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TOOLMAP2 – a powerful tool for digital mapping

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Key words: GIS, vector data, easy drawing, geologic maps, spatial data model.

Abstract

The use of digital geologic data has become part of a geologist's daily business. However, the production of high quality vector datasets is still not simple. Here we present TOOLMAP2, a cost-free, open-source software dedicated for digitizing data and producing complex multi-layer GIS projects. Initially the structure of a map is implemented in TOOLMAP2 as a relational spatial data model. Digitizing is then carried out within three layers: Lines, Points and Labels. Polygons are built afterwards from the combination of lines and label points during data export into shapefiles. This method, coupled with built-in data validation tools, allows the production of topologically consistent GIS datasets. Although digitizing occurs only within three layers, multi-layer GIS projects can be produced by a multi-attribution approach that is tightly coupled with a user-defined spatial data model. TOOLMAP2 has been successfully tested in the production of the Geological Atlas of Switzerland 1:25 000 and smaller map projects. The tests reveal that the software is suitable for digitizing any kind of map, regardless of its size, scale, topic or complexity. Thus, TOOLMAP2 has a big potential as a digitizing tool in various fields of geosciences.

Résumé

L'utilisation de données géologiques numériques fait aujourd'hui partie intégrante du quotidien du géologue. Toutefois, la production de ces jeux de données vectorielles n'est pas toujours chose aisée. Cet article présente TOOLMAP2, un outil de digitalisation «open-source» et gratuit dédié à l'élaboration de produits SIG structurés. La première étape du processus d'édition consiste dans la définition et l'implémentation dans TOOLMAP2 d'un modèle de données spatiales correspondant à la structure de la carte à élaborer. La numérisation de tous les objets géométriques est ensuite intégralement réalisée dans trois thèmes: lignes, points et labels. Les objets surfaciques sont quant à eux construits automatiquement lors de la phase d'export des données sous forme de shapefiles en combinant lignes et labels. Cette méthode, couplée à des outils intégrés de validation des données, garantit la production de jeux de données topologiquement cohérents. Bien que le processus de vectorisation ne mette en jeu que trois couches d'édition, la combinaison d'un modèle de données spatiales configurable et d'une procédure d'attribution discriminante permet l'élaboration de produits vectoriels multicouches complexes. TOOLMAP2 a été testé avec succès dans le cadre du processus de production de l'Atlas Géologique de la Suisse au 1:25 000e ainsi qu'à la faveur de projets de plus petite échelle. Ces différents tests ont démontré que ce logiciel est tout à fait adapté à la production de tout type de carte, indépendamment de la taille, l'échelle, la complexité ou de la thématique concernée. A ce titre, TOOLMAP2 offre un grand potentiel d'utilisation dans les différents domaines des géosciences.

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Riassunto

L'utilizzo di dati geologici numerici è oggi parte integrante della vita quotidiana del geologo. Tuttavia, la produzione di questi set di dati vettoriali non è sempre agevole. Questo articolo presenta TOOLMAP2, uno strumento di digitalizzazione «open-source» gratuito adibito all'elaborazione di prodotti strutturati GIS. La prima tappa nel processo di edizione consiste nella definizione e integrazione in TOOLMAP2 di un modello di dati spaziali corrispondente alla struttura della mappa da elaborare. In seguito, la vettorizzazione di tutti gli oggetti geometrici, è interamente realizzata in tre temi: linee, punti e labels. Questo metodo, associato a degli strumenti integrati di convalida dei dati, garantisce la produzione di set di dati topologicamente coerenti. Nonostante l'intero processo di digitalizzazione si svolga unicamente in tre layers di edizione, la combinazione di un modello di dati spaziali configurabile e di una procedura di attribuzione discriminante permette l'elaborazione di prodotti vettoriali multi-layers complessi. TOOLMAP2 è stato testato con successo nell'ambito della produzione dell'Atlante geologico della Svizzera 1:25 000, così come in progetti di portata minore. Questi test hanno dimostrato che il programma è assolutamente adatto alla produzione di qualsiasi tipo di mappa, indipendentemente dalla dimensione, la scala, la complessità o il tema trattato. Per queste ragioni, TOOLMAP2 possiede un grande potenziale d'utilizzo nei diversi ambiti delle geoscienze.

