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MANAGEMENT OF GEOMORPHOSITES IN HIGH TOURIST VOCATION AREA: AN EXAMPLE OF GEO-HIKING MAPS IN THE ALPE DI FANES (NATURAL PARK OF FANES-SENES-BRAIES, ITALIAN DOLOMITES)

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Abstract: *Management of Geomorphosites in High Tourist Vocation Area: an Example of Geo-Hiking Maps in the Alpe Di Fanes (Natural Park of Fanes-Senes-Braies, Italian Dolomites)***.** Hiking tourism, which combines sport activities and appreciation of Nature, is today one of the main economic activities and among the markets that will experience a great increase in the near future. This paper illustrates a methodology to develop a thematic map, the “geo-hiking map”, which emphasises only the landscape elements that the tourist can recognise and observe, as well as the possible hazards. The geo-hiking map derives from the combination between the geo-tourist map and the geomorphological-hazard map: the first one is a map of geomorphosites enriched with useful indication for tourists (signed paths, refugees, camps etc.); the second one shows hazard levels of different landslide types, snow avalanches and floods. A prototype case study has been chosen within the Natural Park of Fanes-Senes-Braies (Dolomites, Italy). The area has a strong hiking-tourism vocation thanks to its spectacular high-mountain landscape and a dense network of hiking tracks. This innovative study could represent an important instrument for a responsible and safe fruition of high-mountain tourist areas: it combines a cultural dimension of the geomorphological landscape with a conscious respect of its natural behaviour.

Key words: geo-tourism, geomorphological hazards, geomorphological assets, geo-hiking maps, Italian Dolomites

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1. INTRODUCTION

Tourism is the largest economic sector in terms of earnings and in number of people employed among Alpine areas. The hiking tourism, which combines sport activities and appreciation of Nature, is among the markets that will experience a great increase in the near future.

Recently in Italy, like in many other countries, numerous scientific and legislative initiatives have demonstrated an increasing interest towards the geological heritage and the development of a sustainable tourism. Particularly interesting is the "Recommendation Rec (2004) 3 of the Council of Europe on conservation of geological heritage and of areas with special geological interest" (adopted by the Committee of European Ministers on May 2004) and the recent "European Manifesto on Earth Heritage and Geodiversity". In particular, as it is stated in this last document, "Earth Heritage and Geodiversity create opportunities for education, recreation and tourism. [...] Geological landscapes and sites, by themselves or in combination with their cultural, historical and ecological heritage, offer potential for sustainable tourism, education and landscape appreciation".

In this sense, it is a priority of tourism to preserve the assets which its activities are based on, developing itself coherently with the principles of “sustainability”, i.e. answering the needs of present generations without endangering the capacity of future generations to answer their own ones. In fact, the ever-growing consolidation of this kind of tourism places the areas with a high tourist vocation in front of an important challenge: environmental sustainability. As it is defined by the Word Tourism Organization (2004), sustainable tourism should make optimal use of environmental resources, respect the socio-cultural authenticity of host communities, and ensure viable, long-term economic operations, providing socio-economic benefits to all stakeholders.

The issue of sustainable and responsible tourism can be tackled, with good hopes for success, by favouring an easy understanding and comprehension of the landscape and of its hazards. Therefore, only this cultural and multi-spectral approach can guarantee an aware fruition which could be knowledge-based and continuous in time (Panizza & Spampani 1989). This approach represents the most correct mean of awakening public opinion to environment, an unquestionable premise for a correct and safe fruition of environment itself. At the same time, it represents a solid mean to implement and stimulate the need of knowledge of the different environmental components that our society has cancelled from the population’s (and therefore the tourist’s) priority requests.

This paper illustrates a methodology to develop a geo-hiking map. This kind of map will emphasise only the landscape elements that the tourist can recognise and observe as well as the possible hazards that could interfere with the hiking paths: it will therefore allow users to better appreciate the geological-geomorphological features of the surrounding landscape. In particular, the area chosen to explain the first application of this kind of map, the Alpe di Fanes, is characterised by high relief energy, mainly due to the presence of lithologies such as dolomites and limestones. In addition, the morphology is particularly suitable for this educational and tourist purpose, since in the Upper Pleistocene it was affected by intense modelling processes due to the alternation of different agents: glaciers, cryoclastism, landslides, debris flows (to cite the most important ones) that have occurred in different morphoclimatic systems.

2. THE CASE STUDY

The paper has taken the Alpe di Fanes study area (fig. 1) as a methodological example of geo-hiking map, which is likely to be produced in the framework of a joint tourist-valorization project between the University of Modena and the Administration of Fanes-Senes-Braies Regional Park (Dolomites, Italy).

