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REVIEW ARTICLE

Digital Tools for Collection, Promotion and Visualisation of Geoscientific Data: Case Study of Seguret Valley (Piemonte, NW Italy)

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Abstract The work presented here forms part of a cultural and scientific context for the continuous improvement of computer sciences to support geological and geomorphological research, by allowing the development and application of specific tools and innovative methodologies. Cooperation between the Regional Museum of Natural Sciences of Torino and the Department of Earth Sciences of the University of Torino has facilitated the development and implementation of a methodology aimed at the identification and evaluation of the geological and geomorphological heritage of the Piemonte region. The methodological steps applied are described in full in a case study of Seguret Valley (Piemonte, NW Italy). The employment of geomatic tools, such as digital photogrammetry, geographical information systems (GIS) and global navigation satellite system (GNSS), has allowed the production of a geomorphological map of the area and the identification, listing and selection of the most representative and important sites. Terrestrial laser scanner (LiDAR), although currently used for demonstration purposes, has the potential to be used in the identification of potential risks associated with the enjoyment of the site by the public. Web Mapping tools based on GoogleMaps© architecture have also been set up for the web dissemination of geoscientific information—appropriately simplified without prejudicing accuracy—in enable as broad an audience as possible to be reached.

Keywords GNSS · Mobile GIS · Database · Internet mapping · Google Maps

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Introduction

Over recent years, a rapid series of technological innovations have allowed a very fast development of more and more powerful and affordable hardware and software. Geomatic, i.e. the study of an area with computer technology, has greatly benefited from this evolution. The availability and accessibility of powerful and sophisticated geomatic tools has introduced radical changes in the field of landscape analysis, and they can now be considered as essential tools for these types of studies. One of the most innovative aspects concerns the use and the integration of information from different sources, for improving both the static and dynamic interpretation of the different aspects of an area, in order to achieve increasingly real and dynamic representations (Perotti 2007). Similarly to the technological revolution, over the last 20 years, issues related to the management, evaluation and conservation of the landscape have attracted a genuine interest from scientists, media and a general public. The present trend is to consider the physical components of the landscape as its main attractions. As evidence of this, from the early 1990s, there has been a proliferation of research on issues related to different aspect of geological and geomorphological heritage, including: inventory and recognition (Berger and Grandgirard 1996; Giardino and Mortara 1999; Bertacchini et al. 2003; Coratza et al. 2011); assessment (UKRIGS 2001; Pralong 2005; Coratza and Giusti 2005; Bruschi and Cendrero 2005; Serrano and Gonzales-Trueba 2005; Pereira et al. 2007; Reynard et al. 2007); evaluation and information dissemination (Barbieri et al. 2005, Carton et al. 2005; Castaldini et al. 2005; Bailey et al. 2007; Bissig 2008; Ghiraldi et al. 2010, 2012; Martin and Ghiraldi 2011). Developing interest in issues related to geological heritage is evidenced not only by a massive scientific production, but also by an increasing demand from a general public for natural area tourism focused on geological themes, in order that they can discover geosites and understand geodiversity. It is, therefore, necessary before a promotional stage, to investigate the geological and geomorphological conditions which characterise these environments and to identify situations of hazard and risk that a tourist is not always able to deal with (Brandolini et al. 2006, 2011, 2012).

The aim of the work presented in this paper, therefore, is to design a comprehensive methodology for identifying, cataloguing, evaluating, visualising and promoting geoscientific data related to geological heritage, by using geomatic tools. The case study area developed is located in the Seguret Valley in the Western Alps of Italy, within the municipality of Oulx (Turin province). In addition, the area has been selected as a site of geological interest within a European project whose aim is to implement, in the transboundary area between Italy and France, the 'Cottian Alps Geopark project'.

Study Area

The Seguret Valley is a tributary of the Susa Valley in the Western Alps of Piemonte region, at an elevation between 1,050 and 3,217 m above sea level. It faces north–south and is drained by the Seguret River for a length of around 7 km. The main peaks of the area are as follows: Vallonetto (3,217 m), at the head of the valley; Seguret (2,910 m); Vin Vert (2,711 m) and Serre du Kin (2,238 m). The base of the valley, before the confluence with the Susa Valley, is an abrupt rocky step, where the river has shaped an attractive gorge.

