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Digital map databases: No more hiding places for inconsistent geologists!

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Introduction

A geological map is without doubt the visual language of geologists (Rudwick, 1976). Given a geological map of anywhere in the world a geologist will be able to share a basic understanding of the disposition of the rocks that the map author depicted. Further, with a little time to interpret the maps and their legends, most geologists could make sense of two maps of adjacent countries, even though the linework and classification systems may not always be the same.

Unfortunately computers, GIS and digital databases do not possess such powers of interpretation and deduction. They do not comprehend that polygon X on one map is probably the approximate equivalent of polygon Y on the other. Though systems using fuzzy logic are currently being investigated, most GIS and databases require data to be logically structured and relationships between features and attributes to be explicit and not merely tacit.

Using the example of the IGME 5000 project, this paper will explore some of the reasons for the inconsistency in geological maps and classification systems and illustrate why this poses serious problems for those who wish to construct and use geological GIS across regions and countries.

Maps, geologists and the advent of IT

Generations of earth scientists ("Geognosten" and other geoscientists) have summarized the results of their fieldwork and research in map form (Asch, 2003). The geological map has been the means for "geologists" to record, store and disseminate their knowledge and the results of their investigation of the rocks and unconsolidated deposits of the Earth's surface. For several hundred years geological maps have been, and still are, "the visual language of geologists" (after Rudwick, 1976). They represent the " ... knowledge simply of what is where on the Earth surface ..." (Maltman, 1998).

Geological maps have always provided for their users basic knowledge about the distribution of natural resources such as ore, water, oil or building stones. They may, albeit indirectly, warn about the danger of natural hazards or supply information about suitable sites for land-fill, house-building or tourism. They thus provide the basis for environmental planning and protection and support public policy decisions. Geological maps are the basis for understanding the earth and its processes.

In the last quarter of the 20th century, the era of IT arrived and changed the world of geosciences totally and irrevocably. Loudon (2000) points out: "IT influences the way in which scientists investigate the real world, how they are organized, how they communicate, what they know and what they think". We are just at the dawn of that era.

Now many factors that constrained our predecessors no longer exist. Modern computing systems (for example databases, GIS and Internet tools) allow us to store, retrieve and present far more information and knowledge about an area than we could ever display on a 2-dimensional piece of paper. The key point is that we can now separate the storage and recording of information from the means of disseminating it; we are no longer forced to try and serve all purposes with the same "general purpose document". Using IT we can select the area, change the scale and topographic base, choose the theme, amend the colours and line styles. We can distribute the knowledge in an infinitely variable number of ways, delivering it on paper, on CD ROM, or across the Web and choose a variety of resolutions, qualities and levels of complexity. Increasingly, geologists are now using modelling software to create 3- and 4-dimensional models, allowing users, through a variety of visualisation methods, an insight into the original scientist's interpretation of the Earth below our feet.

In many respects the 1:5 Million International Geological Map of Europe and Adjacent Areas (IGME 5000) project is bridging the domains of the traditional paper map and the digital era which have been summarised above. The next sections describe the project and discuss the issues it faces.

GIS and paper map: The IGME 5000 Project

The 1:5 Million International Geological Map of Europe and Adjacent Areas (IGME 5000) is a major European geological GIS project which is being managed and implemented by the Federal Institute for Geosciences and Natural Resources (BGR) under the umbrella of the Commission for the Geological Map of the World (CGMW). It follows a long tradition of the BGR and its predecessors to produce international geoscientific maps of Europe. The IGME 5000 is a collaborative European project involving to date, 48 participating geological Surveys and is supported by a network of scientific advisors.. Its aims are to develop a Geographic Information System (GIS), underpinned by a geological database, and a printed map providing up-to-date and consistent geological information. The main theme of the project is the pre-Quaternary geology of the on-shore and, for the first time at this scale, the off-shore areas of Europe (Asch, 2002). Standard procedures, data structure and dictionaries were developed in order to gather, integrate and constrain the necessary spatial and attri-

