From Geological Cartography to Digital Maps: Spatial Data Model and GIS Tool.

Mario Sartori [(1)]; Pascal Ornstein [(1)]; Cédric Métraux [(1)]; Lucien Schreiber [(1)]; Andreas Kuehni [(2)]

(1) Crealp –Research center on alpine environment. pascal.ornstein@crealp.vs.ch
(2) Swiss Geological Survey / Federal Office of Topography (Swisstopo). andreas.kuehni@swisstopo.ch

KEY WORDS: geology, cartography, geological map, GIS, data model, GIS tool, digital map

GEOLOGICAL ATLAS OF SWITZERLAND

The Swiss Geological Survey is in charge of mapping and publishing the 1:25'000 scale Geological Atlas of Switzerland. These maps of high precision and graphic quality need long time process before publication. Actually, geological mapping coverage represents slightly more than 50% of the country area. In order to improve and reduce publishing process time, a new concept of data management is currently under development. Through the implementation of a national geological spatial data model, the production of the new geological map sheets should be easier and faster without loss of quality.

GIS AND GEOLOGICAL MAPS

A geological map classically gives a 2D-modelling of a complex 3D environment. It combines a great variety of information (lithological, chronological, structural, and morphological) corresponding to various spatial data types (point, line, surface). Each feature of a geological map holds a high semantic content. This is particularly clear when trying to implement this information in a GIS format. The methodology described hereafter concerns the whole processing of map publishing, from the field survey to the editing and publication of the geological map in numerical and paper form. The concept of geological information system and the related geological spatial data model are both the subject of two specific communications in this session.

GEOLOGICAL INFORMATION SYSTEM

The CREALP and the Swiss Geological Survey developed in close collaboration a geological data model and the related methodology and tools for implementing the maps sheets of the Swiss Geological Atlas in GIS format. This new approach was tested and is being used within the framework of the edition of geological map of Sion (Wallis, Switzerland).

The underlying data model of the geological GIS has to fulfil a number of strong requirements, as:

- To accurately describe geological data and in an exhaustive way
- To distribute spatial features in different layers according to their geological significance.
- To develop an efficient method for geometrical construction in order, for example, to solve problem related to superposition of objects dispatched in multiple layers.
- To implement spatial and tabular models offering powerful capabilities of analysis (spatial and aspatial).

The implementation of this methodology should have direct consequences on the geological field survey. For instance, it should be noticed that the analysis capabilities of the geological GIS can be largely improved if a tectonic sketch is drawn up concurrently with the field survey. It is an important step towards the 3D management of the geological data.

GEOLOGICAL DATA MODEL

The geological GIS implements a multi-layer data model allowing producing geological maps and derived geothematic maps by overlaying multiple basic layers (Fig.1). That implies organizing geological information in various themes according to their geological significance and their spatial data type. The third dimension information is naturally integrated in the GIS by the superposition of basic constitutive layers of the geological map such as bedrock geology theme and superficial deposits theme.

GIS BUILDING METHOD

A geological map schematically consists of surfaces differentiated by a color symbology related to the various lithological units. Reality is obviously more complex.

