GEOLOGIJA *46/2,* 329–323, Ljubljana 2003

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

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*Key words:* digital geological map, GIS

## 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-

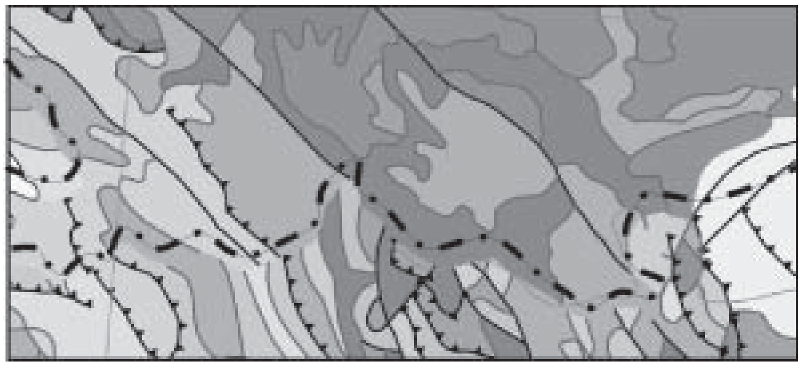

Figure 1. An example of inconsistency at national boundaries from the IGME 5000 project. The differences are notable particularly in regard to geological classification, mapped units and level of detail.

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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GEOLOGIJA *46/2,* 333–338, Ljubljana 2003

# GIS-based assessment of aggregates in Carinthia (Austria)

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*Key words:* mineral resources, assessment, GIS

**Abstract**

For the last thirty years the Geological Survey of Austria (GBA) has made assessments of surface-near mineral resources putting emphasis on regional aspects of land use, environment and economy. In collaboration with land use experts, GIS-tools have been developed to evaluate the sustainability of mineral deposits, taking into account possible conflicts during it's exploitation. An example for the province of Upper Austria, representing the main target of the 1990's, has been shown at 1998's ICGESA (Letouzé et al., 1998). Recent studies have focused on the province of Carinthia, where a Geological Information System has been designed which includes:

• A GIS-based geological map "Setting of gravels, sands and clays" for the whole province of Carinthia (1:50.000 ArcINFO® concept).

• Assessment, input and evaluation of basic data from archives, boreholes, pits and literature in general, in order to advance knowledge about surface-near mineral resources.

Linking digital geological maps to specific data bases allows for the evaluation of mineral resources quality and usability, thereby contributing to a modern planning instrument within the administration of Carinthia. Internet and intranet availability of such data should initiate strategic mineral planning and strengthen sustainable land use in general.

Equivalent treating of solid rocks is ongoing task required to complete land-use relevant mineral resources' assessment in Carinthia.

European regionalization efforts and the common future of Austria and Slovenia within the European Union may support at least comparable structuring of geological data. This paper outlines such an example for Carinthia, one of Austria's boarder provinces to Slovenia.

## Preface

In Austria, each year 42 mio m3 (=75 mio tons) gravels and sand, 1,5 mio tons of clay and 16 mio m3 (=44 mio tons) of hard rocks are produced and used. Nearly the whole amount is used in construction industry. Austria has an average per capita consumption of 15,t tons of such mineral resources (Heinrich, 1995).

Carinthia, Austria's southernmost province, is able to cover the necessities of it's gravels and sand consumption from it's own territory. In detail, significant abundance areas in the south-eastern part contrast with shortage areas (due to lacking geological conditions for reasonable accumulation of such sediments) in the western part of the province.

## Geological setting

Most of the gravels, sands and clays in Carinthia are originally sedimentary products of glaciation through alpine ice ages.

Carinthia during this period was almost completely covered by glaciers, only the easternmost part stayed ice-free. Metamorphic rocks of the East Alpine Cristalline as well as the paleocoic rocks above the ice level were significantly altered and contributing high amounts of debris. Remaining deposits of gravels and sands in Carinthia show a complex suite of glacigene, glaci-lacustrine, glaci-fluviatile and fluvio-lacustrine sediments of the Wuerm glaciation and its residual stages.

## GInS – Geological Information System of Carinthia

For a long period, Carinthia's supply with aggregates was only matter of singular licensing while planning was entirely left to the industry. The only matter of public concern and research was the conservation of relevant groundwater bodies, which - in some way – implicated negative consequences for the supply with aggregates out of the same geological setting. Nevertheless, hydrogeological research generated a lot of informations about aggregate resources too. The 2001 amendment of the Federal Mining Law put executive power for exploitation of gravels, sand, clay and natural stones into the hands of the provincial governments. In Carinthia, this triggered a complete assessment of aggregates as well as leading-off a GIS-based Geological Information System (GInS) at the regional Geological Survey, designed to fulfil an expert role in risk-, hydro-, mineral resources- and environmental geology. GInS is built up on tow major fundaments, the digital geological map and the digital Geo-archive.

### GIS-based geological map "Setting of gravels, sands and clays" (Figure 1)

Out of geological maps of different origin and quality, different scale and purpose, a digital map for the whole province of Carinthia was compiled and processed into a 1:50.000 ArcINFO® concept. This because

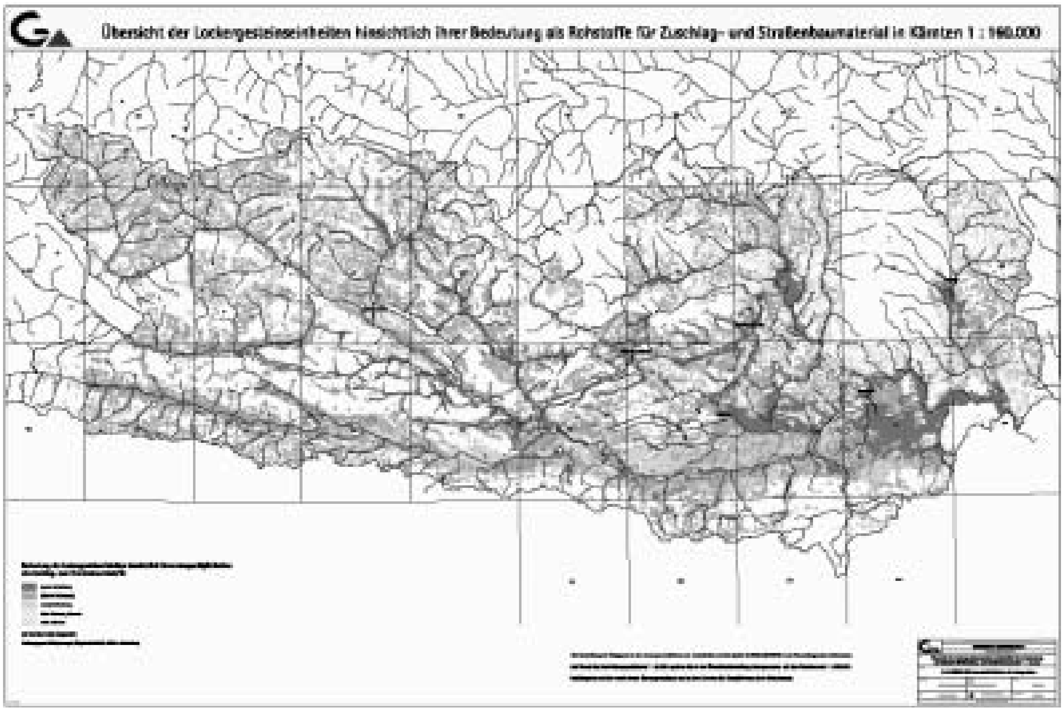


Figure 1. Setting of non consolidated rocks showing their relevance as concrete and road construction material (red/green/brown: high/average/low relevance)

the Survey's official concept of the „Geological Map of Austria 1:50.000" so far only has edited 5 sheets from 34 sheets, which partially or totally cover the province of Carinthia.

All polygons of the new digital map are digitally assigned a) the original legend text and b) a hierarchically structured general legend data base. Classification and description of lithology is according to respective mineral resource's quality. The general legend has turned out to be necessary for combining polygons of different origin and value. This concept should enable the user to generate a map of any scale and any significance, according to his necessities. For the purpose of Carinthia's land use planners the recommended map points out aggregates of "relevance as concrete and road construction material" and distinguishes between high / average / low relevance.

*Digital Geo-Archive*

Carinthia's Geological Survey had a large amount of analogous data derived from decades of daily assessment which have been structured for a GIS-based digital archive and partially have been put into GInS. Items covered are: *General items, garbage water, railroads, chemical hazards, dump sites, land use, power plants, cable ways, scientific projects, bike routes, mining sites, disaster damages, groundwater, road building and geothermal heat pumps*.


Figure 3. Detailed GIS-image of a gravel pit in the vicinity of Bleiburg, Carinthia

Research for archive data may start out of the digital archive (Figure 2) or out of the GIS-application (Figure 3). Lists of search criteria are helpful for data selection. In parts this archive is already linked to existing Intranet facilities of the Carinthian government.

Data input is supported by especially designed MS-Access® applications. Relevant documents could be scanned and linked to the archive. The functionality

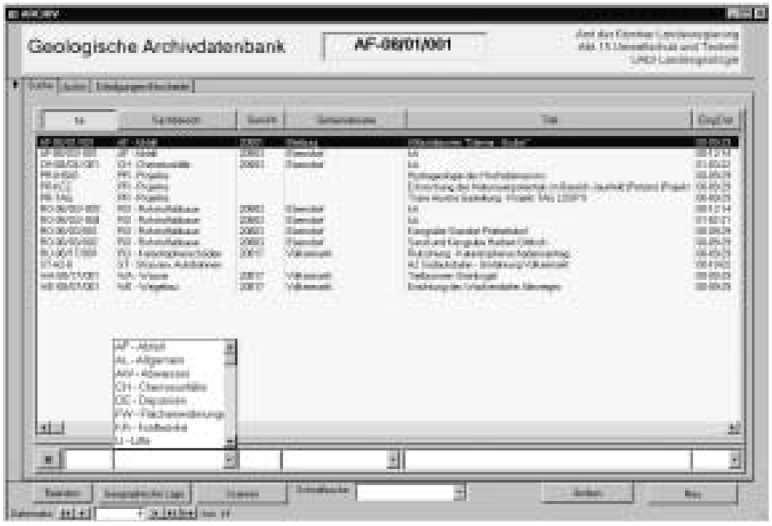


Figure 2. Digital archive at the Geological Survey of Carinthia

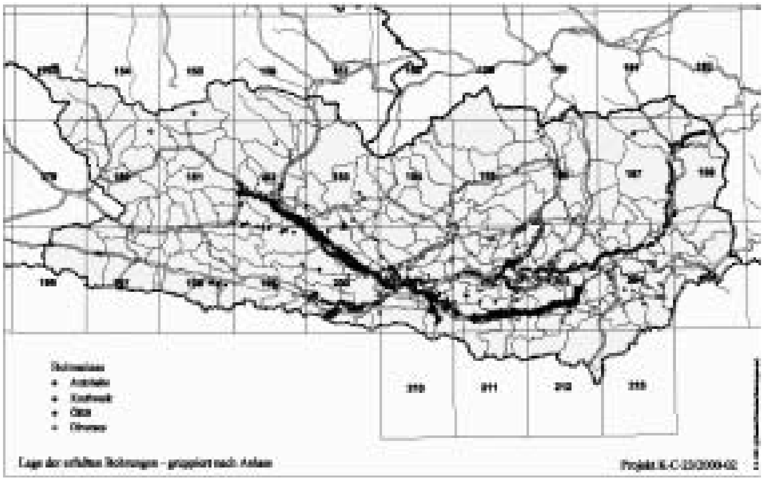

Figure 4. Data input of boreholes for different purpose (highways, power plants, railroads, others)

within MS Windows is optimized through ODBC®-facilities. In order to advance knowledge about surface-near mineral resources, data input for the following items had priority:

### Boreholes (Figure 4)

Data from about 4000 wells have been collected from the archive of the Carinthia's Geological Survey, from the archive of Carinthia's Bridge Building Department, from the archives of two regional power plant companies, from the archive of the railway company, out of unpublished projects and out of geological literature in general.

### Open Pits

Information about open pits was essential for mineral resource's quality evaluation. Contributing archives were once again Carinthia's Geological Survey and the archive of the national Geological Survey, in total the documentation 1250 mostly gravel pits have been evaluated (Figure 5, detail see also Fig. 3). Data input fields are numerous, most of them provide lists of possible input data, others are designed for free textual input.