Zusammenfassung

Die Arbeit mit digitalen geologischen Daten gehört heute zum Alltag eines Geologen. Die Produktion qualitativ hochwertiger und topologisch einwandfreier Vektordaten ist jedoch nach wie vor nicht einfach. In diesem Artikel stellen wir TOOLMAP2 vor, eine kostenlose Open-Source-Software, welche für die digitale Datenerfassung entwickelt wurde und sich für die Erstellung komplexer GIS-Projekte eignet. Als erster Arbeitsschritt wird in TOOLMAP2 die Datenstruktur einer Karte mittels eines relationalen Datenmodells erstellt. Danach erfolgt die digitale Erfassung der Karte auf drei Ebenen: Linien, Punkte und Indexpunkte. Beim Datenexport (in shapefiles) werden die Polygone automatisch aus der Kombination von Linien und Indexpunkten erzeugt. Obwohl die Digitalisierung in nur drei Ebenen erfolgt, können dank des Konzepts der Mehrfach-Attribuierung und des eng gekoppelten, benutzerdefinierten Datenmodells GIS-Projekte mit beliebig vielen Ebenen generiert werden. Die so produzierten GIS-Daten sind topologisch einwandfrei. TOOLMAP2 wurde erfolgreich für die Produktion des Geologischen Atlas der Schweiz 1:25 000 sowie für kleinere Kartenprojekte getestet. Diese Tests haben gezeigt, dass sich die Software für die Digitalisierung verschiedenster Karten eignet, unabhängig von deren Inhalt, Grösse, Massstab und Komplexität. Somit hat TOOLMAP2 das Potential, sich als nützliches Werkzeug in diversen Gebieten der Geowissenschaften zu etablieren.

1. Introduction

During the last decades Geographic Information Systems (GIS) have become widely accepted tools to address questions in pure and applied earth sciences (e.g. Bonham-Carter 1994, Oleschko et al. 2008). More recently, considerable effort has been made to extend the two-dimensional data to the third dimension (e.g. Kessler et al. 2008, Pamer & Diepolder 2010). The increasing interest in GIS and 3D models in the field of earth sciences has heightened the need for efficient and powerful tools to create high quality digital data, such as interpreted bedrock maps. Among the available GIS software, many can handle georeferenced data, but only few consider topology rules. Unfortunately, the most popular vector data storage format used for GIS data exchange, the ESRI shapefile (ESRI 1998, in the following simply referred to as shapefile), does not

contain any topologic restrictions. Nevertheless, ESRI provides two vector data storage formats that take topology into account: coverages and geodatabases.

However, these two file-based storage formats suffer from some limitations. The coverage file is out-of-date and the file geodatabase is a proprietary vector format that is only supported within an ESRI product environment. This motivated the Swiss Geological Survey (SGS) to initiate the ToolMap project, which aims to provide a user-friendly, open-source digitizing software for creating topologically consistent multi-layer GIS projects. The ToolMap project is a joint venture between the SGS and the Research center on alpine environment (CREALP). The first release of TOOLMAP was developed and fully integrated within the ESRI ArcGIS

environment (Sartori et al. 2006a; 2006b). Later, the first freely available standalone version of the software, TOOLMAP2, was launched in November 2010 (CREALP 2010). Continuous improvements have been – and will be – incorporated in follow-up versions. Here we present the basics of TOOLMAP2 and discuss its advantages over the most commonly used GIS tools. Furthermore, we share the first experiences with TOOLMAP2 during the publishing process of the Geological Atlas of Switzerland 1:25'000 (GA25) and point to the potential of this software for applied earth sciences.