The whole area has remarkable erosion landforms with a high scientific interest and a noteworthy scenic impact. It can be divided into three sectors (upper, middle, lower), each having characteristic landforms due to different erosion processes (Fig. 1):

- The upper sector is a wide valley characterised by a sequence of steps, with features related to glacial, karstic and gravitational processes.
- The lowest sector was first shaped by glacial and later by river erosion. The latter is particularly evident at the confluence with the main valley, where a very steep rock step of about 600 m was carved out by the erosive action of the Seguret River.
- The upper and lower sectors are separated by a very steep slope characterised by the presence of large caves commonly referred to as the 'Saraceni caves'.

The geological and structural setting of the area is shown schematically on Fig. 1. It is characterised by the outcrop of several different tectonostratigraphic units: in the eastern sector is the pre-alpine basement of Ambin complex (augen gneiss, metaconglomerate and metapelitic rocks) with overlying Mesozoic cover sequences (mainly quarzite rocks). Overlying the Ambin complex there is the Vallonetto complex (mainly dolomite rocks), which is separated by tectonic contact from the Vin Vert and Valfredda complex (both schist rocks). Near the tectonic contacts, evaporite rocks (gypsum and anhydrites) outcrop. The whole area is displaced by a system of normal faults oriented N 120° E, which have lowered the southern side, displacing the various tectonic contacts.

Methodology

In order to study the geomorphological features of the area, several geomatic tools were used (Fig. 2), allowing a multi-scale territorial analysis:

- Digital photogrammetry;
- Mobile device (pocket PC) equipped with geographical information systems (GIS) mobile software and global navigation satellite system (GNSS) device;
- LiDAR;
- GIS software.

Digital Photogrammetry

Digital photogrammetric techniques together with bibliographic data allowed the definition of a geomorphological framework for the study area and also made it possible to identify the main terrain features and relate them to a wider territorial context. The global planimetric accuracy obtained during the processes of orthorectification was about 2 m, a value that can be considered acceptable when working with a cartographic scale of 1:10.000.

Mobile Device

The use of a mobile device equipped with GIS software and GNSS device fulfilled a triple role:

- Geological and geomorphological survey;
- Identification and recording of geological sites;
- Identification and characterisation of trails to access to identified sites.

Geological and Geomorphological Survey

Whilst investigating faster and more suitable methods for field mapping and data collection, the GeoSitLab (University of Turin, Earth Sciences Department) developed the application 'SRG^2' (an acronym for 'Supporto al Rilevamento Geologico