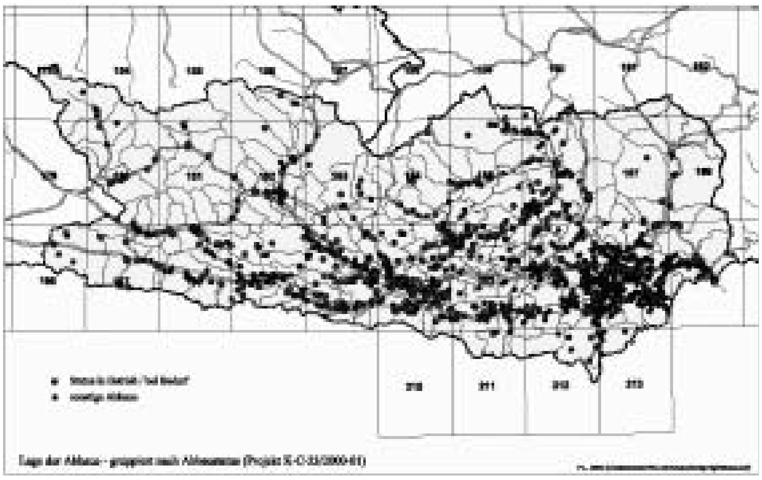

Figure 5. Position of aggregate pits (red/blue: active/inactive)

## Towards an Austrian Mineral Resources' Plan

In October 2000, Austrian Parliament engaged the Ministry for Economy and Labour to develop a National Plan of Mineral Resources. Starting on a generalized level the supply with mineral resources of the entire nation should be outlined verbally, by figures and maps. In a second attempt, supply concepts will be worked out together with the regional governments. Work started in spring of 2002 and is scheduled for five years. Overall target is approaching a sustainable development on the mineral resource's sector.

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GEOLOGIJA *46/2,* 339–342, Ljubljana 2003

# A new Slovenian digital cartographic standard for geologic map symbolization

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*Key words:* digital geologic standards, geology

**Abstract**

Almost four decades have passed since the last "new" graphic standard has been issued by the former Federal Geological Survey of Yugoslavia (1964). Although it was prepared for the project of Basic Geologic Map at the scale of 1:100.000, its use surpassed the primal purpose, and it became broadly used in various graphic representations of geologic information. Through years, however, the standard outdated and have therefore been sporadically upgraded. Constant changes gradually made it unsystematic and inconsistent. An effort was made a couple of years ago to revise it again, and to convert it into digital form but the result provided another conclusive evidence that a total revision of the original is needed. A new digital cartographic standard for geologic map symbolisation is therefore being prepared in Slovenia. The project is run by a team formed at the Geological Survey of Slovenia in close co-operation with contributors from other geologic institutions in Slovenia. The aim of the project is to prepare a consistent and comprehensive set of graphic symbols and rules of representation that would cover the needs of the geologic maps production in scales between 1:10.000 and 1:100.000. The focus of standard's applicability is, however, the new Geologic Map of Slovenia in scale 1:50.000.

## Initial requirements

Requirements that the new Standard needs to meet are:

- uniform graphic appearance of geologic maps,
- employability in maps of scales between 1:10.000 to 1:100.000 with employability focused to the new Geologic Map of Slovenia in scale of 1:50.000,
- employability in litho/chronostratigraphic maps as well as in formation maps,
- employability in geologic cross-sections and stratigraphic/lithologic columns of adequate scales,
- strict systematics,
- employability in various application environments,
- user-friendliness (valid for the maker as well as for the reader of the product)
- applicable in solving local geologic problems yet comparable with global standards.

## Methodology

A work group of 17 experts has been formed to revise existing standards and to prepare proposals by topics. The topics were distributed among group members according to their professional specialities. Each of the group members prepared a Standard proposal on a selected topic given only the rough outlines of the expected joint product. The proposals were then co-ordinated and revised by the whole work group. After all the suggestions and corrections were taken into account, the manuscript proposals were sent to the Geologic Information Centre of the Geological Survey of Slovenia for digitalisation (transfer into the application environment). After the digitalisation is finished, the draft version will be revised again by the work group and published on the Internet for public revision. After the three-month revision period, the work group will consider suggestions, make necessary corrections and finally publish the Standard on the home page of the Geological Survey of Slovenia. The product will stay open for further suggestions through a digital form published aside.

Several Standards exist on the "market", so it has been clear from the very beginning that there was no need for introducing brand new systematics or to apply a completely different approach. The following Standards were used as the basis for the new product: ISO (1974–1989), JUS (2001), USGS-FGDC (2002), OGK 1 (Savezni geološki zavod SFRJ, 1964), the Standard proposal for OGK 2 (Savezni geološki Zavod SFRJ, 1985) and the manuscript proposal for the Slovenian OGK 2 Standard (Premru & Jevšenak, 1996). However, a simple compilation of existing standards proved to be impossible for several reasons. Some of existing standards are inconsistent by their systematics, some are not compatible with the geology of Slovenia, some are too extensive, and the others are too simple. Preparation of the new proposal therefore required plenty of authorial work, in some cases starting completely from scratch.

## The structure of the standard

The Standard consists of three major topical complexes: 1) graphic and alphanumeric symbols, 2) geologic timescale and 3) rules of representation.

**Graphic and alphanumeric symbols** part is the major topical complex of the Standard. It comprises all graphic symbols, hatches and alphanumeric symbols that may apply on a geologic map with an exception of formation, and chronostratigraphic notations. The complex is divided into following topics: 1) sediments, sedimentary rocks and sedimentary environments, 2) volcanic and volcanoclastic rocks, 3) magmatic rocks, 4) metamorphic rocks, 5) minerals, 6) tectonics and structural geology, 7) palaeontology, 8) geomorphology, 9) hydrogeology, 10) engineering geology, 11) mineral resources, 12) special symbols, 13) natural heritage.

The guiding line through the process of preparation was the strict systematics. Namely, there are several examples of existing Standards that have failed in solving the problem of systematics adequately. By comparing them, it became evident that there are three main reasons for a failure: 1) certain geological phenomena are described by two or more symbols, 2) similar or identical symbols are applied to describe different geological phenomena, 3) basic and expanded symbol sets are put together regardless of any hierarchy.

The basic, and the expanded symbol sets are strictly divided in the new Standard. Introducing the basic (obligatory) symbol set along with the expanded set means that the mapping geologist will be able to use the Standard regardless of his field of specialisation. Vice-versa, the specialist should find all the symbols needed to conduct any specialised work with the scale of the map/profile/column taken as a limitation, of course.

All symbols are presented in standardised tables and described by a consecutive number, the name, picture, alphanumeric symbol where applicable and a short comment describing the rules of its use.

**The timescale** is the second topical complex. The main idea that followed the preparation of the timescale was to make a local chronostratigraphic division in accordance with global chronostratigraphic/geochronologic divisions. There is a "near-perfect" global time scale that is being constantly updated by the International Commission on Stratigraphy (ICS) of the International Union of Geological Sciences (IUGS). However, the specifics of Slovenian geology make the global timescales non-applicable in certain cases. It was concluded that, for various reasons, local particularities have to be considered for the Carboniferous, the Lower

Triassic and the Paleogene – Neogene geochrons. The main frame, however, stayed completely comparable with the (semi)official ICS's timescale. The divisions go down to the stage or to the substage where reasonable.

Beside the main timescale, the new Standard will provide links to three additional (informative) scales that are being broadly used for comparison with official chronostratigraphic units. These are: the geomagnetic polarity, $\delta^{18}O$ and the Alpine Pleistocene morphostratigraphy.

In case of the Tertiary and the Quaternary we took the conservative approach. Namely, the ICS ceased to use those two as formal chronostratigraphic units, but we found them both too well-nested in minds of geologists so the decision was made to use them. In addition, the cancellation of Tertiary and Quaternary has not been formalised yet.

**Rules of representation** define the notation rules for chronostratigraphic, and formational geologic units. The aim of the standard is to be applicable for all types of general geologic maps so the rules do not exclude any type of such maps.

## Transformation into the digital form & GIS

To transform the analogue data into the digital form and further into the GIS environment in a effective manner, proper standards are needed. These standards have to be strict, practically perfect and upgradable enough, so that absolutely no divergence from the rules is allowed. At this junction of needs, the concept and the GIS, the consistency and applicability of standards work hand in hand.

Graphic symbols, hatches and alphanumeric symbols are transformed into the digital form in proper scales, using CAD tools. After the shape, colour and dimensions are confirmed by the author and the review group, the symbols will be introduced into the standardised procedure of the map digitalisation. For the purpose of the onscreen digitalisation of the Basic Geologic Map at the scale of 1:100.000, the CAD application "Geolog" (i.e. Geologist) was developed (Fig. 1). This standardised procedure is used to minimise the analogue-to-digital transformation errors. The operator (digitiser) uses simple, user-friendly menus in which symbols from different topics are listed and shown. With the described procedure, the basic attributes of a specific symbol are entered and can be further used for the linkage with the symbol's properties and more detailed description in GIS environment. The already adopted protocol, with necessary updates taken into account, will also be used for digitalisation of geologic maps compiled on the basis of the new Standard.

The new Standard is supposed to support production of maps in various scales (from 10.000 to 100.000), hence graphic symbols have to be adjusted to the specific scale and can not be simply scaled. Each symbol has to be defined and designed for each specific common scale used. Also colour charts will have to be defined for each of the symbols. For hatches the RGB and CMYK values need to be defined due to different screen and printer/plotter properties. For graphic symbols (objects and lines) 8-bit colour palette is advisable, to avoid unnecessary dithering on devices that can only display 256 colours (Brown & Feringa, 1999).

Standard layouts of maps, which will comprise the map itself, the title, the cross-sections, the columns, the legend(s), the design of the scale bar, the north arrow, appendices, and text, will also be defined.

With all described bearing in mind, there are several problems that arise during the process:

- non-systematic (chaotic) symbols (hatches),
- scaling of symbols,
- colour vs. black/white print,
- variable hatch orientation within a single geologic unit (bedding…),
- ironically, the inter-PC compatibility can sometimes pose big problems due to specifics of CE fonts, commonly used for Slovenian.

During the development of the new Standard, all problems stated above should be considered. Than again, geologists should participate in the process of the GIS software development more actively, since our needs sometimes differ from the needs of other spatial related sciences.

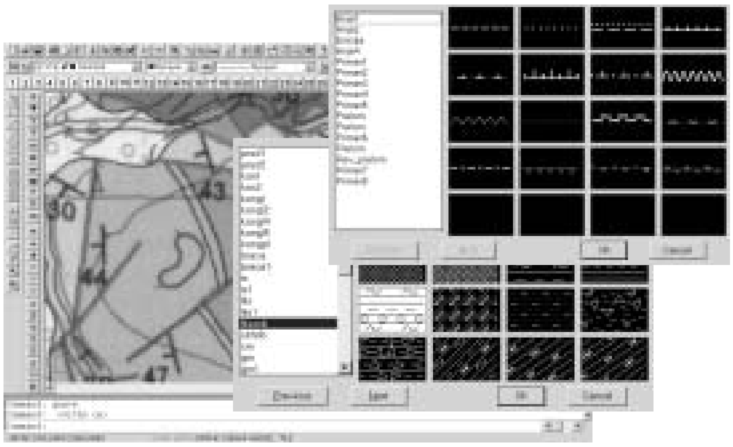

Figure 1. CAD application "Geolog" (Geologist)

## Discussion

Creation of a new Standard consists, in its basics, mostly of compilation of existing standards. However, considering the specifics of regional geology and any kind of special requirements, a pure compilation is practically impossible, and the authorial approach is needed.

Two issues arose along the process of preparation that we have not solved in-full yet. The first is the problem of sytematics and division of symbols according to hierarchical criteria. The second problem, which is in-part specific for Slovenia, is the problem of translations. Beside grammatical issues that demonstrated while translating names of chronostratigraphic units, we are still discussing the decision on whether to derive alphanumeric symbols (two- to three letter) from the original (Greek, English....), from English, or from Slovene.

Prior to creating data presentation standards for the whole country, three levels of consistency have to be addressed: consistency of the original survey (standardised data collection), consistency of descriptive information (standardised data model) and consistency of coding (Johnson et al., 1997). The former two can be controlled and "enforced" up to a certain degree, while the first one depends purely on the knowledge and consistency of the field geologist.

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GEOLOGIJA *46/2*, 343–348, Ljubljana 2003

# The Architecture of the Georgia Basin Digital Library: Using geoscientific knowledge in sustainable development

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*Key words:* Digital Library, architecture, geoscientific knowledge, GIS

**Abstract**

To address societal issues such as sustainable development, geoscience knowledge must be transformed from its conventional packaging. A holistic approach to this transformation requires that (1) geo-information be used to develop indicators such as mineral potential, material availability, groundwater capacity, etc., and that (2) the indicators are combined with socio-economic factors to guide generation of future scenarios for land use, population, urban growth, etc. In this paper we discuss the architecture of a prototype system designed to support these two activities. The system consists of a geoscientific data and knowledge repository that is loosely linked with a future scenario modeling tool (Quest™). The repository supplies transformed information to the tool, and also provides explanations for the input variables and output results. An example implementation, Georgia Basin Digital Library, is also presented.

