# THE DIGITISED GEOLOGICAL CARTOGRAPHY OF THE EMILIA ROMAGNA REGION TO SCALES 1:10,000 AND 1:50,000. THE CARTOGRAPHIC GENERALISATION PROCESS

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The production of geological cartography to scale 1:50,000, normally generated on the basis of a field survey to a higher scale (1:10,000 - 1:25,000), requires cartographic generalisation processes. There are three fundamental factors: informative content, geometrical accuracy and graphics and symbols related to the printing process. The Emilia Romagna Region is currently working on a prototype involving a comparison between a geological map to scale 1:50,000 produced by conventional means and the same map obtained through a process of cartographic generalisation of the geological data to scale 1:10,000 in the regional database.
The procedure consists of the following phases:
a) definition of the CRITERIA for simplification of the information content, the geometrical conversion and the representation in printed form of the geological data in the Emilia Romagna Region database. These geological data have been stored using a conceptual, logical and physical model designed by the authors of this paper, on the basis of geological maps to scale 1:10,000 produced in the conventional way;
b) preparation of the algorithms and their utilisation in ARC/INFO environment for automatic use of the criteria established in point a);
c) quality and quantity comparison between the results obtained in point b) and the geological map to scale 1:50,000 of the same area produced conventionally and then converted into numerical form using the data model described in point a);
d) critical evaluation of the results obtained.
This evaluation enabled us to define the most efficient process for production of the geological maps to scale 1:50,000 of the hill and mountain areas of the Region, and also generated some very stimulating theoretical considerations.

## 1. FOREWORD

### *1.1 The Context*

The context in which this project was implemented can be summarised as follows:
- the Emilia-Romagna Region has been working for some years on the production of the geological cartography to scale 1:10,000 of its hill and mountain areas (about 10,000 km2) by the conventional methodology
- in 1990, the Region started the digitisation of the geological maps to scale 1:10,000 on the basis of a conceptual, logical and physical data model developed by a group of its own staff. The Emilia Romagna Region currently possesses a geological database covering an area of over 3,000 km2, equivalent to about 100 geological maps to scale 1:10,000.
- the Emilia-Romagna Region, in the "Geological Map of Italy 1:50,000" national project, coordinated by National Geological Survey, is currently working on the geological maps 1:50,000 of its regional area, generated from geological maps 1:10,000 (syntetized on 1:25,000). This is a national project that also provides the production of geological national database to scale 1:25,000.

### *1.2 The Objectives*

The aim of the project was to assess the possibility of obtaining a geological database to scale 1:25,000 and a printed geological cartography to scale 1:50,000 using "automatic" procedures.

starting from the existing regional geological database. There are two very important aspects here, one practical and one theoretical.

The first, practical aim was to provide the Emilia Romagna Region with a highly efficient process for the production of the database and geological maps to scale 1:50,000 envisaged as part of the national CARG project. Such a process would also allow a solid linkage between regional and national geological databases, with safe, controlled paths for the two-way exchange of information.

On the theoretical side, there are many members of the scientific community of geologists who maintain that the contents of a geological map to scale 1:50,000 can only be "derived" from a detailed map to scale 1:10,000 by "reinterpreting" the geology of the area under consideration, and that thus this "reinterpretation" cannot be carried out using paths definable by means of algorithms to be applied to larger scale data.

The aim of this paper is to demonstrate that this hypothesis is only partly true. A reinterpretation is required, but for a large proportion of geological data this reinterpretation can be made using algorithms that enable others to read and retrace the method used by the map's authors. We have no intention of claiming categorically that geological maps to scale 1:50,000 can be obtained automatically from those to scale 1:10,000, but we do believe that they can be generated using a method more open to control than those often previously employed. Moreover, this procedure actually enhances the scientific aspects of the geologist's work.

## 2. CRITERIA

For each geological entity in the database, the proposed cartographic generalisation criteria concern the information content, geometrical accuracy and questions of graphics and symbols related to the printing process.

*2.1 Information Content*

With regard to the information content, the operations carried out involved elimination (partial or total) after selection based on one or more items of the entity considered. In some cases, after the selection, entities were transformed through a combination procedure (with or without reclassification).

*2.2 Geometrical Accuracy*

The procedures adopted with regard to geometrical accuracy depended on the topology of the entities (points, arcs or polygons), but consisted essentially of elimination, transformation and generalisation (in the sense of the ARC/INFO "generalise" command).

Elimination

The parameter used for elimination procedures was minimum dimension (minimum area for polygons and minimum length for lines). Obviously, this operation could not be applied to points. For polygons, the possibility of using the perimeter and shape coefficient as parameters for elimination, in addition to the minimum area, was also considered.

Transformation

The transformations envisaged were of the following types:

a) point -> point

b) line -> line; line -> point

c) polygon -> polygon; polygon -> line; polygon -> point.