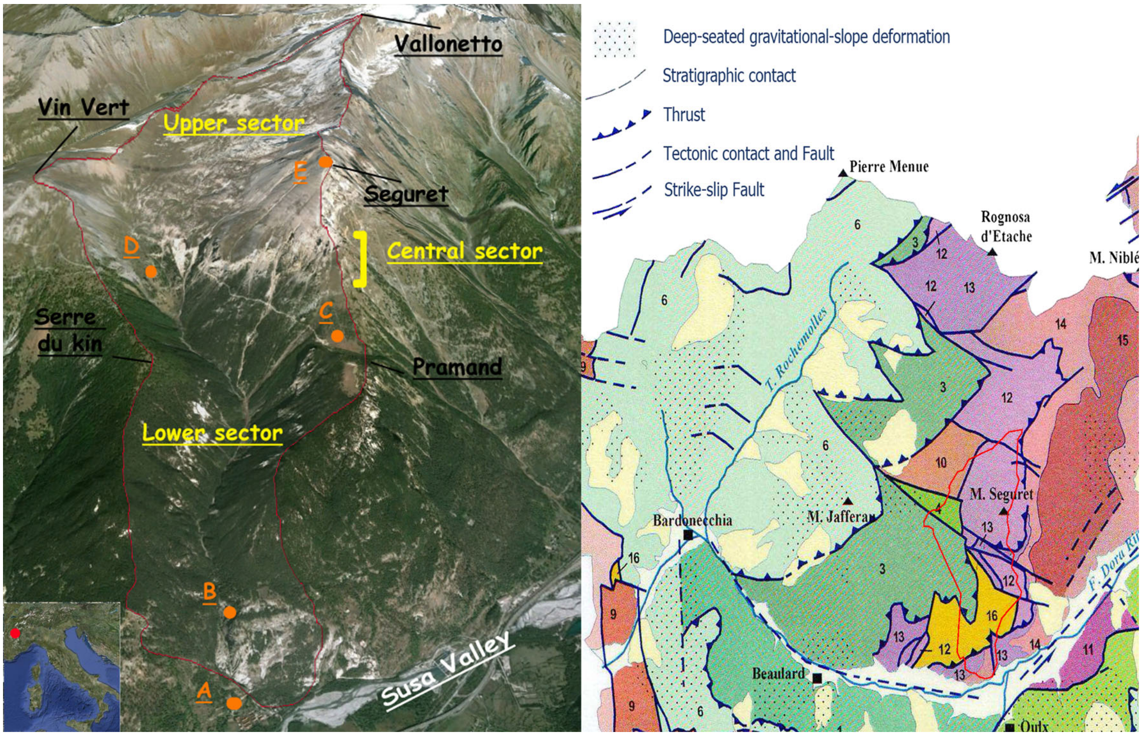
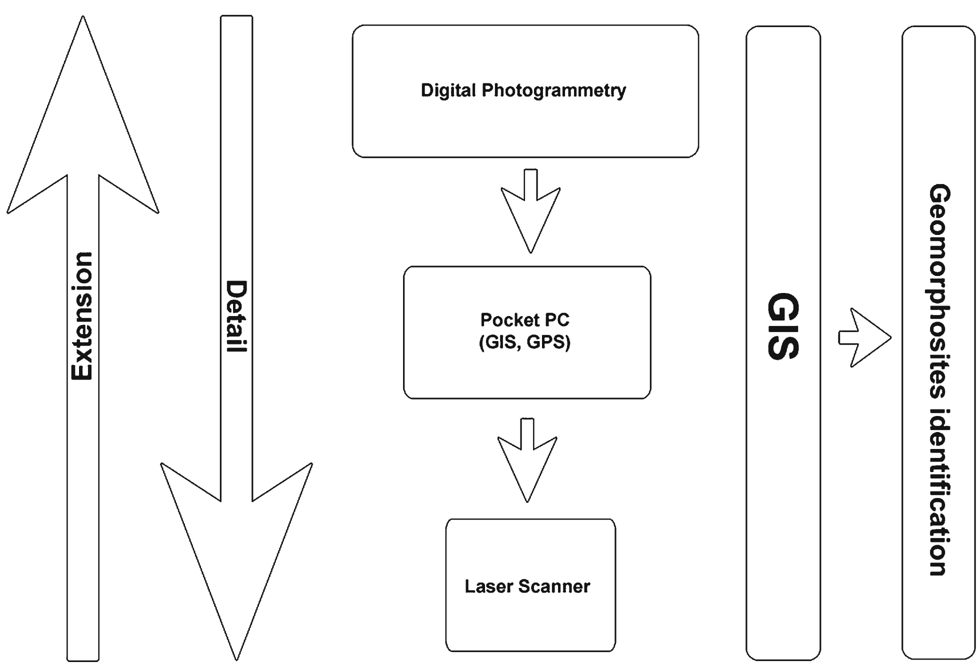


Fig. 1 *Left*: geographical outline of the study area (scale 1:50.000). The *red line* indicates catchment of the Seguret Valley; *orange circles* indicate the location of geomorphosites selected. **a** Beaume Cave; **b** Seguret Gorge; **c** Pramand Pass; **d** Saraceni Caves. **e** Geomorphological landscapes of the upper sector of Seguret Valley. The three sectors of the study area are shown in *yellow*. *Right*: the *red line* indicates the catchment of the Seguret Valley with a geological and structural summary of the study area (scale 1:200.000). *Numbers* indicate the main lithological units: continental unit: 10—Valfredda complex (schists); 12—Vallonetto complex (Dolomite rocks, schists, marble); 13—Mesozoic sequences (quarzite rocks); 14—Ambin complex (augen gneiss, metaconglomerate and metapelitic rocks). Ophiolitic unit: 3—Aigle complex (schists); 4—Vin Vert complex (schists). Evaporitic rocks (gypsum and anhydrites): 16—outside of the study area, but shown in the figure are the following: 6—Lago Negro complex (schists); 9—Chaberton—Grand complex (dolomite rocks, limestone); 11—Gad complex (dolomite rocks, schists); 15—Clarea complex (metapelitic rocks)

Fig. 2 Methodological framework for territorial analysis



e Geomorfologico', i.e. Support for Geological and Geomorphological Surveys) as an extension for ArcPad software (ESRI). Within the ArcPad environment, the SRG^2 extension adds a toolbar containing 16 default layers in shapefile format in order to catalogue features relevant to geological and geomorphological studies. Each shapefile has an associated attribute table, which contains all the information necessary to facilitate a very detailed description (Giardino et al. 2010).