## Introduction

It is commonly understood by geoscientists that geoscience information has a vital role to play in how significant issues, such as climate change, sustainability, biodiversity, natural hazard prevention and mitigation, are to be addressed. Though the importance of geoscientific information may be self-evident to geoscientists, the information itself is nevertheless generally overlooked by non-geoscientists dealing with those issues. Improving accessibility to geoscientific information through database construction and web delivery raises the visibility and availability of geoscientific information, but may not increase its use in non-geologic domains where the information is not well understood, largely because the information is complex and primarily aimed at geoscientists rather than at biologists, environmental scientists, etc. Geoscience information must therefore be transformed from its conventional packaging, typically as a map, to modes specifically usable by other disciplines prior to its delivery to those disciplines. This transformation may involve the development of geoscientific indicators that reduce significant geological situations into a single region-specific value for prediction or assessment purposes, such as estimates of mineral resource potential, building material availability, groundwater capacity, etc. It may further involve the incorporation of such geoscientific indicators into broader models that integrate natural resource indicators with socio-economic factors for purposes of generating region-specific predictions for land use, population growth, urban expansion, etc.

In this paper we focus on the latter approach and discuss the architecture of an internet-based system that integrates geological information into natural resource-socio-economic models. The system was developed within the Georgia Basin Futures Project (www.basinfutures.net/), an academic research project carried out at the University of British Columbia (UBC) and the Geological Survey of Canada (GSC). The ultimate goal of the project and resulting system is to better inform decision-making in sustainable development by allowing future scenarios to be developed and inspected. The main notion here is firstly, that using geoscientific information as an additional input will improve the accuracy and utility of future scenarios, and secondly, that exploring the nature and consequences of future scenarios will ultimately lead to better decisions. To achieve these two goals we develop a system that links two main modules: (1) an information and knowledge repository (i.e. *ontology + data*), called the Georgia Basin Digital Library (Journeay, et al., 2000), that allows relevant information and related knowledge to be stored, accessed and explored, and (2) a modeling tool (Quest™), from UBC, that uses the repository information to generate future scenarios. These linked modules constitute a simple decision support system for sustainability.

## The Georgia Basin digital library

The knowledge and information repository is structured as a web-based digital library that contains 64 significant geospatial information layers such as land use, transportation, various natural resource layers, etc. It also contains a network of *concepts*, organized as *ontologies* and described using *stories*, to explain what role the layers and their contents play in the sustainable development of the region. So, the repository not only holds information but also possesses knowledge elements that explain what the information means and how it applies to sustainable development. The repository can thus be viewed as also supplying a knowledge layer to the stored information. Because initial implementation of the repository is focused on the southwestern region of British Columbia, the repository is called the Georgia Basin Digital Library (GBDL).

Coupled to the repository is a web-based user interface that enables repository contents to be viewed and explored. The interface also connects the repository contents to other relevant sources of information and knowledge, such as publications in other digital libraries, and news stories from web-based news agencies. It further allows individuals and groups to input their own geospatial sites and descriptions, to foster the input of local knowledge and thereby stimulate dialog on issues of sustainability in the context of a community or region. This user interface is called the Georgia Basin Explorer (GBX). The repository is coupled with the user interface via web-enabled functions. As shown in Figure 1, the system architecture has 3 tiers: information, web-services and presentation.

### *The information tier*

There are three types of information sources that together comprise the information and knowledge repository: metadata, geospatial layers, and a knowledge-database. The metadata component stores in-

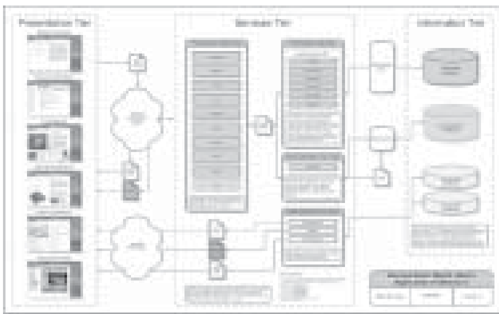

Figure 1. The three tier technical architecture of GBDL.

formation about users, projects, and information content. The 64 geospatial layers represent different geospatial themes for the Georgia Basin and are stored as ESRI shape files. The knowledge-database maintains the ontologies in a relational database (SQL Server): it consists of concepts, their relationships to each other, and to the metadata and geospatial data. The Figure 2 depicts the main elements of the logical schema used by the knowledge-database, and illustrates how geologic information can be stored in the design (c.f. Brodaric & Hastings, 2002; also Brodaric & Gahegan, 2002).

### *The Service Tier*

The Service Tier provides a suite of web-based functions that manipulate the contents of the Information Tier. Spatial data is exposed via the WMS service specified by the OpenGis Consortium (www.opengis.org), metadata about spatial layers is exposed via the Z39.50 protocol, and project metadata and the knowledge-database are exposed through a custom-built web service. The service tier thus serves as a bridge from the repository to external web clients who can be either persons or software agents. It also serves as an internal bridge between the repository, metadata and spatial data for operations internal to GBDL such as building and updating the repository. The custom web interface is divided into two sets: low-level foundation services operating on the knowledge-base, spatial data (WMS) and metadata (Z39.50), and high-level presentation services that perform dedicated procedures for specific interface components. The services are currently accessed via http, but we are migrating these to SOAP/WDSL platforms. XML encoding standards are used to pass requests and results between tiers (Figure 3).

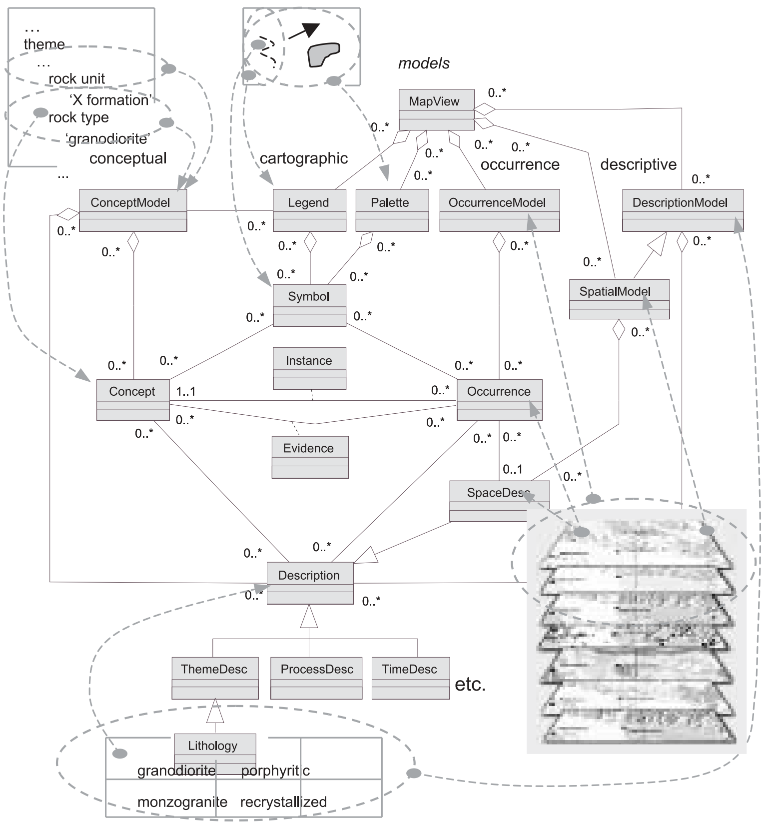


Figure 2. Logical schema for the knowledge-database (c.f. Brodaric & Hastings, 2002).


Figure 3. Example requests to the web services tier, encoded in XML.

### *The Presentation Tier*

The presentation tier (GBX) provides a user interface to the information and knowledge repository—it acts as a client to the services tier, exclusively using the services tier to access the library contents. GBX aims to build awareness and understanding about sustainability amongst municipal and scientific communities in the Georgia Basin by directly engaging those communities using the world-wide-web. GBX operates by using the services tier to access the information and knowledge repository. It has five components: (1) *News and Information*, which connects specific concepts from the knowledge-database with topically relevant web-based news stories and other pages; (2) *Library Collections*, which uses specific concepts to search web-based catalogs for maps, images and reports and displays them for viewing; (3) *Local Stories*, which allows users to annotate geospatial layers with personal geospatial sites and related stories that convey local knowledge about issues of sustainability in the community or region; (4) *Ideas and Perspectives*, which enables concepts and their story-like descriptions (from the knowledge-database) and related geospatial layers to be explored interactively; and (5) *Future Scenarios*, which connects with the Quest modeling tool for generating future scenarios for the region. Particularly significant is the *Ideas and Perspectives* component, as it presents community, academic and NGO (non-govn't organization) perspectives on sustainability, each organized as a separate ontology in the knowledge-database. Figure 4 displays the *Ideas & Perspectives* component, which enables the perspectives (ontologies) to be explored by browsing a semantic network of concepts (top left) triggering the display of related maps (bottom left) and story-like documentation (right).


Figure 4. Exploring sustainable development concepts in GBDL.

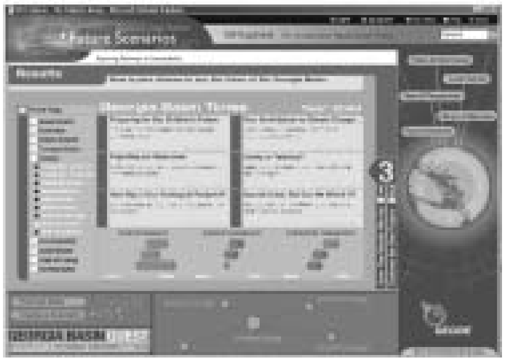

Figure 5. Explaining the results of a Quest future scenario in GBDL.

### The quest scenario modeler

Apart from its representation and presentation roles, GBDL also provides dynamic connection to the Quest scenario modeling environment, in which future scenarios, such as land use, economic and demographic projections, are constructed. Quest is a computer simulation that enables people from all walks of life to construct alternative futures for a region and view the trade-offs and consequences of their choices. The scenarios are controlled by input from the user and are driven by an integrated suite of system models that reflect the expert knowledge of more than 35 researchers in the fields of environmental, social and economic health. In this modeling procedure GBDL is designed to serve as an information repository, supplying information to Quest for modeling, and as an explanatory tool, allowing the user to browse input variables and output results, thus helping build a context for understanding. The results of a Quest scenario are uploaded to the GBDL scenario library (Figure 5), where the various input parameters and modeling assumptions can be reviewed and further explored in the *Ideas & Perspective* module (described above). At the time of this paper, the dynamic interaction between the GBDL and Quest is still under development, with positive initial results.

Of broader significance is the fact that geoscientific knowledge is utilized as an input theme and therefore as part of the modeling system, clearly demonstrating the relevance of geoscience information in the context of sustainability planning and decision making. In our work to date we have prototyped a sub-model that integrates the potential socio-economic impacts of earthquakes into the Quest modeling framework; we are currently working on developing an integrated surface/groundwater sub-model to help address issues of sustainable yield and aquifer vulnerability in the region.

### Conclusions

The GBDL concept has been prototyped in two geographic regions: Bowen Island and the Georgia Basin (http://georgiabasin.info/). The Bowen Island prototype is most mature to date, as it has been used extensively in a grade 10 experiential learning environment where students were asked to develop their own *Local Stories*. GBDL is just recently coming on-line as part of a larger research project, the Georgia Basin Futures Project (http://www.basinfutures.net/). Our experiences from this project indicate that the combination of knowledge representation techniques, modeling tools, geoscience information and the world-wide-web is practical, informative and useful. We anticipate developing these further, specifically by introducing more geoscientific information into the modeling component, tighter coupling of the modeling and knowledge repository components, and applying the system in different geographic regions.

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GEOLOGIJA *46/2,* 349–360, Ljubljana 2003

# Feature Map Classifier – a possible approach to morphological/ geological evaluation of terrain

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*Key words*: Classification, geology, image processing, neural networks, self organising maps

**Abstract**

This paper investigates the practicability of new classification approach to image processing. Landsat TM image of Slovene coastal area was used to perform lithological classification. Standard classification methods, based on statistical principles do not always give satisfactory results. Therefore a variety of new approaches are being tested in order to achieve better accuracy. One of the most promising fields is artificial intelligence where artificial neural networks (ANNs) have proven to be usefull. An artificial neural network represents a limited analogy of the neural functioning of the biological brain (Sejnowski, Koch and Churchland, 1988). Several ANN methods have been developed to solve classification problems. The one represented in this article is a combination of two methods: Self Organising Maps and Backpropagation network. This kind of ANN, also called Feature Map Classifier, is not the best in sence of accuraccy but has one big advantage in comparison with other ANNs – it is much more transparent.

In comparison with standard approach better results were gained especially in more complicated cases, where classes are not linearly separable. The separability of classes is shown to be one of the most important factors. ANN methods tend to give better results as statistical clustering technique especially in cases when classes overlap and are not easily separable.

