# Mapping Geology in Geosites: Two case studies

Geosite:
A site with remarkable geological significance
to take care, highlight, and make known
to the lay public.

# Map of the Sangonetto Valley Geosites (Western Alps): Geological research and tourism enhancement

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ABSTRACT

As part of a research on geosites in the Province of Turin (NW-Italy), an experimental thematic cartography project, with a focus on geological tourism, was developed. This project was based on the starting assumption that activities aimed at protecting geological-geomorphological heritage should be supported by initiatives to make the natural landscape the natural landscape and its evolution more easy accessible and understandable even to non-geologists. The working procedure adopted enabled the gathering and description, in synthetical and accessible manner, not only of the crucial elements required to understand the geological evolution of the area (main lithological and structural units, deformational elements connected to tectonic and metamorphic evolution of the Alpine mountain range and Pliocene-Quaternary landforms and deposits linked to Pleistocene glacial morphogenesis and its subsequent post-glacial phase), but also of the essential information needed to identify safe tourist and educational routes of great educational importance. Representations were produced using computer mapping techniques and 3D modelling.

AIMS

The Map of the Sangonetto Valley Geosites is a thematic geological map intended for alpine excursionists.
In particular it aims:
- to make the alpine landscape and its evolution easier to understand, even for non-geologists;
- to highlight certain sites or territories of relevant geological and geomorphological interest;
-to promote awareness of the need for conservation of natural heritage.

In order to achieve the above goals, a complex methodology was devised and tested, including:
- detailed surveys for collection of geological and geomorphological field data;
- advanced digital cartography and computer graphics techniques for data visualization and interpretative models;
- use of color and text matching as part of a general strategy for communicating geological information.

KEY WORDS

Geological mapping, geomorphology, geosite, geological education, geotourism, Alps, glacialism, geodinamics, 3D visualization.

*RIASSUNTO*

*Nell'ambito di uno studio sui geositi della Provincia di Torino è stato sviluppato un progetto di cartografia tematica sperimentale di argomento geologico-turistico. Nel progetto si è partiti dal presupposto che le iniziative di salvaguardia del patrimonio geologico-geomorfologico devono necessariamente essere associate ad azioni che facilitino la lettura del paesaggio naturale e la comprensione della sua evoluzione anche ai non-geologi.*
*La metodologia di lavoro ha consentito di raccogliere e rappresentare, in forma sintetica e divulgativa, non solo gli elementi essenziali per comprendere l'evoluzione geologica (principali unità litologiche e strutturali ed elementi deformativi connessi all'evoluzione tettonica e metamorfica della catena Alpina, unità di copertura pliocenico-quaternaria, principali forme legate al modellamento glaciale pleistocenico ed alla successiva fase post-glaciale) ma anche le informazioni indispensabili per sviluppare in sicurezza alcuni percorsi di fruizione turistica e didattica densi di significato. Per la rappresentazione Si è fatto ricorso a tecniche di cartografia informatica e modellizzazione tridimensionale.*

# GEOLOGICAL AND GEOMORPHOLOGICAL MAP OF THE SANGONETTO VALLEY GEOSITES

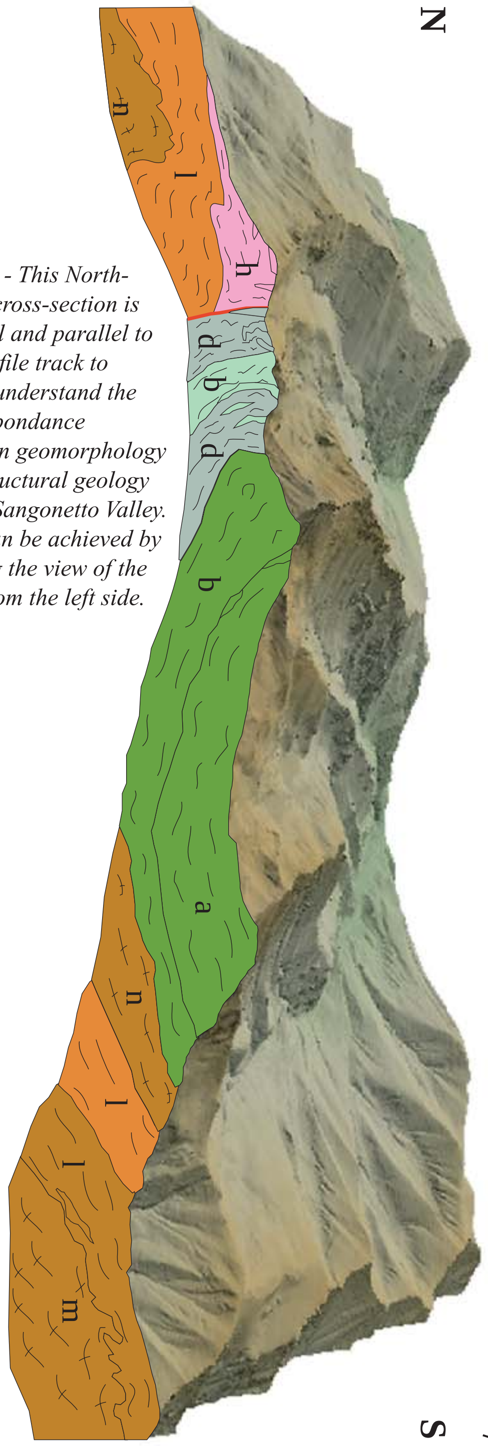



Fig. 2a - *This North-South cross-section is vertical and parallel to the profile track to better understand the correspondance between geomorphology and structural geology in the Sangonetto Valley. This can be achieved by turning the view of the map from the left side.*

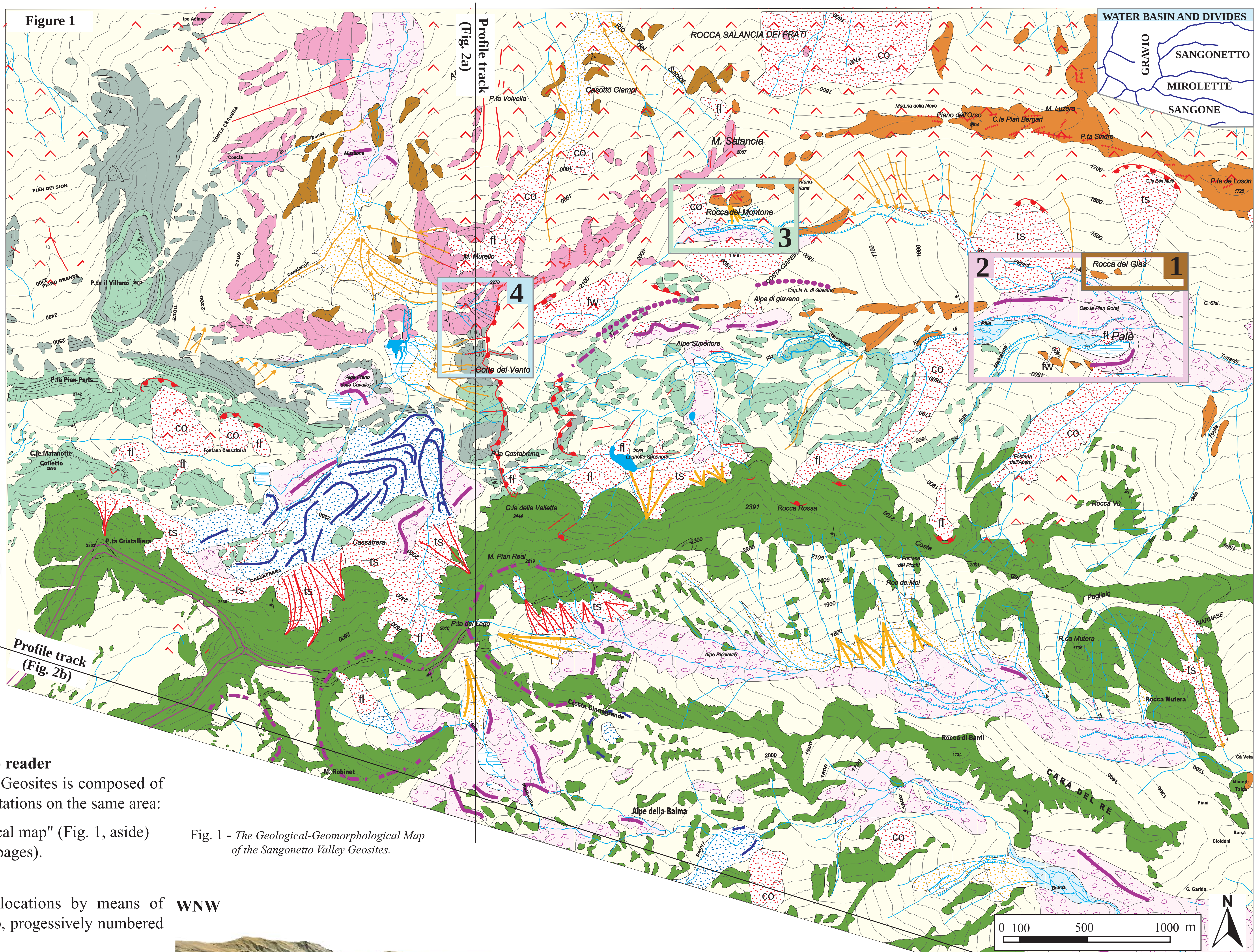



Fig. 1 - *The Geological-Geomorphological Map of the Sangonetto Valley Geosites.*

Cross-section of Fig. 2b continues outside the Geosite Map

## Guide to the map reader

The Map of the Sangonetto Valley Geosites is composed of two different cartographic representations on the same area:

- the "geological-geomorphological map" (Fig. 1, aside)
- the "geosite's route map" (next pages).

Both maps show the Geosites' locations by means of colored rectangular insets ( ), progessively numbered along the route.

The **"geological-geomorphological map"** (Fig. 1, aside) shows through different colors main natural features of the Sangonetto Valley related to superficial and deep Earth processes. Two "families" of features and related processes have been individualized in the map's legend:

- landforms and deposits of the natural lanscape;
- rocks and structure of the mountain relief.

Two geological cross-sections (Figs. 2a and 2b; horizontal and vertical) are presented aside the Map. They are coupled with 3-D model of the mountain relief.

WNW

ESE

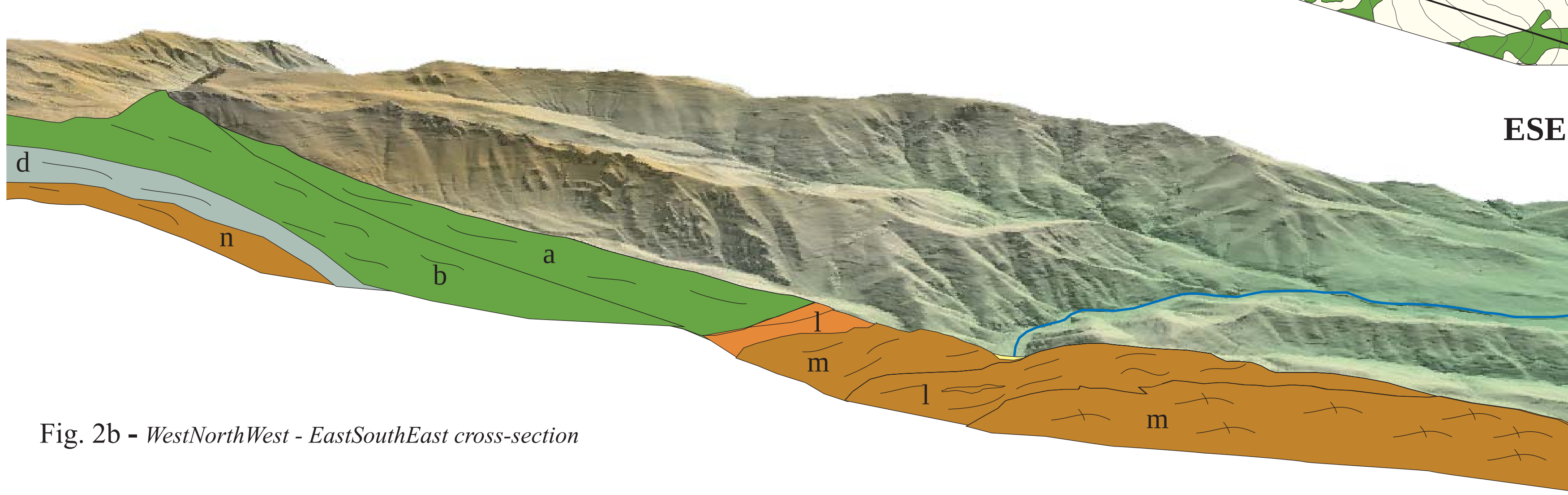



Fig. 2b - *WestNorthWest - EastSouthEast cross-section*

Research activity by agreement between the Soil Protection Office of the Torino Province and the Earth Sciences Department of the University of Torino. Project chief: Donatella Aigotti (Torino Province). Scientific coordinator: Marco Giardino (University of Torino). Technical support: Gabriella De Renzo (Torino Province).

# LANDFORMS AND DEPOSITS OF THE NATURAL LANDSCAPE

Linear and punctual symbols refer to erosional and depositional landforms. Polygones indicate allocation's areals of superficial Quaternary deposits. Same colors of the legend's units and groups will be used through the text to frame and to define similar topics.

