

THE DESIGN AND DEVELOPMENT OF A GEOLOGIC HYPERMAP PROTOTYPE⁽¹⁾

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ABSTRACT

A geologic map provides information about the currently accepted model regarding the subsurface structures in a given area. It is based on various types of information such as field observations, drill hole logs and fossil records. From this information the geologist develops a conceptual model describing the geological processes that shaped the observed phenomena. For historical reasons, the model is represented by a geologic map with which is associated explanations, legends, geological profiles, photos and basis data.

Today, this wide spread of information can be better handled by converting it into a digital or even hypermedial form. Therefore it is necessary to develop and implement a geologic "hypermap model". The main objective of our project is to design models and tools well-suited for the interaction between end-users and geologic hypermaps. The particularity of this family of applications is that users in general are both end-users such as engineers and designers (e.g., geologists, map makers). In order to gain insight in users' needs, interviews have been made with various geologists. The output has been used both to develop a hypermap model for structuring the geological information and to design a user interface for displaying the available information.

Objectives, concepts and methods have been tested using a prototype which was developed using the GIS environment ArcView from ESRI. Generic tools to improve the accessibility of the model have been implemented, as well as tools especially developed to meet specific geologic requirements. Tests with various types of users have shown that the prototype matches their expectations and serves as a good basis for further development work.

In this paper, we report on our design choices and the current status of our project.

1 INTRODUCTION

A geologic map is based on the conceptual model of the geologist about the geological phenomena and the processes which shaped them during the earth's history. To convey this model to the user, the map must be accompanied by an explanatory booklet containing notes, profiles, pictures etc.. From the information available to the mapping geologist, only a part can be shown in an analogue map and included in the explanations due to technical limits. For this reason, significant freedom of interpretation still remains with the user.

Digital storage is not subjected to these technical limits. Today it is possible to store the entire information of a map in a database. However, there is still no standard regarding geospatial data modeling, storing and querying. Assuming such an environment would be SQL-compliant, the retrieval of the requested pieces of information would still require experience in formulating SQL-statements. This is unacceptable as many users are not experienced with it (EGENHOFER 1992). In addition, these applications encompass many different types of data that should be handled by a powerful query language as well.

Therefore, a suitable interface between the map user and the associated data must be found. Hypermedial methods are a solution for this problem. They allow one to access different types of information in the same way. Hypermaps, in which digital maps are connected by means of hyperlinks with background information (LAURINI & THOMPSON 1992) are currently in use for touristic (KRAAK & DRIEHL 1997) and cartographic purposes (FUHRMANN & STREIT 1997).

To our knowledge, the potential of the use of hypermedia in geology has not yet been fully investigated. A geologic map is a 2D representation of 3D subsurface structures (POWELL 1992). Besides that, it is based on assumptions and interpolations, in contrast to a touristic map which comprises hard data. Therefore, there exist other requirements for geologic maps than for touristic maps.

A geologic hypermap is only useful if it is structured in a sensible manner. Because of the different fields in geology a user specific structuring of the interface and the data is needed. A hydrogeologist uses the map to solve other questions than an economic geologist. In order to spare him or her the need to search the whole volume of information, it is necessary to provide different specialized geologists with specific tools and data. By

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means of these tools, the interpretation of the map can be partly automatisated. This would significantly facilitate e.g. the preparation of environmental impact assessments.

Because of the technical limits in the textual explanations of analogues maps the assumptions and the specific way of working of the author cannot be recorded completely. In a hypermap this information can be stored as metadata (in the sense it commonly takes in geosciences). This facilitates updating of the maps whenever investigation methods change or new knowledge becomes available. A data model for metadata for geologic maps has currently been prepared by the U.S. Geological Survey (U. S. GEOLOGICAL SURVEY 1997). A hypermap model can be used for any geologic map set regardless of the quantity of data. It is particularly interesting for geological surveys because they are the publisher of geologic map sets.

Requirements of geologic hypermaps go beyond those for traditional hypertext applications (VOISARD 1998). Very important are in particular the various types of semantic relationships, both at a regular and at a metadata level. The underlying database model needs to be powerful enough to handle these relationships. Besides spatial dependencies, time dependencies (e.g. paleographic development) have to be considered by the hypermap model. In addition, geologic map making is an incremental process in which all steps count (being on the field or on paper). Keeping map evolution may change radically a geologic map making process.