CASE a): in practice, points were simply thinned out using a buffer of pre-set radius.

CASE b): lines were also thinned out using pre-set linear buffers; in addition, line->point transformations were made on the basis of a minimum length, and point entities were applied to the barycentre of the original line.

CASE c): polygons were combined using a pre-set buffer (after which the buffers were merged); in some cases, we considered increasing the size of a polygon (again with a pre-set buffer) to make it visible at a smaller scale.

Polygon-line transformations were made using the shape coefficient and by drawing the "centre line" of the polygon. Finally, for polygon-point transformations we used the minimum area (with or without shape correctives), locating the point in the barycentre of the initial entity.

Generalisation (in the sense of ARC/INFO)

By generalisation. in this context we are referring to the definition of a tolerance which optimises the distance between the vertices of an arc in the ARC/INFO data structure. This operation allows us to act on the geometrical accuracy of a linear or polygonal entity. redefining it to suit the reduction in requirements involved in the passage from 1:10.000 to 1:50.000. The object is to streamline the database by cutting the number of co-ordinates to be processed.

*2.3 Graphics and symbols (related to printing)*

When generalising geological data for the passage from 1:10.000 to 1:50.000. cartographers are also forced to solve a vast range of problems related to graphics and symbols. to permit the printing on paper of geological maps to scale 1:50.000. Examples include exaggeration of the dimensions of an entity. graphic congruity with the topographic basis for printing. and so on. We have not yet dealt with the printing process and we intend to tackle these problems during a further experimental phase in the next few months.

*2.4 Conclusions*

All the criteria were formulated in a manner which allowed them to be drafted in the form of very simple algorithms. In practice. these algorithms consisted of a sequence of commands in ARC/INFO environment implemented on every geological "entity". to which a real transformation procedure was applied. It is important to note that in some cases the transformation procedure proposed for an entity also necessarily affected other entities conceptually linked to it in the entity-relation model. in order to assure the overall congruity of the data. At the same time. we agreed that for some entities no geometrical or information transformation was required.

Naturally. any transformation (or non-transformation) process had its own geological justification. and the principles applied here are summarised in the next section.

## 3. ALGORITHMS

First phase: common to all entities regardless of type.

Initial composition of all the Sections at 1:10.000 which make up a map sheet to 1:50.000 (for this project we used sheet 265 "San Piero in Bagno"): dissolution of all the cartographic borders between the various sections. with consequent merger of the adjacent polygonal entities of the same type into a single polygon.

Second phase: generalisation of the entities in the sheet at 1:50.000 obtained by simply assembling the sections at 1:10.000.

There were two fundamental objectives in the geometrical and information generalisation of the geological data in the regional database:

- to eliminate the polygonal entities too small for representation at scale 1:50.000 and belonging to categories which were negligible at the new scale;
- to eliminate or transform the linear and point entitles at a level of detail too high for the new scale.

The subsections which follow describe the operations carried out on the geological entities: for convenience. these have been grouped into four categories.

*3.1 Geological Units*

All polygons of 30.000 m2 or less in area were eliminated. since this size was considered an appropriate limit in view of the information content and legibility of a geological map to scale 1:50.000 and the geological nature of the studied area

It is important to bear in mind that unlike geological maps to scale 1:10.000. those at 1:50.000 represent the geology of a given area in a highly interpretative. symbolic form.

The combination procedure involved the dissolution of adjacent areas which had been allocated the different code in the original geological database and after we gave them the same code in the analysis of the geological units at a regional scale: a number of stratigraphic limits were thus deleted.

The San Piero in Bagno zone contains many marker beds. which had been mapped as polygons where the scale 1:10.000 allowed.

In agreement with the author of the original map. we decided to transform these polygons into linear elements. since it was not possible to represent them correctly at 1:50.000.

To do this, these polygons had to be extracted from the level of the geological units, and the borders of the remaining units originally next to them had to be modified.

The polygons which had been removed were then transformed into lines running along their barycentres and inserted into the layer of the linear elements, where the marker beds mapped at lines had already been included.

*3.2 Quaternary cover*

The criteria adopted for these polygonal entities depended on the type of cover. For landslides, which were subdivided into dormant and active, we chose a threshold area for elimination of 20,000 m2, although no landslides less than 50 metres from population centres or other urban infrastructures (roads, railways, etc.) were eliminated, so that even small landslides which might pose a threat to urban life would be visible on the map at 1:50,000.

For the debris category, the minimum area threshold was 30,000 m2.

For other types of deposits, including terraced alluvial deposits and alluvial fans, the minimum area adopted was 8,000 m2.

All the polygons in the category of current alluvial deposits were retained at the new scale.