**Hydrography and elements due to running waters**

- Lake
- Erosional scarp
- Gorge
- Stream
- Drainage basin border
- Fluvial deposit
- Lacustrine deposit

**Elements mainly due to gravity**

- Degradational and/or landslide scarp
- Depression, trench, tension crack
- Deep-seated gravitational deformation
- Eluvial-colluvial deposit
- Landslide accumulation (type of movement: fl=fall; sl=slide; fw=flow; co=complex) or other gravitational deposit (ts=talus debris)
- Debris cone
- Complex fan
- Complex deposit of mixed origin (stream, debris flow, avalanche)
- Incision of mixed origin (stream, debris flow, avalanche)

**Cryogenic and nivation elements**

- Rock glacier
- Nivation hollow
- Cryogenic and nivation deposit

**Relict elements due to past glacial activity**

- Edge of cirque
- Rocky crest line
- Moraine ridge
- Relict ridge
- Glacial deposit

This group involves Quaternary deposits and landforms linked to different present-day or ancient exogenetic processes.
Present-day features are mainly connected to the hydrographic network (Fig. 5), and to the modelling action of **running waters** and **gravity** on and within slopes and valleys.

Active and or inactive landforms are also related to **cryogenic and snow** action, which is significant at the highest elevations.
**Relict glacial landforms** and deposits are linked to Pleistocene glaciations and later glacial stages.

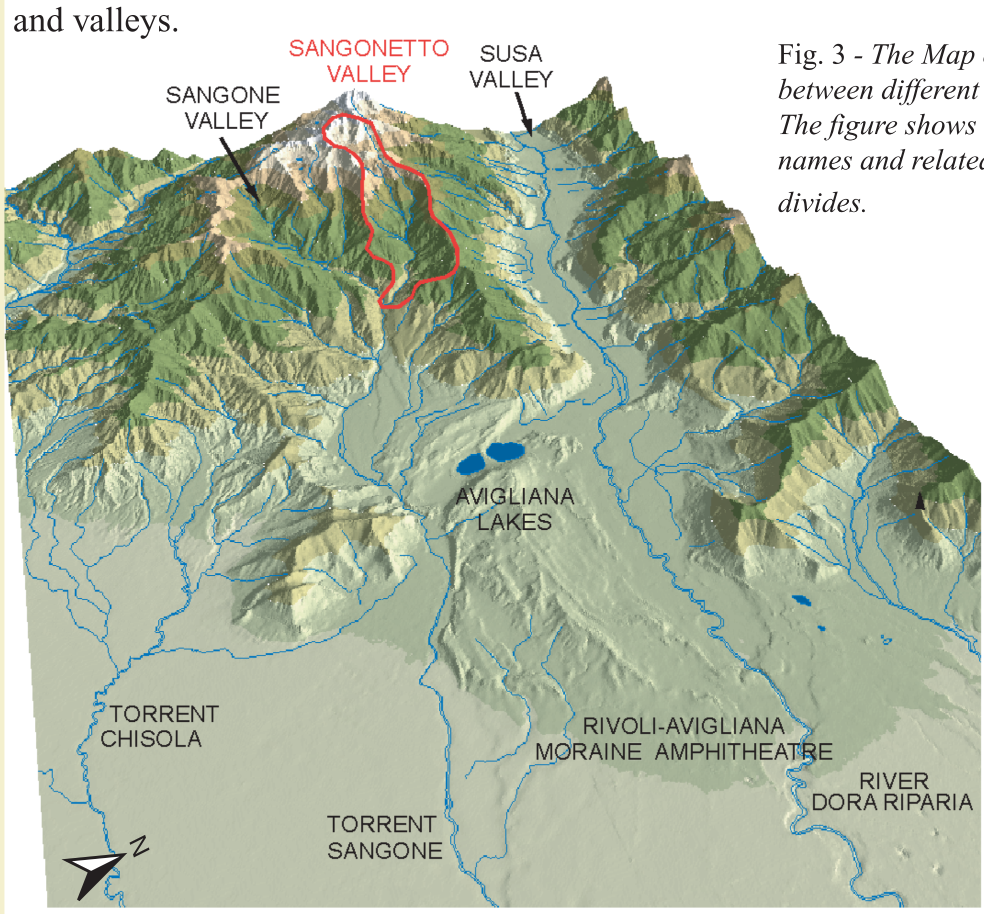



*Fig. 3 - The Map cover an area between different hydrographic basins. The figure shows their names and related divides.*

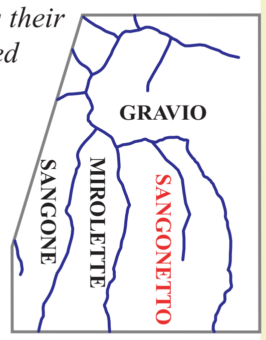



Fig. 4 - *Three-dimensional model of the internal side of Italian NW-Alps, where Sangonetto Valley is located. In the foreground the Alpine front range and the terminal moraines of the Pleistocene glacier of Susa Valley.*

# ROCKS AND STRUCTURE OF THE MOUNTAIN RELIEF

Areal symbols indicate rock units belonging to different parts of the Alpine structure (litho-structural units). Units are also distinguished on the basis of their original formation environment or for features due to metamorphic processes. Linear and punctual symbols refer to meaningful structural and deformational elements. Same colors of the legend's units and groups will be used through the text to frame and to define similar topics.

**Litho-structural units with rocks of oceanic origin ("Piemonte Nappe")**

- Units with metamorphic rocks derived from oceanic crust and sedimentary cover related to oceanic trench (a = metagabbro; b = serpentinite; c = prasinite)
- Units with metamorphic rocks derived from oceanic crust and related sedimentary cover (a = metagabbro; b = serpentinite; c = prasinite; d = calcschiste e = quarzite; f = marble)
- Units with metamorphic rocks derived from oceanic crust (a = metagabbro; b = serpentinite)

**Litho-structural units with rocks of continental margin origin (basement rocks and related sedimentary cover "Dora-Maira Massif")**

- Units with metamorphic rocks derived from sedimentary cover of the continental crust (g = metadolostone; e = quarzite; h = calc-micaschist; i = paragneiss)
- Units with metamorphic rocks derived from originary sedimentary and magmatic rocks of continental crust (l = micaschist; m = metagranite and orthogneiss; n = eyed orthogneiss)
- Units with metamorphic rocks derived from originary metamorphic rocks of continental crust

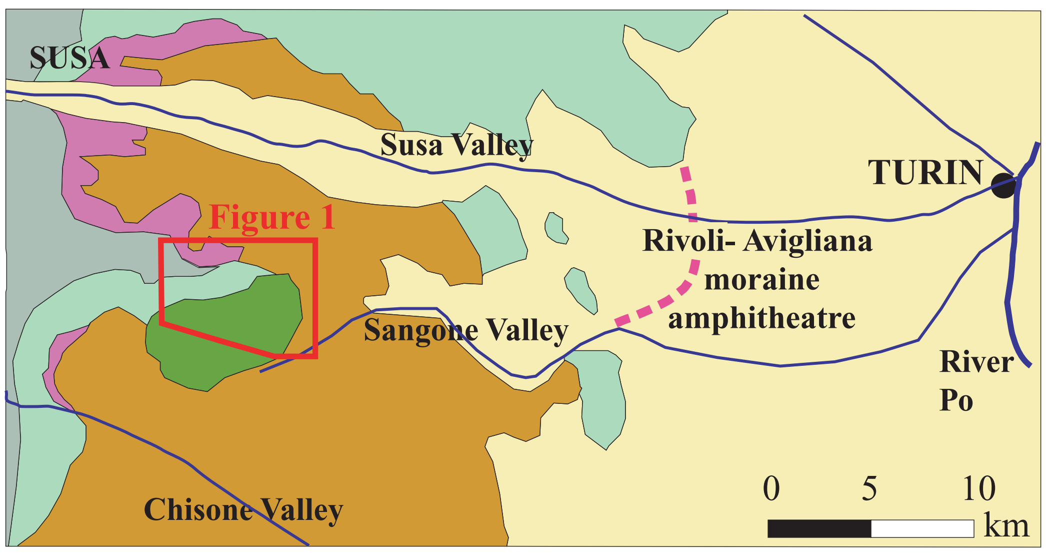
Metamorphic and tectonic elements

- Attitude of main schistosity
- Fault and other tectonic contact
- Main lithological contact

This group involves lithological and structural units and deformational elements connected to tectonic and metamorphic processes of the Alpine mountain range, subdivided according to environment of origin (**oceanic crust, basin or trench**; **continental crust** and related sedimentary cover) or metamorphic and tectonic history (mono- or polimetamorphic).

Two geological cross-sections (Figs. 2a and 2b) have been associated to the map, showing links between geological structure and mountain relief in the Sangonetto Valley and surrounding areas.
The geostructural sketch-map of Fig. 5 presents the geological framework of the Sangonetto Valley in the context of the internal side of the Western Alpine chain.
Elements for the reconstruction of the geomorphological and geological evolution of the area will be presented on the next pages.

Fig. 5 - *Geological overview of the internal side of the Italian NW Alps. Different units are represented with the same colors of the map's legend.*



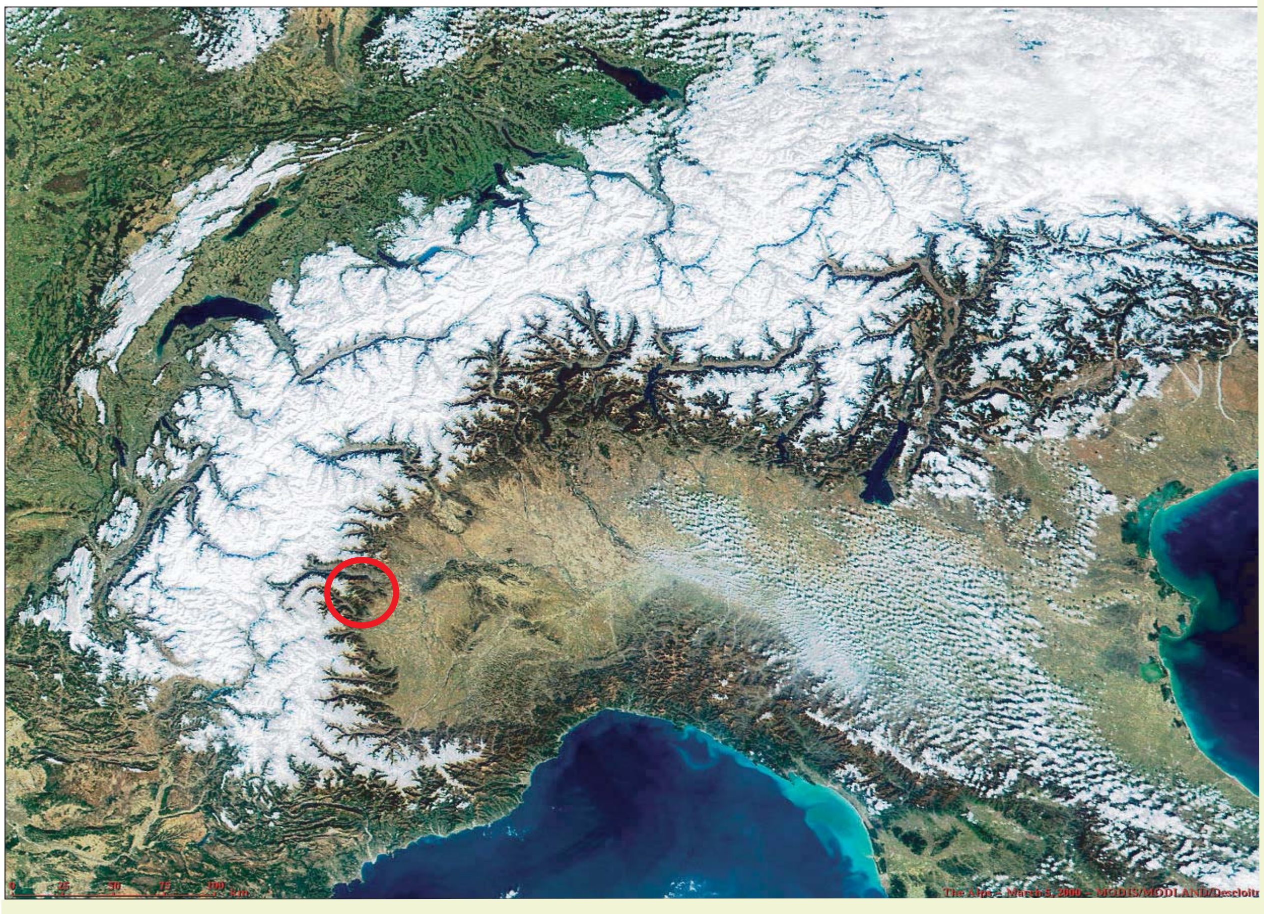


Fig. 6 - *Satellite image of the Alps (NASA EOS AM, 1999). When compared to the great valley furrows cutting through the Alpine mountain range, the surveyed area of the Sangonetto Valley ( O ) holds little significance from the point of view of dimensions; on the other hand, it has much to offer in terms of the variety of geological and geomorphologic features contained within a narrow area of 25 km².*

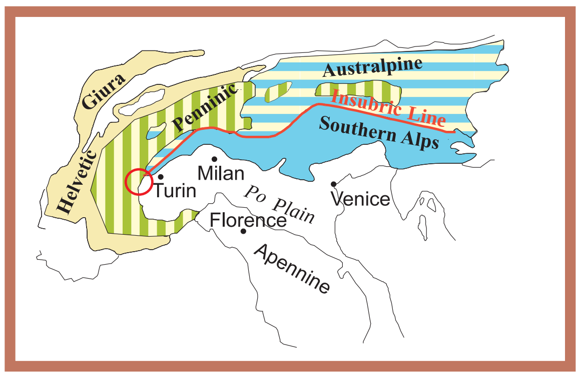



Fig. 7 - *Sketch-map of the main geostructural domains of the Alps. These are parts of the Alpine range that can be distinguished on the basis of a series of lithological, tectonic, and metamorphic features connected to their different geological history. As shown on Fig. 8, their differences recall both their original formation environment and the subsequent deformational processes they underwent.*

## GEOMORPHOLOGICAL AND GEOLOGICAL SETTING

The Sangonetto is a small tributary valley falling inside the drainage basin of the Sangone torrent (Fig. 4); the latter extends a few km west of Turin (Fig. 5), from the edge of the Po Valley to the Alpine front range, between the valleys of Susa (to the north) and Chisone (to the south).
Despite its small size (Fig. 5), the Sangonetto Valley shows valuables traces of the Alpine geological heritage, from a geomorphological (Fig. 4) or geological point of view (Fig. 5). In this perspective, all selected Geosites (highlighted in the map of Fig. 1 by frames of different colors, each corresponding to the relative legend color for the related geological-geomorphological processes responsible for their formation) relate to interesting features from the point of view of scientific interest and landscape value.
By following the legend's outline and analysing its "informative layers" from one end to the other, users will be able to gradually unfold the elements making up the geological landscape, from the most recent and active to the most ancient and relict.