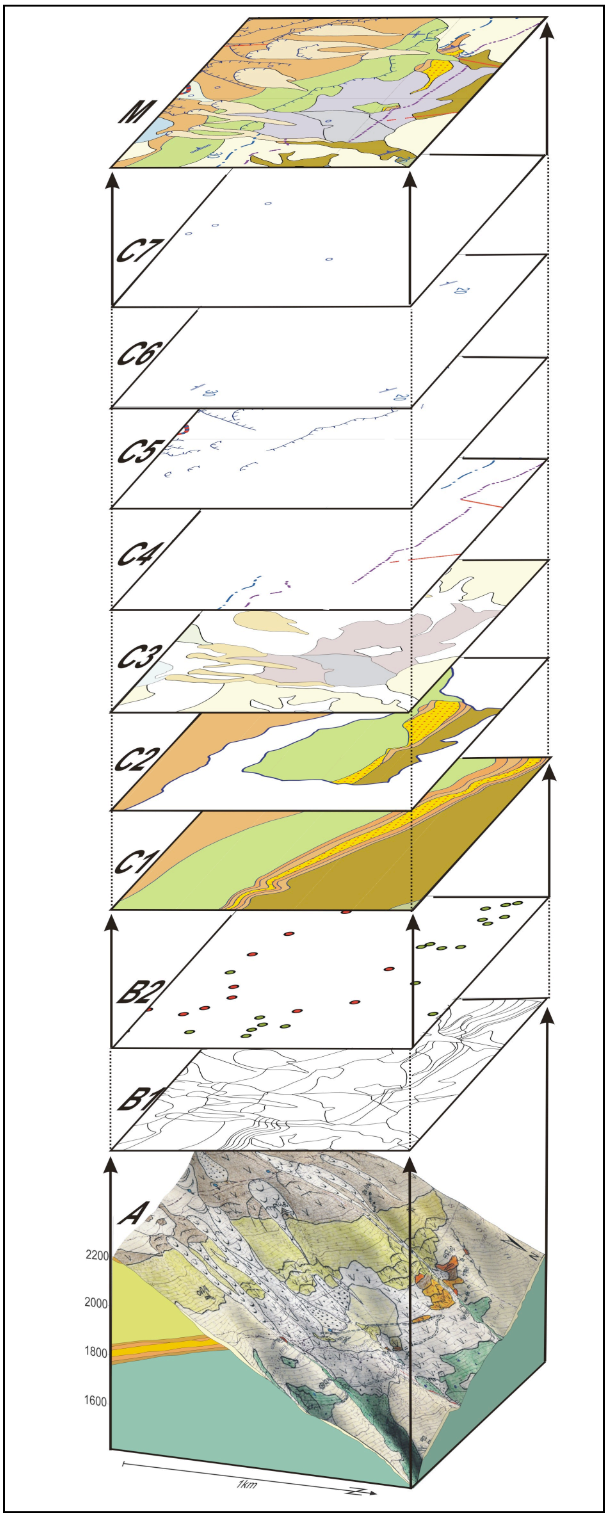

Figure 1 – Geological data model. A: Field mapping manuscript. B: GIS layers; B1: Composite build-up theme; B2: Point theme holding polygons attributes. C: Geothematic layers; C1: Bedrock geology, C2: Mass movement deposits, C3: Superficial deposits, C4: Structural map features, C5: Morphological map features, C6: Oriented symbols, C7: Non-oriented symbols. M: Final geological map resulting from spatial combination of the different thematic layers.

Each surface is delineated by linear features (arcs) which represent the "elementary objects" of the map. One feature can hold several geological meanings (e.g. limit of outcrop, scar and limit of mass movement). Depending on its geological functionalities, one line can refer to one or more layers, either as geological boundary and/or as structural or morphological feature. To ensure a perfect matching between linear features dispatched in multiple layers, the so-called methodology "Sion" consists in digitizing the whole set of lines of the geological map into a unique composite layer called *"build-up theme"* (Fig.1, 2).

Each individual feature of the *build-up theme* is then linked with one or more descriptive attributes according to its geological meaning. A complementary attribute called layer-index is used to assign the arc in the different themes which it is constitutive. This discriminating attribution process allows to extract the basic elements defining map features as polygons and polylines in a semi-automatic way. In addition, an iterative processing including validation tests, spatial errors correction and topology reconstruction, guarantees the geometrical and semantic consistency of the spatial database. The attribution of the polygon features is achieved through an associated point theme which holds polygons attributes. This process makes it possible to reconstruct the topology of the polygons as often as needed without losing their attributes. All the subsequent corrections or updates of the original geological information are first reflected in the *build-up theme* and then propagate in the relevant layers following the same process in order to maintain data integrity.

TOOLMAP: ACQUISITION, ATTRIBUTION, AND VALIDATION OF GEOLOGICAL DATA

The implementation of the geological data, in such a way, requires digitizing and attributing a great number of objects (arcs). To facilitate this time-consuming task, a specific tool called TOOLMAP was developed within ArcGIS. It offers a set of functions, accessible via menus, toolbars, or shortcuts and dedicated to map features digitizing, attributing and symbolizing. Attributes tables can be easily updated and addressed. Oriented and non-oriented geological symbols are managed in a very simple and efficient way trough the use of specific functionalities and cartographic font. TOOLMAP integrates also the tools needed to perform topological and semantic checking as well as to manipulate information between the *build-up theme* and the various geological layers. Although initially dedicated to the implementation of geological GIS, TOOLMAP is very suitable for the mapping of other types of data because of its open design and its comprehensive functionalities.