2. TOOLMAP2 basics

Working with TOOLMAP2 is quite easy because the user interface is simple and restricted to the minimum functions. As in common GIS programs, various georeferenced background data can be added as images. In addition it is possible to import linear and punctual features from shapefiles. Apart from these standard features, the main difference between regular GIS software and TOOLMAP2 concerns the editing process of data. Digitizing with TOOLMAP2 strictly follows the concept of Sartori et al. (2006a, 2006b), known as the «Méthode Sion». The first basic principle of this method is that only two types of geometries, lines and points, are used for editing all two-dimensional «real-world» objects. No polygon layer exists in TOOLMAP2. Polygons are built from the combination of lines, which delineate surfaces (i.e. borders of polygons), and label points while exporting the data into shapefiles. Digitizing all lines, line features (strictly speaking) and borders of polygons within one single layer yields the following advantages:

- No redundancy in the digitizing process: geometric shapes referring to multiple object types are digitized and stored only once.
- Perfect match between geometric shapes occurring in different thematic GIS layers:

all objects are extracted from the same construction layers.

2.1 Data acquisition and attribution

Only three layers are reserved for data acquisition. All geologic features are digitized and attributed within these layers.

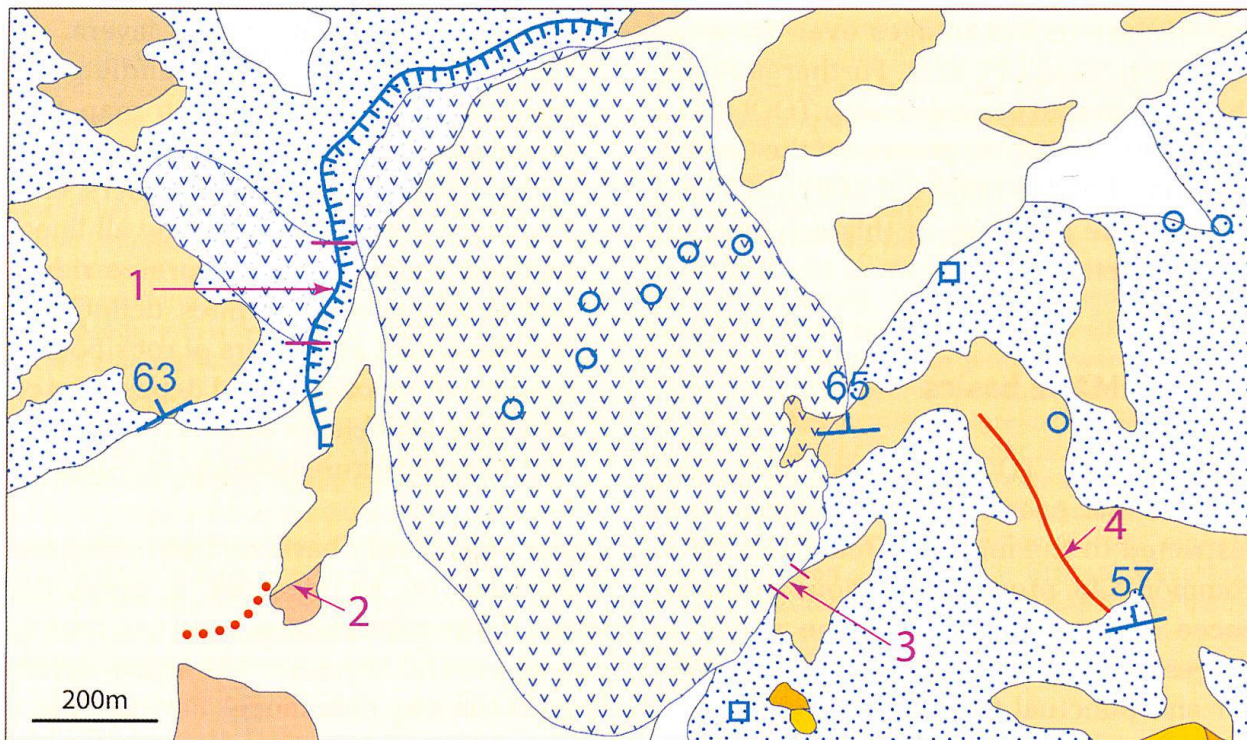
1. The layer «Points» is for handling the whole set of objects on the map that occur as point representations such as springs, boreholes, erratic boulders, etc.
2. The layer «Lines» is for editing all linear features such as faults, moraine ridges and scars, as well as lines delineating polygons such as borders of rock bodies, borders of unconsolidated deposits, etc.
3. The layer «Labels» is reserved for points that hold the future polygon information.