## Introduction

The morphologic/geologic mapping of a territory is one of the preliminary steps in selecting the optimal highway route. Slovene geologists are under pressure to provide planners with fast solutions, for all intended areas of the extensive highway construction program covering the entire country. Mapping requires extensive fieldwork, the cost and duration of which is directly linked with the feasibility study. Developed is an morphologic/geologic map. It, being derived by the interpretation of field data, is subject to many different influences such as the availability of data, impassability of a territory, it's overgrowth, and human expertise. The question then remains, whether it is possible to obtain a low cost and relatively quick solution that would be independent of human subjectivity. The solution consists of two parts.

First, there is a problem of input data. The acquisition should be based on already existing or easily derived data. One of the fastest ways is to use remotely sensed data. Nowadays, there are a variety of commercial satellites supplying a multitude of data that can be used in different ways. High-resolution satellite multispectral imagery (LANDSAT, SPOT, Ikonos) is useful for the analysis of vegetation and soil characteristics, whilst radar (RADARSAT, ERS) and stereoscopic pairs (SPOT, Ikonos) imagery can be used for the creation of digital elevation models. In the work presented hereafter, an attempt was made to compensate for the contribution of lithology with the use of the LANDSAT Thematic Mapper image. Besides satellite data, other already existing sources of data were considered, including digital geologic and geodetic maps that were used to derive various derivative data layers. The classical approach to aerophoto imagery was also used to delineate different vegetation cover types.

Second, the processing of data should be automatic. This means that all data should be gathered or converted into a digital format, then processed at a later stage by computer. The digital georeferenced data can be considered as digital imagery, whilst the procedural methods can be considered as digital image processing. In order for them to be performed, a knowledge base about examined phenomena, must be designed. Several different designs exist. For instance, expert systems try to incorporate expert knowledge, in the form of IF-THEN rules. The problem arises, when one makes an attempt to reshape expert know-how to comply with strict rules. Mapping is usually described as a highly intuitive process, which is often very difficult to describe. Therefore, a methodology with self-learning capabilities is needed. In the field of digital image processing, various parametric and nonparametric methods (classifiers) have won wide recognition, and are now widely used. With this work, an attempt was made to investigate the application of a special nonparametric method, inspired by the human brain – artificial neural networks.

## Study area

The study area occupies approximately 50 square kilometres of the Slovene coastal area, near the Italian border (Fig.1). It bears all the morphological, lithological and vegetation properties of the whole coastal region, and can be considered to be representative.

The examined territory was first mapped using standard techniques, such as fieldwork and aerophoto interpretation. The mapping produced a morphologic/geologic map, where 7 different area categories were extracted: stable areas, labile areas, landslides, sinkholes, debris, moist areas and erosion zones. In the later course of work, this map was used for the random extraction of learning, and for testing samples.

The resulting map is mainly an interpretation of lithological and morphological factors. In this place it should be pointed out that the morphological shape of terrain exibits strong correlation with lithology. The flysch, composed of sandstone and marl, is less resistant to weathering than limestone. As a consequence, clastic sediments are covered with a thick, overgrown, weathering cover and the morphological shape of flysch area is heavely ditched and full of ravines. Areas with limestone are re-


Figure 1. Geographical position of Črni Kal region.

sistant to mechanical but non-resistant to chemical weathering. Ordinarily, they are seldom found with any significant weathering cover and are marked with a variety of karstic phenomena such as sinkholes and doline.

In the mapping (classification) process the problems arise because it is possible that certain areas belong to multiple categories at once. For instance, labile areas and landslides are much alike. Furthermore, erosion zones and debris areas are often subject to sliding. The problem is twofold. First, logic of the model obliges us to select only one category, and second, categories are highly overlapping. Consequently, decisions are made by experts, according to their knowledge and experience.

## Input data

*Lithological data*

Lithological mapping of the entire Slovene coastal area in a scale of 1:5000 took place in 1994. The authors (Ribičič et al, 1994) found 12 different lithological units. For the purposes of this project, they were combined to form 5 units (Fig. 2a): alluvium, limestone, deluvium, and two types of flysch – one with a majority content of sandstone, the other with majority content of marl.

*Digital elevation model and derivatives*

A digital elevation model (DEM) with 5 meters of spatial resolution was made using isolines from base topographic plans in a scale of 1:5000. The information derived from a DEM (see Fig. 3 – shaded relief) does not alone contribute heavily to a model, but is very important as a foundation for several DEM based derivatives. The slope data layer is expressed as the change in elevation over a certain distance. In this case, the distance is the size of a pixel. The slope of the terrain is directly connected with weathering, erosion and deposition. It was expected to directly influence in the occurrence of landslides and labile areas. The aspect data layer describes the direction of the slope at each pixel. The aspect data was not expected to have a direct influence on the model, but is important nevertheless for the creation of related statistic layers. Both slope and aspect data layers were derived using 1$^{st}$ order derivative filters (gradient operators). By employing a 2$^{nd}$ order derivative filter (Laplacian operator), data layers describing convexity/concavity of landscape morphology were made. Two different filters, using neighbourhood sized 7×7 and 11×11 cells were used to produce two different data layers. The curvature data layer was produced using the 4$^{th}$ polynomial function (ESRI, 1992) to describe curvature of landscape morphology. This calculation uses the neighbourhood sized 3×3 cells and is closely related to convexity/concavity of data layers. The outputs were three data layers: general curvature, planform curvature – curvature perpendicular to the slope direction and profile curvature – and curvature of the surface in the direction of the slope. Curvature, convexity/concavity, slope and aspect data layers are all strongly related to the physical characteristics of a drainage basin and can be used to describe erosion and runoff processes. The slope affects the overall rate of downslope movement, whilst the aspect defines its direction. The profile curvature affects the acceleration and deceleration of flow, therefore influencing erosion and deposition. The planform curvature, together with convexity/concavity, influences convergence and the divergence of flow. The flowlength data layer details the downstream distance along a flow path of the hypothetical rainfall/runoff events. This layer is used with the intent of extracting erosion zones that are typically formed in the upper flow areas of flysch lithology. In calculating the standard deviation for slope and aspect data layers using two different neighbourhood sizes (5×5 and 8×8 cells), four standard deviation data layers were derived. The variability within the aspect data layer is closely connected with ridge/ravine detection, where slope direction opposes one another. The variability of slope is related to the undulation of the surface – a typical phenomena for unstable areas.

*Distance to surface waters*

This layer, made by a calculation within an individual cell, measures the minimum distance to surface waters, and could assist in defining the process of erosion in non-karst areas.

*Vegetation data*

The coarse vegetation map (Fig. 3b) separating three different categories (dense, medium and non-overgrown areas) was compiled using aerophoto interpretation.

*LANDSAT TM image*

Two models, the first using a lithological map, the second using a LANDSAT Thematic Mapper image, were made in order to study the application of a model in cases where no lithological data was accessible. The LANDSAT TM image consists of 7 spectral bands: blue, green, red, near infrared, thermal infrared and 2 mid-infrareds, with an 8-bit radiometric and 30 meter spatial resolution (except thermal infrared – 120 meters). The satellite image was, due to coarse spatial resolution and occasional cloud cover, not expected to completely substitute lithological data contribution.

## Methodology

The modelling of a terrain is primarily a classification process. The input data is clustered into homogeneous and separable groups according to an appropriate measure of similarity.

With the intention to improve the classification process, new methods, among them

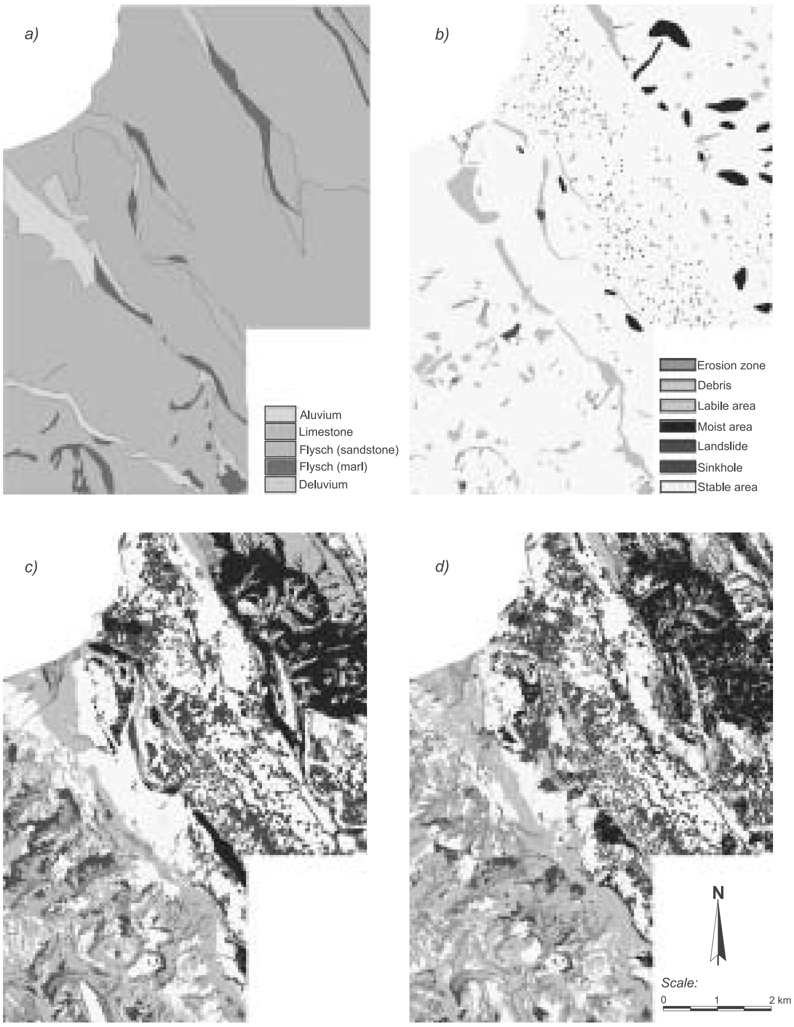


Figure 2. Lithological input data (a), morphological/ geological map obtained by standard mapping methods (b), result of classification using lithological data (c) and result of classification using satellite data (d).

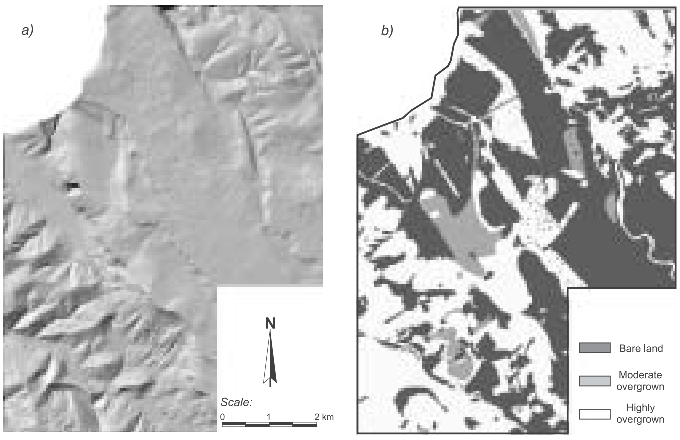


Figure 3. Shaded relief (a) and vegetation data layer (b).

also the subject of this article – artificial neural networks (ANNs), are being developed. Although similar to the k-NN, they are more efficient and require less data for training. The distribution free nature enables them to join remote sensing and geographic data of multiple type/statistical distributions, in the single classification model. The overall objective of this paper is to investigate and discuss their application in the morphological/geological evaluation of an examined area.

An artificial intelligence technique, ANN, inspired by the human brain, has shown promising results and is now considered to be an alternative method in digital image processing. The human brain forms a massive communication network, consisting of billions of nerve cells, known as neurones. In functional terms a neuron can be seen as a processing unit receiving and transmitting electrical impulses. Learning, and the storage of knowledge take place by modifying the conductivity between the neuron connections. ANNs are mathematical models that try to mimic the biologic brain. Artificial neurons, also called processing elements, or *PEs,* are interconnected through numerical weights that function analogously to conductivity connections.

The selected ANN method FMC (Feature Map Classifier) combines great representational and analytical power of Self Organising Maps (SOM) with the classification abilities of Backpropagation (BPG) networks. A backpropagation network can be used as a classifier itself, and as such it remains the most popular ANN classification method, but there is an inherent problem. That is, it is very difficult to give physical meaning to the weights connected to the neurones. The use of an SOM method makes the evaluation of classes and the classifier itself much easier. When confronted with multidimensional data it is often very difficult to determine how the data is structured; therefore, it is desired to reduce the dimensionality. The statistical method usually used in performing this task is factor analysis. However, as with parametric statistical classifiers, there is again a problem of normal distribution and linear relations among variables. To solve this problem a special ANN, Self Organising Map was developed by Tuevo Kohonen (Kohonen, 1984). It reduces a multivariable space into two (sometimes three) dimensions in such a manner that makes it possible for every n-dimensional input pattern to occupy its place in a 2-D map.

## Results

Two FMC models were made, the first for the classification using lithological data, whilst the second substituting lithological data with 7 bands of LANDSAT TM image. Both artificial neural networks constituted of an input neural layer (with 20 and 22 neurones), Kohonen's layer (matrix of $20 \times 20$ neurones) and an output layer (7 neurones representing 7 categories).