Identification and Recording of Geological Sites

A customised function called 'Geosite' allows the mapping and description of geological sites. As previously, an attribute table is used to describe the features. The table is an electronic image of a inventory and assessment card proposed by the Natural Sciences Museum of Turin in cooperation with the Earth Sciences Department of Turin University (Ghiraldi et al. 2012), which was developed by comparing inventory and evaluation forms presented in other works (e.g. Berger and Grandgirard 1996; Giardino and Mortara 1999; UKRIGS 2001; Bertacchini et al. 2003; Pereira et al. 2007; Reynard et al. 2007) and with the guidelines detailed by the Italian Institute for Environmental Protection and Research (ISPRA) for the 'National Inventory of Geosites' project (D'Andrea and Di Leginio 2002). Once the geometric feature on the digital map has been edited, the extension automatically enters data into the attribute table, acquiring the information from the vector layers in the ArcPad project.

Identification and Characterisation of the Trails to Access the Sites

This extension (Giardino et al. 2010) allows the description of paths to the geosites, by informing visitors about the timing, difficulty and nature of the trail surface. A descriptive card was created to help this process and then associated with a vector layer of the ArcPad project. Additional functions allow the collection of new georeferenced data, such as potential geomorphological hazards or multimedia content (Table 1).

Terrestrial Laser Scanner

Terrestrial laser scanner (LiDAR) was used to assess the geomorphological hazards of geosites in order to identify the associated risks. The best test site was identified in the caves located in the southwestern sector of the study area, as these have been affected by collapses in the past.

The scanning process of the rocky bank created a point cloud with an accuracy of 6 cm. The cleaning, orientation and georeferencing phases helped identify discontinuities present in the rocks (Fig. 3), and hence identify unstable areas which may pose a risk to enjoyment by a general public. Given the high cost of the instrument and the need for massive post-processing operations, the use of this technique was purely demonstrative. Nevertheless, the process can still be considered as potentially very useful for identifying geomorphological hazards.

Table 1 Inventory and assessment card for geosites

Inventory and assessment card		
Inventory	• Location • Type • Scientific description • Scientific interest • Contextual interests • Geological hazards • Vulnerability • Anthropic impact	This first part of the card is very descriptive, and requires rigorous and detailed scientific information as well as a description of the physical characteristics of the site—including relationships with other aspects such as aesthetic, ecological and cultural values. This detailed description underpins the evaluation process.
Assessment	• Scientific • Educational • Aesthetic • Ecological • Accessibility • Dangerousness	This second part of the process is an objective approach. Every aspect contains four variables, each with a value between 0 and 1. The sum of the scores provides a value for each aspect. Accessibility and safety values represent the most important factors for selecting areas for tourism.

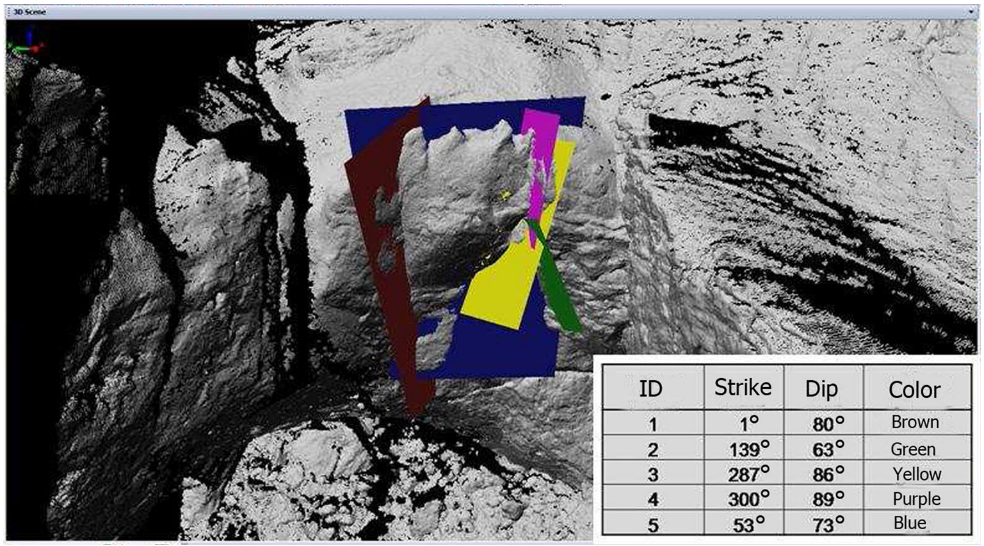
Data Integration in a GIS Environment and the Selection of Geosites

GIS tools allowed the integration of data from different sources. Bibliographic and field survey information were used for territorial analysis, leading to the compilation of a geomorphological map (scale 1:10.000) of the study area through interpretation and identification of the dynamics and processes that shaped the landscape.