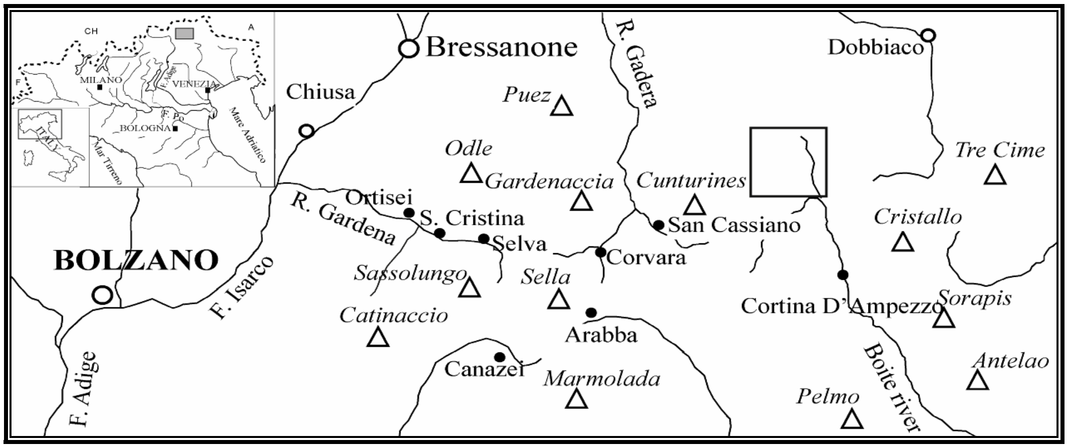

Figure 1. Geographical outline of the study area

The study area is some 10 km² and it lies within the Alpe di Fanes (Eastern Dolomites). It covers the Parom valley, the Conturines valley and some portions of the Fanes and Medes valleys. Characterized by elevations from 2200 m to 3064 m, it is reachable through hiking paths both from Santa Croce's pass and from Fanes and Rudo valleys. From north to south it is possible to get an overview of the following mountain peaks: Mount Stiga (2786 m), Parom Peak (2953 m), Lavarella Peak (3055 m), Taibun Peak (2928 m) and Mount Conturines (3012 m). Precipitations are represented by storms in summer and by heavy snowfalls in winter. The drainage network is rather irregular, formed by gullies and rills active during strong rainfalls and during the melting season.

The area has a strong hiking-tourism vocation thanks to its spectacular high-mountain landscape and a dense network of hiking tracks. The well developed network of hiking paths and slopes for many different climbing skills offer a lot of possibilities for high-mountain excursions and back-country skiing. Permanent dwelling-places are absent with the exceptions of a few tourist structures nearby opened during certain periods of the year.

2.1. Geological setting

The rocks outcropping in the area are mainly sedimentary rocks which formed from the Upper Triassic to the Jurassic. They are represented by stratified dolomites, grey and red limestones. The principal geological formations outcropping in the area are shortly described hereafter (Bosellini 1996; Bosellini et al. 1996; Sauro & Meneghel 1995).

Dolomia Principale (Upper Carnian – Norian)

It is a thick, thin-bedded formation, forming the majority of the eastern dolomitic massifs. The thickness ranges from 300 m to at least 1500 m in the most subsiding regions. It is characterized by sequences of well stratified stromatolitic dolomites and more massive dolomites, the latter formed in deeper waters and rich of Megalodons. Together with the *Calcari Grigi di Fanes*, it is the most extensive formation of the area.

Calcari Grigi di Fanes (Norian – Rhaetian)

It is a series of micritic limestones characterized by thin strata. Sometimes they are rich of fossils such as brachiopods, lamellibranchs, crinoids and echinoids. They are often composed by oolites, sediments generally forming in shallow tropical waters. They extensively outcrop on top of the Alpe di Fanes.

Rosso Ammonitico (Bajocian – Tithonian)

This formation is made of red and nodular limestones deposited in thin layers in deep sea waters. The limestones can contain stromatolites some centimetres thick, abundant ammonites, foraminifera and a few echinoderms. Their extent is quite limited in the study area.

2.2.Geomorphological characters

The geomorphology of the area (Sauro & Meneghel 1995) is the result of different morphogenetic agents that have acted in shaping the landscape throughout time (fig.2). Tectonics has strongly folded the sedimentary sequences of limestones and dolomites, generating large synclines and anticlines, but also chevron folds and kink bands whose extent can be sometimes traced for several hundreds of meters. Thrusts have generated high structural scarps and monoclinal relieves.