After the learning stage, the recall procedure took place to actually perform the classification of the studied area. Results are shown in figure 2.

*Classification accuracy*

The assessment of classification accuracy of multivariate data unfortunately does not reach the ability to produce digital land cover classification. In fact, this problem sometimes precludes the application of automated land cover classification techniques, even when their cost compares favourably with a more traditional means of data collection (Lillesand & Kiefer, 1994). Methods originate from the field of image processing and are often described in expert literature. The most common way to represent the classification accuracy is in the form of an error matrix (Congalton, 1991).

*Accuracy assessment results*

Accuracy was assessed using a test sample taken by stratified sampling. This kind of accuracy is not dependent upon categories existent in the examined territory. The solution is a general model that describes the model's behaviour, not just in this case but also for any other resembling region. Another fact in favour of the general model is the nature of input data. All the data, except the satellite image, is independent of the acquisition time and, therefore, dependant only upon the mode of acquisition. Ideally, where procedures are standardised, input data generation should yield identical or at least similar results. This leads to the conclusion that the model using lithological data is general and the model using satellite images is less so.

The error matrixes of both models were used as the basis for an accuracy table (Table 1 and Table 2) generation. The equality of average produced accuracy and overall accuracy is the result of equivalent sample sizes for singular categories. The results show satisfactory accuracy. Significant difficulties arise only in the case of labile and stable areas. Whilst the stable areas in both models show similar proclivity to moist areas, the labile areas in the model with lithological data are mixed with a debris category, and the model using satellite images is mixed with erosion zones. Despite the mixing problem, both of the models are within the borders of serviceability, especially in the feasibility stage of study where one strives to yield a fast and low-cost outcome.

The comparison of models (Table 3) shows that the model using satellite images yields a somewhat weaker result than the model using lithological data. This confirms the conjecture of the ability of LANDSATs TM images to substitute the contribution of the lithological data.

Table 1. Accuracy table for the classification – usage of lithological data

| | REFEREN | CLASSIFIED | CORRECT | PROD. A. | USER. A. | KHAT |
|---|---|---|---|---|---|---|
| EROS | 250 | 260 | 197 | 78,80% | 75,77% | 71,73% |
| DEBRIS | 250 | 278 | 223 | 89,20% | 80,22% | 76,92% |
| LABIL | 250 | 195 | 106 | 42,40% | 54,36% | 46,75% |
| MOIST | 250 | 301 | 216 | 86,40% | 71,76% | 67,05% |
| LANDS | 250 | 254 | 207 | 82,80% | 81,50% | 78,41% |
| SINKH | 250 | 275 | 240 | 96,00% | 87,27% | 85,15% |
| STABIL | 250 | 186 | 109 | 43,60% | 58,60% | 51,70% |
| AVERAGE: | | | | 74,17% | 72,78% | 68,24% |
| OVERALL KHAT: | | | | 69,87% | | |
| OVERALL ACCURACY: | | | | 74,17% | | |

Table 2. Accuracy table for the classification – usage of satellite image

| | REFEREN | CLASSIFIED | CORRECT | ***PROD. A.*** | ***USER. A.*** | ***KHAT*** |
|---|---|---|---|---|---|---|
| ***EROS*** | *250* | *311* | *200* | *80,00%* | *64,31%* | *58,36%* |
| ***DEBRIS*** | *250* | *224* | *139* | *55,60%* | *62,05%* | *55,73%* |
| ***LABIL*** | *250* | *216* | *94* | *37,60%* | *43,52%* | *34,10%* |
| ***MOIST*** | *250* | *289* | *208* | *83,20%* | *71,97%* | *67,30%* |
| ***LANDS*** | *250* | *263* | *213* | *85,20%* | *80,99%* | *77,82%* |
| ***SINKH*** | *250* | *278* | *236* | *94,40%* | *84,89%* | *82,37%* |
| ***STABIL*** | *250* | *168* | *91* | *36,40%* | *54,17%* | *46,53%* |
| AVERAGE: | | | | ***67,49%*** | ***65,99%*** | ***60,31%*** |
| OVERALL KHAT: | | | | ***62,07%*** | | |
| OVERALL ACCURACY: | | | | ***67,49%*** | | |

Table 3. Comparison of accuracies

| ACCURACY | | LITHOLOGICAL DATA | SATELLITE DATA |
|---|---|---|---|
| Overall | acc. | 74,17% | 67,49% |
| Overall | KHAT | 68,87% | 62,07% |
| Average | Prod | 74,71% | 67,49% |
| | User | 72,78% | 65,99% |
| | KHAT | 68,24% | 60,31% |

Another way to evaluate the application of the model is to use expert opinion. In spite of the fact that such judgements are heavily affected by human subjectivity, it can still be used as a quick and approximate method. In this case, expert opinion is in favour of both models. The thick vegetation cover of flysch terrain makes it difficult to investigate. This affected the quality of learning/testing data. The resulting classification for this region, therefore, is evaluated to be even better than the actual input (reference) data. The explanation could lie in the ability of ANNs to reduce the noise of learning data, and thus produce a highly generalised solution. The classification of moist areas is inappropriate. That is why it would be reasonable for this category to be either excluded from the model, or to be joined with the stable area category.

The feature map classifier has proven to be a useful tool. High delimitation abilities of input feature space and a capacity to work with distribution free data of various data types makes it superior in comparison with statistical classifiers. ANNs in general are criticised because of nontransparent functioning – the black box effect. Fortunately in the case of FMC, this statement does not apply. While the usual classification of ANNs enables users to perform only one single analytical operation – impact analysis, it is the SOM part of FMC, which is known for its great power to present data in the form of 2D matrices.

*Impact analysis*

Impact analysis is a technique where the relevance of each input variable is determined using the leave-one-out method. The effect of disabling each input neuron in turn is determined in terms of its percentage reduction in the accuracy of the classification. Figure 4 and table 4 illustrate the results of impact analyses for both models. The Y coordinate is defined as a portion of accuracy reduction when an input neuron for a certain category is turned off. On the X-axis, all the individual and, in cases where they constitute a logical unit, joint categories (preceded by SUM) are presented.

The result for the first model indicates lithology to be the most important input data. Seven bands of LANDSAT TM satellite image do not represent proper compensation. Nevertheless, the accuracy of the second model is affected to a smaller extent than expected. The contribution of lithological data is compensated by the increased importance of other factors, particularly vegetation, ridge/ravine data and wa-

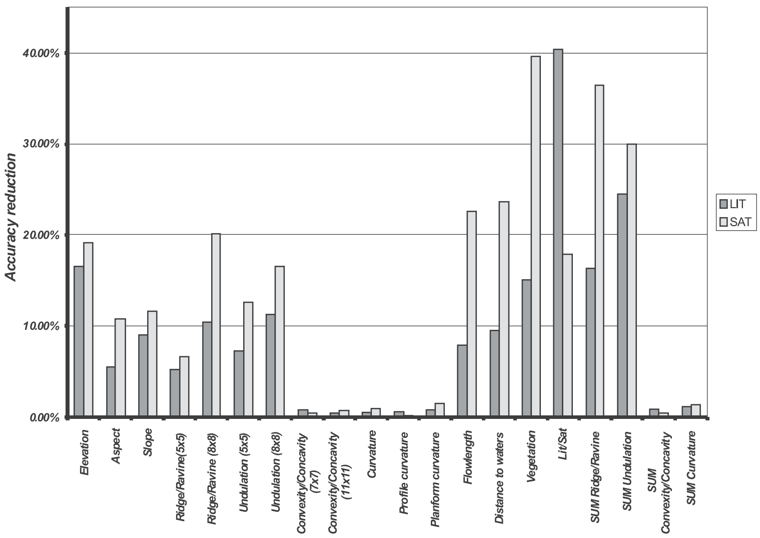


Figure 4. Result of impact analyses.

Table 4. Importance of input variables according to impact analysis

| | LITHOLOGICAL DATA | SATELLITE DATA |
|---|---|---|
| IMPORTANT | *Lithology*<br>*Undulation*<br>*Elevation*<br>*Ridge/Ravine*<br>*Vegetation* | *Vegetation*<br>*Ridge/Ravine*<br>*Undulation*<br>*Flowlength*<br>*Distance to surface waters* |
| *LESS IMPORTANT* | *Distance to surface waters*<br>*Slope*<br>*Flowlength* | *Elevation*<br>*Satellite image*<br>*Aspect* |
| *UNIMPORTANT* | *Aspect*<br>*Curvature*<br>*Convexity/Concavity* | *Slope*<br>*Curvature*<br>*Convexity/Concavity* |

ter related factors. The examined territory is especially characterised by high lithology-vegetation correlation, bare limestone and highly overgrown flysch. Data on the basis of standard deviation, ridge/ravine and undulation data, shows that the neighbourhood of $8 \times 8$ cells is more important than the neighbourhood of $5 \times 5$ cells. The low importance of slope data (Table 4) upon analysis gave an unexpected result. It was expected that the slope would strongly affect the stability of the ground. This presumption however, holds only for flysch areas. An imbricated limestone region is, on the other hand, characterised with almost vertical, but fully stable slopes.

An important point to note here is that there still exists a variety of attributes not included in this model. Human intervention especially in the form of irrigation, civil engineering activities, tree cutting and water dams often decisively influence the nature of environment.

*Competitive layer analysis*

While the impact analysis gives an impression about the importance of the input variables, questions about their mutual relationship, the separability of output categories and the impact of input variables on a particular category remained unanswered. Self-organising maps, as a part of FMC, offer perhaps the best solution at this point in time, that artificial neural networks are able to produce. The unsupervised learning that takes place in the self-organising phase forms so-called Kohonen's maps, where bright tones represent characteristic regions, and dark tones uncharacteristic regions. Organising data into groups depends of course upon the purpose we are seeking to achieve. Groups can be organised according to output categories. In this way Kohonen's maps, describing categories, are made (Fig. 5). Examination of their mutual relationship enables a resemblance/separability study of the classification model to be made. Ideally, each category would occupy its own part of the Kohonen's map, and would not overlap with any other categories.

The importance of input variables can be studied by partitioning data into classes, according to individual variable values. The Kohonen's maps in this case represent inner-variable groups (Fig. 5). Variables can be differentiated either by their individual class values (vegetation: dense, medium, non-overgrown areas) or by some other kind of arbitrary values (curvature: concave $[-\infty, -1]$, flat $[-1,1]$, convex $[1,\infty]$). The differentiation of inner-variable groups serves as an indicator of variable importance – the better the discrimination, the more important the variable. For instance, the differentiation of variable *Slope* (Fig. 6) shows that three different groups for slope: <10°, 10° to 20° and >20° exist.

The comparison of inner-variable Kohonen's maps of different variables is used for the study of their relationships, whilst the comparison of inner-variable Kohonen's maps with output category Kohonen's maps is used to estimate the influence that the individual inner-variable group has on the particular category (Fig. 5). Visual comparison of Kohonen's maps is useful only in cases where there is a likeness/dissimilarity of the two maps. Obviously, in

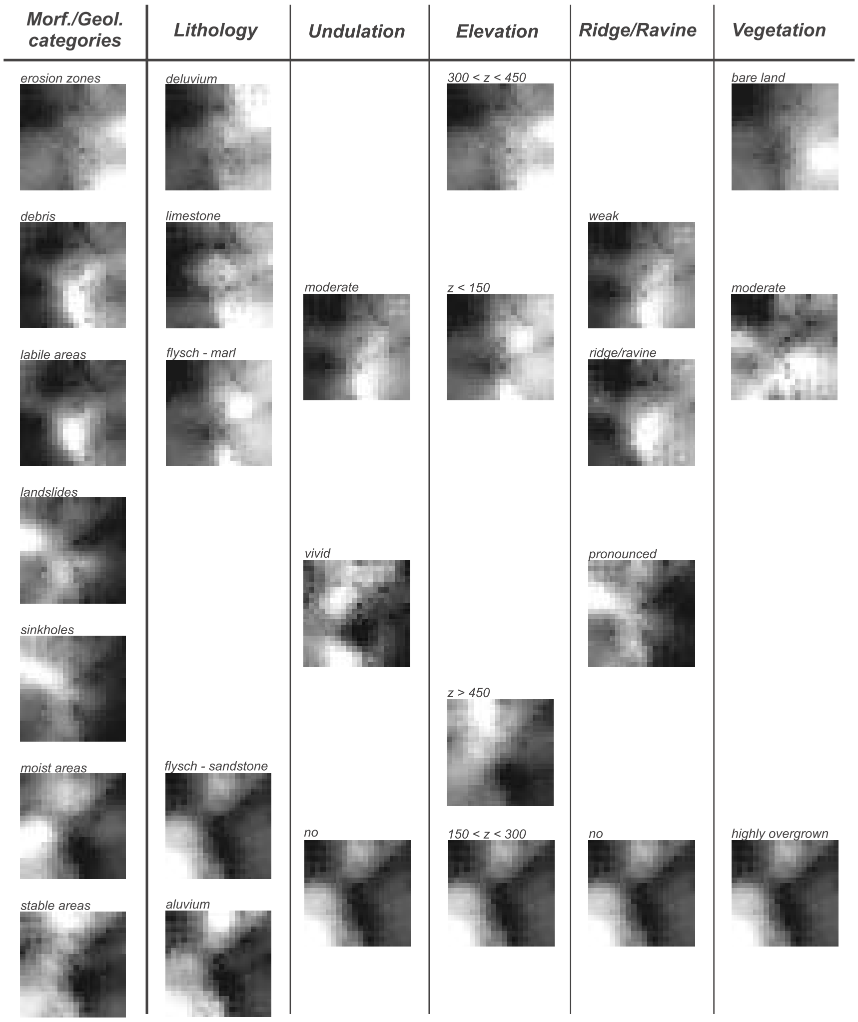


Figure 5. Kohonen's maps for output categories and 5 most important input variables (usage of lithological data).

vague cases, one requires a distinct measure of separability. The proposed separability measure is

$S_{a,b} = 1 - r_{a,b}$ ,

where $r_{a,b}$ is the Pearson correlation coefficient for classes $a$ and $b$. The range of values for $S_{a,b}$ is [0,2], where values close to 0 indicate high overlapping, values around 1 indicate that there is no significant relationship and values close to 2 indicate high dissimilarity.