After the assessment phase, focused on tourist and educational use, five sites were selected (on the left of Fig. 1), taking into account scientific value as well as contextual, accessibility and safety. These results also considered the geological sites not as isolated features within the territory, but as a part of a complex system, hence helping elucidate the morphological evolution of the study area.

Site No. 1: Geomorphological Landscape of the Upper Sector of the Seguret Valley

The upper sector of the valley is characterised by the presence of karstic and glacial landforms, mainly dolines and narrow gorges developed in dolomites and 'pseudocarnioles'(Alberto



ID	Strike	Dip	Color
1	1°	80°	Brown
2	139°	63°	Green
3	287°	86°	Yellow
4	300°	89°	Purple
5	53°	73°	Blue

Fig. 3 Identification of the discontinuities on the rock surface scanned with terrestrial laser scanner

et al. 2004) rocks, as well as glacial cirques, *roche moutonnées* and moraine that can be referred to a post-LGM phase and to the ‘Little Ice Age’. To help explain these geomorphological processes and forms, the top of Seguret Mountain was chosen as a viewpoint that combined educational and scenic values (Fig. 4).

Site No. 2: Saraceni Caves

These represent a beautiful example of the subaerial exposure of karst conduits. Being located in a dynamic environment, this geosite presents a high potential risk for development. For this reason, a safe observation point was chosen, with very high educational and scenic values. In addition to karstic and geomorphological aspects, this geosite also shows the tectonic features of the area and many other contextual aspects, such as cultural and historical values related to legends associated with the caves (Fig. 5).

Site No. 3: Pramand Pass

This site can be interpreted as the remnant of an ancient valley of Middle Pleistocene age. Although the site is difficult to interpret, it was selected for its contextual historical interest as it forms part of an former military road that linked many Second World War’s forts; Pramand Fort, in particular, being a perfect viewpoint for the southern part of the Seguret Mountain—a complex relief characterised by numerous rock towers composed of dolomite, gypsum and limestone breccias (Fig. 6).

Site No. 4: Seguret Gorge

This is an incision on the southern side of Seguret, set along a fault line across the main axis of the Susa Valley. The gorge is developed within quartzite cap rocks, characterised by a steep slope which makes it virtually inaccessible. The only access

Fig. 4 Upper sector of the Seguret Valley from the top of Seguret Mountain. This portion of the valley is included within a large glacial cirque. The floor of the valley is flat and wide and clearly shows karstic and glacial erosion landforms

Fig. 5 Section of the rocky bank into which the 'Saraceni caves' are set. The caves provide evidence of subsurface karstic dissolution phenomena

Fig. 6 Southern sector of the Seguret Mountain. View from the roof of Pramand Fort