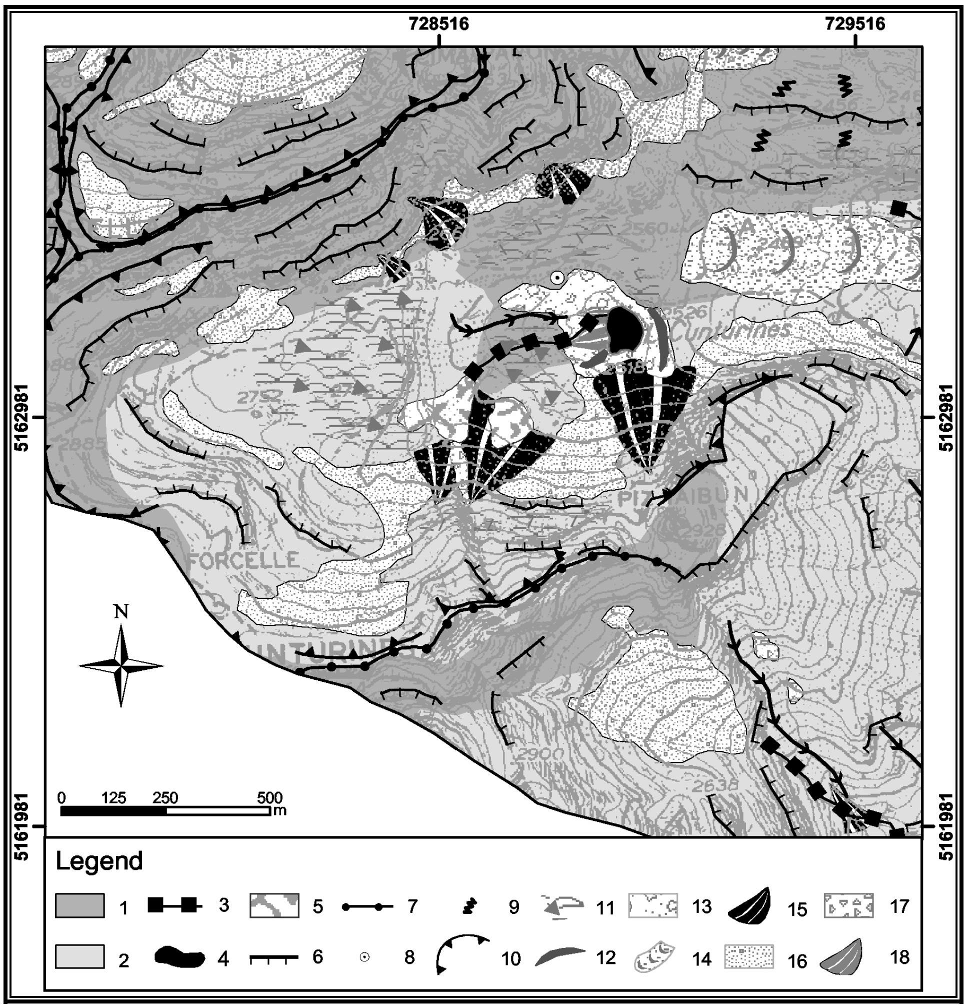

Figure 2. Geomorphological sketch of the Conturines valley.

Legend: 1) Calcari grigi di Fanes (bedrock); 2) Dolomia Principale (bedrock); 3) Conturines stream; 4) Conturines lake; 5) Permanent snowpack; 6) structural scarps 7) mountain edge; 8) doline; 9) karren; 10) edge of glacial cirque; 11) roche moutonné; 12) morainic ridge; 13) till; 14) rock glacier; 15) debris cone; 16) scree slope; 17) rock fall deposit; 18) alluvial fan.

Depending on the lithology, different litho-structural forms have developed: dolomitic outcrops have been highly fractured under tectonic pressure, developing large and deep channels that cut through the massifs and a dense network of several fracture systems that amplify cryogenic processes. Limestones have been mainly subject to karst processes that created wide surfaces sculptured by karren (mainly solution runnels and toothed blades), specially on top of structural surfaces of strata, but also on roches moutonnées and on landslide blocks. Valley glaciers have left their clear signs starting from the Lateglacial, with frontal moraines, scattered drift, roches moutonnées, glacial lakes and depressions of glacial erosion, the latter reshaped most of the times by karst action.

Periglacial processes are testified by some inactive rock glaciers, protalus rock-glaciers and protalus ramparts, accumulations of cryoclastic debris forming cones and scree slopes, sometimes smoothly reshaped by snow-avalanche activity.

Gravitational processes have acted since the end of the Lateglacial, when the pressure released after the melting of the glaciers has favoured the collapse of huge rock masses, already fractured by tectonics and quarried by glacial erosion. Collapses have mainly occurred on steeply inclined monoclines, along surfaces of strata, creating block slides that in cases could have evolved into rock avalanches: the latter testified by huge accumulations of large blocks far away from potential source areas, but not as scattered as the glacial drift appears.