Linear objects may have multiple meanings. Depending on its meaning, a geometric shape in the construction layer can refer to one or several thematic GIS layers predefined in the map data model. For example, if a line delineating a polygonal surface of unconsolidated deposits has a portion that is coincident with a scar, then this portion is represented in the construction layer by a single linear object with two geologic attributes. Through data export, the same linear object is used once to represent a scar in the thematic layer «Instability structures» and once to build a polygon in the thematic layer «Unconsolidated deposits». This attribution process that allows assigning more than one meaning to a specific line portion (multi-attribution) and that discriminates between construction layers and thematic GIS export layers according to a predefined map data model is the second basic principle of the «Méthode Sion» and is illustrated in Fig. 1. The user is guided in an interactive way through the attribution process with an intuitive interface based on forms, lists and check boxes. The coupled data model can be any user-defined spatial data model.

2.2 Technical features

TOOLMAP2 is a cost-free, open-source software tool. It is based on proven open-source technologies such as MySQL, wxWidgets,

GDAL, GEOS and libCurl. TOOLMAP2 is implemented in C++ and is cross-platform compliant (Windows, Linux and Mac). To ensure topologic and semantic consistency, TOOLMAP2 manages data through an



ArcMap©ESRI Display

Legend

Instabilities

Rockslide mass

Unconsolidated deposits

Alluvium
 Talus, scree
 Alluvial fan
 Till

Bedrock

Schists with two micas
 Pontino Zone
 Sasso Rosso Zone
 Quartenschiefer
 Triassic carbonate

Planar structures

Dip / dip direction

Surface water

Spring (untapped, tapped)

Instability structures

Scar

Glacial and periglacial structures

Moraine ridge

Tectonic boundaries

Fault

Line attribution examples

- 1) Border of Instabilities and Scar
- 2) Border of Bedrock
- 3) Border of Instabilities and Border of Unconsolidated deposits
- 4) Fault

Fig. 1: The principle of multi-object type attribution. Section of the geologic map of Ambri-Piotta represented by the superposition of eight thematic layers (see single layers in Fig. 2). Some examples (numbers 1–4) show how the appropriate attribution of the lines allow multiple polygon layers to be built from a single construction layer (the limits of the bedrock formations are drawn beneath the Quaternary cover, thus the outcrop borders are not considered as bedrock borders, cf. number 3).

embedded MySQL relational database that allows the handling of geospatial data (geometry and attributes) with various levels of complexity.

The compliance with other commercial and non-commercial GIS software is achieved through the data export process implemented in TOOLMAP2. The export process allows exporting different individual thematic layers as shapefiles (Fig. 2). The topologic and semantic consistency of the resulting dataset is implicitly guaranteed by the way that TOOLMAP2 manages source data.

3. Experiences and advantages with TOOLMAP2

The SGS is currently applying TOOLMAP2 within the production process of the GA25. The first pilot project has been realised through the editing of the GA25 sheet «Sion». A particularity of this project was to incorporate a complete bedrock map based on the interpretation of the surface geology by the authors of the map. Thus the data model of the GIS project comprised the thematic polygon layers «Unconsolidated deposits» and «Bedrock» to describe the surface and the near subsurface geology, respectively. Almost 18,500 line segments, 1,500 label points and 1,200 points were digitized and attributed with TOOLMAP2. The GIS version was then successfully imported into graphic-design software for editing and preparing the printed map, which has recently been published by the SGS (Sartori et al. 2011). The successful application of TOOLMAP2 in this pilot project has led the SGS to fully integrate this tool into the GA25 map production workflow. Currently, three GA25 sheets are being digitized and attributed with TOOLMAP2 and according to the specifications of the Swiss geologic data model (Strasky et al. 2011). Although the digitizing projects of the GA25 map series are very large and complex, TOOLMAP2 is also appropriate for much smaller map projects