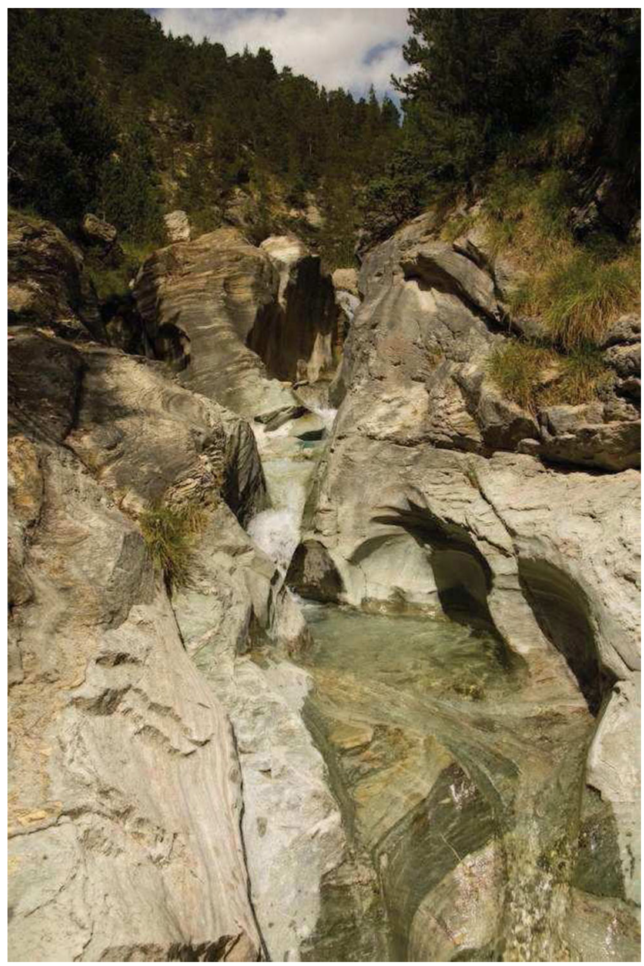


Fig. 7 Torrential erosional forms in the Seguret Gorge

point is at the apical portion where visitors could appreciate many river erosion features such as wells, potholes and waterfalls (Fig. 7).

Site No. 5: Beaume Cave

This is a large cave at the base of the southern slope of Pramand Mountain. The cave is part of an ancient karstic system which developed at the head of the valley. As the cave has a high religious interest, the geosite is easily accessible as the interior of the cave has been transformed into a small shrine and a place of pilgrimage (Fig. 8).

Dissemination and Evaluation

Knowledge of an area necessarily passes through a cartographic representation. In recent years, dynamic mapping has constantly grown as direct consequence of the development of digital technologies and the wide diffusion of the Internet. This has created new methods of map production, making them more accessible both technologically and economically. This new cartography has become one of the best tools for disseminating information and making it accessible to all.

According to Cartwright and Hunter (2001), modern cartographic applications must have the power to transform data into information and then into knowledge. To achieve this ambitious goal the instruments have to be accessible and easy to use by a general public. The added value is in transferring knowledge to the users and not only unstructured information. Important contributions on to this theme include Carton et al. (2005), who discuss the reading of technical information contained in maps and proposed a division of cartographic production, distinguishing between maps for specialists and

Fig. 8 Beaume Cave. The cave represents the mouth of an ancient karstic system whose origin was probably in the upper sector of the valley

for non-specialists users. With specific reference to the latter, Castaldini et al. (2005) and Bertacchini et al. (2007) proposed a methodology based on the simplification of the scientific information included in the maps for specialists and the addition of basic tourist information. Pelfini et al. (2009) and Brandolini & Pelfini (2010) focused attention, respectively, on the assessment of geomorphological risks and the vulnerability of users and on the classification of the trails. Coratza & Regolini-Bissig (2009) and Regolini-Bissig (2010) proposed a new approach for the implementation of interpretative maps: These authors developed guidelines for Earth Heritage mapping that integrate a series of interpretation principles.

A different kind of approach is based on the use of the so-called virtual globes, such as NASA WorldWind, GoogleEarth, GoogleMaps, Microsoft Virtual Earth and others. These applications have the power to integrate satellite imagery, aerial photograms, and digital maps and can present a three dimensional interactive representation of data on a global scale.

In order to disseminate geoscientific data and supply tourist and cultural information, GoogleMaps with the GoogleAPI V.3 option was chosen for the following reasons:

- Typical web GIS;
- Wide dissemination and handiness of use;
- Basic cartography always available and up to date;
- Ability to display three-dimensional view (GoogleEarth Plugin);
- Customisable interface using GoogleAPI, HTML and JavaScript;
- Power to manage data through connection to a relational database or through the use of XML or KML file.
- Power to be used on mobile device.

The application developed is structured according to the scheme shown in Fig. 9.

The interface (Fig. 10) is structured with all the space dedicated for displaying the map; at the bottom, there is a button for opening a table of contents where the user can query, toggle on/off layer information, locate themselves on the map, as well as performing spatial query searching for geosites within a radius. InfoWindow balloon presents three tabs: the first for generic information and for opening a detailed card in PDF or HTML format; the second contains a photo gallery; the third is for multimedia content.

These features and the ability to interact with data, the power to link different kinds of documents and to display many layers of spatial information, allows the access and retrieval of more information. The digital representation of the real world allows not only the transmission of static information but also the creation of an application that can provide a teaching tool, even for those not involved in the Earth science disciplines.