Active processes are represented by widespread karst solution and by rock falls, the latter along all crest lines and at fractured steep monoclines. Potential topplings may occur at places where structural slopes coincide with the sub-vertical limb of a fold.

3. METHODOLOGY

The workflow that leads to the creation of a geo-hiking map is composed by different steps as it is shown in figure 3.

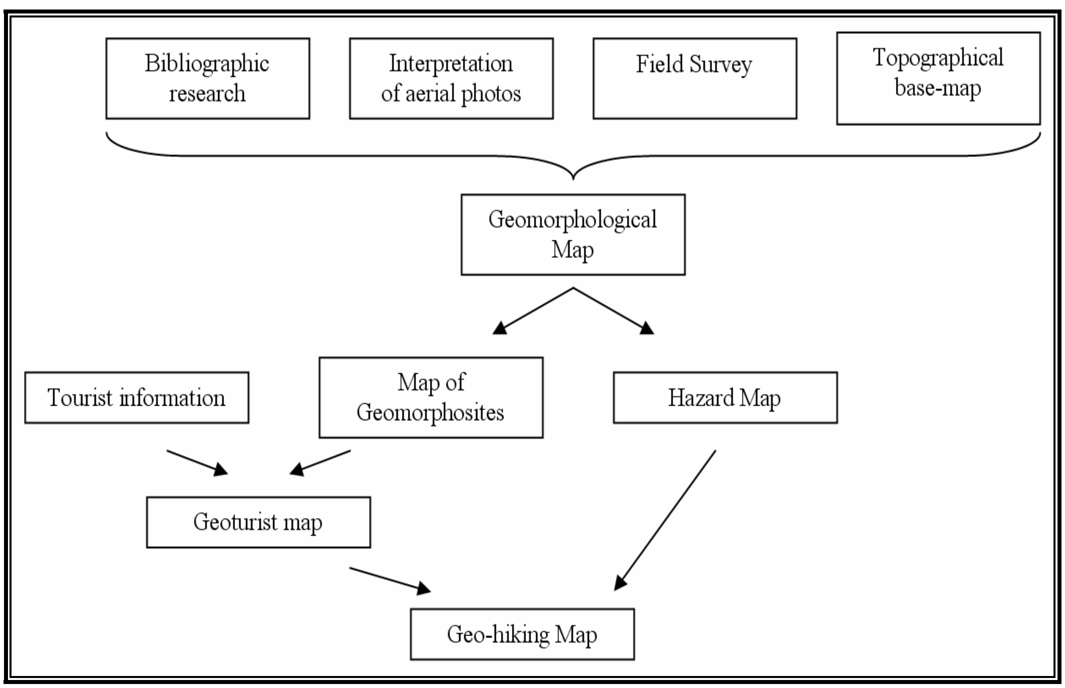

Figure 3. Methodological flowchart to build a geo-hiking map

The main step to build a geo-hiking map is a detailed field mapping that allows to identify the principal geomorphological elements which can be later organized into a geomorphological database using a GIS software. Geomorphological field-mapping is undertaken using a topographical base-map at the 1:10.000 scale and following the geomorphological-mapping guidelines developed by the *Gruppo di lavoro per la Cartografia geomorfologica* (Working Group for Geomorphological Cartography) of the Italian Geological Survey (1994). According to those guidelines, geomorphological forms and processes are drawn on a simplified geological map using symbols and colours that identify their genesis and state of activity. Previously to mapping, a bibliographic study and the interpretation of aerial photographs and digital ortho-photographs are fundamental to get a first insight into the geomorphological characteristics of the area and to help the surveyor organize the field-mapping campaign. The aim of the mapping campaign is to identify and outline all geomorphological forms and processes, assessing their genesis and their state of activity: this represents the core for all further analyses and representations, functional to different purposes.

First of all, the geomorphological map may lead to reconstruct the geomorphological evolution of the area: forms and processes typical of past morphoclimatic conditions may share the stage with forms and process active in the current morphoclimatic conditions; their spatial and geometrical relationships may be sufficient to trace a relative time-line of the geomorphological history of the area. That history represents an important piece of information to be properly translated and explained to hikers: as cities are visited by tourists thanks to their historical heritage (monuments etc.), also the landscape has its own historical heritage (geosites and geomorphosites) to be discovered, understood and therefore appreciated. Therefore, the most representative geomorphosites (geosites with a geomorphological character) are selected from the geomorphological map and represented on a specific thematic map: the map of geomorphosites, that is then enriched with usual indications for tourists giving as output a so called geotourist map.