*3.3 Linear entities*

In the conceptual model of the Region's 1:10,000 geological database, all entities mapped as lines are contained in a single level, even if they belong to different groupings when strictly geological criteria are applied.

Within this data model, we eliminated all lines of a geomorphologic nature, such as scarp-edge, abandoned river beds and landslide niches.

The various types of fault, indicated separately at scale 1:10,000, were all grouped together in a single overall fault category, subdivided into those identified with certainty and those presumed to exist.

For linear structural elements, such as overthusts and faults, we decided to eliminate all sections which intersected quaternary cover polygons, and those classified as presumed, while all sections classified as identified with certainty were retained, even if they intersected the polygons, since they dislocated the cover itself.

In agreement with the author, we decided which linear structural elements bordering quaternary polygons were of sufficient importance to justify their retention.

This selection was possible thanks to the structure of the database, in which every arc is allocated a flag for every geological theme to which it belongs.

After this elimination of excess information, the geometrical data were also streamlined where too many lines made the map to scale 1:50,000 difficult to read.

The linear marker beds were also thinned out on the basis of a selection made by the author of the original map, with elimination of those considered less important.

However, the remaining marker beds were far too disjointed for effective mapping to scale 1:50,000. This was because of the high level of detail in the survey to 1:10,000, in which the beds were mapped where they were really outcropping, without any interpolation and/or correlation by the author.

*3.4 Point entities*

Like linear entities, point entities are contained in a single level of the regional geological database.

All cataclastic zones, slumping, fossil-bearing zones, turbiditic palaeo-currents, inter-bed thrusting, palaeo-surface deposits and associations of minor folds were eliminated, while all points indicating quarries, mines, springs and caves were retained.

Stratified deposit measurements (strike and dip of beds measurements) were cross-correlated with the geological units to obtain a indication of the measurement frequency for each unit.

We strike and dip all stratimetrical data for units for which relatively few such measurements were available, while for other units a criterion of one measuring point every 500 m (about one measurement every cm2 at scale 1:50,000) was adopted.

A grid of points 500 metres apart was created, and the strike and dip of bed measurement obtained closest to the point on the map (within a radius of 150 m) was represented.

## 4. COMPARISONS AND CONCLUDING ASSESSMENTS

*4.1 Comparisons*

In the last phase of our study, we made a quantity and quality comparison between the entities obtained by applying the generalisation algorithms to the initial geological data and those derived from the digitisation of a conventional geological map of the same area printed last year after an ad hoc survey to allow an overall review of the data on the previous map to 1:10.000.
Since the same database structure was maintained, it was possible to make an entity by entity comparison for any polygonal, linear or point feature, with the same unit of measurement (square metre, linear metre, number).
As it is not possible to give all the results of this comparison in full in a paper of this kind, we will describe a number of particularly important polygonal entities: the geological units and the quaternary cover structures.
For the geological units, the comparison was made using two indicators: the number of polygons per type (or grouping) of units, and the total area of the polygons of that type (or grouping).
The result of the comparison was extremely encouraging.
We found that our map had slightly reduced the number of polygons compared to the conventional map, easily explained by the fact that the application of an algorithm allows stricter application of the elimination threshold than a manual procedure.
The result with regard to the total area of polygons per type was truly astounding: a difference of less than 5% for almost all types of geological unit present, and no variations in area exceeding 10%.
The results for the quaternary cover structures were less promising, due mainly to some gaps in the information on the conventional map (for example, the codes of many terrace polygons were not provided because of their small size) or because the two databases merged structures in different ways.
As for the geological units, and for the same reason, our map contained fewer polygons per type than the conventional map.
The comparison in terms of area gave less stable results than for the geological units, although for the most important entities (such as landslides) the variations did not exceed about 10%. From the quality point of view, the only comparison we have been able to make so far is between a plotting of the results of our cartographic generalisation and the equivalent plotting obtained from the digitised data of the conventional map.
The results are definitely good, since the results of the generalisation in terms of graphics and symbols are quite encouraging.
However, we will not be able to give an in-depth assessment of this aspect until we have the results of the printout of a geological map to 1:50.000 derived from the cartographic generalisation.

*4.2 Concluding comments*

We consider that we have fully achieved the objectives set out at the beginning of this paper. The quantitative and qualitative results encourage us to state that it is really possible to use "automatic" procedures to generalise the information content and geometry of a highly detailed geological database (scale 1:10.000) in order to obtain geological maps at a smaller scale (1:50.000).
We are naturally prepared to confess that there are still many limitations, and in our project the author was forced to carry out numerous procedures "manually"; often the existing data structure was unable to provide the information needed to proceduralise the whole of our transformation process.
More work is therefore required in many directions (improvement of the structure and information content of the regional geological database, identification of more efficient algorithms, the solution of problems of graphics and symbols relating to printing, and so on) but we believe it is important to have made a small contribution in the right direction.

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