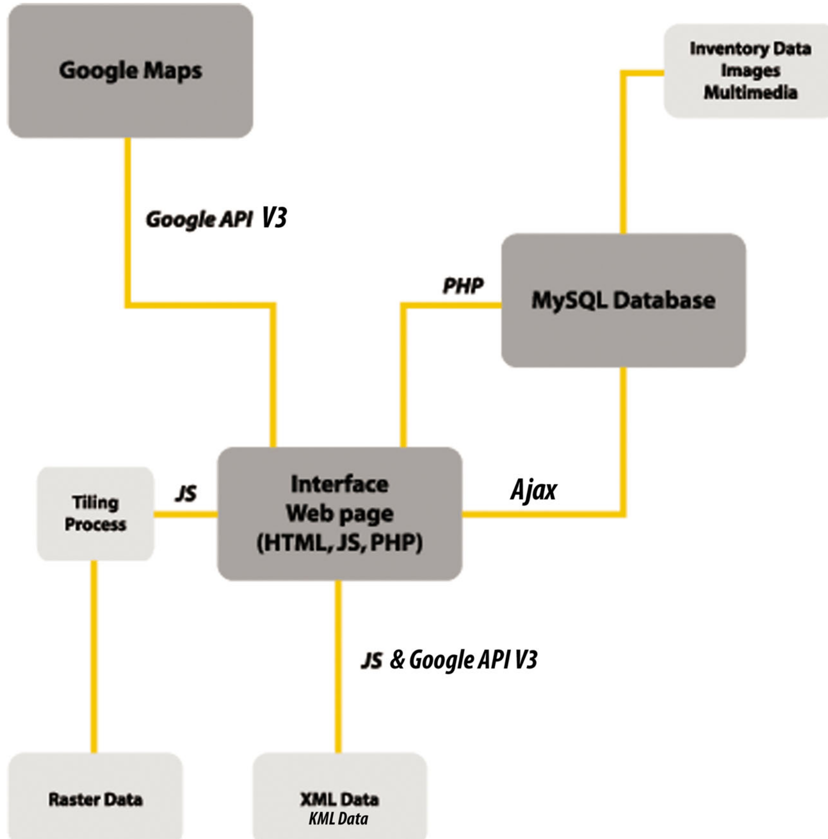


Fig. 9 The structure of the application developed using GoogleMaps interface. Data can be stored into a database or added using KML or XML files

Conclusions

The work described was designed and developed with the aim of promoting the geomorphological heritage of the Piedmont region (NW Italy) through experimentation with geomatic tools. To achieve this goal, we touched on various different topics (identification, evaluation, exploitation and dissemination) related to the theme of geological heritage.