Secondly, landscapes, and particularly high mountain ones, may have forms and processes that represent potential hazards for human beings: already identified as part of the geomorphological map, their frequency of reactivation and magnitude must be assessed and properly represented on a specific map, serving as behavioural indication to hikers. The geomorphological-hazard map considers mainly phenomena with high velocity (like rock falls, debris flows etc.), more significant for an intermittent vulnerability like the one given by the passage of hikers. The frequency of reactivation and magnitude of the hazardous phenomena can be assessed on the basis of direct geomorphological evidence and, when possible, from the output of statistical and/or cinematic models.

The geo-hiking map will be a leaflet which derives from the overlay of the geotourist map and the hazard map. In this cartographic document the interpretation of geomorphological sites is aided by the use of photographs, simple sketches and short simple explanations; behavioural indications to hikers, concerning the interpretation of geomorphological-hazard attributes, are given using symbols similar to road signs.

4. APPLICATION AND PRODUCTS

4.1 The map of geomorphosites

The proper way to start with the making of the geo-hiking map is to use the geomorphological map (Fig. 2) and identify those forms, or associations of forms, which can be assessed as geomorphosites. Geomorphosites are part of our natural heritage, which also belong to our cultural heritage. According to the definition given by PANIZZA (2001), a Geomorphosite is a landform with particular and significant attributes which qualify it as a component of the cultural heritage (in a wide sense) of a given territory. Attributes which can confer value to a geomorphosite are the scientific, cultural (in a strict sense), socioeconomic and scenic ones. Therefore, following that definition, Geomorphosites make up the landscape, habitat, elements of geodiversity, knowledge of the dynamics of the Earth's past, memory of biological evolution and Man's life from its very beginning, and essential resources for economic and scientific development. From a scientific point of view - the only attribute taken into account in this study - the importance of a geomorphosite may be assessed on the base of tree characters (Panizza 1996):

1. model of geomorphological evolution;
2. object used for educational purposes;
3. paleogeomorphological example.

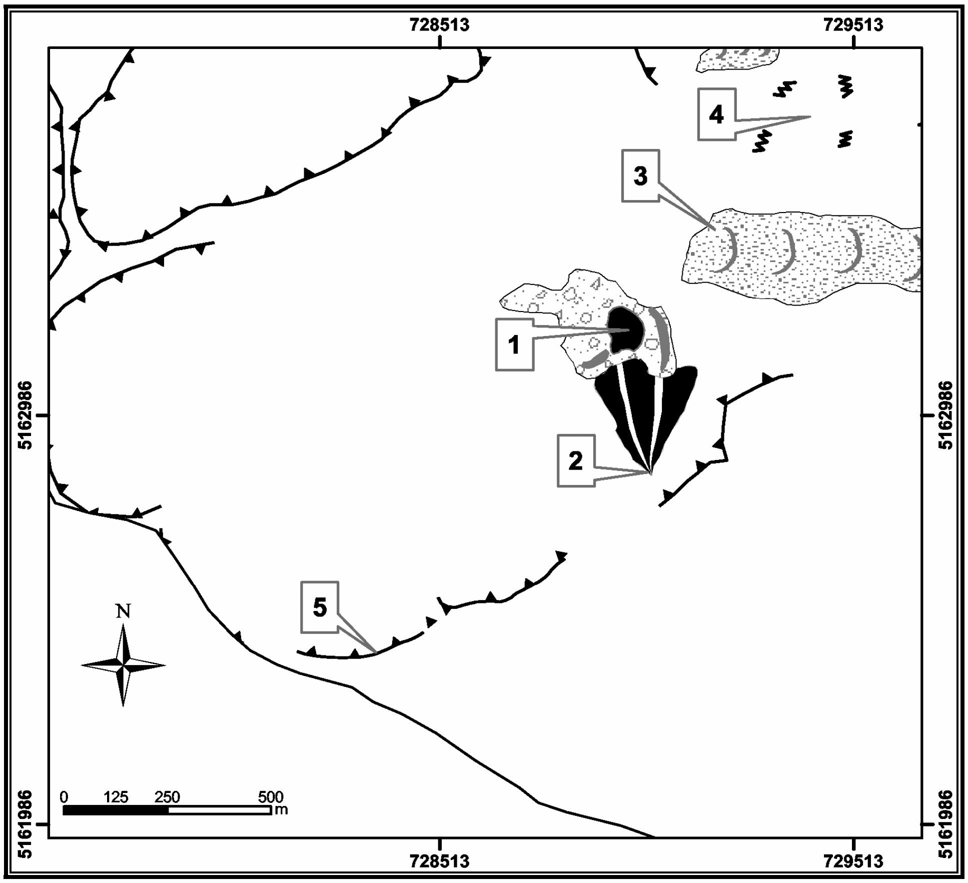

Figure 4. Sketch of the map of geomorphosites of the Conturines valley.
Legend: 1) lake of glacial origin, surrounded by till and frontal moraine; 2) debris cone; 3) rock glacier; 4) karren; 5) edge of glacial cirque.