Such models also have to take into account the possibility of versioning on multidimensional data, i.e., on time, space and assumptions.

Geological Surveys gain considerably with the results of such applications. Within the framework of our geologic hypermap project, we are working closely with the Geological Survey of Northrhine-Westfalia (GLA NRW) since the beginning of the project. Our hypermap approach is tested in a pilot study using the geologic map set Brilon, 1 : 25 000. This geologic map set has been newly surveyed between 1987 and 1992 by STEUERWALD (GLA NRW).

The paper is organized as follows. Section 2 describes the structure of our prototype. In Section 3 our developed tools are illustrated. Section 4 draws our conclusions.

2 HYPERMEDIAL DATA STRUCTURE

For a hypermedial organisation of a geologic map set, the geologic map has to be considered together with the special maps (e.g. structure map, hydrogeologic map, soil map). Depending on the objective of the study, they will be combined and interpreted in different ways. The user interface plays a crucial role to help users to retrieve data from the available data set in an easy way. To conceive, develop and realise a user-friendly and powerful interface interviews were made with different specialized geologists (e.g. hydrogeologists, structural geologists and economic geologists) in order to obtain information about their specific needs.

This study showed that according to the specialisation of the geologist different data and methods for interpretation have to be provided. For the development of the user interface a flexible expert solution is adopted where the

layouts are fixed by the dialogue author (WETZENSTEIN-Ollenschläger & Wandke 1990). To implement a first prototype, we selected the GIS development environment ArcView 3.0 (ESRI 1996). This system offers a graphical user interface which can be expanded by user-defined methods. Additionally, the layer-orientated concept has the advantage that the graphical data can be stored separately and related to each other in different ways.

The prototype has been evaluated by various test users during the development phase. The results were used to make the prototype as user friendly as possible which is the most important acceptance criterium stated by various authors (e.g. CAREY 1994, KHOSHAFIAN et al. 1992).

A hypermedial map set is built which can be used in an easy way: If the user selects one part of the map he or she gets a pull-down menu which offers a choice of background information and interpretation methods. Besides that, the user is guided through the system by dialogue boxes.

The prototype is structured in five parts which are described in the following sections.

2.1 Map Objects

The available graphical and textual information were organized in the following themes: geology, profiles, structure geology, hydrogeology, soil science, basis data and overview. Basis data as locations of drill holes, fossil records, tectonic and other measurements were geometrically seen as point objects. The location of profiles and secants between topology and tectonic areas (e.g. faults) are classified as line objects. Geologic, hydrogeologic and soil units were interpreted as polygon objects. The instances of the map objects are separated from each other by their attributes. To define the attributes of the map objects the textual explanations and the map legends were analysed beforehand. That way, the map objects could be stored in the database with their respective attributes describing the selected properties (e.g. the stratigraphic age of a geologic unit).

2.2 Hyperlink Structures

The connection of the data by hyperlinks is useful to reflect the relation between map objects and their explanations. The construction of the hyperlink structures allows direct access of detailed informations by mouse clicking the geological symbols on the map. For example, the textual explanations about a geologic unit will be shown by selecting the corresponding symbol on the map. By clicking on a profile line the full profile can be called up. For location points of outcrops photos, drill hole logs, sketches or video sequences can be viewed.

These background informations allow the user to get an image of the region in a fast and easy way. Fig. 1 shows some examples of hyperlink structures.