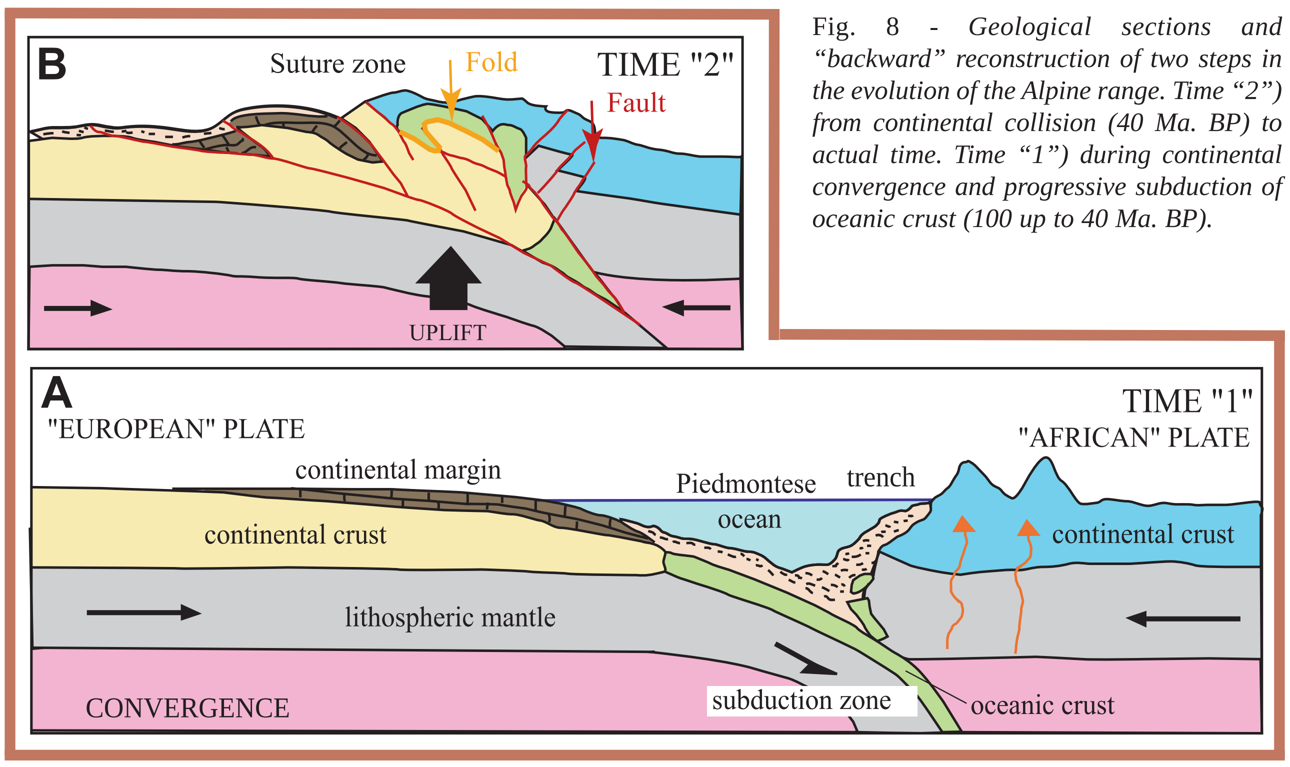



Fig. 8 - *Geological sections and "backward" reconstruction of two steps in the evolution of the Alpine range. Time "2") from continental collision (40 Ma. BP) to actual time. Time "1") during continental convergence and progressive subduction of oceanic crust (100 up to 40 Ma. BP).*

## LANDFORMS AND DEPOSITS OF THE NATURAL LANDSCAPE

Today, the Sangonetto Valley is mostly actively modelled by the flowing of surface waters and the effects of gravity (BAGGIO *et alii*, 2003); the mountain range is engraved by landforms of torrential erosion and covered by landslide accumulation and deposits of mixed origin (mainly stream and debris flows, followed by avalanche accumulations).
The modelling action of ice and snow is, at present, restricted to a few areas at the highest altitudes. Conversely, relict glacial traces of Pleistocene age (Figs. 21, 22 and 23) account for the dominant features of the landscape at various altimetric heights, both in the Sangonetto Valley (Florian, 1996; e.g. Geosite 2: Palè's moraine amphitheatre, connected to local glacialism in the Sangone Valley basin) and in the surrounding area (Fig. 4; e.g. Rivoli-Avigliana's moraine amphitheatre, connected to the main glacialism in the Susa Valley), where the glacier reached the valley mouth on the Po plain (SACCO, 1921; PETRUCCI, 1970; NICOLUSSI ROSSI, 1992; CARRARO *et alii*, 2002).

## ROCKS AND GEOLOGICAL STRUCTURE OF THE MOUNTAIN RANGE

The rocks of the Sangonetto Valley are, in almost all cases, metamorphic rocks formed during the Alpine orogenesis. However, their mineralogical and structural characteristics also show some traces of the primary sediments and rocks which have undergone many changes over geological time; this fact allows for an identification of the environments they were formed in, the pressure and temperature conditions they have subsequently been subjected to, and the deformations they suffered.
On the basis of the above characteristics, the rocks of the Sangonetto Valley can be interpreted as being parts of different "lithostructural units" of the Alpine range (see Fig. 5 and legend of Fig. 1; further description below). From a regional geological point of view, these units belong to the "Penninic Domain" (Fig. 7) and are located in the central-internal part of the Western Alps, a complete geological cross-section which shows an imbricated stack of continental crust and oceanic units ("orogenic wedge").
This Alpine "orogenic wedge" is the result of a complex geodynamic process due to plate convergence; following a lithospheric oceanic subduction (Fig. 8a), a continental collision occurred (Fig. 8b) between the "European" (lower plate) and the "African" ("Adria", upper plate; POLINO *et alii*, 1990) palaeocontinents. Similar colors in Figs. 7 and 8 are used to highlight the major alpine "structural domains" and to recall their different role in the geodynamic evolution of the Alps, as outlined in geological literature (COMPAGNONI *et alii*, 1977; TRÜMPY, 1980, CASTELLARIN & VAI, 1986; HUNZIKER & MARTINOTTI, 1987; DAL PIAZ & POLINO, 1989; CNR, 1990):
- The "Southern Alps" are part of the Adria continental margin, show internal vergence and lack alpine metamorphism; they are separated from the external domains by the Insubric Line.
- The "Austro-Alpine Domain" is a structurally

elevated complex in the alpine building, correlated to the Southern Alps.
- The "Penninic Domain" is a multilayer complex with preserved Mesozoic oceanic crust units, several continental crust sheets and related Mesozoic covers, which recorded and preserved well its alpine tectonometamorphic history.
- The "Helvetic Domain" is the most external structural element of the chain, and represents the European foreland portion involved in the Alpine orogenesis.
As shown previously, the Sangonetto Valley's lithostructural units belong to the "Penninic Domain". In local geological literature (Pognante, 1979, 1980; Cadoppi, 1988; Compagnoni & Sandrone, 1981; Carraro *et alii*, 2002), they are interpreted as being part of two different tectonometamorphic complexes, the "Piemonte Nappe System" and the "Dora-Maira Massif".

The lithostructural units belonging to the "Piemonte Nappe System" include metamorphic rocks derived from primary magmatic lithotypes (both intrusive and effusive), and the related sedimentary cover of an ancient oceanic crust (Piedmontese ocean) that gradually disappeared because of subduction due to tectonic convergence phenomena between lithosphere plates (Polino *et alii*, 1990; Deville *et alii*, 1992; Lagabrielle, 1994).
The lithostructural units belonging to the "Dora-Maira Massif" (Borghi & Sandrone, 1990; Cadoppi & Tallone, 1992; Sandrone *et alii*, 1993) include metamorphic rocks derived from a crystalline basement and related sedimentary cover, originally belonging to a continental margin overlooking the ancient ocean. From a classical paleogeographic point of view, in the same way as the other "internal massifs" (Monte Rosa and Gran Paradiso), this massif has been interpreted as being part of the palaeo-European margin (Debelmas & Lemoine, 1970).
However, more recent interpretations (Hunziker & Martinotti, 1987; Polino *et alii*, 1990) propose a palaeo-African margin position for the Dora-Maira.
Aside from the "disappearance" of the ocean, the crust's subduction and the growth of a first series of mountain reliefs and volcanic arcs, the Alpine tectonic convergence phenomena brought about the collision of the overlooking continental margin, and its progressive deformation and uplift. This is the reason why lithostructural units of a different origin can now be found metamorphosed, deformed and piled up, creating the Alpine range.
As regards metamorphic markers of the Alpine orogenesis, only a few rocks in the Sangonetto Valley reveal high temperature and high pressure conditions ("eclogitic facies"), while the majority shows prevailing traces of low-temperature metamorphic events ("green schist facies").
Among the tectonic elements connected to the Alpine orogenesis, a number of folds and faults can be recognised along the Sangonetto Valley. These are mainly characterised by E-W and N-S directions, and testify the most recent tectonic activity (Ambrosetti *et alii*, 1987). Superficial deformations induced by the release of seismic energy can be found locally; this marks the Sangonetto Valley as belonging to the "Pinerolese Seismic District" (Capponi *et alii*, 1980), the area of the Western Alps characterised by the highest historical seismicity (Fig. 9; Capponi *et alii*, 1981; Collo & Giardino, 1997).

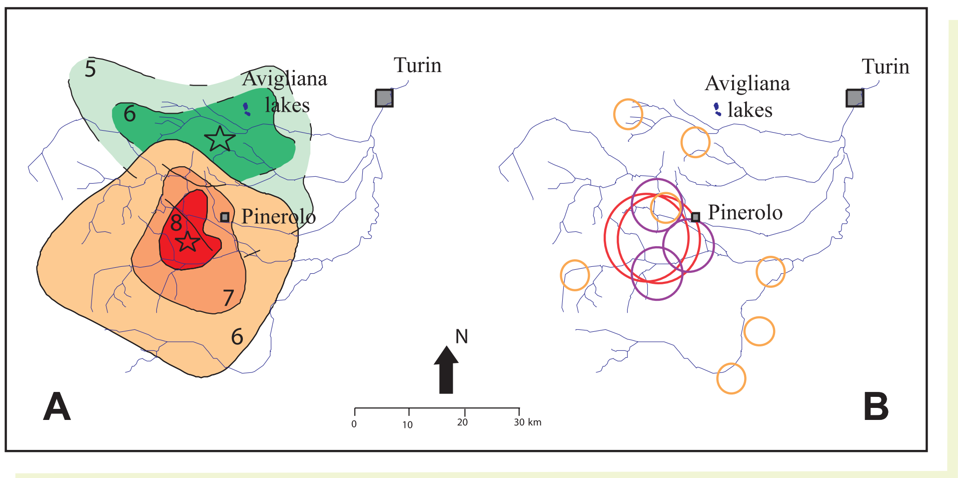



Fig. 9 - *Seismicity of the Pinerolese Seismic District. A) affected areas and intensity of main earthquakes: April, 2, 1808 (red) and January, 5, 1980 (green); stars show epicentres. B) Epicentres and magnitude of other historical earthquakes (◯ M=4, ◯ M=4 to 5.5, ◯ M>5.5; circumference proportional to M).*

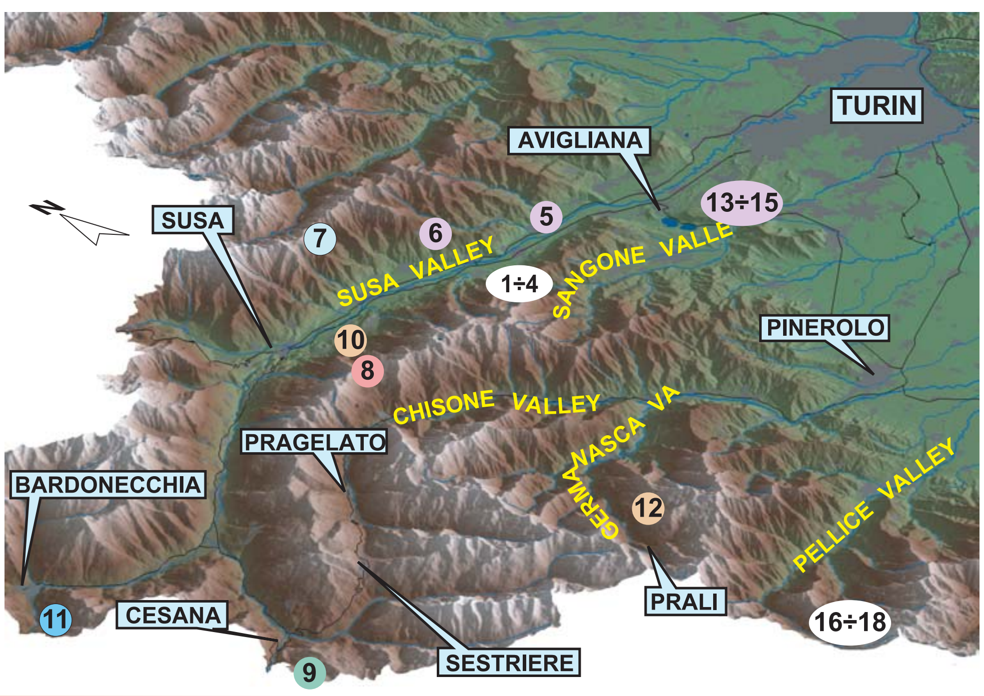



Fig. 10 - *Distribution of Geosites and Geosite Routes in the Province of Turin, in the 2006 Winter Olympics area. The colors of the Geosite symbols are matched to their geological and geomorphological meaning: violet = glacial; deep blue = periglacial; sky blue = fluvial; scarlet = tectonic; orange = slope dynamics; green = rock-forming processes; white = combination of several processes.*