Geomorphosites can occur singly or in groups and their outlines can take various forms and trends. In cartography, geomorphosites can be represented by three geometries: polygons, lines and dots. A polygonal geomorphosite is made up of a set of simple two-dimensional forms, such as a moraine amphitheatre. A linear geomorphosite is made up of one or more simple forms developed preferentially in a single direction, such as a canyon. A punctiform geomorphosite is a single form or object, for example, a pothole or an erratic boulder (Carton et al. 2005).

In the assessment of geomorphosites, a strong relevance has been given to educational aspects: this because the geo-hiking map has been thought particularly for a wide and not specialized public. Processes and landforms representing the past and present geomorphological evolution of the area have been preferred because they are quite easily explainable to people and they capture their interest.

For deriving the map of geomorphosites (fig. 4), the most representative geomorphosites are selected from the geomorphological map and represented on a thematic map with their specific geomorphological symbol (i.e. scarp, ridge, moraine) and pattern corresponding to their morphogenetic type (i.e. fluvial, glacial) and activity.

Figure 4 shows a sketch of the map of geomorphosites, on purpose drawn without topography to enhance the geomorphology: the geomorphological symbols have been limited to the representation of the single forms that, together, identify the geomorphosites.

4.2 The geotourist map

The map of geomorphosites is then enriched with usual indications for tourists: signed paths, refugees, camps, springs etc. Tourist information will be represented by using conventional symbols for identifying nature and accommodation sites. Observation points, from where is possible to better appreciate the geomorphosites, are also added together with simple, but exhaustive scientific details and photographs (Castaldini et al. 2005).

The geotourist map guides the hikers through the most spectacular geomorphosites, following existing paths found also on usual hiking maps. To help the tourist to better understand what he is looking at, panoramic photographs have been shot from the paths and, using a simplified symbology, modified in order to highlight the landforms, which are then described with an easy scientific language.

4.3 The hazard map

The evaluation of hazard – that is the "probability that a certain phenomenon of geomorphological instability occurs in a certain place within a certain time period" (Panizza 1987) – represents a starting point for the evaluation, management and prevention of risk and, ultimately, for the development of a correct, safe and enduring tourism.

The methodology applied in this study to assess the geomorphological hazards derives from the one suggested by the Bundesamt fur Umwelt, Wald und Landschaft (Heinimann et al. 1998), that was developed for the Cantonal Pilot Plans in Switzerland and adopted by the Autonomous province of Bolzano (Italy).

This specific approach allows to take into account the fundamental components for the assessment of hydrological hazard: the typology of the phenomenon, its spatial, temporal and kinematic components. Afterwards, it allows to assess the hazard combining those components through pre-defined matrixes. The approach considers different typologies of instability phenomena: different landslide types, snow avalanches and floods.

Hazard levels result from the combination of the kinematic attribute with the temporal one within the combination matrix and they depend uniquely on the phenomenon itself, independently from the typology of the possible elements at risk (fig. 5). Three hazard levels are identified through this methodology: high, medium and low.

Hazards within the study area are represented mainly by rock-falls and debris-flows, both connected with the abundant production of cryoclastic debris, favoured by the dense fracture systems affecting the thin-bedded dolomitic outcrops. Rock-falls build scree slopes and talus cones while debris-flows are currently cutting through the cones they have built during different past environmental conditions.

