminifers (*Hedbergella* s.p., *Talmanninella* s.p., *Ticinella* s.p.) and radiolarians occur (Figure 4(b)). The thickness varies between 20 and 40 m.
- VAA2 – calcareous lithofacies (lower Turonian *p.p.* – upper Albian). It is formed by well bedded, white to grey limestone and marly limestone (Figure 3(e)), bearing dark chert nodules and lists, with subordinated centimetric marly beds. A 40–60 cm thick bed of black shale, representing the OAE2 'Bonarelli Level' (e.g. Coccioni & Luciani, 2005; Premoli Silva et al., 1999) occurs toward the top of the member. Planktonic foraminifers (*Rotalipora cushmani*, *Rotalipora ticinensis*, *Planomalina buxtorfi*) and radiolarians (Figure 4(d)) are common throughout. The texture is that of a mudstone – wackestone (Figure 4(d)). The thickness varies between 40 and 60 m.

**Scaglia Rossa Fm** (lower Eocene *p.p.* – lower Turonian *p.p.*) The unit is represented by well bedded and laminated reddish to red limestone and marly limestone (Figure 4(f)), including red to orange chert nodules and lists. The unit lower contact is transitional and marked by a significant increase of the calcareous content, whereas the upper contact is transitional, heteropic and marked by a significant increase of the clay content. Locally, centimetre to decimetre thick laminated and ooidal resedimented beds occur (Figure 3(f)). The unit contains planktonic foraminifers (*Globotruncana lapparenti*, *Marginotruncana coronata*, *Globotruncana stuarti*, *Rosita contusa*, *Morozovella velascoensis*) and rare ammonites (Figure 4(d)–(f)). The texture changes from that of a mudstone, to wackestone and to packstone (Figure 4(d)–(f)). The thickness varies between 120 and 180 m.



**Figure 3.** Stratigraphy of the investigated area. (a) Schematic stratigraphic column of the mapped succession; (b) top nodular and cherty lithofacies of the Rosso Ammonitico Veronese Fm (ARV); (c) calcareous and cherty lithofacies of the Maiolica Fm (MAI); (d) marly lithofacies of the Scaglia Variegata Alpina Fm (VAA1); (e) calcareous and cherty lithofacies of the Scaglia Variegata Alpina Fm (VAA2); (f) calcareous portion of the Scaglia Rossa Fm (SAA). Hummer for scale (in red) in (b), (c) and (d).

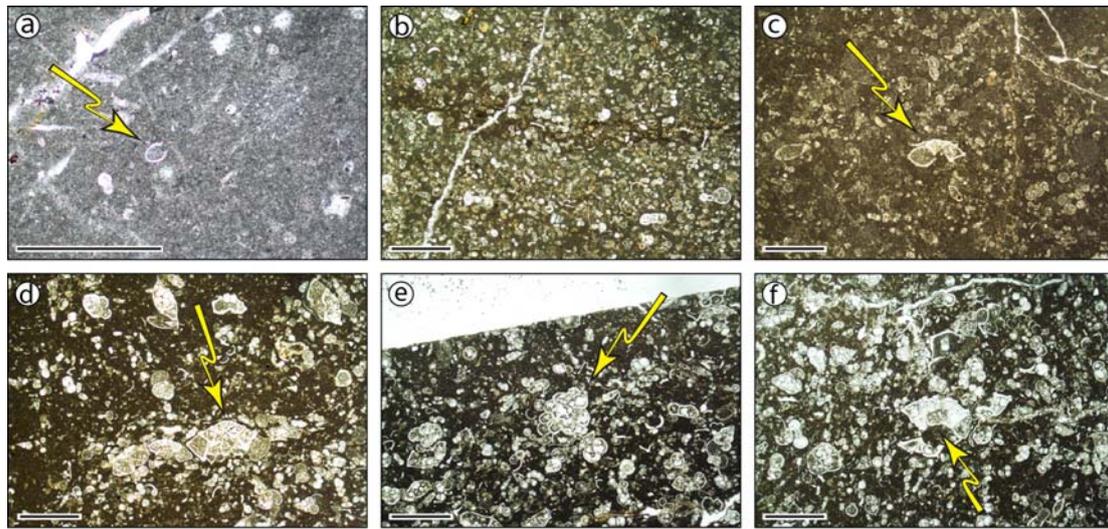
**Marna della Vena D'Oro** (lower Eocene *p.p.* – upper Palaeocene). This unit is the youngest formation outcropping in the area. It is defined by polychrome, thinly bedded, foliated and laminated marl. The unit crops out poorly, only allowing for a few analyses and considerations. The texture, for the most calcareous portion, is that of a mudstone – wackestone. The fossil content is given by benthic and planktonic foraminifers (Morozovelloids). The outcropping thickness is of c. 130 m.