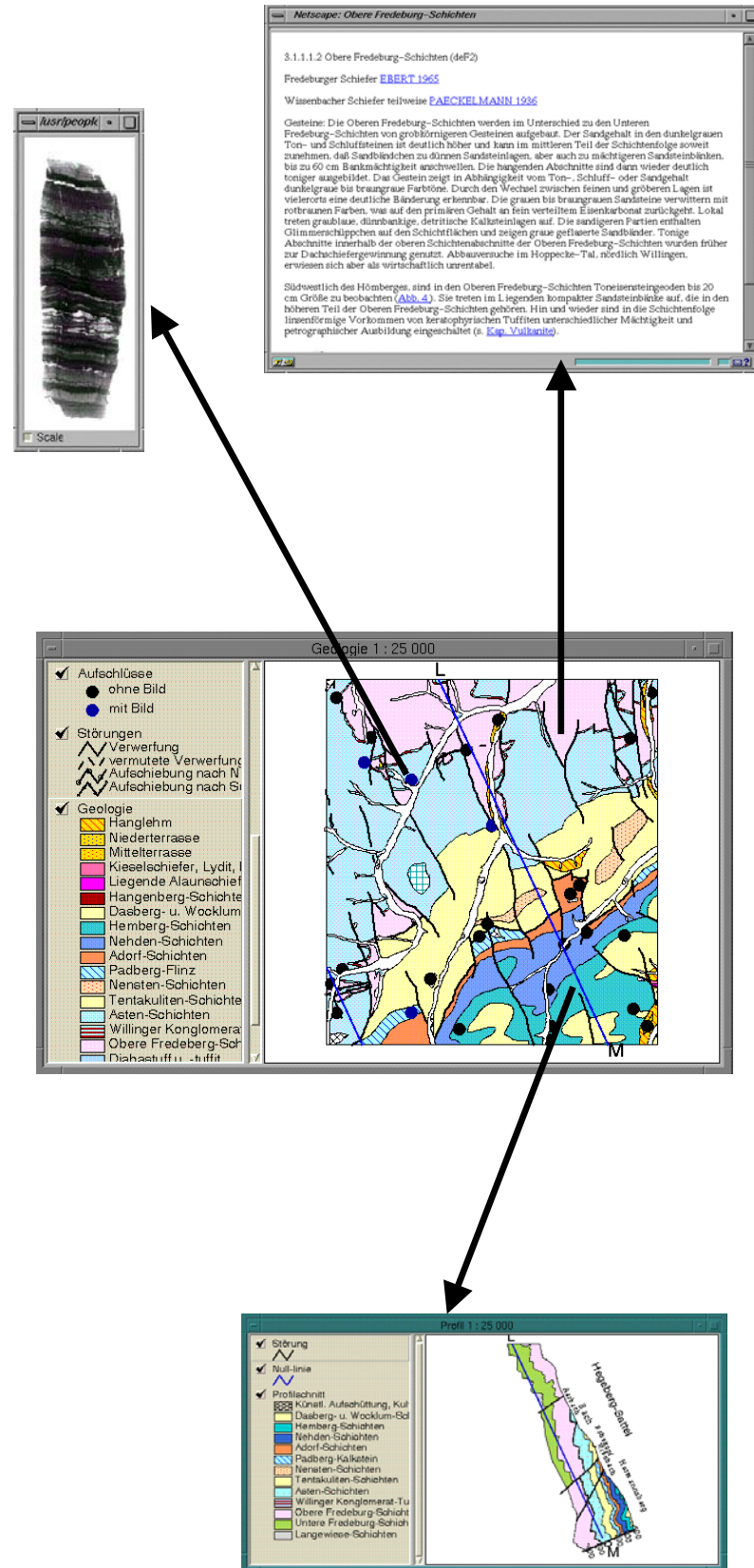


Fig. 1: Examples of hyperlink structures

2.3 Database aspects

The relational database defined within the prototype includes three kinds of information, all stored in separate tables: geometric data, attribute data and data to organize the hypermap. They are stored in tables. The geometric data describe the spatial location of the map objects whereas the attributes are used to store their properties. From some attributes additional thematic maps can be made. As illustrated in Fig. 2 geologic units can be classified by their impact on groundwater permeability.