of various scales and domains (e.g. detailed geologic mapping, environmental impact assessment, geographic and biologic studies). Since the last two years, TOOLMAP2 has a growing clientele. For example, it is being used by SGS contractors to compile maps from different sources and to combine them with their own map production. Moreover, geological institutes of universities use the software to produce maps within the framework of Master's theses.

Feedback from several projects using TOOLMAP2 for digital map production shows that the software is suitable for digitizing maps with different complexities. Using TOOLMAP2 for digitizing maps offers several benefits over other existing computer programs. The following list gives some examples:

- Open-source tool free of charge.
- Powerful editing and attribution processes and associated tools to ensure the topologic and semantic consistency of the spatial database.
- Numerous dedicated tools, such as user-defined queries and spatial validation tools that help to produce high quality data.
- Embedded and scalable relational database for handling data of various complexities and ensuring data integrity during the complete digitizing process. The use of a relational data model provides a structure for the organisation and the storage of all information from which the map will be created (i. e. digital map data model). This stage of conception always reveals the wealth and the complexity of the data.
- Intuitive graphic user interface with contextual tools dynamically linked with the content of the spatial database.

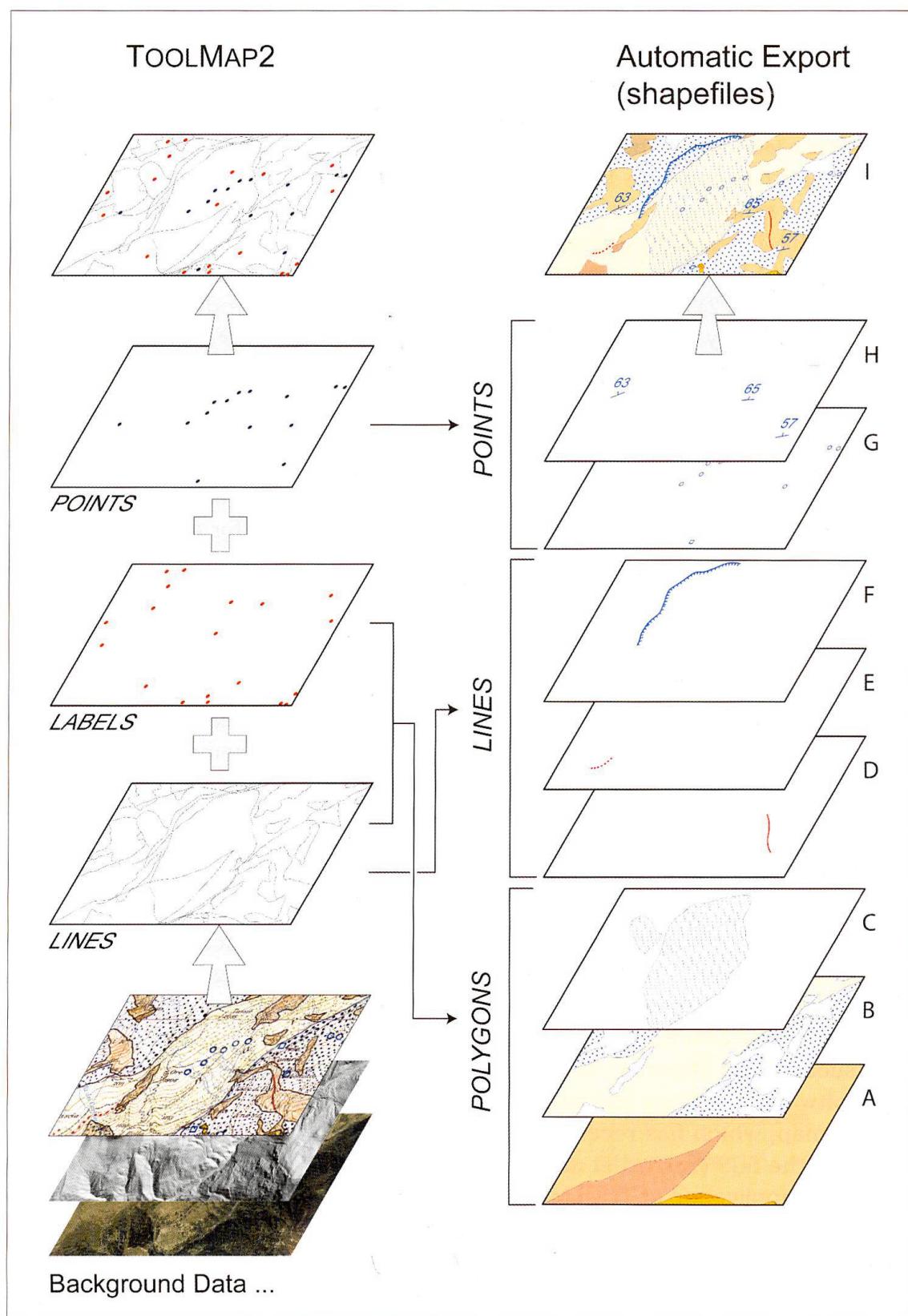


Fig. 2: Schematic representation of the export process. The left part in the figure illustrates the working area within TOOLMAP2. Vector data are produced from various background data and stored in three construction layers. In the building of thematic shapefiles during data export, all features from the construction layers are organised according to the related data model (right part in the figure). The letters A to I represent thematic layers according to the Swiss geologic data model (Strasky et al. 2011). A = Bedrock; B = Unconsolidated deposits; C = Instabilities; D = Tectonic boundaries; E = Glacial and periglacial structures; F = Instability structures; G = Surface water; H = Planar structures; I = resulting vector map from the combination of layers A to H.