## THEORETICAL AND PRACTICAL FRAMEWORK OF THE GEOSITE MAP

The environment around us is rich in resources, not only in terms of raw materials, but also resources of cultural, scientific and even just purely landscape value, which are no less important. Many of these resources are part of our geological heritage, the "Memory of the Earth" (UNESCO & EWGESC, 1994), written in its depths as well as on the surface, and well-preserved in the rocks and the landscape. Over the last decades, many scientific interests (by research institutions) and demands for nature preservation and the promotion of environmental tourism (by public administrations) have converged in efforts to identify and protect sites or territories of geological and geomorphological interest for the purposes of environmental heritage conservation ("geosites"; Wimbledon *et alii*, 1995).
Geosite studies in the Italian Western Alps began with research projects by the CNR-IRPI and the University of Turin, supported by territorial Institutions (Municipality of Cesana Torinese, Province of Turin, Region of Piemonte), in the context of programs aimed at promoting sustainable tourism in the alpine area (European Union Interreg III: "The mountains born of the sea. Sustainable tourism, geology and environment between the Dora and Durance rivers"; Province of Turin: Geosites Project "Landscape 2006").
The above-mentioned collaborations were born at a particular time in the history of Western Piemonte, that of the groundworks for the 2006 Winter Olympics, to be held in Turin. The Winter Olympics, which are seen by many environmentalists to be a calamity for the mountains, due to the adjustment/building works for sporting and tourist structures they involve, are considered by others to also provide a chance to promote and exploit the cultural and natural resources of this alpine territory. These challenges were taken up, and research institutions are now working alongside public administrations to analyse the most interesting geosites, in order to divulge "geological" knowledge and activate consistent avenues of sustainable tourist fruition.
The first results of the geoconservation effort in the Italian Western Alps were:
- The working out of a specific methodology for geosite analysis and mapping in the Alpine environment (Giardino & Mortara, 1999);
- A popular presentation booklet on the first series of geosites studied in the Province of Turin (Aigotti *et alii*, 2001; the booklet was *ex aequo* winner of the 2001 "FIST-Geositi" prize at the national competition held by the Italian

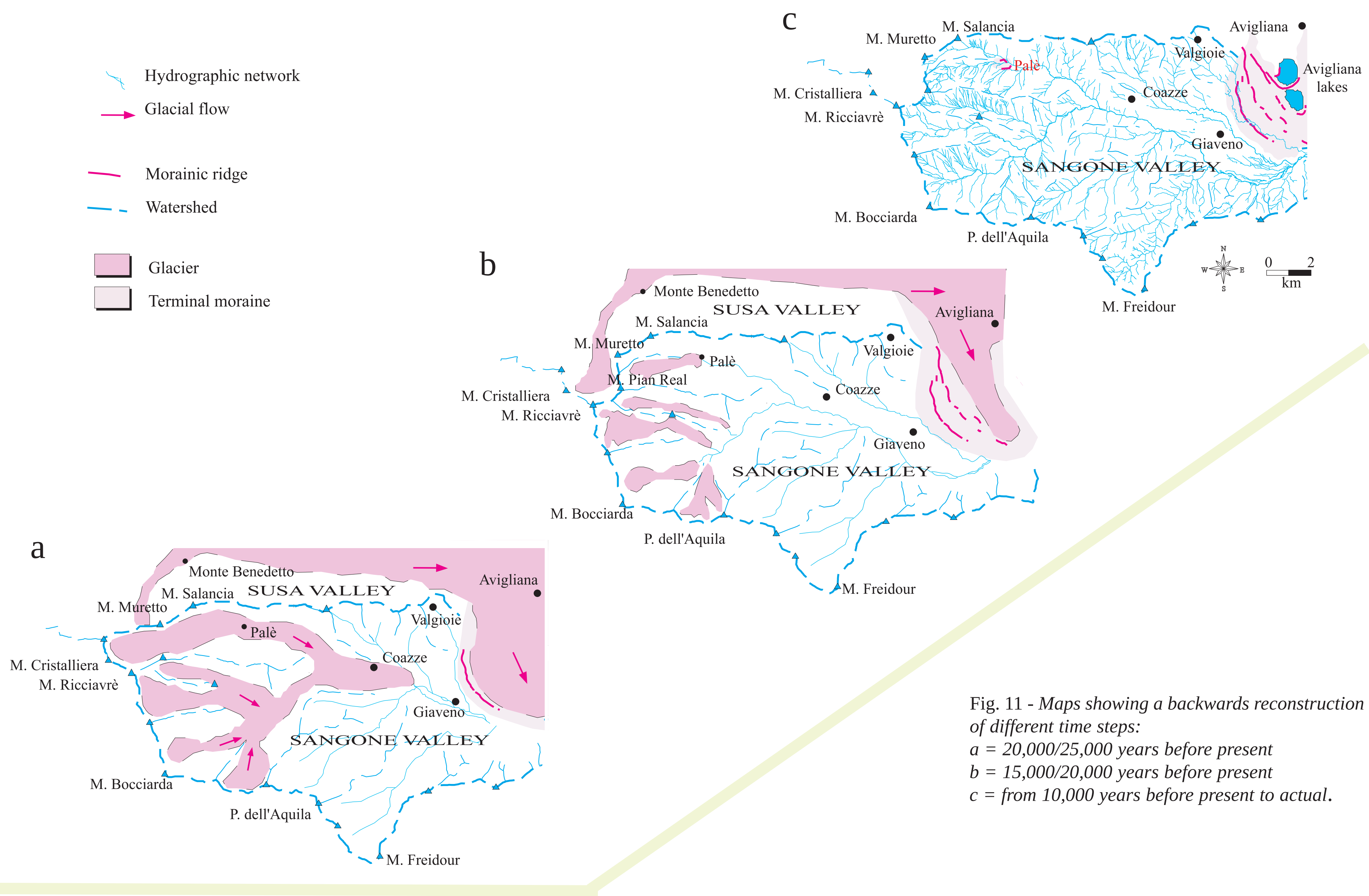


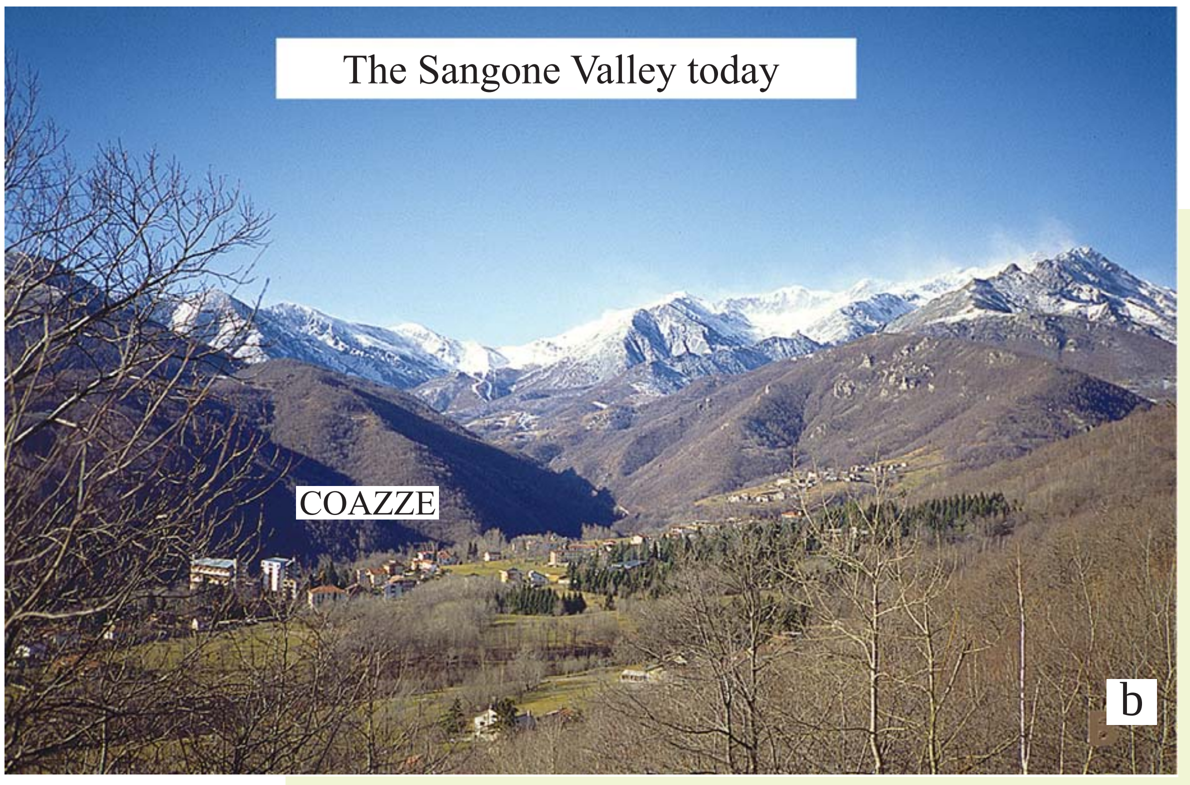

Fig. 11 - *Maps showing a backwards reconstruction of different time steps:*
*a = 20,000/25,000 years before present*
*b = 15,000/20,000 years before present*
*c = from 10,000 years before present to actual.*

Federation for Earth Sciences);
- A new complete geosite selection for the Winter Olimpics area of the Province of Turin (GIARDINO *et alii*, 2002).
An area was then identified among all the selected Geosites (Fig. 10) for the realization of an experimental thematic map including geological, educational and tourist elements. It was important that the area selected should display peculiar characteristics in order to enable the easy and complete mapping of Alpine geological and geomorphological features in a restricted area.
Such a map should make it easier for excursionists to "read" and interpret the landforms of the Alpine landscape and to understand both its evolution and dynamics and the lithostructural conditioning resulting from its ancient or recent geological history.

## METHODOLOGY AND RESULTS

The choice of the sample area for the elaboration of a thematic geological, educational and tourist map turned to the Sangonetto Valley (Figs. 4 and 5), as an important "Alpine" geological environment and anthropic territory offering:
- A high concentration of geosites, defined by rarity, significance, scenic and historical-cultural value, and, most of all, easily within reach for direct (*in situ* visit) or indirect (panoramic route) enjoyment (GIARDINO *et alii*, 2002).
- An exceptionally high and up-to-date level of scientific knowledge, since the area was the object of very recent studies during the CARG Project for the "Susa" Sheet of the new Geological Map of Italy (1:50,000 in scale; CARRARO *et alii*, 2002), and other detailed base studies and applicative surveys (POGNANTE, 1979; FLORIAN, 1996).
- Strong Alpine landscape identity and peculiar geological-geomorphological history, condensed in a mountain basin that is not exceptionally wide (POGNANTE, 1979; BAGGIO *et alii*, 2003).
The starting points for the project for the Map of the Sangonetto Valley Geosites " were:
- The assumption that activities safeguarding geological heritage need to be associated with actions that will make for an easier reading of the natural landscape in order to make its evolutions more easily understandable even for non-geologists (from "geoconservation" to "geodiffusion"; PIACENTE, 2003).
- The development of a "complex map working procedure" that allows the gathering and description, in synthetic and accessible manner, not only of the crucial elements towards understanding the geology and geomorphology of the area of interest ("geological and geomorphological map"; Fig. 1), but also of the essential information needed to identify safe tourist and educational routes of great geological importance ("geosites' route map; next pages).
In order to put into practice the project's aims, a specific research, exploitation and management strategy for geological and geomorphological assets is needed.
Therefore, mapping activities are part of a complex strategy comprising a path which begins with the knowledge of geosites and leads to their exploitation.
Environmental study is the starting point of the research. The natural and cultural geological-geomorphological Alpine resources potentially able to activate a tourist demand have been studied through analyses of scientific literature, historical researches and technical reports, remote-sensing studies and field activities.
The instruments of scientific analysis used have led to the drawing up of thematic maps employing sets of symbols developed on the basis of legends introduced by the Italian national research team of Physical Geography and Geomorphology (GNGFG, 1986) and by researchers of the Project for the New Geological Map of Italy (PASQUARÈ *et alii*, 1991; CARG, 1994). These, however, were relieved of some classic heavy "areal" themes (e.g. mapping of rock outcrops, granulometric patterns for superficial deposits), in this way making room to add specific "monodimensional" (meaningful landscape elements, observation points) or linear (excursion itineraries, access paths) indications later on.
In a "simplified map", it is also possible to clearly outline main geological and geomorphological processes; among these, the specific features and/or particularly interesting areas (Geosites) that should be studied in greater detail have been highlighted. The geosites have been selected according to their rarity, significance, scenery-landscape value, accessibility and historical-cultural value (WIMBLEDON *et alii*, 1995).
On the basis of visualization and map format needs, the "geological-geomorphological map" of the Sangonetto Valley was surveyed on a base of a 1:10,000 in scale, then cut out of peripheral parts, reduced and represented on a 1:20,000 scale (Fig. 1). The map includes 4 the-

During last glaciation's phase of maximum expansion, (Fig. 11a) the main glacier of Susa Valley stretched down to the plains, occupying almost entirely the valley outlet and obstructing Sangone Valley to the east. Sangone Valley glaciers merged together into a main tongue reaching all the way to Coazze (Fig. 12a). During following pulsations (Fig. 11b) Sangone Valley glaciers did not merge into a single mass anymore, but stopped more uphill; in the case of the Sangonetto Valley, the front range was withdrawn to the site of present day's Palè. Later on, the settling of current climatic conditions gave rise to the ultimate withdrawal of glacial masses from the Sangone Valley, leaving room to the water streams as main agent in intravalley modelling (Figs. 11c and 12b).