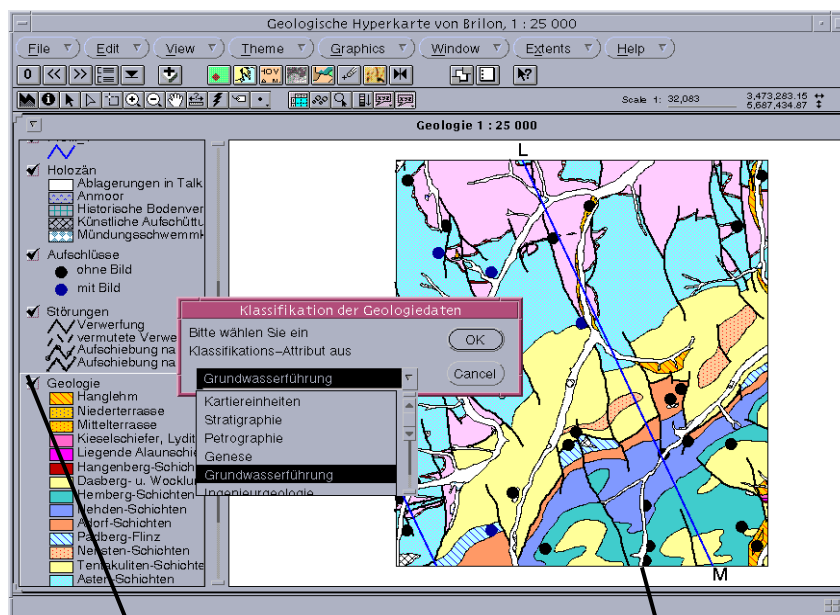
The data to organise the hypermap consist of reference attributes which store the destination of a hyperlink from a map object. They are necessary to realise the hyperlink structures in the final map (see Section 2.2).

2.4 User-Specific Data Grouping

To get the requirements for user-specific data grouping, interviews with experts (i.e., different specialized geologists) were made. In addition to that study, the textual explanations of the geologic map set Brilon were analysed.

In the prototype, different types of interfaces for different user groups (such as general geology, hydrogeology, soil science, structure geology, etc.) are provided. They can be invoked from a start-up menu (see Fig. 3).

According to the choice of the user, he or she obtains tools and data matching the specific requirements. These tools are described in the following section.