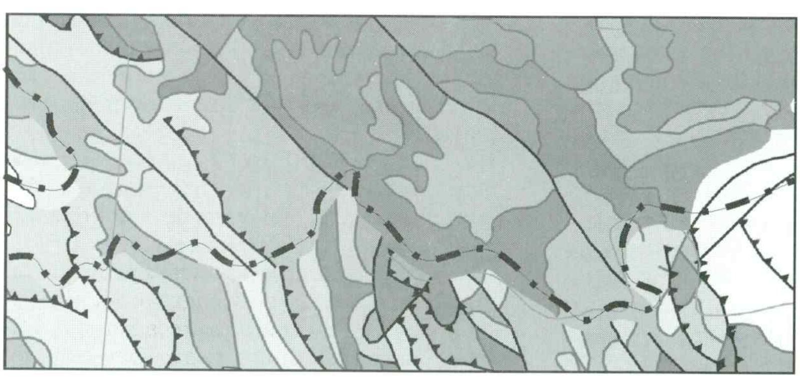

Figure 1. An example of inconsistency at national boundaries from the IGME 5000 project. The differences are notable particularly in regard to geological classification, mapped units and level of detail.

bute information from the participant organisations.

Some Recurring Problems

Organising the co-operation of so many participating nations and compiling their input proved to be a considerable information management task. Without doubt the major challenge was coping with the inconsistency of approach by the participants: different interpretations, variable data input, generalisation and drawing quality techniques. It seems that almost every geological survey organisation in Europe has created its own conventions (and sometimes several conventions) to produce traditional paper maps, and now their digital representation within a GIS (a fact subsequently reinforced by a FOREGS census of 29 Geological Surveys (Jackson & Asch, 2002).

Significant discrepancies (Asch, 2001) were found in the following items:

- geological classification, such as lithology and chronostratigraphy,
- mapped units (emphasis, number, ...),
- topographic base (co-ordinate system, ellipsoid, drainage system, projection),
- draft map scale,
- level of detail and completeness (especially off-shore),
- colours, symbols,
- data structures and hierarchies.

Not unexpectedly these differences gave rise to discontinuities at the political boundaries - the well known "national boundary faults" (Figure 1), not to mention highlighting the substantial differences between the mapping of onshore and offshore areas.

Generic Reasons behind Inconsistencies

There may be numerous reasons for the inconsistencies described above, inconsistencies that are repeated within the mapping of most national territories. The amount of data available in areas will vary; different classification schemes have been used; the mapping may be of different ages and advances in the scientific techniques and new data will have occurred. But perhaps the underlying and most fundamental reason is surely that geology is a deductive science, and a geological map is the result of the interpretation of often sparse and variable data by individual geologists, each with their own idiosyncratic approaches.

Are Standards Important?

Does it matter if we have these inconsistencies? After all, given a little time, geologists can usually establish the intended equivalence or otherwise between the "apparently different" rock types on adjacent maps? Given time, they may be able to, but the total effort taken to research and solve these discrepancies in an ad hoc way must consume an enormous amount of time. These variations and the adjustments made to correct them will inevitably also lead to misunderstandings between geologists and make it more difficult to recognise relationships and associations between geological sequences. This will result in obstruction of the progress of cross-border scientific understanding.

Further, those without the benefit of geological training will not be able to appreciate or resolve the inconsistencies, a fact which seriously limits the worth of geological maps and databases outside the geological profession.

In addition, when the maps are used as the basis for applied products, e.g. geohazard or mineral maps, the differences may lead to potentially serious inconsistencies in future risk or resource prediction. In this context should be also considered the need to provide coherent geoscience information for pan-regional or pan-national initiatives, e.g. the European Water Framework Directive (EU, 2000) or Mineral Waste directive initiative (Cliford & Fernandez Fuentes, 2002).

Last but not least, while geologists may be able to deal with uncertain relationships, computers, GIS and database systems find it extremely difficult, if not impossible. Such systems demand a much more rigorous approach to geometry, data structure and attribution.

Thus, the potential benefits of Information Technology, i.e. interoperability, data integration and the ability to share and supply harmonious information for scientific research to address pan-national geological problems across frontiers, are entirely dependent on the continuity and consistency that standards would bring.

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