Figure 5 and the corresponding separability table (Table 5) illustrate the functionality of Kohonen's maps, for a model using lithological data. The leftmost column contains output category maps and the following 5 columns display Kohonen's maps for the 5 most important factors, as determined by impact analysis. The less important factors are shown in Figure 6.

The similarity study of output categories shows evident resemblance between debris – labile areas, landslides – sinkholes and stable – moist areas. The comparison of lithological units shows that the model is able to discriminate between two lithological groups: alluvium + flysch-sandstone and deluvium + limestone + flysch-marl. On the basis of other factors it is possible to infer with some certainty that the first lithological group is identified as being a highly overgrown, flat region with an altitiude of 150 to 300 meters above sea level. All together they serve as the identifier for stable and moist areas.

On the other hand the identifiers for sinkholes and landslides are much less frequent.

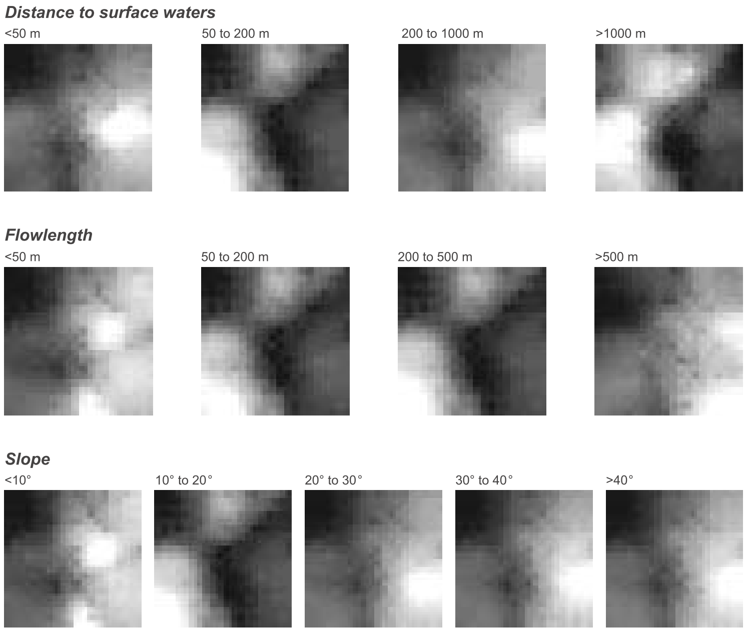


Figure 6. Kohonen's maps for less important input variables (usage of lithological data).

Both categories are marked with vivid undulation and pronounced ridge/ravine occurrences. Debris and labile areas are viewed as moderately overgrown limestone and flysch-marl lithology, with moderate undulation and intermediate configuration. Erosion zones show similarities with debris and labile areas, but represent the category most distinctive of all. Usually these are high, upper-stream and poorly vegetated areas marked with a short flowlength. The analysis of Kohonen's maps is a useful tool that can be used for studying operational aspects of FMC. The application strongly depends upon purpose of the work to be undertaken and, therefore, differs from case to case.

## Summary and conclusions

This paper has demonstrated the possible use of alternative classification algorithms for the morphological/geological classification of the Slovene coastal region. A specially developed artificial neural network classificator – FMC (feature map classificator) has proven itself to be a useful tool for the morphologic/geologic category predictions. Its main advantage over classical statistical methods includes the use of freely distributed data, thus enabling one to incorporate multisourced data, without almost any restrictions. The artificial neural networks, as massively parallel and highly distributed computational models, exhibit features such as fault tolerance and generalising abilities. The resulting model, made on the basis of a small territorial area, is general in its nature even when employing site (elevation) and acquisition time (satellite) dependent data. Therefore, it can be used for any other region of similar geomorphological and lithological characteristics.

The most common criticism made of artificial neural network classifiers is the unintelligible mode of operation. It was clearly demonstrated that this does not apply to the feature map classifier. While the impact analysis offers a common ANN tool for the evaluation of input-variable contribution, the self-organising part of FMC is much more powerful. The use of visual and statistical analysis of Kohonen's maps to evaluate the distinctive abilities of input variables, relationships among them, their influence on output and separability of output categories, turned out to be a clear and accurate technique of great analytical power.

Altogether, the employment of FMC is recommended in the feasibility phase of such works. Combining the ability to use

Table 5. Separability table of important factors for the classification using lithological data

| | | ***Ridge/Ravine*** | | | | *Elevation* | | | | ***Undulation*** | | | ***Vegetation*** | | | ***Lithology*** | | | | | ***Morph./Geol. categories*** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No | Weak | R/R | Pron | <150 | <300 | <450 | >450 | Vivid | Moder | No | High | Moder | Bare | Alluv | Lime | Fl-s | Fl-m | Deluv | Eros | Debris | Labil | Moist | Landsl | Sinkh | Stab |
| ***Ridge*** | No | 0,00 | 1,48 | 1,52 | 0,76 | 1,28 | 0,00 | 1,18 | 0,64 | 0,45 | 1,48 | 0,00 | 0,00 | 0,78 | 1,16 | 0,12 | 1,45 | 0,00 | 1,29 | 1,34 | 1,14 | 1,56 | 1,59 | 0,20 | 0,70 | 0,94 | 0,27 |
| | Weak | 1,48 | 0,00 | 0,08 | 1,51 | 0,15 | 1,48 | 0,30 | 1,82 | 1,44 | 0,00 | 1,48 | 1,48 | 0,40 | 0,27 | 1,48 | 0,13 | 1,48 | 0,16 | 0,32 | 0,33 | 0,09 | 0,28 | 1,79 | 1,35 | 1,56 | 1,65 |
| | Ridge/Ravine | 1,52 | 0,08 | 0,00 | 1,45 | 0,27 | 1,52 | 0,28 | 1,83 | 1,64 | 0,08 | 1,52 | 1,52 | 0,36 | 0,30 | 1,55 | 0,16 | 1,52 | 0,26 | 0,33 | 0,32 | 0,08 | 0,18 | 1,80 | 1,26 | 1,51 | 1,70 |
| | Pronounced | 0,76 | 1,51 | 1,45 | 0,00 | 1,76 | 0,76 | 1,83 | 0,37 | 0,45 | 1,51 | 0,76 | 0,76 | 1,13 | 1,81 | 0,56 | 1,70 | 0,76 | 1,76 | 1,79 | 1,84 | 1,41 | 1,09 | 0,52 | 0,13 | 0,06 | 0,47 |
| ***Elevation*** | <150 | 1,28 | 0,15 | 0,27 | 1,76 | 0,00 | 1,28 | 0,19 | 1,73 | 1,38 | 0,15 | 1,28 | 1,28 | 0,57 | 0,11 | 1,32 | 0,14 | 1,28 | 0,01 | 0,14 | 0,20 | 0,33 | 0,67 | 1,61 | 1,66 | 1,79 | 1,54 |
| | <300 | 0,00 | 1,48 | 1,52 | 0,76 | 1,28 | 0,00 | 1,18 | 0,64 | 0,45 | 1,48 | 0,00 | 0,00 | 0,78 | 1,16 | 0,12 | 1,45 | 0,00 | 1,29 | 1,34 | 1,14 | 1,56 | 1,59 | 0,20 | 0,70 | 0,94 | 0,27 |
| | <450 | 1,18 | 0,30 | 0,28 | 1,83 | 0,19 | 1,18 | 0,00 | 1,75 | 1,56 | 0,30 | 1,18 | 1,18 | 0,46 | 0,09 | 1,40 | 0,15 | 1,18 | 0,18 | 0,22 | 0,01 | 0,34 | 0,61 | 1,51 | 1,59 | 1,83 | 1,54 |
| | >450 | 0,64 | 1,82 | 1,83 | 0,37 | 1,73 | 0,64 | 1,75 | 0,00 | 0,32 | 1,82 | 0,64 | 0,64 | 1,65 | 1,79 | 0,49 | 1,74 | 0,64 | 1,71 | 1,62 | 1,74 | 1,72 | 1,57 | 0,21 | 0,65 | 0,29 | 0,26 |
| ***Undul.*** | Vivid | 0,45 | 1,44 | 1,64 | 0,45 | 1,38 | 0,45 | 1,56 | 0,32 | 0,00 | 1,44 | 0,45 | 0,45 | 1,22 | 1,52 | 0,25 | 1,46 | 0,45 | 1,42 | 1,45 | 1,54 | 1,50 | 1,49 | 0,36 | 0,67 | 0,50 | 0,20 |
| | Moderate | 1,48 | 0,00 | 0,08 | 1,51 | 0,15 | 1,48 | 0,30 | 1,82 | 1,44 | 0,00 | 1,48 | 1,48 | 0,40 | 0,27 | 1,48 | 0,13 | 1,48 | 0,16 | 0,32 | 0,33 | 0,09 | 0,28 | 1,79 | 1,35 | 1,56 | 1,65 |
| | No | 0,00 | 1,48 | 1,52 | 0,76 | 1,28 | 0,00 | 1,18 | 0,64 | 0,45 | 1,48 | 0,00 | 0,00 | 0,78 | 1,16 | 0,12 | 1,45 | 0,00 | 1,29 | 1,34 | 1,14 | 1,56 | 1,59 | 0,20 | 0,70 | 0,94 | 0,27 |
| ***Veget.*** | Highly overgr. | 0,00 | 1,48 | 1,52 | 0,76 | 1,28 | 0,00 | 1,18 | 0,64 | 0,45 | 1,48 | 0,00 | 0,00 | 0,78 | 1,16 | 0,12 | 1,45 | 0,00 | 1,29 | 1,34 | 1,14 | 1,56 | 1,59 | 0,20 | 0,70 | 0,94 | 0,27 |
| | Moderate ov. | 0,78 | 0,40 | 0,36 | 1,13 | 0,57 | 0,78 | 0,46 | 1,65 | 1,22 | 0,40 | 0,78 | 0,78 | 0,00 | 0,42 | 0,94 | 0,56 | 0,78 | 0,59 | 0,79 | 0,48 | 0,51 | 0,57 | 1,24 | 0,80 | 1,35 | 1,23 |
| | Bare land | 1,16 | 0,27 | 0,30 | 1,81 | 0,11 | 1,16 | 0,09 | 1,79 | 1,52 | 0,27 | 1,16 | 1,16 | 0,42 | 0,00 | 1,35 | 0,20 | 1,16 | 0,12 | 0,24 | 0,09 | 0,46 | 0,76 | 1,53 | 1,59 | 1,84 | 1,58 |
| ***Lithology*** | Alluvium | 0,12 | 1,48 | 1,55 | 0,56 | 1,32 | 0,12 | 1,40 | 0,49 | 0,25 | 1,48 | 0,12 | 0,12 | 0,94 | 1,35 | 0,00 | 1,46 | 0,12 | 1,34 | 1,36 | 1,34 | 1,55 | 1,55 | 0,26 | 0,69 | 0,77 | 0,10 |
| | Limestone | 1,45 | 0,13 | 0,16 | 1,70 | 0,14 | 1,45 | 0,15 | 1,74 | 1,46 | 0,13 | 1,45 | 1,45 | 0,56 | 0,20 | 1,46 | 0,00 | 1,45 | 0,15 | 0,18 | 0,16 | 0,18 | 0,43 | 1,76 | 1,64 | 1,72 | 1,53 |
| | Flysch-sands. | 0,00 | 1,48 | 1,52 | 0,76 | 1,28 | 0,00 | 1,18 | 0,64 | 0,45 | 1,48 | 0,00 | 0,00 | 0,78 | 1,16 | 0,12 | 1,45 | 0,00 | 1,29 | 1,34 | 1,14 | 1,56 | 1,59 | 0,20 | 0,70 | 0,94 | 0,27 |
| | Flysch-marl | 1,29 | 0,16 | 0,26 | 1,76 | 0,01 | 1,29 | 0,18 | 1,71 | 1,42 | 0,16 | 1,29 | 1,29 | 0,59 | 0,12 | 1,34 | 0,15 | 1,29 | 0,00 | 0,12 | 0,20 | 0,32 | 0,65 | 1,60 | 1,66 | 1,78 | 1,55 |
| | Deluvium | 1,34 | 0,32 | 0,33 | 1,79 | 0,14 | 1,34 | 0,22 | 1,62 | 1,45 | 0,32 | 1,34 | 1,34 | 0,79 | 0,24 | 1,36 | 0,18 | 1,34 | 0,12 | 0,00 | 0,22 | 0,40 | 0,70 | 1,59 | 1,75 | 1,78 | 1,50 |
| ***Morph./Geol. categories*** | Erosion zone | 1,14 | 0,33 | 0,32 | 1,84 | 0,20 | 1,14 | 0,01 | 1,74 | 1,54 | 0,33 | 1,14 | 1,14 | 0,48 | 0,09 | 1,34 | 0,16 | 1,14 | 0,20 | 0,22 | 0,00 | 0,38 | 0,66 | 1,49 | 1,62 | 1,86 | 1,48 |
| | Debris | 1,56 | 0,09 | 0,08 | 1,41 | 0,33 | 1,56 | 0,34 | 1,72 | 1,50 | 0,09 | 1,56 | 1,56 | 0,51 | 0,46 | 1,55 | 0,18 | 1,56 | 0,32 | 0,40 | 0,38 | 0,00 | 0,09 | 1,77 | 1,26 | 1,43 | 1,61 |
| | Labile areas | 1,59 | 0,28 | 0,18 | 1,09 | 0,67 | 1,59 | 0,61 | 1,57 | 1,49 | 0,28 | 1,59 | 1,59 | 0,57 | 0,76 | 1,55 | 0,43 | 1,59 | 0,65 | 0,70 | 0,66 | 0,09 | 0,00 | 1,69 | 0,93 | 1,11 | 1,55 |
| | Moist areas | 0,20 | 1,79 | 1,80 | 0,52 | 1,61 | 0,20 | 1,51 | 0,21 | 0,36 | 1,79 | 0,20 | 0,20 | 1,24 | 1,53 | 0,26 | 1,76 | 0,20 | 1,60 | 1,59 | 1,49 | 1,77 | 1,69 | 0,00 | 0,57 | 0,54 | 0,24 |
| | Landslides | 0,70 | 1,35 | 1,26 | 0,13 | 1,66 | 0,70 | 1,59 | 0,65 | 0,67 | 1,35 | 0,70 | 0,70 | 0,80 | 1,59 | 0,69 | 1,64 | 0,70 | 1,66 | 1,75 | 1,62 | 1,26 | 0,93 | 0,57 | 0,00 | 0,21 | 0,72 |
| | Sinkholes | 0,94 | 1,56 | 1,51 | 0,06 | 1,79 | 0,94 | 1,83 | 0,29 | 0,50 | 1,56 | 0,94 | 0,94 | 1,35 | 1,84 | 0,77 | 1,72 | 0,94 | 1,78 | 1,78 | 1,86 | 1,43 | 1,11 | 0,54 | 0,21 | 0,00 | 0,60 |
| | Stabile areas | 0,27 | 1,65 | 1,70 | 0,47 | 1,54 | 0,27 | 1,54 | 0,26 | 0,20 | 1,65 | 0,27 | 0,27 | 1,23 | 1,58 | 0,10 | 1,53 | 0,27 | 1,55 | 1,50 | 1,48 | 1,61 | 1,55 | 0,24 | 0,72 | 0,60 | 0,00 |