respective legend

New coloring according to the selected attribute

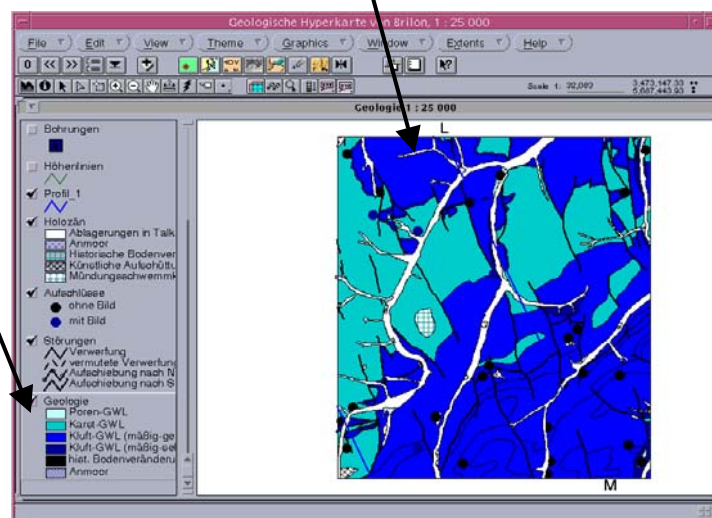


Fig. 2.: Classification of geological units

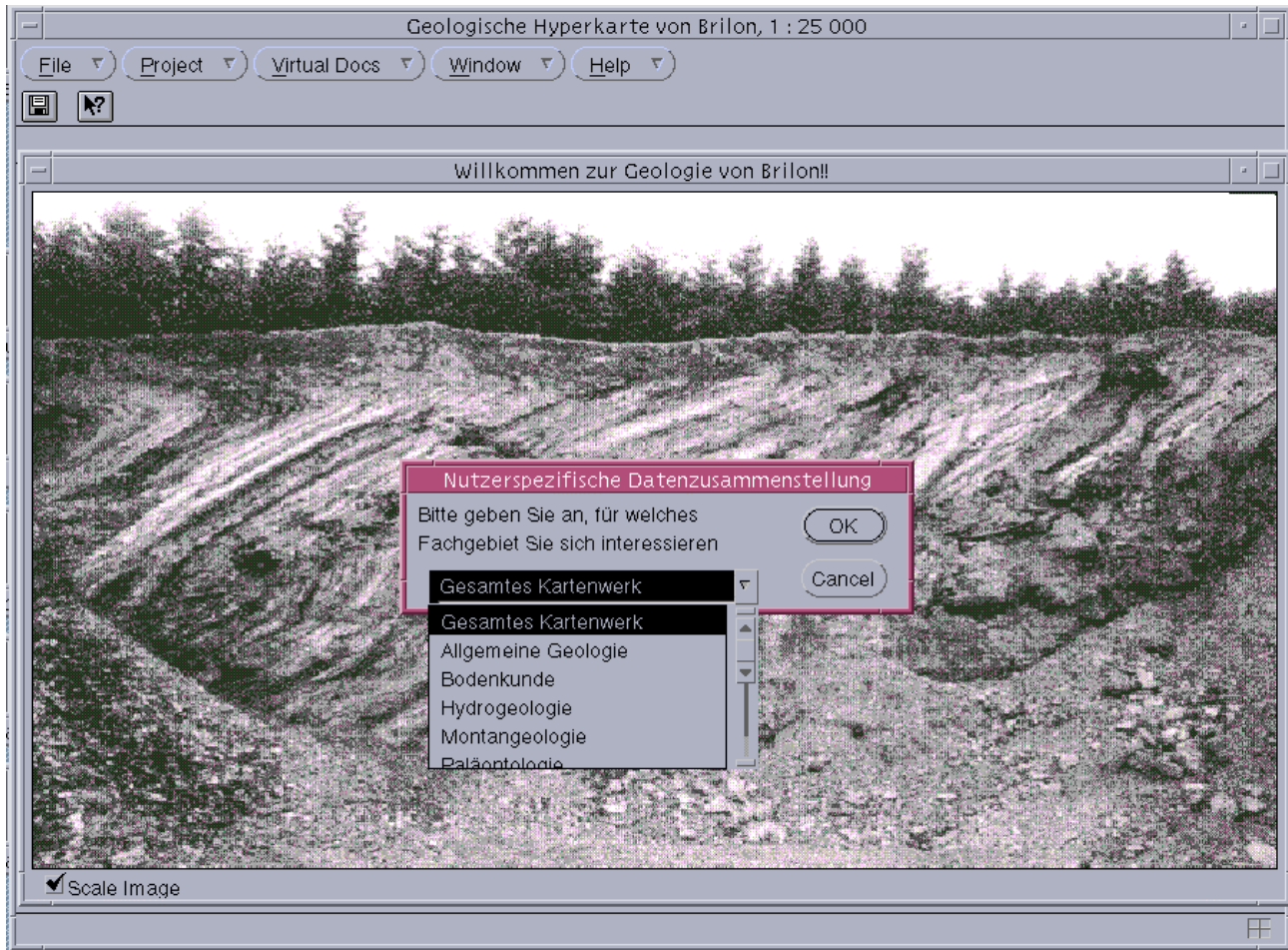


Fig. 3: Menu to choice a user group

3 SPECIFIC TOOLS FOR GEOLOGIC REQUIREMENTS

Based on the results of the interviews with different specialized geologists we could draw a requirement list for accessing and analysing geologic hypermaps. It became clear that the standard tools of ArcView are not enough to satisfy the user's needs. For that reason, we developed diverse specific tools with AVENUE (programming language of ArcView, ESRI 1996). These tools can be called from the GUI by buttons or a menu which appears if the user selects one part of the digital map (see Fig. 4).

The developed methods can be grouped into the themes "querying background information", "selection of map objects" and "database views". In the following text they are illustrated by representative examples.

3.1 Querying Background Information

In geology, there exists often the question which objects support the classification of a geologic unit and which information is available for them. Concretely these are questions like

- Which outcrops, fossil records or drill holes exist in a geologic unit or in a given search radius?
- Where is the nearest drill hole?
- In which distance from a selected drill hole exist natural outcrops?

These questions can be answered by using the following tools:

Point objects like locations of outcrops, fossil records and drill holes can be selected either by choice of a geologic unit or by a user-defined search radius. In both cases the corresponding point objects will be marked.

Besides that, the user is enabled to select one part of the map. That results in indicating the nearest location of a drill hole.

Another tool makes the calculation of distances between point objects possible. The calculated distances will be automatically written into the database.