**Quaternary deposits** (Pleistocene – recent). This group includes:

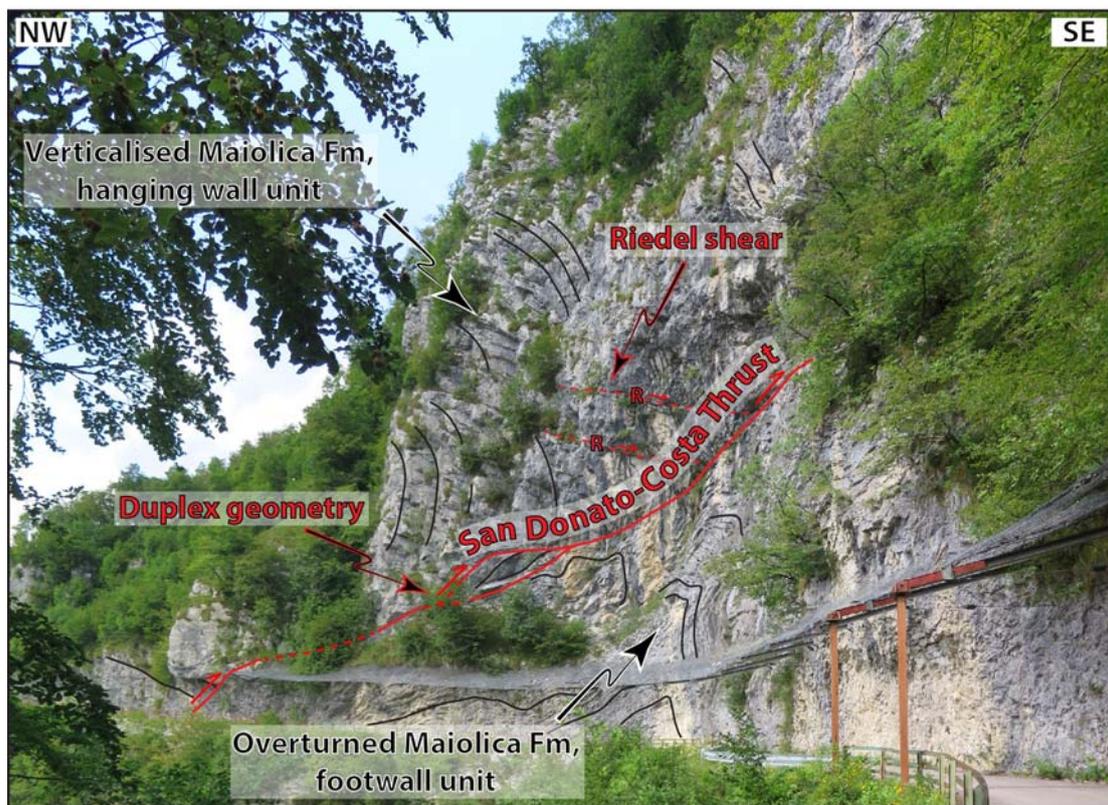
- Heterometric and weakly cemented talus deposits within red, sandy-clayey matrix.
- Eluvio-colluvial deposits, formed by unconsolidated evolved red soil, characterising the topographically higher zones.