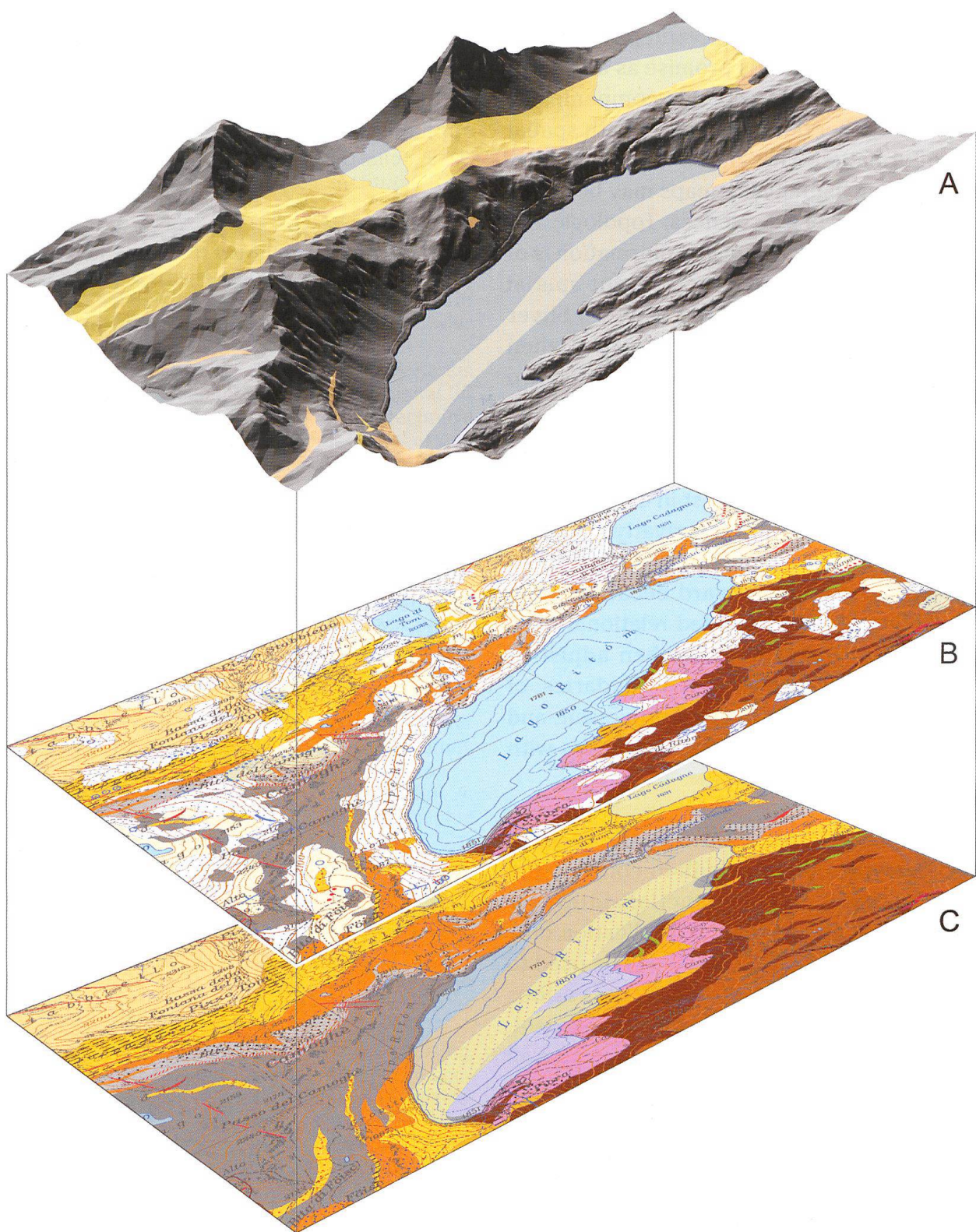


Fig. 3: Application of georeferenced vector data illustrating the appearance of Triassic carbonates on the digital elevation model of the Lake Ritòm area [A]. Such visualisations, together with similar representations of instabilities, can serve as a basis for studying potential reservoir sites. The geologic input data used to produce A), are given with the geologic vector map [B] and the derived bedrock sketch map [C]. Despite the Triassic sediments that cross the lake basin and thus a critical expertise of Heim et al. (1911), the Lake Ritòm reservoir was created successfully between 1918 and 1920.

4. Potential for applied earth sciences and outlook

The above-mentioned advantages indicate that TOOLMAP2 holds promise as an important tool in private geologic companies as well as in other domains dealing with spatial geoinformation. The simple way of efficiently digitizing high quality maps may be useful in many fields of geosciences. Topologic and semantic consistency of geoinformation is of particular importance for relevant spatial analysis and 3D modelling (Fig. 3). Sliver polygons, a typical digitizing error when attempting to draw a boundary between two polygons twice and often observed in the superposition of two polygon maps, are not an issue when digitizing with TOOLMAP2. This is of particular interest in cases such as maps of phenomena and derivative geologic hazard maps. Modifying existing TOOLMAP2 projects is straightforward because of the scalability of the embedded relational database. This is very helpful when adjusting borders of polygons, e.g. boundaries of debris slides after a major storm event, and it allows maintaining updated datasets with minimal effort.

Although initially developed for the needs of geologic mapping, the built-in concept and the comprehensive functionalities of TOOLMAP2 do not restrict application only to geologic data. TOOLMAP2 can be used to produce a variety of maps in various domains such as natural hazard assessment, hydrogeology, engineering geology as well as biological, soil and environmental sciences.