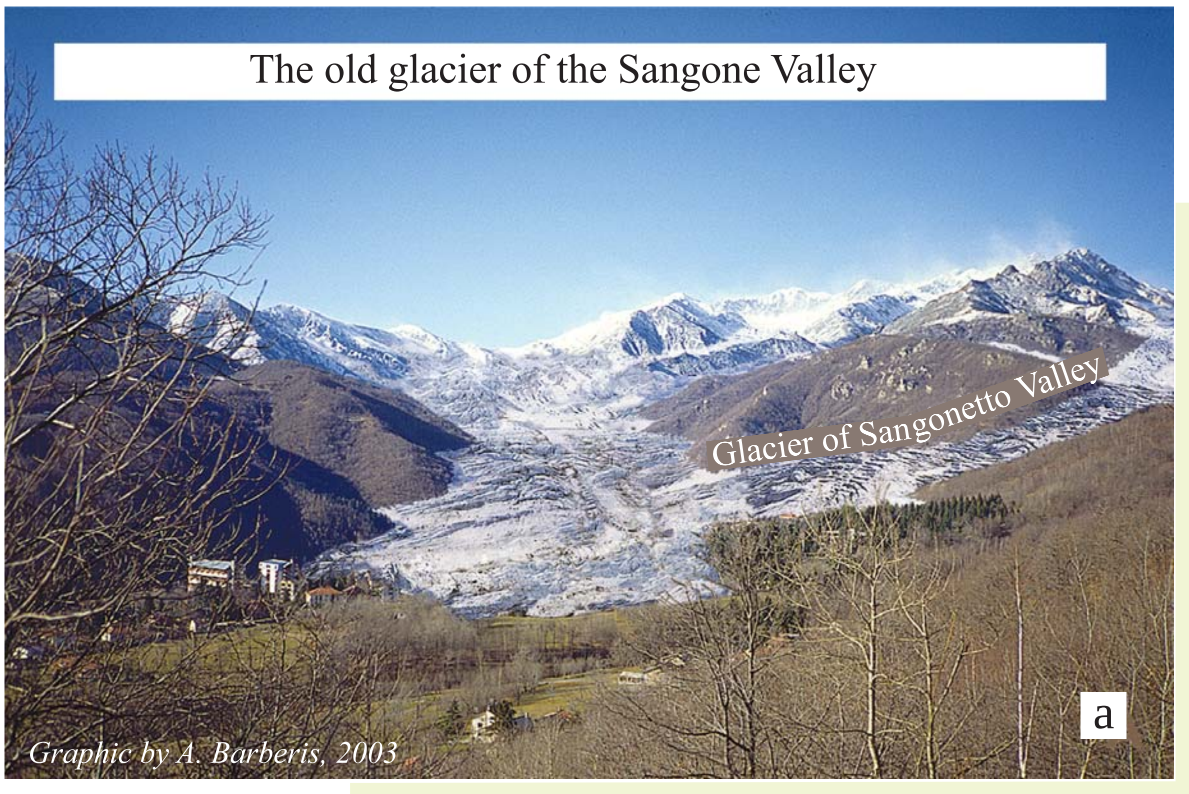




Fig. 12 - *Synthesis of the evolution of the glacialism in the Sangone basins and nearby areas, as reconstructed by present-day field evidences.*
*a = visual reconstruction of the ancient glaciers (20,000/25,000 years before present);*
*b = present picture of the Upper Sangone Valley.*

matic close-examination areas (e.g.: map insets of Fig. 1 and Geosites' Route Map; areas surveyed and represented 1:5,000 in scale), framed in the same color on the main map and on the following pages, so as to enable easier identification of the elements defining the geological landscape and a better understanding of their meaning.

The Geosites' Route Map is focused on directions for tourists; it also contains information on both natural landscape features and human artefacts. Also in this map, distinctive colors have been used to define similar topics so as to enable an easier connection between map graphic contents, text notes and figures.

Among the instruments used to promote an easier understanding of scientific studies on geomorphology, digital models of the area were created and associated to geological profiles (Figs. 2a and 2b), prompting map readers to analyse the links between geological structures and mountain reliefs. Further digital model and three-dimensional sketch-views (Figs. 4 and 22) are used to facilitate understanding of the geomorphological context within which the Sangonetto Valley falls.

As for the photographs, these comprise an invaluable means to clearly highlight the main attractions of any geosite (e.g. Figs. 20 and 21); on the map, information is given to enable the identification of the shooting point and visual angle of the photographs (see legend and Geosites' Route Map). Moreover, they have been pasted and enlarged in the attached text, and furnished with explanatory graphic insets clarifying their geological meaning, for instance concerning plicative deformations and elements tied to palaeoseismicity (Fig. 16).

Similarly, on the themes of recent geological evolution (e.g. Palè's moraine amphitheatre), illustrative sectors have been included in this paper, and a sequence of pictures presented, allowing readers to follow the steps of the process carried out by researchers, from terrain analysis to the recognition of the elements, and finally their interpretation (Figs. 14a, 14b and 14c).

A broad overview of recent geological events has been presented in the simplified explanatory maps, allowing to connect each individual element depicted in the main map to its own context, and to compare their area distribution in the whole Sangone mountain basins (Figs. 4, 5, and 15). Said overview was also linked to a synthesis of the evolution of the Sangone basin; these maps allow the reader to understand how the landscape may change over geological time, and which agents are responsible for shaping of mountain range. In order to facilitate understanding of the cartographical representations mentioned, computer graphics and 3D modelling have once more been used to depict both the glacial dynamics (Figs. 12 and 15) and the resulting evolution of hydrographical basins (Figs. 22 and 23).

A trial series of these cartographical products (the "geological and geomorphological map", Fig. 1; and the "Geosites' Route Map"), accompanied by descriptive cards of the geosites (presentation booklet on the geosites of the Province of Turin; Aigotti *et alii*, 2001) and local information on the difficulty of routes, have been supplied to tourist promotion companies and Regional Park Officers (locally: Orsiera-Rocciavrè Regional Park), as a useful interpretation tool not only for the most seasoned excursionists, but also for tourist only accustomed to the simplest pedestrian routes.

As a suggestion to those intending to visit the Sangonetto Valley, the best period for visiting the Geosites and walking the Route safely is late spring to early winter; during winter snow, avalanche hazards affect the upper part of the Sangonetto Valley.

## GEOSITE 2: PALE'S MORAINE AMPHITHEATRE

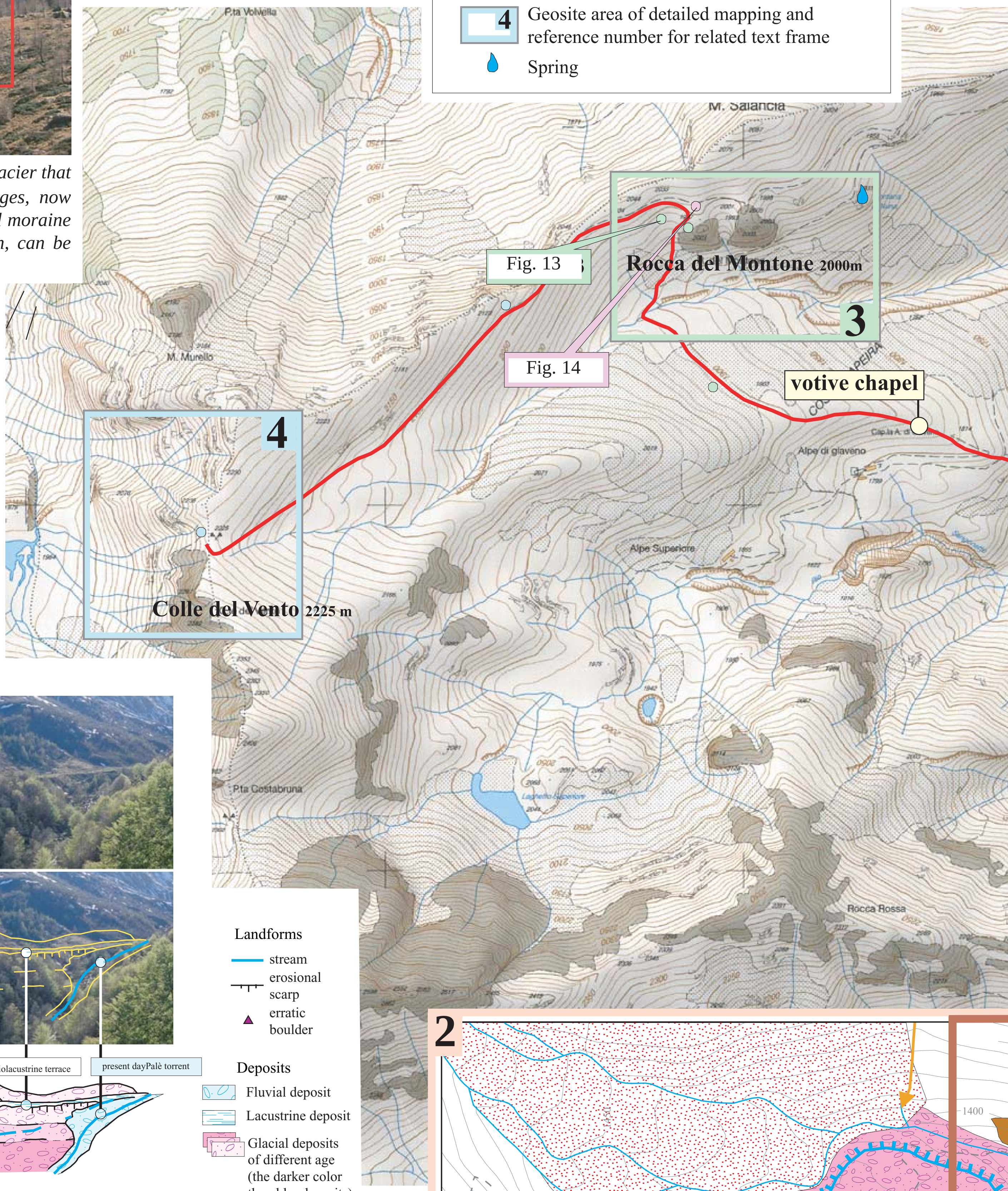
Fig. 13 - *This geosite displays a good set of traces left by the glacier that laid on the Sangonetto Valley during the Pleistocene ice ages, now disappeared completely. Three different more or less preserved moraine ridges, each of which was formed during a glacial pulsation, can be identified.*

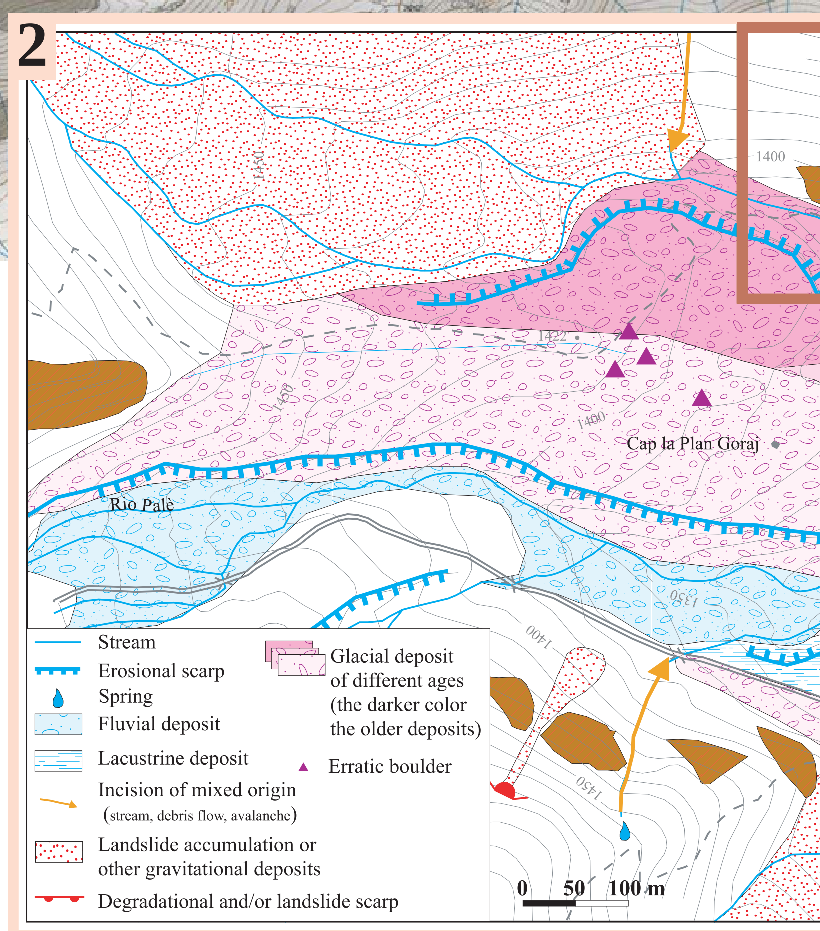
Fig. 14 - *Procedure for the scientific study of the Palè's Moraine Amphitheatre:*
*A = terrain analysis;*
*B = identification of geomorphological features;*
*C = their interpretation.*
*Thanks to the incision made by the Palè torrent, it is possible to appraise the characteristics of glacial deposits and, through a comparison between landforms, distinguish their relative ages, starting from the most ancient (1) to the most recent (3).*
*The interpretative key is offered by the landforms' relative position and degree of preservation.*