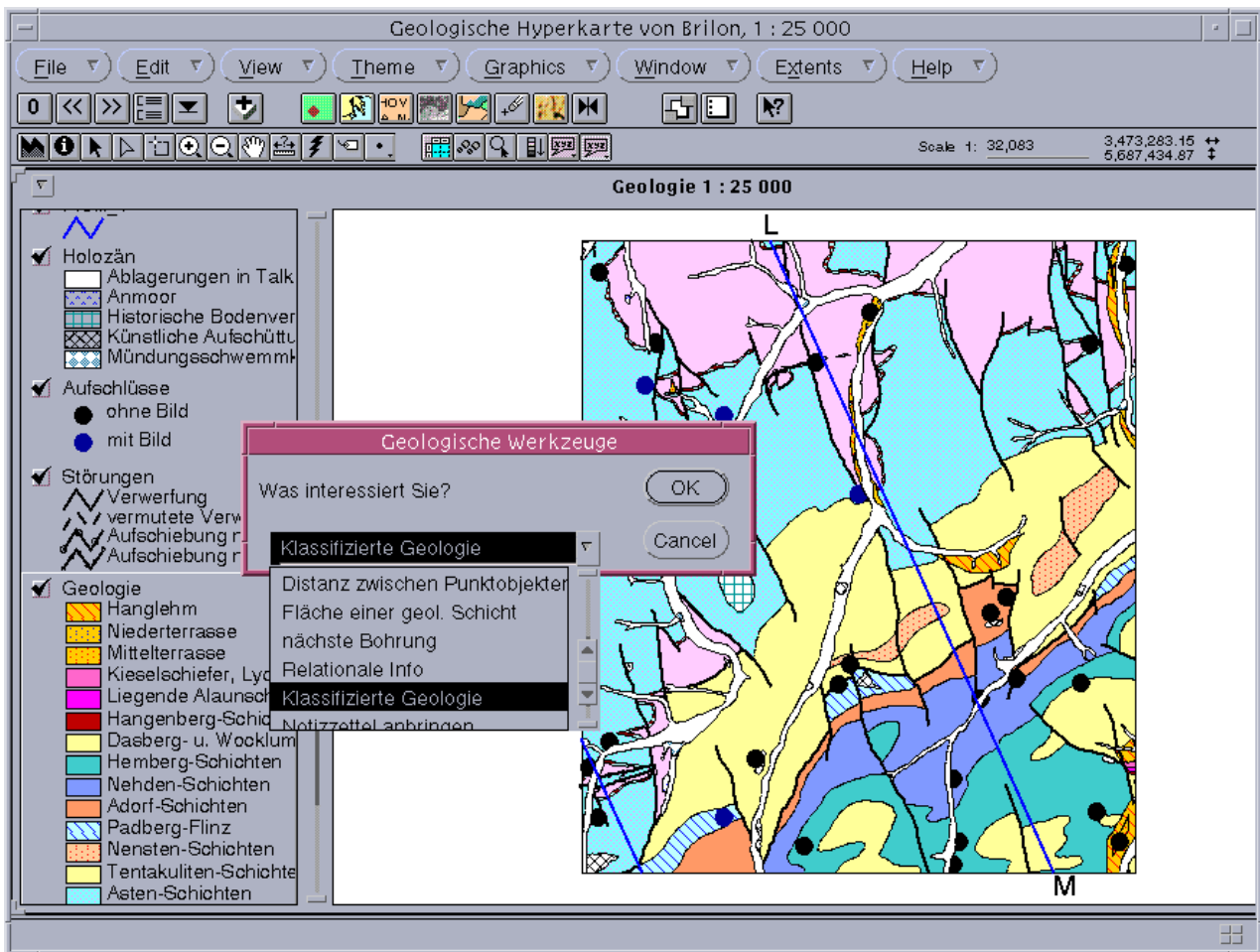


Fig. 4: Menu to choose specific tools

3.2 Selection of Map Objects

During the analysis of a geologic map one often searches after defined objects, geologic or stratigraphic units (maybe all geologic units which are older than a given stratigraphic age). These queries are supported by the following tools:

By means of a menu which includes an index of the available map objects the name of a map object, for example the name of a fault can be chosen. The corresponding object will be marked and the map will be zoomed in the respective region.

Another menu enables the user to select a defined geological unit or units of a defined stratigraphic age. The corresponding objects will be indicated and can be stored in a separate thematic map.