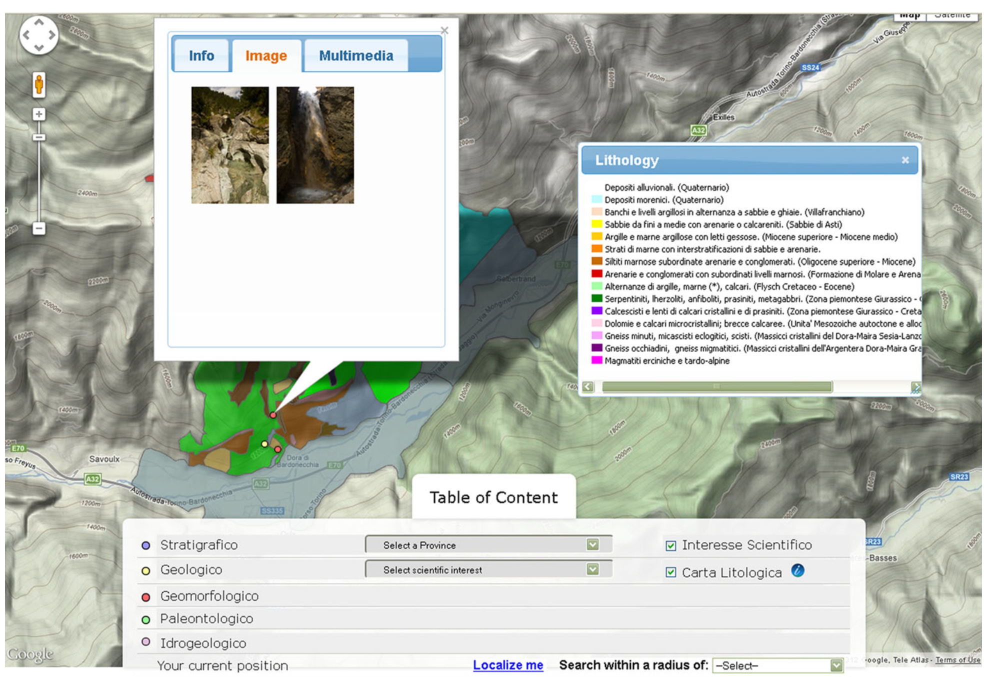


Fig. 10 The application based on GoogleMaps. *Bottom*: Table of Content with geosites legend, select box to query the database and check box to toggle on/off additional layer information (XML or KML). *Right*: pop-up legend related to additional layer. *Left*: tabbed InfoWindow balloon

The geomatic tools used for surveying the study area proved useful for carrying out specific activities in a well-defined territorial context and each tool used showed both potential and limitations.

Digital aerial photogrammetry proved to be an essential tool for a global overview and to make a small scale geomorphological map of the terrain features characterising the study area. The main disadvantages of this technique, however, is that the photogrammetric process takes time, and dedicated instruments and technical skills are needed for the orthorectification of the frames and the implementation of the stereoscopic model necessary for interpreting the morphology of the terrain.

Detailed terrain survey carried out with mobile devices equipped with GIS software and customised extensions allowed the acquisition of the data necessary to produce a large scale geomorphological map, a database of potential geomorphosites and information for the classification of the walking trails. These types of tools can load data into GIS project-creating thematic maps both in raster and vector format. In addition, we can also collect georeferenced information in real time in order to create a geographical and alphanumeric database directly exportable into a GIS desktop environment for further processing. The main disadvantages are the small size of the screen and the difficulty of describing observations with long texts. It is necessary, therefore, to create a form in which the collection of data mainly takes place using select menus, check boxes, radio buttons, etc. In addition, the quality of the instrument is a limiting factor for computing power, GPS accuracy and battery life.

The LiDAR used in this work was a long range type, and it was employed for test purpose in order to investigate the potential instabilities of a section of the slope where the Saraceni caves are set. This type of tool allowed us to scan a rock wall whose dimensions were about 600 m long and 150 m high with an accuracy of around 6 cm. The use of the instrument in a context, such as the assessment and promotion of geomorphological heritage, can have a double advantage in that it creates a high-resolution digital model for educational or exhibition purposes as well as helping identify potential instabilities in geomorphological elements during a phase of assessment of geotourist paths. The main limitations in using this technique are that it was time consuming both in the preparatory phase where it was necessary to collect information for the accurate georeferencing of the cloud of points, and in the scanning process itself that was conditioned by the accuracy required, by the distance of the feature, and by the number of scans carried out for surveying the entire rock wall. Last but not least, the time and skills needed to process the data in order to detect potential instabilities is also very significant.

With regard to the dissemination of geoscientific and touristic information we decided to use an interactive web-mapping tool such as GoogleMaps, because it is widespread, dynamic, easy to use, customizable and works in a multiscale environment. Furthermore, it allows us to present data in an integrated manner, combining the requirements of different types of user.

These types of feature make GoogleMaps a valuable tool to promote sites or virtual itineraries with geological or geomorphological interests. The main advantage is that digital virtual tours will overcome the different theoretical and practical problems related to the development of educational field excursions. Theoretical difficulties involve the complexity of geological or geomorphological items, in terms of: observation scale, spatial understanding of the described objects and their 'deep time' evolution. In addition, these tools are useful for those sites where there are difficulties of accessibility—indeed, some of the sites proposed are not easily accessible because of the difficulty of the terrain or the geomorphological risks present. Nevertheless, these sites have a significant scientific and cultural content and, therefore, deserve presentation. In addition, the development of virtual tours is much less expensive than the traditional on-site equipment of geoitineraries. The main drawback of this kind of tool is that basic computer programming skills are needed for its implementation.

Based on this study, we can conclude that the concept of geological heritage cannot go beyond the scientific knowledge of the territory and that the application of geomatic tools must follow a rigorous scientific methodology linked with the technical skills necessary for its practical management. Finally, we would like to emphasise the importance of disseminating information related to geological heritage. This phase can be considered to be a critical step for the creation of a background of knowledge within a heterogeneous audience, in order to develop the awareness necessary to provide support for the successful development of conservation policies for natural heritage and landscapes in general.

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