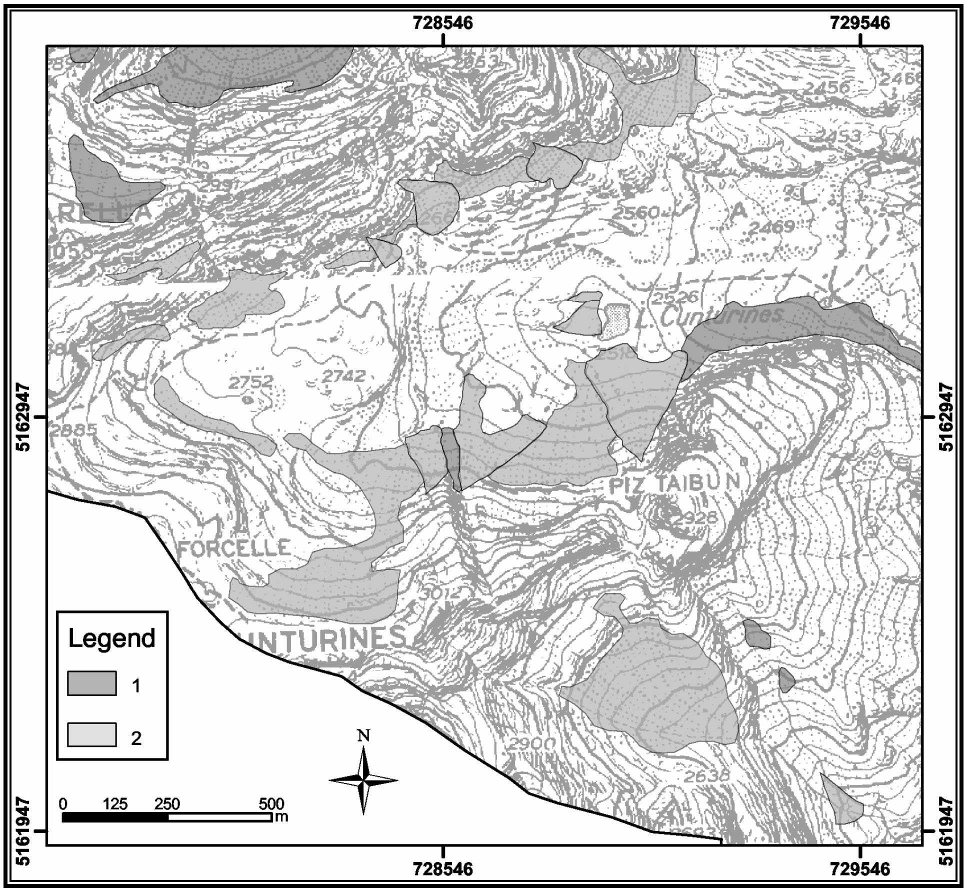

Figure 5. Sketch of the hazard map of the Conturines valley.
Legend: 1) High hazard level; 2) Medium hazard level.

4.4 The geo-hiking map

The geo-hiking map derives from the combination between the geotourist map and the geomorphological-hazard map.

Since only geomorphologists have the scientific background to assess what is a geomorphosite and what is not, they have the duty to translate to hikers, with simple terms, the reasoning behind their assessment. Only this translation from strictly-scientific terms to more common ones can drive hikers to go and have a closer look to what they would have otherwise missed. Translating may sound rough and somehow mysterious, because economy of words, specially on a map, is a duty. As a counterbalance, it is therefore necessary to enrich the text with simple drawings that must complete the mysteriousness left by words.

An example can be given considering the signs left by the glaciers, which are certainly one of the most spectacular and valuable sets of geomorphosites of the area (fig. 4). A simple description of what cirques are can be the following: glacier cirques are usually surrounded by rock walls with an amphitheatre-like shape, partly covered by debris cones, with a small lake and a frontal moraine. Still well preserved, those cirques represent the evolution of valley heads from the Lateglacial until now: the frontal moraine marks the ultimate retreat of the valley glacier, the lake could form in a hollow created by the glacial erosion and dammed by the frontal moraine, while frost action in tectonic fractures has been producing debris that still feeds the cones laying at the foot of gullies. Hikers may want to know what “Lateglacial” is: this could be represented by the drawing of a timeline, with dates and symbols of the main glaciations. They may want to know how a frontal moraine forms: one can use for instance the classic drawing of a bulldozer that pushes an earth heap. Finally a clue of how frost and thaw act to give debris cones may be represented with the volume increase of water frozen within a crack in the rock.

Every path segment gets a specific symbol that corresponds to a particular type of possible hazard and gives the hiker appropriate behavioural suggestions. Since those symbols mainly represent attention signs and/or prohibition signs, an eye-striking representation could be adopted from road signs: red triangles pointing to potential hazards, red circles indicating what behaviour is better to avoid. Another indication that should be added is represented by the meteorological conditions that are thought to favour certain hazards (like storms etc.). In order not to fill the output map with too many symbols, hazard signs can be placed just at the two ends of an hiking path which is particularly subject to a certain type of hazard and, in case, highlighting also the path with a peculiar colour or pattern (fig. 6).