generalisation and already existing data, it serves as an efficient tool to produce fast, low-cost estimations of morphologic/geologic properties. This kind of modelling is, however, constrained for usage in the preliminary stages of such works, and should be in the later course of work, combined with standard fieldwork.

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GEOLOGIJA *46/2,* 361–366, Ljubljana 2003

# Why geologists don't listen and the public can't read geological maps[1]

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*Key words*: geological map, GHASP, GIS

## Introduction

Geology is a science that is not only tremendously interesting and exciting; it is also of fundamental importance to our lives, our environment and our assets? No argument with this is there? This statement is obviously true, right?

Well if your answer is yes, then why are the majority of our politicians completely unaware of the financial and human cost of ignoring geological hazards?; why had the guy you met in a bar the other evening never heard of your organisation?; why are geological surveys so poorly funded?; and just in case you are still not convinced, why are you so poorly paid?

Geology is not irrelevant, but for decades we geologists have been largely creating products that appeal only to one audience: ourselves. I concede they may be much sought after for colourful wall posters, but have you ever met anyone outside the profession who could understand a conventional geological map, let alone comprehend what that map has to say about risks and resources? And what geological maps are trying to reveal of the 3$^{rd}$ dimension remains a mystery to the majority.

Hold on, I hear you say, now we are in the 21$^{st}$ Century and things have changed; we've got sophisticated new computers with GIS and 3D modelling software, and we can devise all sorts of colourful coverages, dynamic databases and mutating models! OK, but how convinced are you that the public (who, I might add, provocatively, probably pay your salary though their taxes) now understand our message any better? Geological maps and models (digital or analogue) are crucial, but they must not be seen as the end point; they are only a means to an end; and that end must be ensuring our science is understood and meets the needs of our users and not just us. If you work for a geological survey this has to be your over-riding priority.

In addition to examining the relevance and perception of geological surveys, this paper will take a critical look at traditional products (and some recent digital ones), review some alternative options and discuss the issues which arise when a geological survey tries to take the products of geological

[1] With acknowledgements and apologies to Allan & Barbara Pease, authors of the best-selling book "Why men don't listen and women can't read maps"

surveying and research out of the sophisticated, but limited, circles of the geoscience cognoscenti (yes, that's us!) into the real world.

### Relevant – Yes; Understood and appreciated - No

Geological factors are important in disaster mitigation and planning, environmental protection and resource exploitation. An understanding of them is essential in establishing policies for sustainable development and can assist in addressing a range of socio-economic, biodiversity and landscape issues. However, decision–makers, the politicians, planners, financiers, businessmen and the legal profession, often fail to take geology into account, leading to increased financial costs (e.g. badly located construction schemes, inadequate planning for the use of natural resources), reduction in the quality of life of citizens (e.g. radon emission, pollution of water supply) and at worst, loss of life (e.g. landslides).

Examples from Great Britain (a relatively geologically stable country) show the majority of politicians and planners seemingly unaware of, for instance, the swelling and shrinking properties of clay or the dissolution of gypsum, and allowing housing development that is inappropriate in terms of both location and design. Roads and car parks have been constructed over landslipped ground causing death and injury. The importance of including geoscience knowledge in the prediction of radon-affected areas is only just being recognized. In GB a lawyer would be deemed as professionally negligent if s/he did not obtain a report into possible coal mining beneath a property prior to purchase. But at the moment there is no compulsion to seek out information on potentially damaging natural hazards and yet the case is equally compelling. The estimate of insured losses due to natural geological instability in GB is approximately 450 million Euros per year.

There are more than 40 individual nations in greater Europe and each of these countries has a geological survey organisation (GSO). There exists within each geological survey an enormous wealth of relevant geological data and knowledge. Information, that can, for example, help to mitigate the affects of radon, flood-risk and subsidence. But this is a knowledge base that is grossly under-used and it will stay that way until we understand better how to convert it into the products and services that people want.

At the beginning of the 21st century, at a time when "the environment" has the highest of profiles, geoscience knowledge should be occupying a more prominent role. But it is not. It is a sad fact that the importance of geology to the environment, and to human health, property and assets is not well understood outside the geological profession. Geoscientists and geological surveys and research institutions must accept a substantial part of the responsibility for this lack of understanding and for the failure to persuade potential users to use the geoscience knowledge base. Traditionally the output of a geoscientist's work has been complex, technical and academic maps and reports. The quality of the science is not in question but too often that science remains obscure and remote from the end-user and its significance to society and the environment is not obvious to the public, to governments and to commerce.

It is worth making clear that this paper is not challenging the absolute necessity of a strong foundation of high quality geoscience research and information. But there is an need to reassess the balance and the traditional focus on "academic" output. There is a need to build products that genuinely meet society's requirements. These products must be expressed and provided in a way that is meaningful to an audience that does not, for the most part, have geological training. Traditional geological output, such as lithostratigraphical maps, may be perfectly clear to a professional geologist, however, they convey little or nothing to the non-geologist. The various "stratigraphical" schemes and codes that we use, almost without exception, on geological maps, may allow geoscientists to share information, but they are just impenetrable *secret codes* to other potential users. These users seek straightforward information on the rock types, their physical properties and their hazard or resource potential. They want our knowledge articulated in a way that will help them solve their problems.

If we try and understand what the users want, we have never been better equipped to be able to meet it. The availability of inexpensive, powerful and sophisticated IT tools provides all surveys with the facility to provide customised and flexible products based on their unique geoscience knowledge bases. But how well are we doing with this? Not as well as perhaps we might. Instead of helping to disseminate our message to a wider audience, GIS and other software is often only being used to recreate digitally products as equally indecipherable as those we produced by manual methods in the past.

There may be another factor in our failure to reach the wider audience – the tension between short-term research/scientific advancement, and reliable long-term survey programmes. Many of the new users of geological survey digital data not only seek information that is intelligible to them; they also expect data that are consistent and available nationally. It is a fact that much of our work in the past has taken the form of local (spatially restricted) research projects, which, however innovative and scientifically stimulating, collectively produce neither consistency, nor extensive geographic cover. In the geological surveys of many countries there is a powerful case for spending a greater proportion of the funding on managing existing datasets more coherently and effectively, converting more legacy data into digital form and making these data consistent; rather than focusing excessively on new research and acquisition. This would put us in a position to be able to exploit our already extensive knowledge bases more fully. While this may be a deeply unpopular strategy amongst some geoscientists, many of our potential may view it differently.

## Think like a wise man, but communicate in the language of the people?

The quotation is from W B Yeats, an Irish writer; perhaps this should be a guiding principle behind our new products and services?

Over the last 20 years the British Geological Survey (BGS) has had to progressively increase its earnings from external sources to around 50% of its income, i.e. the BGS grant from the UK Government now covers only half its costs. While this funding model has at times produced a number of problems for the organisation, one obvious benefit has been that, because of the need to earn income, priority and much effort has been devoted to trying to better understand what BGS' users want, and then to attempt to design and deliver appropriate products and services for them. In business-speak BGS is aspiring to market-pull and not product-push. A variety of products has been developed, some very successful, some less so, but in many of them there is no longer a presumption that the user must have a qualification in geology, the talents to visualise 3D objects from a 2D representation, locate themselves by grid reference or even be able to read a map!

In 1993 BGS developed GHASP (GeoHAzard Susceptibility Package) aimed at the UK insurance industry. It was a simple assessment of geohazard potential, which by utilizing digital mapping and GIS, effectively distilled geological knowledge down to a spreadsheet containing a list of GB post(zip)codes and a potential hazard rating between 1 and 10! GHASP proved to be a considerable success. Subsequently BGS developed ALGI (Address Linked Geological Inventory) for the urban areas of Bristol and London. This was a prototype turnkey system to supply geological information for those involved in property transactions. It used GIS, in combination with an address/coordinate database and automated report writing scripts to deliver a standard geological report on any specific address. It was a major advance, but its restricted geographic extent and the geoscientific nature of the information provided, limited its usefulness and take-up.

Developing GHASP and ALGI provided experience and the basis for a range of products and services that BGS is offering today. In 2002 the GeoReports service was launched (Figure 1 and http://www.bgs.ac.uk/georeports/home.cfm). This is a full e-commerce service that uses a number of national databases of geohazards, GIS, address-linking, and automated report-writing scripts. It allows customers to select from a variety of report types using postal address or grid reference and then receive the report (in secure PDF format) by email. Report types range from a simple listing of the data BGS


Figure 1. "The location entry" screen of the BGS GeoReports e-commerce service

holds for the specified area, to reports describing potential radon risk or natural ground stability hazards in non-technical language. A portion of a report on natural ground stability is included as Figure 2. Note that after assessing the likelihood of any hazard the report first advises the client on what they should do next and only then gives information on the likely cause; the concern of most members of the public is not what may cause the geological hazard, but what they should now do about it.