#### 4.3. Structural setting

The San Donato-Costa Thrust dominates the entire E-W areal extension of the map (Figure 5) and represents the most important structural feature of the study area. It is a moderately N-dipping thrust zone



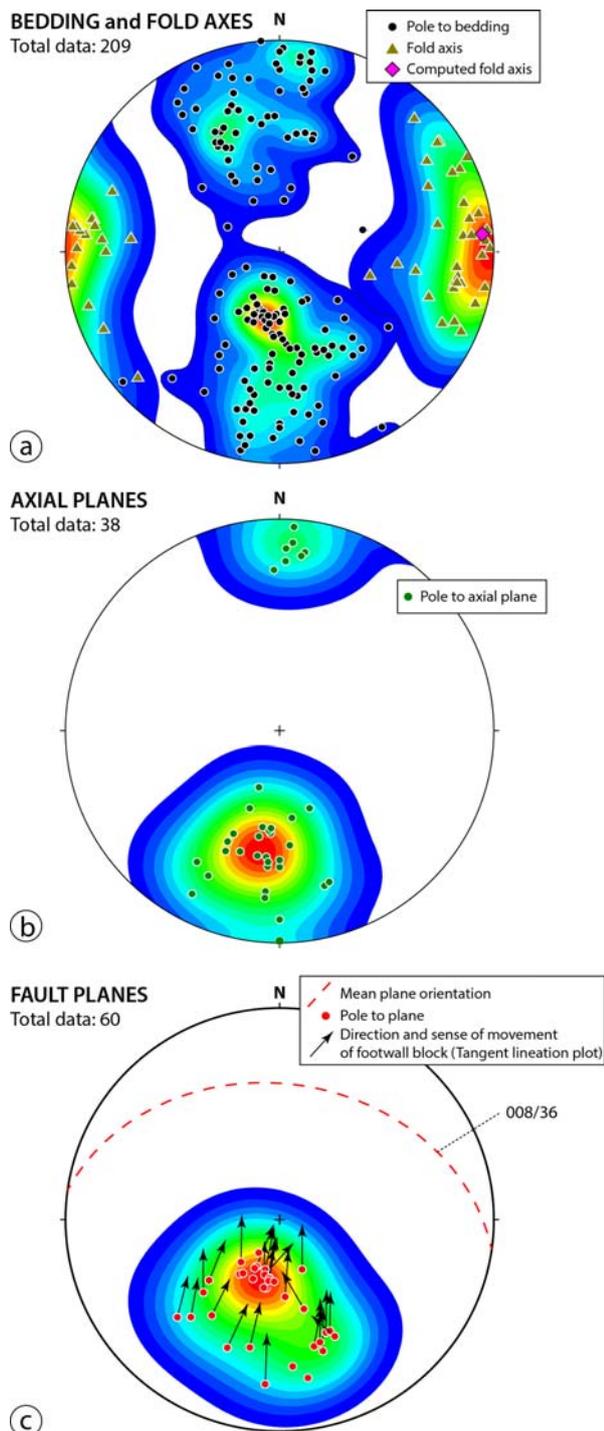
**Figure 4.** Microphotographs of lithofacies with information about biostratigraphy: (a) calpionellids (*Calpionella alpina*) rich mudstone associated with radiolarians (Maiolica Fm.); (b) bioclastic packstone with planktonic foraminifers (*Hedbergella* sp., *Ticinella* sp.) (Scaglia Variegata Alpina Fm; VAA1 lithofacies); (c) bioclastic wackestone with planktonic foraminifers (*Rotalipora ticinensis*) and radiolarians (Scaglia Variegata Alpina Fm; VAA2 lithofacies); (d–f) bioclastic wackestone and packstone with planktonic foraminifers representative of the entire Scaglia Rossa Fm (Campanian – Maastrichtian *Globotruncana stuarti* (d), Maastrichtian *Ventilabrella* sp. (e), uppermost Paleocene – lower Eocene *Morozovella* aff. *velascoensis* (f)). The scale bar corresponds to 500 µm for all microphotographs. Examples of the described taxa in each sample are indicated by yellow arrows.



**Figure 5.** Panoramic view of the San Donato-Costa Thrust along the Via Crosere Molin Pian (Lamon, Belluno Province) in the Copolét locality (Main Map).

striking ~ E-W (Main Map, Geological Cross section A–B, C–D, Figure 5). The SCTZ exhibits a complex internal architecture that changes along the strike. Whereas the thrust is characterised by a single main fault surface in the eastern portion of the study area,

to the west the thrust splays into an imbricate fan formed by several N-dipping, subparallel fault planes (Geological cross section A–B, Structural station 2, 3). The hanging wall succession of the SCTZ is folded by a major anticline (Figure 2(b), geological cross



**Figure 6.** Stereographic projections (Schmidt net, lower hemisphere) of the measured structural elements. (a) Contour of poles to bedding, fold axes and computed fold axis ('Bingham Analysis' on pole to bedding); (b) contour of pole to axial planes (green circles); (c) contour of poles to fault planes detected in the study area. The *tangent lineation plot* displays the direction and sense of movement of the footwall blocks of the plot (c).