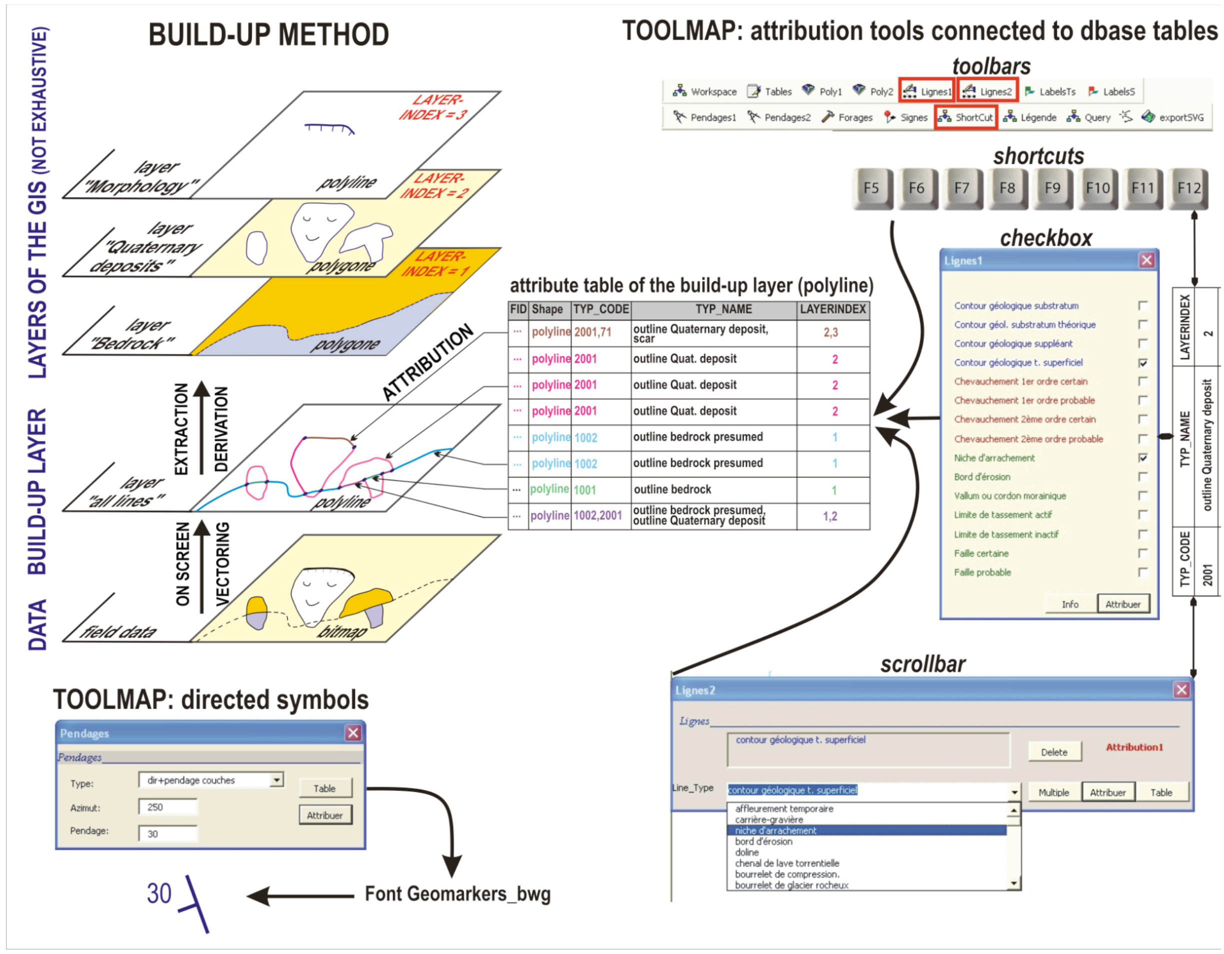

Figure 2 – Schematic process of the geological GIS implementation. All the constitutive linear objects of the geological map are digitized into a unique generic build-up layer. One or several attribute values are assigned to each linear map feature according to their geological meaning. The layer-index attribute is used to dispatch arcs in the relevant theme or themes. This technique ensures data consistency and perfect matching between features common to different layers. A specific tool (ToolMap) was developed to carry out all steps of the process from data acquisition to editing and errors correction.

CONCLUSIONS AND PROSPECTS

The methodology "Sion" developed by the CREALP and the Swiss Geological Survey brings GIS in the heart of the geological data management process. It does not only concern the digitizing of geological maps but also encloses a large didactic content for students and has, for cartographers a lot of potential implications on geological field survey. The geologist can improve field data acquisition and map accuracy by combining, at each stage of map production, geological data with other georeferenced products such as DEM, digital orthophotos, various sets of topographic maps, etc. The GIS data can be easily transferred towards the classical map publishing process using a third-party application (e.g. MAPublisher). This procedure which is a part of the project has been successfully tested.

The geological information system under development by the Swiss Geological Survey will offer a common platform for the edition and the publication of the future map sheets of the Geological Atlas of Switzerland. It aims at providing to a wide range of users (practitioners, researchers, students, etc.) more powerful cartographic products (numerical and analogical) especially in terms of spatial analysis and geological data management.

ACKNOWLEDGMENTS

We cordially thank Mr. Laurent Jemelin (Swiss Geological Survey) and Pr. Jean-Michel Jaquet (University of Geneva) for the many ones and profitable discussions we had with them.