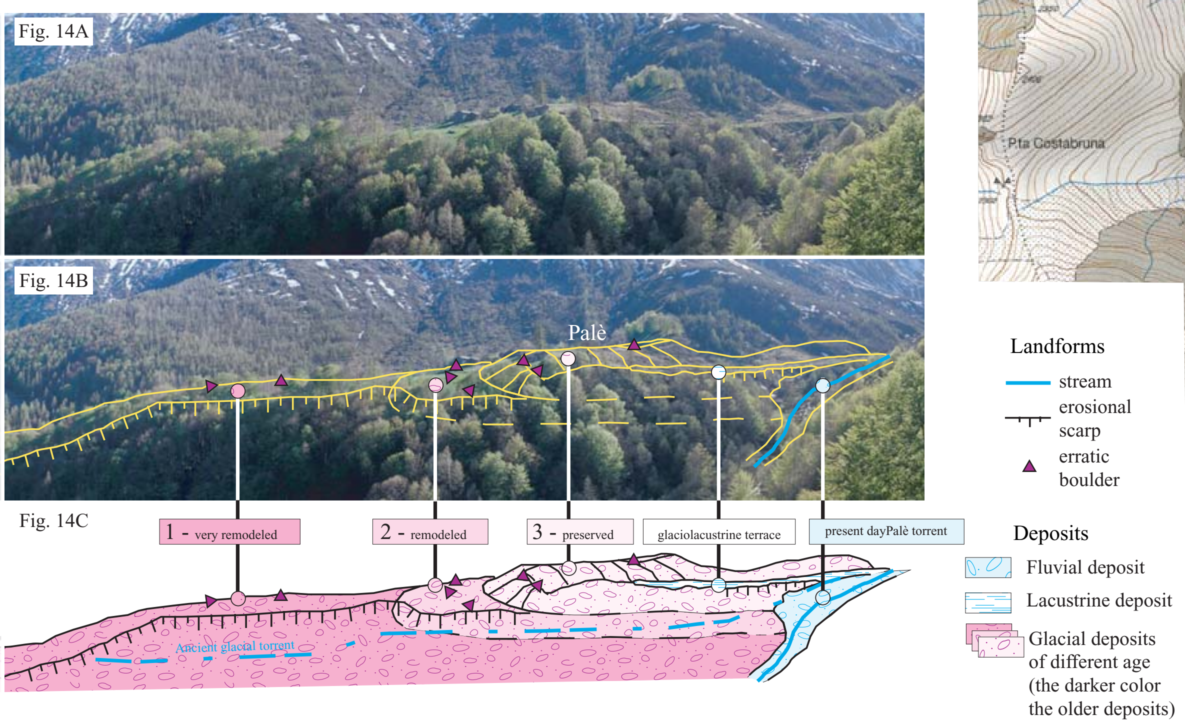
**Anthropic elements, route tracks and "tools" for understanding informations**

Hereby are listed man-mada features and other information have proven to be of interest for the route. This section also describes cartographical and graphical elements created as a halp to orientation in the area and as a link between the informations included in text and pictures attached to the map.

- **EASY ROUTE TRACK**
- **EXPERT ROUTE TRACK**
- Observation point and reference number of related figures (**Figure 14**)
- Geosite area of detailed mapping and reference number for related text frame (**4**)
- Spring



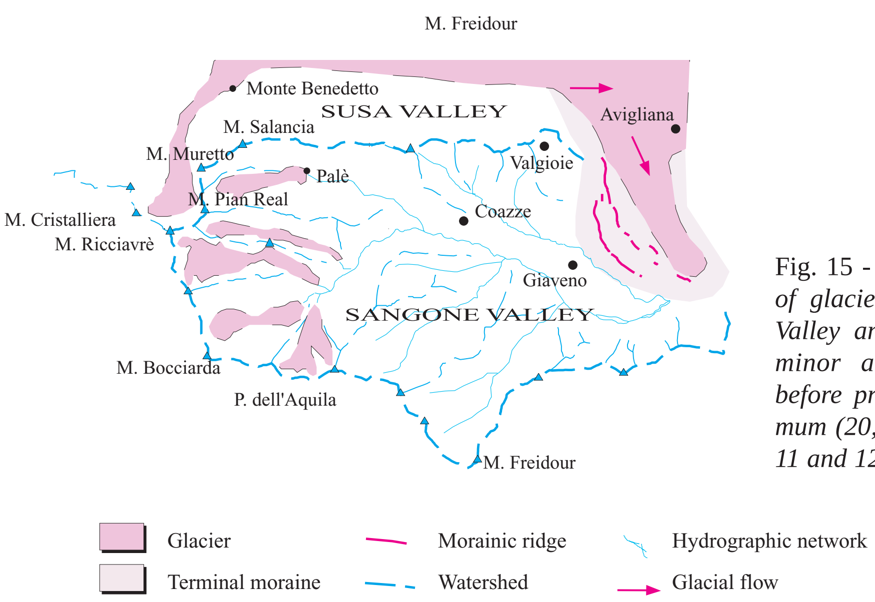




Fig. 15 - *Maps showing a reconstruction of glaciers distribution in the Sangone Valley and surrounding areas during a minor advance (15,000/20,000 years before present ) after last glacial maximum (20,000/25,000 years BP). See Figs 11 and 12, for further explanations.*

# ROUTE MAP OF THE SANGONETTO VALLEY

## GEOSITES 1 AND 2

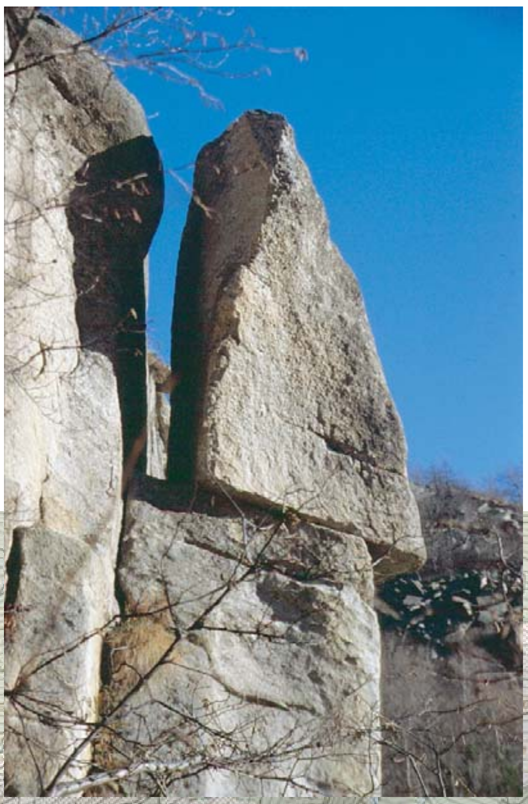
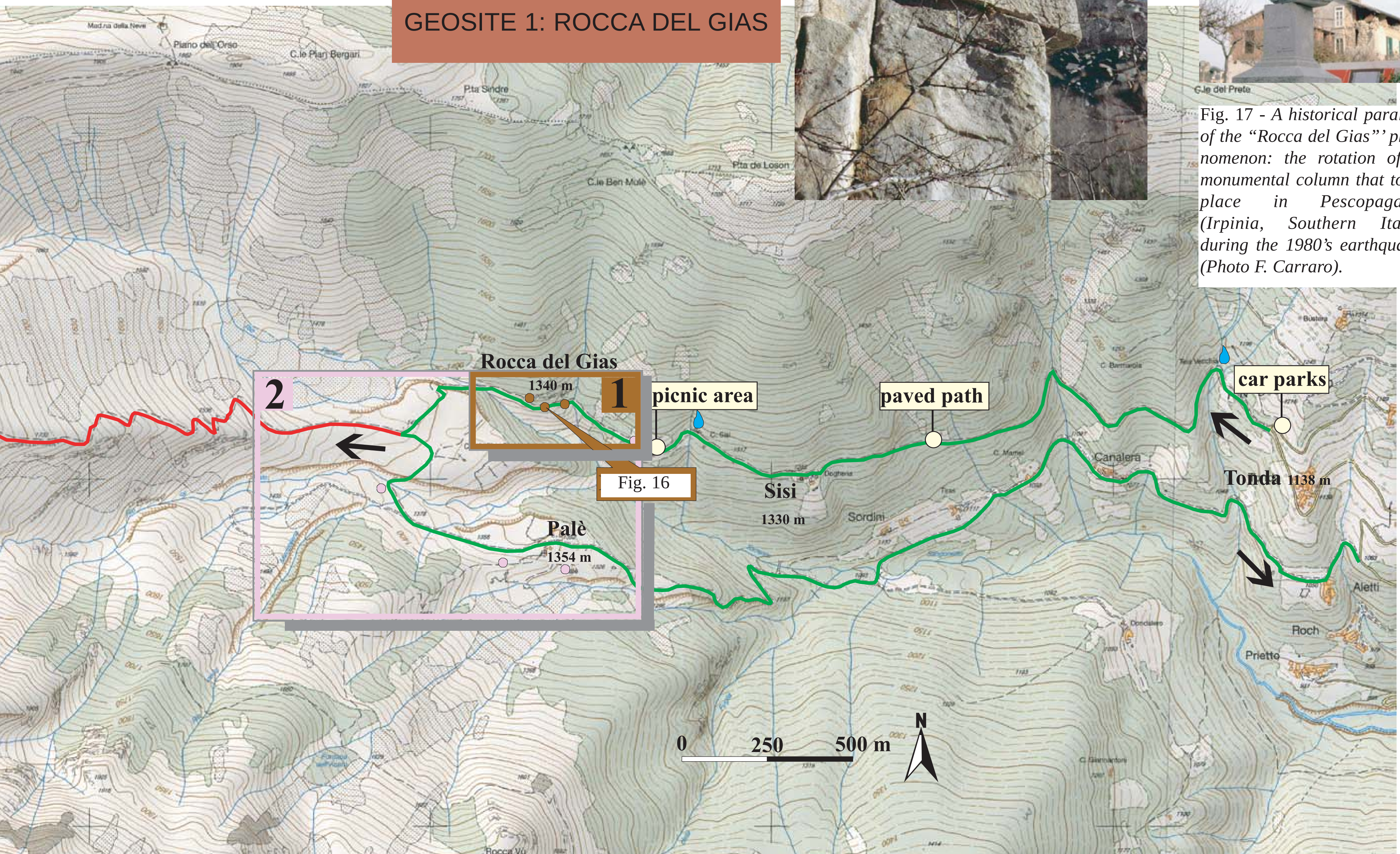
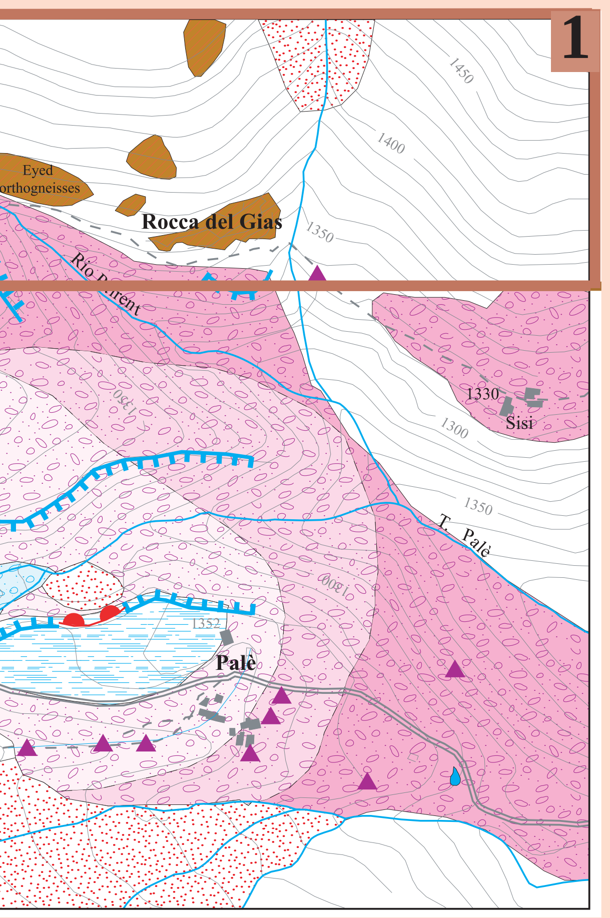


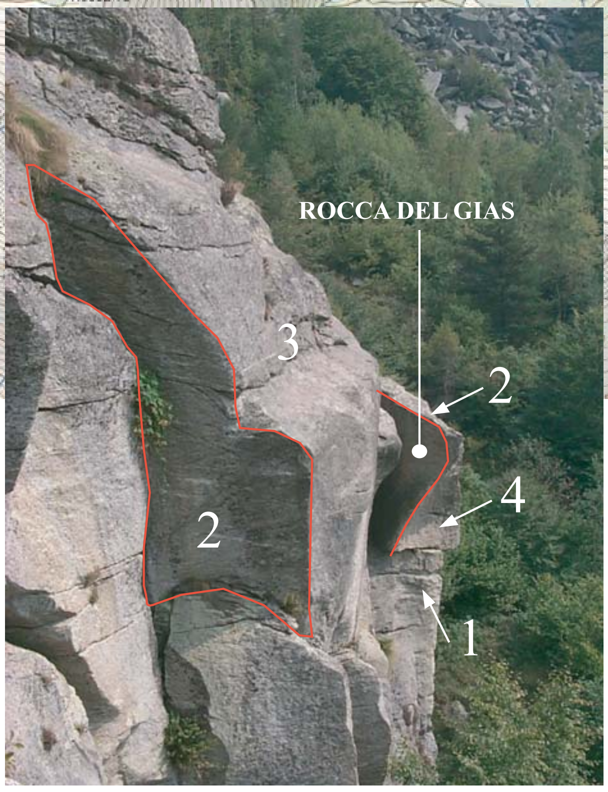
Fig. 16 - *A weird rocky pillar rotated because a prehistorical seismic event.*