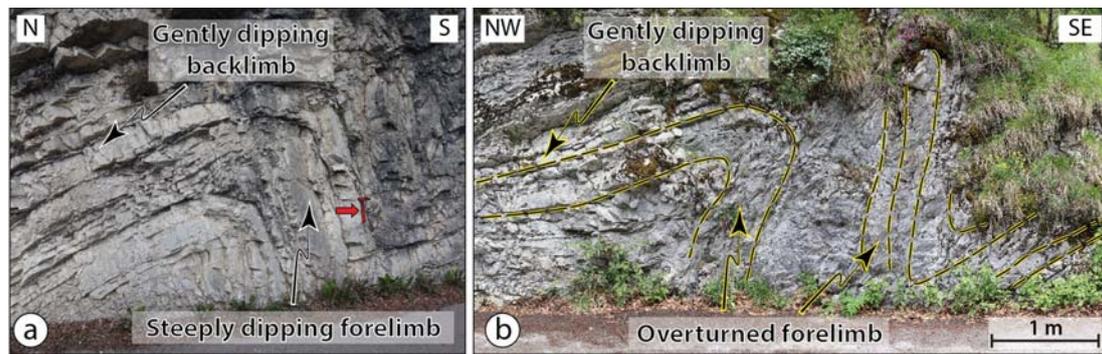
section A–B and C–D), which is characterised by a c. E–W trending axis, a gently N-dipping backlimb and a steep to subvertical locally overturned S-dipping forelimb (geological cross section A–B, Figure 7). To the east, this anticline passes to an open geometry. A lesser order anticline is associated with a NW–SE

striking thrust splay in the northern part of the map (Geological cross section CD 'Col Torond locality', structural station 5). The hanging wall succession is also cut by thrust-related structures, such as mesoscopic reverse faults with metric displacements, m spaced synthetic shear features (Riedel shears) and south verging duplexes (geological cross section A–B, structural station 1, 4, Figure 5).

The footwall succession is characterised by a large, overturned E–W syncline that progressively opens toward the east, where its core, made of MVD rocks, crops out (Geological cross sections A–B, C–D). The footwall syncline is generally defined by a steep N-dipping overturned limb toward the SCTZ and by a normal, gently N-dipping limb in the southern part of the map (Geological cross sections A–B, C–D). Moving to the east from the tectonic contact at Copolét (Figure 2 (a), Main Map), the succession tends to become overturned. Folding within the footwall succession also increases moving toward the SCTZ (Figure 5). Fold wavelength, which is generally short in the western sector of the footwall (up to 1–2 m; structural stations 2, 3, 4), tends to become longer toward the east, where folds are characterised by gently dipping limbs and by steeply dipping axial planes within the normal succession (Geological cross section C–D, 'Col de Demo' locality, Figure 2(b)).

The total stratigraphic throw estimated for the SCTZ is c. 60 m in the eastern sector of the Map (Geological cross section C–D), but it increases to several hundreds of metres in the western sector of the map, moving toward the most deformed portion of the succession.

We used mesostructural observations (attitude of bedding and orientation of folds and faults) to constrain the structural framework of the SCTZ. The bedding orientation defines two main clusters, dipping north and south (Figure 6(a)). Some N-dipping measurements refer to overturned beds that define the stratigraphic framework in the southern portion of the map, along the foothills of Colle Costion and to the north of Col de Demo (Main Map, Geological cross sections A–B, C–D, Figure 2(b)). The normal polarity bedding characterises the hanging wall of the SCTZ, at higher altitudes. Fold axes define one main, subhorizontal to gently E- and W-plunging cluster, (Figure 6(a)) which is consistent with the fold axis computed from the folded bedding (red diamond on pole to bedding in stereonet of Figure 6(a)) and with the axis of the already described SCTZ hanging wall anticline and footwall syncline. Two further minor data maxima can be also seen, oriented N70° and N110°, plunging at an angle generally between 5° and 20° (Figure 6(a), Structural stations on Main Map). The contouring of 38 poles to axial planes is shown in Figure 6(b); it highlights N- and S-dipping axial surfaces (Figure 6(b)). Most plotted axial planes