3.3 Database Views

Geologic maps with the scale 1 : 25 000 often serve as an overview, e.g. in the scope of environmental impact assessments. When using an analogue map set, the geologist has to compare the region in different special maps (hydrogeologic map, soil map, etc.), search for the

corresponding textual explanations and finally draw a conclusion. This troublesome way of work will be facilitated by the geologic hypermap:

As illustrated in Fig. 2 the content of the database can be visualized by classification of the geologic units by their attributes (stratigraphic age, petrology, etc.). After choosing one attribute out of a menu the map will be drawn automatically with the new colouring and a corresponding legend.

Besides that, the user is enabled to define a search radius and to choose one attribute of the database from a menu. Thereupon the database entries of that attribute will be presented in a window. This might be the land use of soil units in the given area (see Fig. 5).

Additionally the user has the option to see database views after selecting one unit of the map, e.g. data of the water budget of a selected soil unit (see Fig. 6).

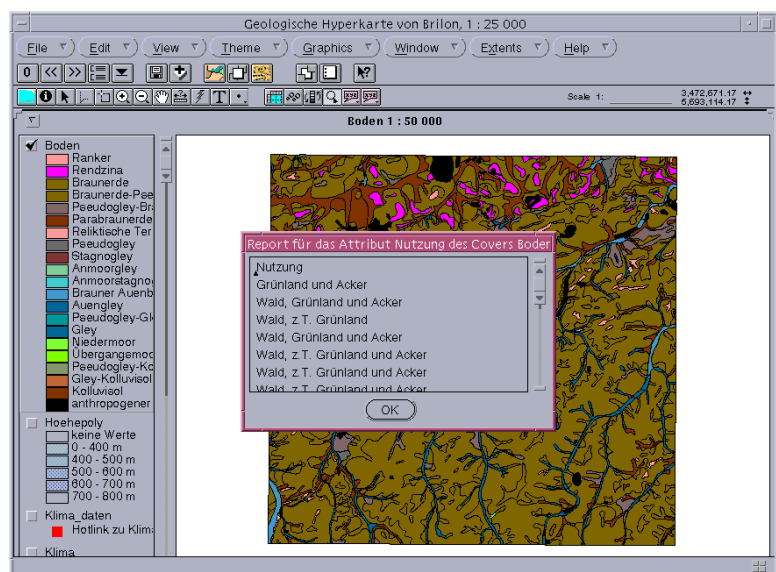
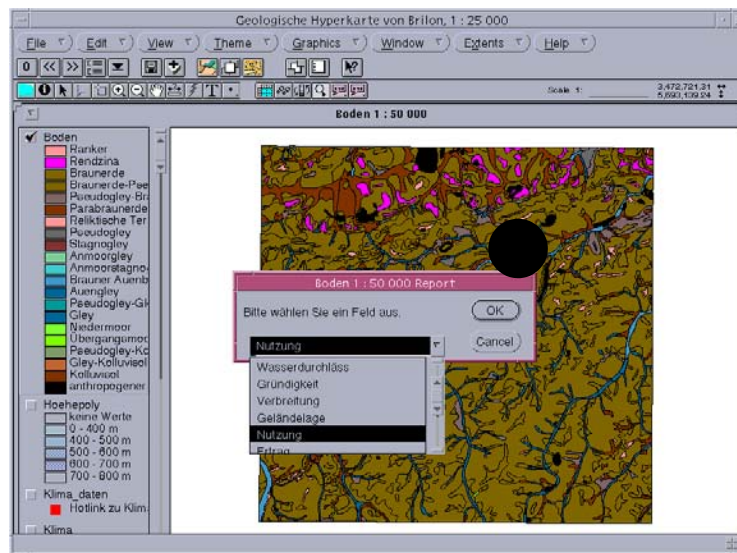
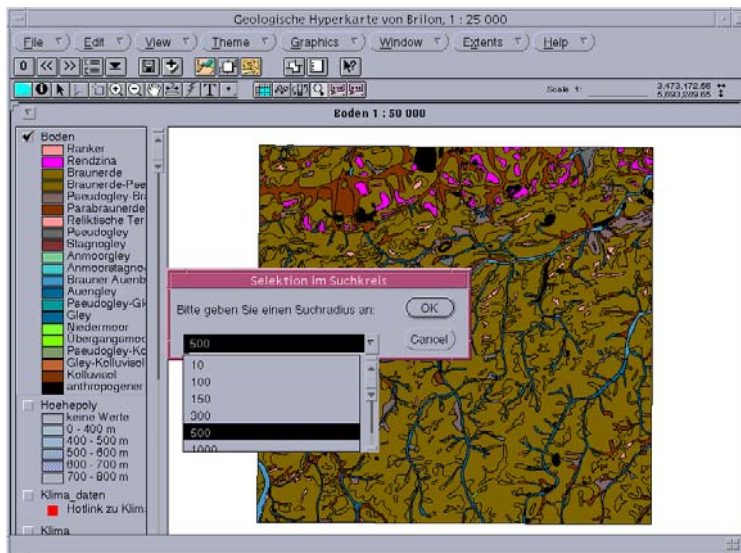