The current version of TOOLMAP2 meets the requirements for producing high quality vector data. Nevertheless, continuous refinements will further improve future versions of the software. In addition, the ongoing development of a field version will enable data acquisition or modification on-site. TOOLMAP2 has already proven to be suitable for building complex multi-layer GIS

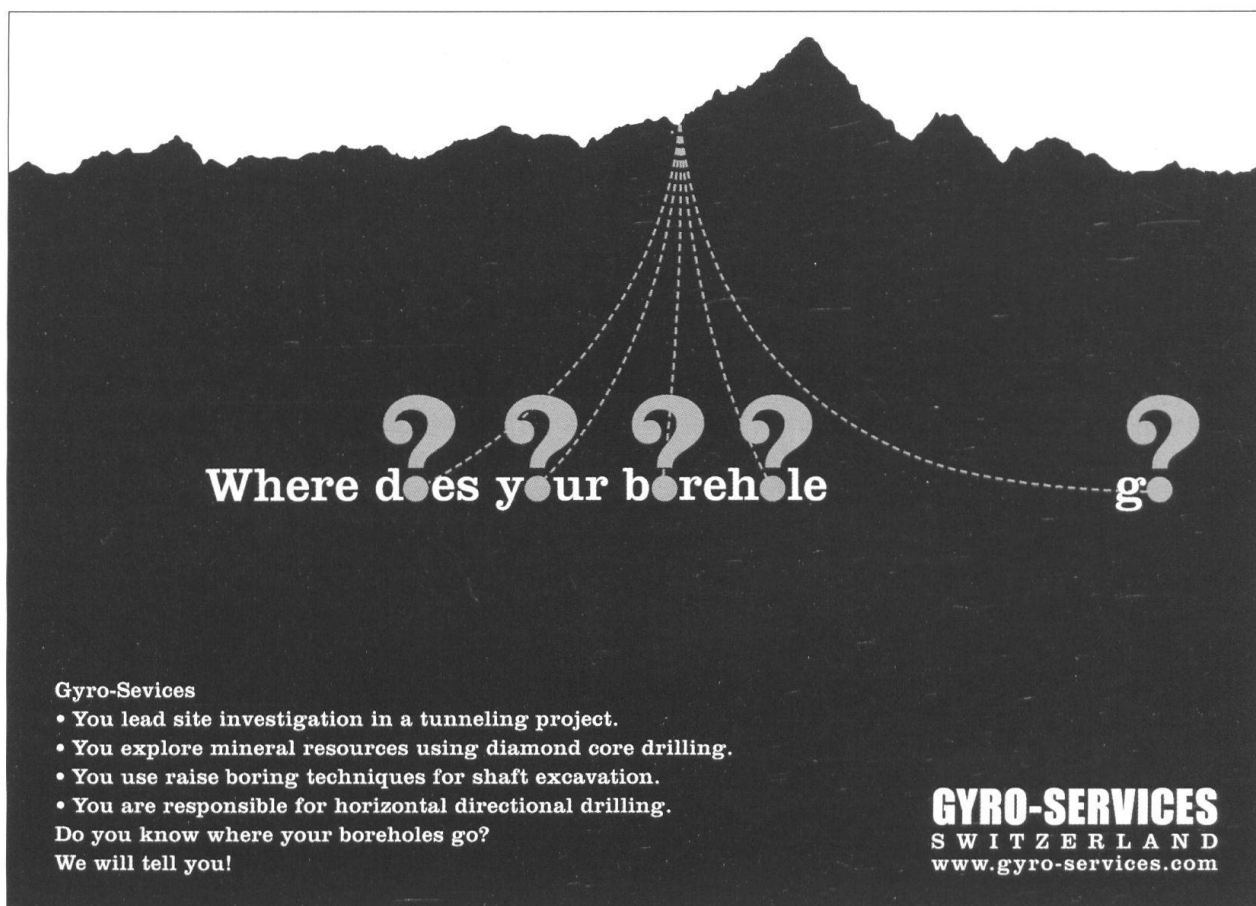
projects, and with its continuing improvements it has the potential to become a widely used application in various pure and applied sciences.

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