**Figure 7.** Asymmetric folds within the Maiolica Fm along the Via Crosere Molin Pian (Lamon, BL), at the footwall of the SCTZ. (a) asymmetric and south-verging fold with a high-dipping forelimb; (b) asymmetric and south-verging fold with vertical-to-overturned forelimb. Hammer (in red) and bar for scale in (a).

are associated with highly asymmetric folds, containing steeply ( $70^{\circ}$ – $80^{\circ}$ ) S-dipping forelimbs (Figure 7(a)), or even N-dipping overturned forelimbs (Figure 7(b)), and gently N dipping backlimbs (Figure 7(a) and (b)). Axial plane and fold axis orientations, when interpreted in combination with the vergence of the corresponding folds, are consistent with the regional top-to-the SSW tectonic transport within area, as shown by the measured fault planes and their kinematics (Figure 6(c)). Discrete fault surfaces, often associated with faulted-folds, dip mainly to the NNE, with only a few planes dipping to the NNW. The mean fault orientation is 008/36 (dip direction/dip; Figure 6(c)). Twenty-five slickenlines (mostly corresponding to abrasion striae) are also plotted, constraining a consistent top-to-the SSW tectonic transport for the SCTZ, compatible with the orientation of fold axes and axial planes.

## 5. Discussion and conclusions

The geological map at the 1:7500 scale proposed in this work formalises and describes a new thrust zone, named herein the San Donato-Costa Thrust Zone (SCTZ). It represents a kilometric splay of the Belluno Thrust of the ESA.

The structural architecture of the SCTZ (Geological cross section A–B, C–D, structural stations 2, 3, 4, Figure 7) was constrained by integrating structural- and high-resolution stratigraphic analysis (Figures 3 and 4), allowing us to (i) constrain the lateral and vertical variations (e.g. normal vs overturned polarity) of the stratigraphic setting and (ii) document differences in deformation style (faulting vs folding) occurring both along- and across-strike the SCTZ. Also, our geological map and cross-sections constrain the total throw accommodated during the development of the thrust zone affecting the Jurassic-Palaeocene multi-layer sedimentary succession.

In comparison to existing maps, our results offer a refinement of the knowledge of the footwall succession

of the Belluno Thrust. In particular, the analysis of meso-scale structures within the SCTZ indicates that the style of thrust-related deformation recorded by the studied Meso-Cenozoic stratigraphic succession includes large folds in both the hanging wall and the footwall blocks, and the development of discrete fault surfaces that accommodated the overall top-to-the SSW SCTZ tectonic transport. At the regional scale, the identification of the hitherto unreported SCTZ suggests that shortening-related strain in the area is partitioned onto multiple and subparallel thrust splays and cumulated during repeated faulting episodes also involving secondary thrust splays, indeed like the SCTZ, of the main regional thrusts (e.g. Belluno Thrust, Valsugana Thrust, Figure 1(b) and (c)).

Our new map and analyses stress the often forgotten importance of field work and detailed geological mapping. Similar efforts in other key areas of the ESA will certainly lead to the definition of a much-refined reference geological model for purposes connected to, among other things, an improved environmental planning, territory administration and hazard mitigation. Our contribution can thus be of inspiration to further studies of the region and the ESA, with the potential to better constrain the tectonic evolution of the orogen.

## Software

The map was digitalised and georeferenced with the opensource software Qgis (version 2.18.13 and 3.8.3. <https://www.qgis.org/it/site/>). Final editing of the map and the geological cross sections was realised with Adobe Illustrator (version CC).

Stereographic projections were realised using the software Stereonet 11 (version 11.0.7, <http://www.geo.cornell.edu/geology/faculty/RWA/programs/stereonet.html>) and Wintensor (version 5.8.9, <http://damiendelvaux.be/Tensor/WinTensor/win-tensor.html>).

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## Disclosure statement

No potential conflict of interest was reported by the author(s).

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## Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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