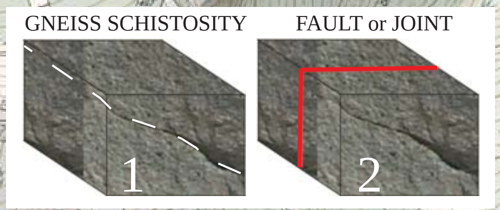

Fig. 17 - *A historical parallel of the "Rocca del Gias"' phenomenon: the rotation of a monumental column that took place in Pescopagano (Irpinia, Southern Italy) during the 1980's earthquake (Photo F. Carraro).*

## GEOSITE 1: ROCCA DEL GIAS



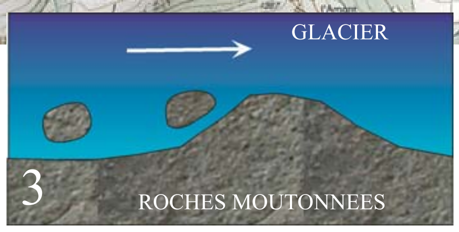





Fig. 18 - *The "Rocca del Gias" owes its peculiar shape to a sequence of phenomena: first of all "static" conditioning, of a lithostructural kind, imposed by eyed gneisses with intense planar schistosity (1) and by the presence of subvertical structural discontinuities (2 = faults and fractures); secondarily, to exogenic processes connected to glacialism (3 = traces visible in the shape of smoothed out and striated rock walls and surfaces; 4 = "pot-holes", forms of erosion by pressured water); and finally by "dynamic" conditioning, represented by seismic activity, able to produce the "Rocca del Gias" rototranslation on its subhorizontal basement.*

GEOSITE 1: ROCCA DEL GIAS

## GEOSITE 4: COLLE DEL VENTO

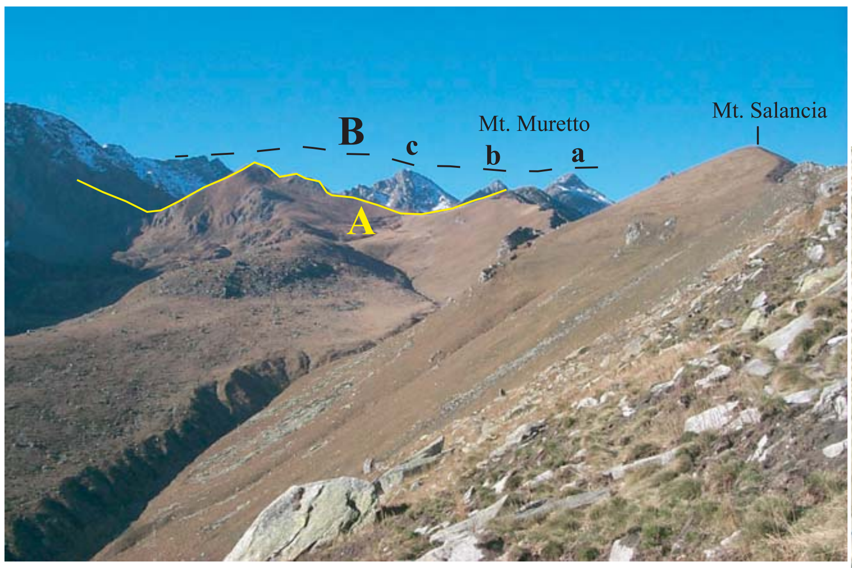
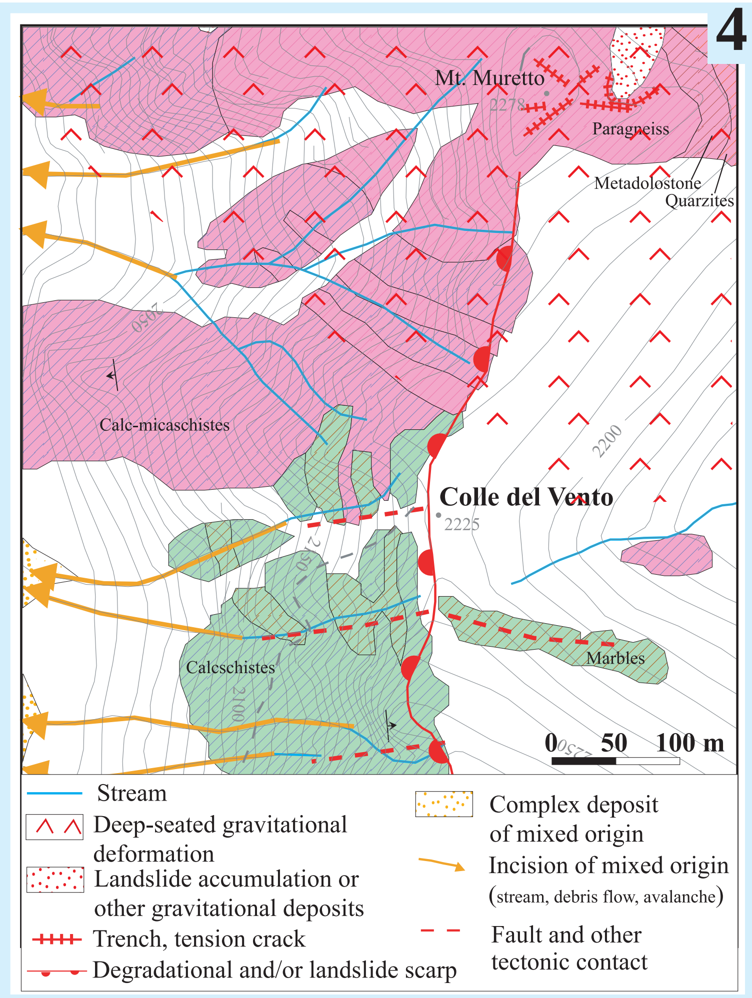



Fig. 19 - *The current head of the Sangonetto basin at the "Colle del Vento" saddle (A) is a remnants of an ancient thalweg which is actively eroded from the West by the deepening of the Gravio basin. In the background are the peaks (a, b, c) which made up the ancient head (B) of Sangonetto Valley.*




*The geosite 4 summarizes the geomorphological evolution of the valley head of the Sangonetto basin.*
*The hydrographical basin of the Sangonetto Torrent (1) underwent a head capture due to the erosional deepening caused by the Gravio Torrent.*
*The sequence of maps and models of the drainage basins (Figs. 22 and 23) visualizes the streams and watershed's distributions before (A) and after (B) the capture. The three-dimensional terrain models and maps show:*
*- The ancient valley floor (1) and flow direction (arrow) of the Sangonetto drainage;*
*- The interpreted location of the ancient Sangonetto-Gravio watershed (2);*
*- The current head (3), corresponding to a scarp intensively eroded by the Gravio Torrent.*

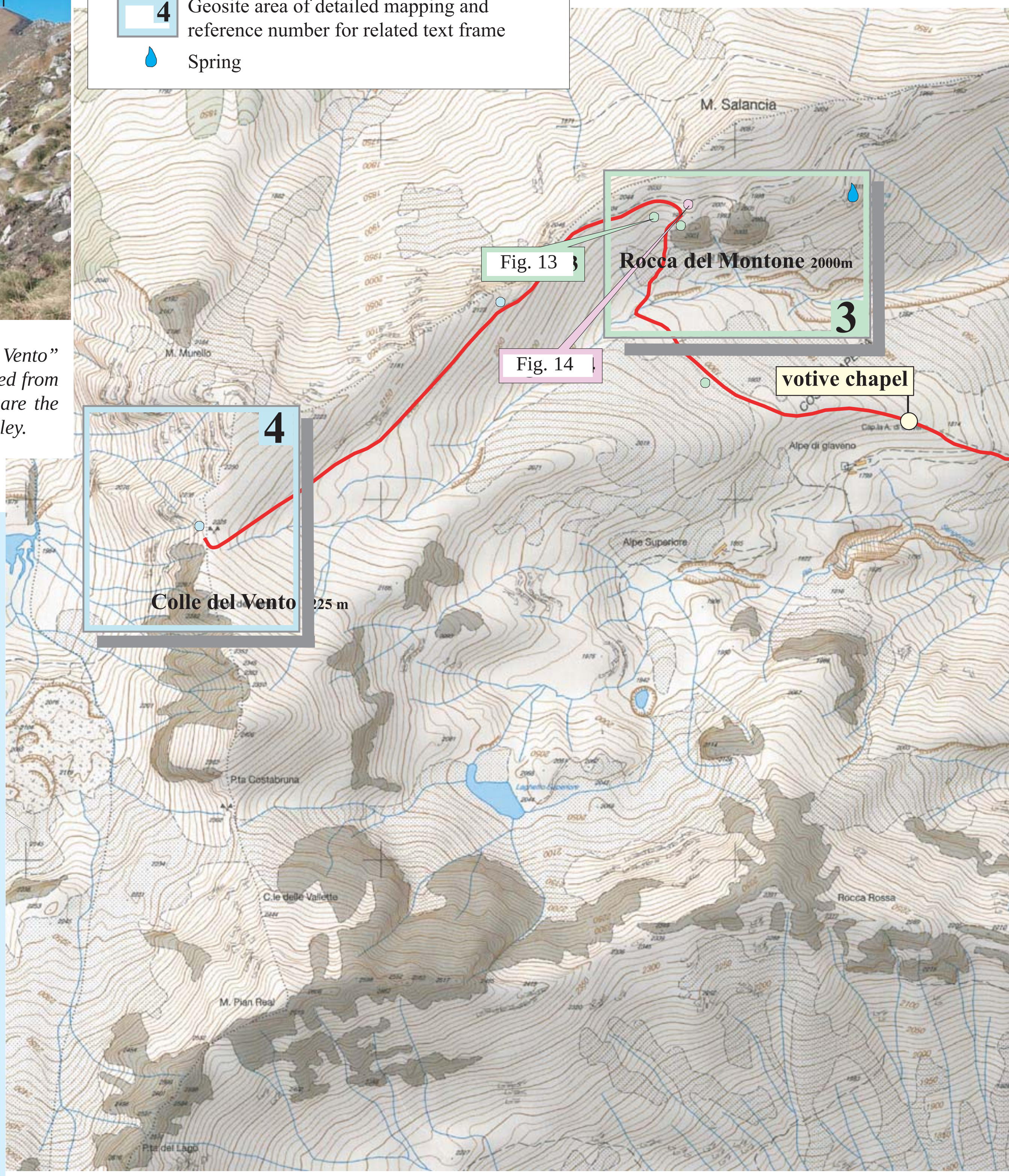
**Anthropic elements, route tracks and "tools" for understanding informations**

Hereby are listed man-mada features and other information have proven to be of interest for the route. This section also describes cartographical and graphical elements created as a halp to orientation in the area and as a link between the informations included in text and pictures attached to the map.

- **EASY ROUTE TRACK**
- **EXPERT ROUTE TRACK**
- Observation point and reference number of related figures (**Figure 14**)
- Geosite area of detailed mapping and reference number for related text frame (**4**)
- Spring

## ROUTE MAP OF THE SANGONETTO VALLEY

## GEOSITES 3 and 4



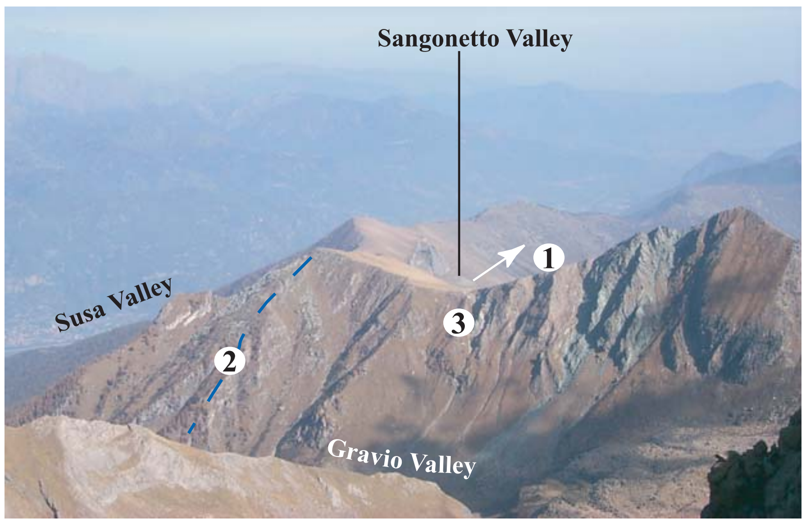
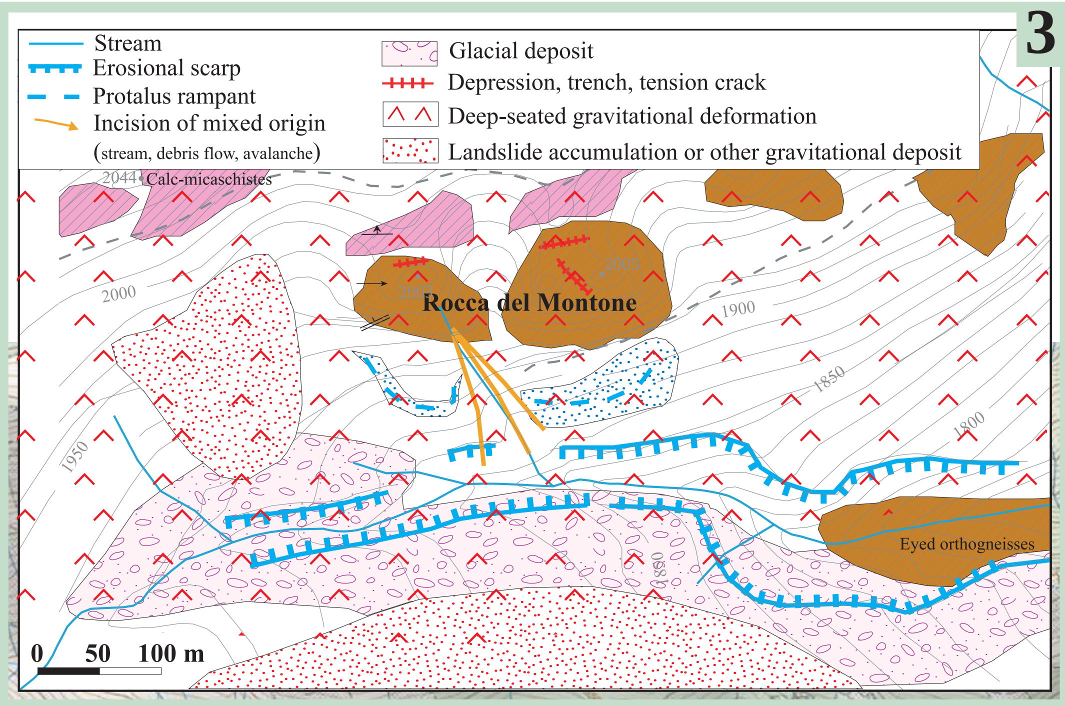