Fig. 5: Database entries of one attribute in a given area

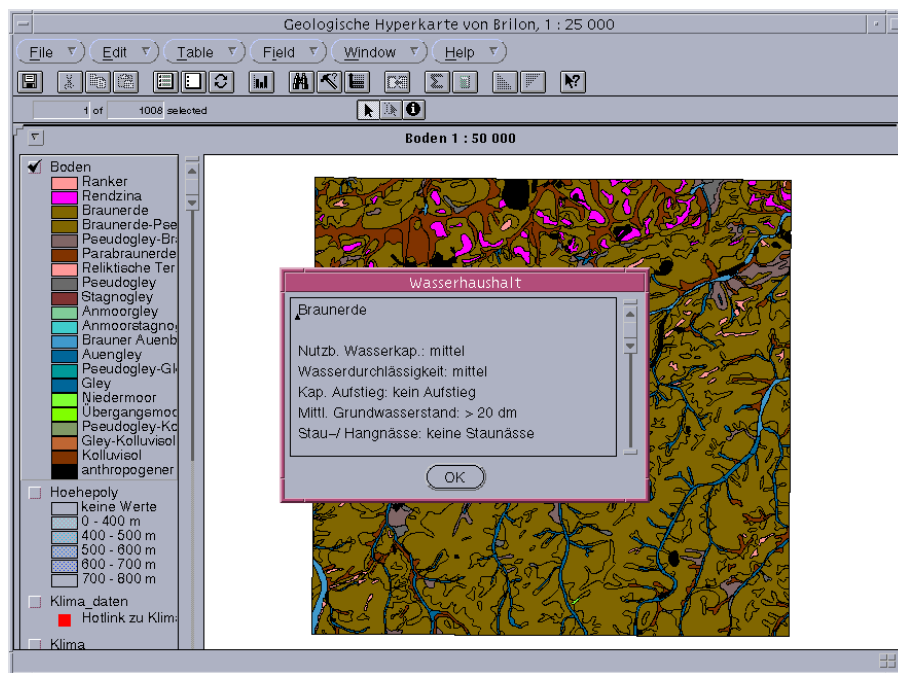


Fig. 6: Database view of a selected soil unit

4 CONCLUSIONS AND PERSPECTIVES

In this paper, we described the first version of our prototype. Our study was carried out in the area Brilon in Northrhine-Westfalia. Based on interviews with different specialized geologists a hypermap model and a user interface has been developed. By the user interfaces various specific tools can be called up. These tools help the end-user to access the available data and to analyse the map objects.

Tests with various types of users have shown that the prototype matches their expectations and serves as a good basis for further development work. A generic data model shall be realised which enables the conversion of any geologic map set into a hypermap.

Multimedia methods offer new possibilities for the presentation of geologic phenomena. Dynamic procedures including facies developments of a region or the evolution of a reef can be visualised by animations. Video sequences can provide an overview of a region or give impressions of interesting geologic phenomena (e.g. water which trickles away in karst holes). Virtual Reality allows dynamic changes of perspective by the examination of 2D/2- or 3-dimensional models. A possible application is draping of geologic units on digital elevation models. The user gets thereby an immediate impression over the geologic structures which cut the surface.

Storing of metadata including the assumptions and the individual way of work of a map's author improves the comparability of neighbouring map sheets. Besides that, updating of maps will become easier. The underlying database has to be powerful enough to store such types of metadata.

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