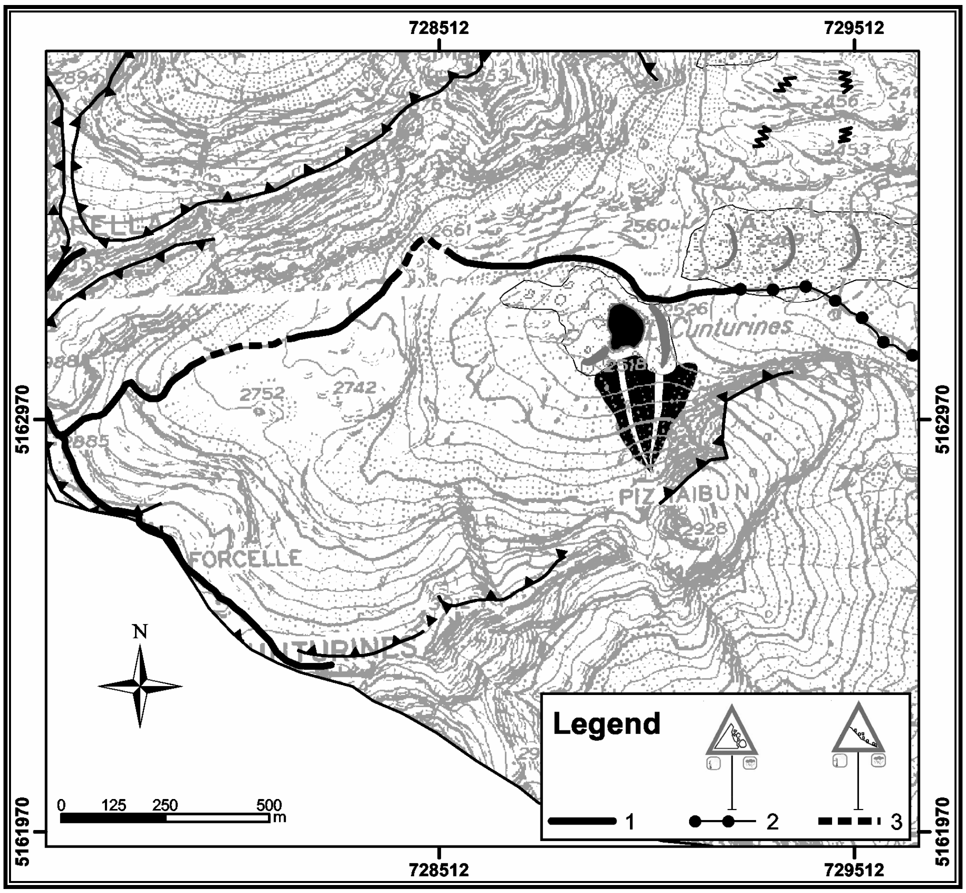

Figure 6. Sketch of the geo-hiking map.

Legend: 1) hiking path; 2) part of hiking path potentially subject to rock falls; 3) parto of hiking path potentially subject to debris/rock slides/bouncings. Special symbols under hazard signs help tourists understand under which meteorological condition(s) those hazards may occur. Due to the lack of space, hazard and meteorological symbols have been restricted to the legend area, although in the geo-hiking map they should be more properly placed at the two ends of each path under hazard. For the symbols of geomorphosites, see fig. 4.

CONCLUSION

The ever-growing consolidation of hiking tourism places the areas with high tourist vocation in front of an important challenge: environmental sustainability. The issue of sustainable and responsible tourism can be tackled, with good hopes for success, only by favouring an easy understanding and comprehension of the landscape and of its hazards. Spreading knowledge through maps can be particularly effective since they use an international language which is easily transmittable and cannot be misunderstood.

Starting from these remarks we have realized this innovative prototype study in order to propose methodological guidelines for the elaboration of a geo-hiking map. This document, an important instrument for favouring a responsible and safe fruition of high-mountain tourist areas, combines a cultural dimension of the geomorphological landscape with a conscious respect of its natural behaviour. It has to be underlined that its graphical representation has to be adapted according to the extent of the study area, the scale, the density of spatial information and printing costs. In this paper the representation has been adapted to black and white only in order to follow the journal printing format.

The paper has taken the Alpe di Fanes study area as a methodological example of geo-hiking map which is likely to be produced in the framework of a joint tourist-valorisation project between the University of Modena and the Administration of Fanes-Senes-Braies Regional Park.

The map could be considered as a powerful means of communication, which should spread awareness of geoconservation among the general public. Spreading knowledge through maps can be particularly effective since they use an international language which is easily transmittable and cannot be misunderstood (Carton et al. 2005). Moreover, it tries to aid the understanding and appreciation of geomorphological forms and processes under their double aspect: geomorphological sites and hazards. In fact the map could be an adequate tool to identify potential-risk areas and to develop an appropriate educational document for tourists, aiming to show correct behaviour in risk situations.

We think that proper knowledge of the territory around us is indispensable to favour its correct management and appraisal: only by means of in-depth analyses and investigation it is possible to identify and develop new planning and management strategies directly involving local communities.

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