Fig. 20 – *The present Gravio-Sangonetto watershed view from the west side of the Gravio Valley.*

## GEOSITE 3: ROCCA DEL MONTONE



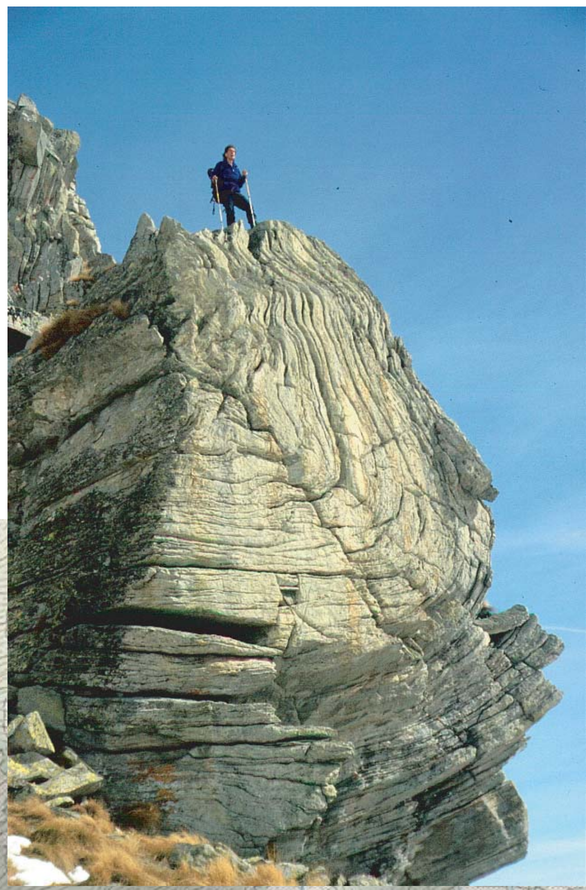
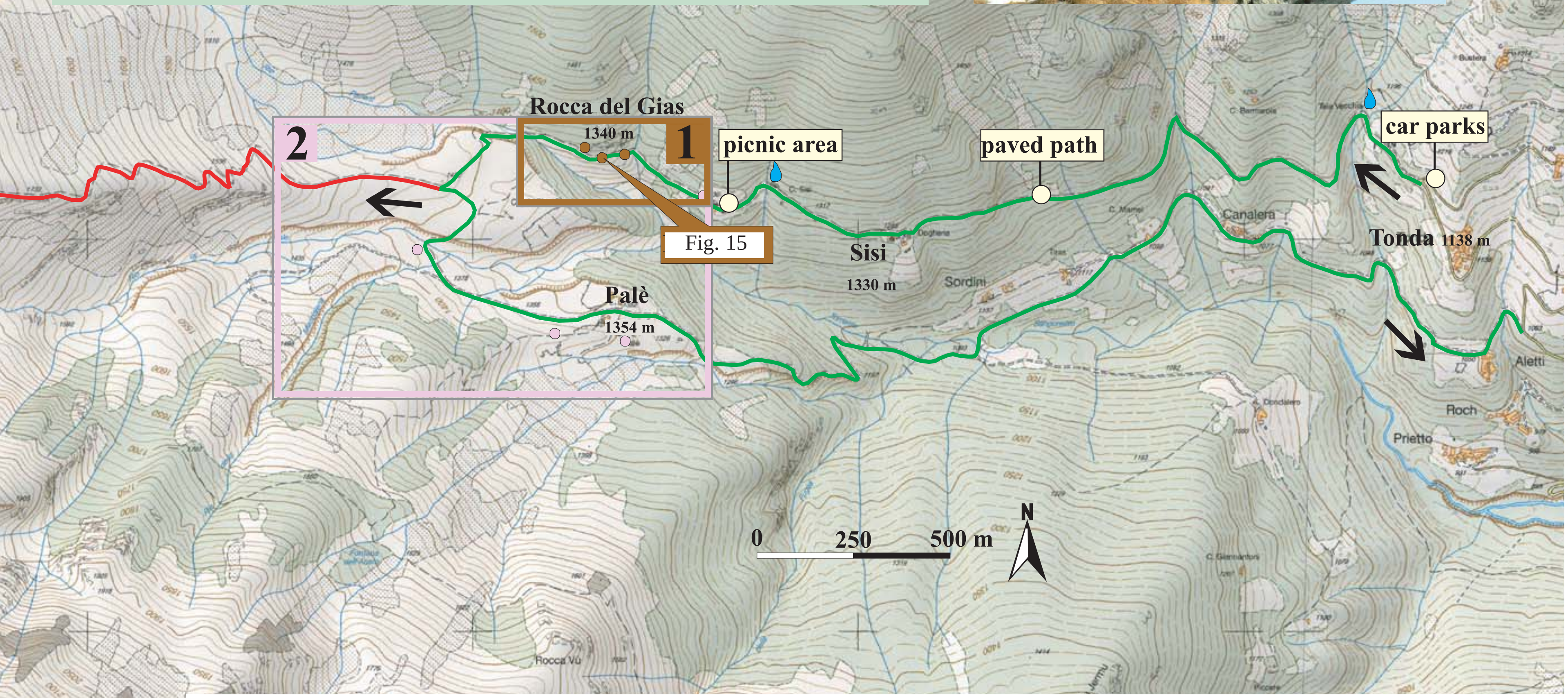
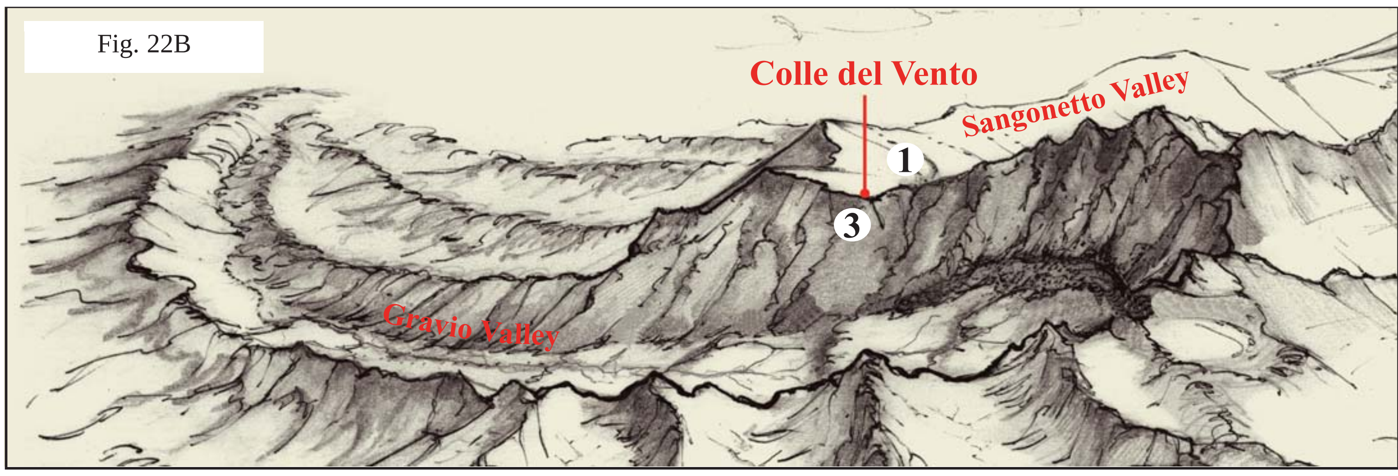
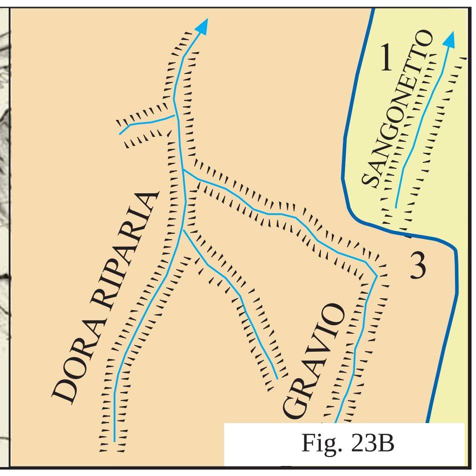



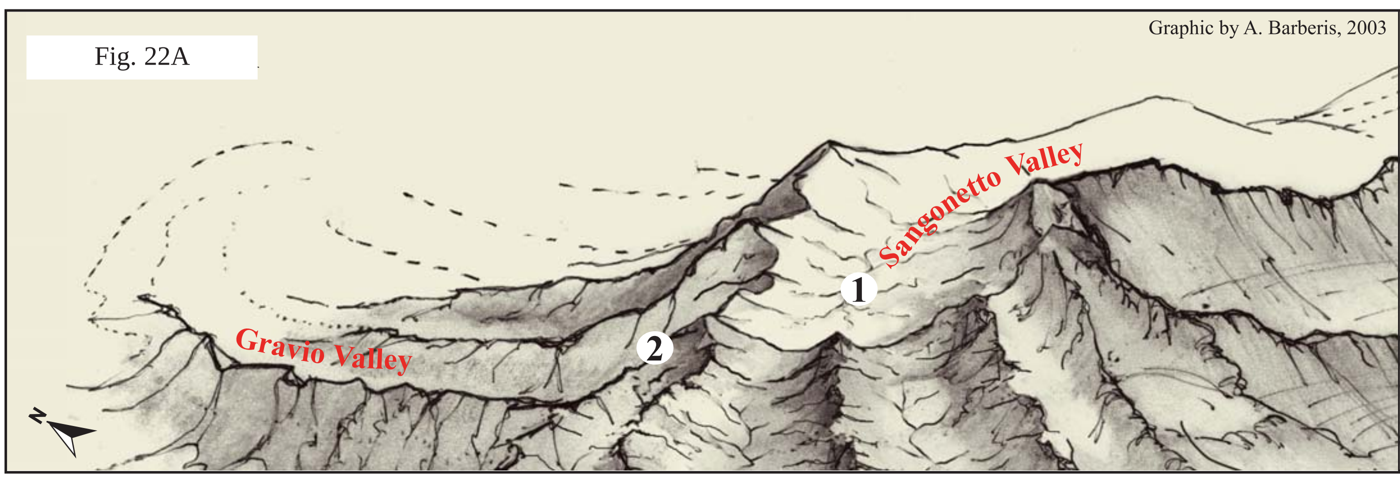
Fig. 21 - *Peculiar rockface in which various tectonic deformations can be seen, connected to the oldest geological history of the investigated site and tied to the formation of the Alpine range: from folds ("ductile" mechanical behaviour) to faults ("brittle" behaviour).*

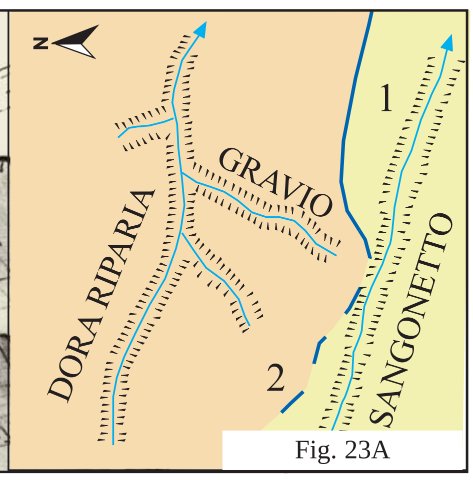



## GEOSITE 4: COLLE DEL VENTO



## CONCLUSIONS

The peculiar characteristics of the Sangonetto Valley (large variety of rock units from different palaeoenvironmental, structural and metamorphic contexts; present-day highly dynamic geomorphological environments and anthropic territories) have made possible the development of geological/educational products (Fig. 24) accessible to the public and managing institutions, with the aim of promoting environmental awareness.

The production of an experimental thematic cartography for geological tourism necessarily required a mediation between the thoroughness of scientific research and the need for simplicity for the purposes of accessibility. The tools used to achieve this purpose were: detailed field surveys, advanced digital cartography and computer graphics techniques, as well as the use of color and text matching as part of a general communication strategy.

The resulting Map of the Sangonetto Valley Geosites, already produced in a trial version which was presented to visitors and officers of the Orsiera-Rocciavrè Regional Park, makes it easier for excursionists to "read" the landforms of the mountains and to understand both their current and recent evolution and dynamics and the lithostructural conditioning resulting from their ancient or recent geological history.

This Map can be considered to be part of the development of an appropriate "global" strategy for the study and exploitation of natural environmental resources, and could therefore comprise a tool for the promotion of an "alternative", environmentally-friendly brand of tourism, able to promote awareness in this respect.

The research methods used for the Map of the Sangonetto Valley Geosites, and some examples of its applications, show how the conditions exist to promote the success of geosite preservation projects and develop their accessibility for the purposes of tourism. This basically means developing promotional activities that are strongly grounded in a thorough knowledge of the elements, the processes and the factors affecting the environmental system, supported by appropriate theoretical elaborations, methods and instruments to make scientific content accessible to the public.




Fig. 24 - *Examples of geological/educational products along the Geosites' Route of the Sangonetto Valley. Information boards at the Palè's moraine amphitheatre (a) and at the starting point of the Geosites' Route (b). Close view of a low-standing board (c) and its position aside of the path (d).*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