BGS continues to try and understand users' needs better. This is not an easy task, in part because many users are not really aware of the range of data and potential services a geological survey can offer and often have difficulty articulating their needs. But through one-to-one dialogues, partnerships and user forums (including a regular Parliamentary briefing) our appreciation of the real requirement is slowly growing. In recent months new discussions have taken place with representatives of the insurance companies, the legal profession and the financial sector on the content and design of potential new products they might wish BGS to supply. Additionally, continuing negotiations are taking place with local administrations, transport infrastructure organisations and national environmental and conservation agencies. For these major organisations, which have an ongoing need for geological data, the opportunity of direct and dynamic, customised access to BGS knowledge via Virtual Private Networks and web services is being explored.

**Working outside the comfort zone?**

Going beyond the delivery of conventional geological maps and reports and reaching out to a non-traditional user base means facing a new set of problems. If a GSO then charges for these products and services, even if on a non-profit making basis, only to recover costs, then these problems are compounded.

The first of the problems is resources; in addition to the costs of defining and developing the products, there are the operational costs of delivery and maintenance. Creating the products may divert staff away from their (perhaps preferred?) core duties of survey and research and cause tensions in the organisation. Running a service which provides information to the public will probably require a help-line or inquiry point to deal with enquiries and complaints. The issue of liability and the risk of being sued for supplying erroneous information is not new, but it does increase considerably, as these new products are going to an audience that

GeoReports

**_Natural Ground Stability Professional Search_**

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Search Results:
Important notes
The term 'search **area**' as used throughout this report means the property extent and a 150m buffer zone. The property extent will be defined using the original details specified by the client
This search is concerned with potential ground stability related to NATURAL geological hazards only. It does not search for man-made hazards, such as contaminated land or mining. Searches of coal mining should be carried out via The Coal Authority Mine Reports Service (*www.coalminingreports.co.uk/*)

| **Question 1** | **Answer** |
|---|---|
| **Is significant natural ground instability possible in the area?** | YES |

| **Question 2** | **Answer** |
|---|---|
| **How significant could natural ground instability be in the area on a scale of 1 to 4 (low to high)?** | **Level 3** |

| **Question 3** | **Answer** |
|---|---|
| **What action should be taken?** | If natural ground instability has been indicated, then this means there is potential in your area for some properties to suffer subsidence damage. However, it does not necessarily mean that your property will be affected, and in order to find out if this is the case or not you, should obtain further advice from a qualified expert, such as a building surveyor. Show them this report and ask them to evaluate the property and its surroundings for any signs of existing subsidence damage as well as advise on the likelihood for subsidence to occur in the future. The notes at the end of this report may be useful in this regard.<br>Note that the type of building and its surroundings (e.g. the presence of trees) are also very important when considering subsidence risk. Many types of properties, particularly newer ones, are very well constructed and unlikely to be affected by subsidence, even in areas of very significant ground movements. |

| **Question 4** | **Answer** |
|---|---|
| **Which natural geological hazards could be contributing to the ground instability in the area?**<br>*How much ground instability each hazard may cause is indicated by the Level 1 to 4 in brackets. This corresponds to the ('low' to 'high' significance) scale used in Q.2* | Clays that can swell when wet and shrink when dry, causing the ground to rise and fall ('Swelling Clays Hazard') (LEVEL 2)<br><br>Weak or unstable rocks that could slip downhill on steep slopes (greater than c. 5 degrees) or into excavations ('Landslip Hazard') (LEVEL 1)<br><br>Very soft ground that might compress and progressively sink under the weight of a building ('Compressible Ground Hazard') (LEVEL 3) |

Figure 2. Part of a sample report on natural ground stability from the BGS GeoReports service

is not familiar with the "fuzzy" nature of geological information and may misuse them. The cost of legal advice to make sure the products are properly described and "caveat-ed" must be taken into account, as must the potential cost of legal representation, should someone actually take you to court.

National and European directives and statutes may prescribe whether a GSO may provide such services and also what and how they may charge for them (if anything!).

The whole issue of charging and pricing policy is complex; should data be licenced or sold outright, how much should be charged, should the charges differentiate between commercial use and public good use? In the UK the 1998 Competition Act, enforced by the Office of Fair Trading, introduces a further set of rules with which BGS must comply; these relate to operating fairly within the commercial market place,. Intellectual Property Rights (IPR) and copyright are equally complex issues, not only in terms of the protection of data originating in the GSO but also because data from other organisations may have been used in developing the new product (for instance a digital elevation model or mine plan data).

Perhaps one of the most difficult issues is the dilemma posed by the problem of "blight". Geological maps have always contained implied information about hazards and resources that may affect decisions about planning in general and property in particular, but that information has been understood by only a few. When one develops products and services that make that information accessible to and understandable by the general public, suddenly any potentially damaging implications for health and property are there for all to see. It is not difficult for, instance, to envisage the affects on property prices of a GSO releasing information that describes a particular area of a city having a potential risk from subsidence or landslipping. Some will argue that making such information available (information which can only ever be indicative and never site specific or definitive) is irresponsible, others will assert that this is precisely the duty of a responsible public body. Making the potential hazard information available has not increased the actual level of risk, but it has given it a higher profile. It is also true that, however comprehensive the disclaimers or explanations, there is always a possibility that some users will, innocently or otherwise, misinterpret the information. Bringing science to the public is not always easy.

GEOLOGIJA *46/2,* 367–372, Ljubljana 2003

# Geohazard map of the central Slovenia – the mathematical approach to landslide prediction

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*Key words:* Geology, Landslide prediction, Geomorphology, Multivariate statistics, Analytical Hierarchy Process (AHP), Geohazard map, Slovenia

**Abstract**

Issues connected with unwanted natural occurrences, such as landslides, floods or earthquakes, are a source of concern around the world and Slovenia is no exception. Landslides belong to the category of "manageable" natural disasters. Today, we cannot envisage spatial modelling and prediction of various events without the information technology. GIS is also used to analyse the landslide data and satellite images can serve as a support to the ground reconnaissance. Using the methods of univariate statistics, the influences of individual spatial factors on the different landslide types and on landslides generally were tested. Using multivariate statistical methods, the interactions between factors and landslide distribution, and defined the importance of individual factors on the landslide occurrence were tested. Having combined all the spatial data available, several models were developed. Those that produced best results were then used to determine and locate the potentially hazardous areas and to draw the map of landslide risk. The landslide risk-map permitted the assessment of the hazard to the inhabitants and infrastructure (roads) on the tested area.

## Introduction

As a result of the recent natural disasters in Europe, like floods in 2002, the need for a better understanding of natural phenomena has arisen. Independently of whether these events result from human actions or are the work of nature, their prevention or mitigation is an important factor when the preservation of the modern man's environmental quality is at stake. Hence the need for better understanding of these phenomena, especially when their consequences can be to some measure controlled, like in the case of landslides. For this purpose, the statistical approach to analysing the influence factors and their contribution to landslide occurrence was chosen (Carrara, 1983; Carrara et al., 1991). For the study area, the central part of Slovenia, west of Ljubljana, was selected (Figure 1), covering approximately 35×35 km. A better understanding of the described relationships should enable a more precise and a more affordable identification of the landslide-prone areas. In order to determine the capacity of an accurate spatial prediction of landslides or landslide-prone areas, several linear prediction models, using AHP (Saaty, 1977), were developed. The applicability of the AHP (Analytical Hierarchy Process) method to landslide prediction has been shown before (Barredo et al., 2000; Mwasi, 2001; Nie et al., 2001).


Figure 1. The study area

## Data acquisition

To successful predict landslide occurrence and to produce the map of landslide-prone areas, relevant spatial data are needed. The data needed for this investigation were obtained from several sources. The landslide data were obtained from the landslide database that was constructed at Geological Survey of Slovenia. For the study area, it contains data on 614 landslides. Further, the digital elevation model (DEM) data were obtained from the national 25 m resolution DEM (InSAR DMV 25) (Survey and Mapping Administration, 2000). All the additional data on the terrain morphology (curvature, elevation, slope, aspect, basins, primary slope-units) were derived from the DEM. The Basic Geological Map of Yugoslavia at the scale of 1:100.000 served as a source for the geologic data of the area (Buser et al., 1967; Buser, 1973; Buser, 1986; Grad & Ferjančič, 1976). For the land use and the vegetation cover, satellite images from different sources were used and combined, using PCA (Principal Component Analysis) merging method. The multi-spectral part of the satellite data was obtained from the Landsat-5 TM images, and the high-resolution part was obtained from the Resurs-F2 MK-4 images. The topologic map in scale 1:50.000 was used as a source of the surface water net data (Survey and Mapping Administration, 1994). The population density data were obtained from National Office of Spatial Planning et al. (1997) and infrastructure data from Survey and Mapping Administration (2000).

## Data analysis

The aim of the paper was to examine several topics, related to the landslide prediction in the central part of Slovenia, west of Ljubljana. One of the project's main goals was to study spatial factors that influence the occurrence of landslides, individually and conjointly, and to statistically establish the univariate and multivariate relations with the landslide distribution. A better understanding of the described relationships should enable a more precise and a more affordable identification of the landslide-prone areas. In order to determine the capacity of an accurate spatial prediction of landslides or landslide-prone areas, several linear prediction models, based on various methodologies were developed.

*Univarate statistical analysis*

Using methods of univariate statistics, the influences of individual spatial factors on the different landslide types and on landslides generally were tested. For the categorical variables, Kolmogorov-Smirnov and $\div^2$ test were used, where actual frequency of the landslide occurrence was compared to the expected frequency. Bigger difference represents stronger influence of the observed factor. Continuous variables were also tested with Student's *t* test. On the basis of these results the stability characteristics of the individual classes of the observed factors were assessed. The factors that proved to have played an important role are shown in the following table (Table 1). The steepness and the curvature of the slopes,

Table 1. Factors that play an important role in landslide occurrence (univariate statistical methods)

| *Variable* | *All landslides* | | *LS_type1* | | *LS_type2* | | *LS_type3* | | *LS_type4* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $\chi^2$ | **K-S** | $\chi^2$ | **K-S** | $\chi^2$ | **K-S** | $\chi^2$ | **K-S** | $\chi^2$ | **K-S** |
| ***Slope*** | **0,0** | **0,01** | **0,0003** | **0,01** | **0,0** | **0,01** | **0,039** | **0,01** | 0,28 | **0,01** |
| ***Elevation*** | **0,0** | **0,01** | 0,107 | **0,01** | **0,0** | **0,01** | 0,124 | **0,01** | 0,2515 | **0,05** |
| ***Aspect*** | **0,001** | 0,2 | 0,088 | n.s. | **0,008** | n.s. | 0,886 | n.s. | **0,008** | **0,01** |
| ***Curvature*** | **0,0** | **0,01** | 0,18 | **0,01** | **0,0** | **0,01** | 0,38 | **0,05** | **0,011** | **0,01** |
| ***Lithology*** | **0,0** | **0,01** | **0,0** | **0,01** | **0,0** | **0,01** | **0,002** | **0,01** | **0,005** | **0,01** |
| ***Dist_geo_bound*** | **0,0** | **0,01** | **0,0164** | **0,01** | **0,0** | **0,01** | **0,002** | **0,05** | 0,327 | **0,05** |
| ***Dist_structures*** | **0,01** | **0,01** | 0,282 | **0,05** | 0,2569 | **0,05** | 0,869 | n.s. | 0,067 | n.s. |
| ***Dist_waternet*** | **0,0** | **0,01** | **0,0** | **0,01** | **0,0** | **0,01** | **0,001** | **0,01** | **0,0** | **0,01** |
| ***n*** | | 614 | | 68 | | 413 | | 57 | | 60 |

the distance to the geological borders, the distance to the rivers, lithology, and the type of vegetation proved to play an important role in landslide occurrence. LS_type1 stands for fossil landslides, LS_type2 for dormant landslides, LS_type3 for creeping, and LS_type4 for slides. Confidence limits for means were set to 95 %. Significant variables (statistical significance is higher than 95 %) are shown in bold text in the Table 1.

## Satellite images

Prior to analysis, the multi-spectral satellite data, obtained from the Landsat-5 TM images, were merged with the high-resolution satellite data, obtained from the Resurs-F2 MK-4 images,. The merging of the two was done using the PCA joining method, where first principal component of the multi-spectral satellite data is replaced with the first principal component of the high-resolution satellite data (Cliché et al., 1985; Chavez et al., 1991; Sanjeevi et al., 2001; Vani et al., 2001). A part of the images were transferred from RGB colour model to the CIE L*a*b* (CIE, 1986) colour model (Figure 2). All images were than classified according to landslide prediction rate (areas or land-types where more landslides occurred have higher possibility of future landslide occurrence) using unsupervised classification and advanced RGB clustering method (ERDAS, 1999). The best results gave the image that was the composite of channels 3, 4 and 5, transformed with the CIE L*a*b* model. The landslide prediction error was 12,6 % (portion of the area that was classified as non-landslide, but where current landslides do occur) and the non-landslide area prediction error was 8,1 % (portion of the area that was classified as landslide-prone, but where no landslides can be found).

## Multivarate statistical analysis

Using multivariate statistical methods (factor analysis and multiple regression analysis), the interactions between factors and landslide distribution were tested, and the importance of individual factors on the

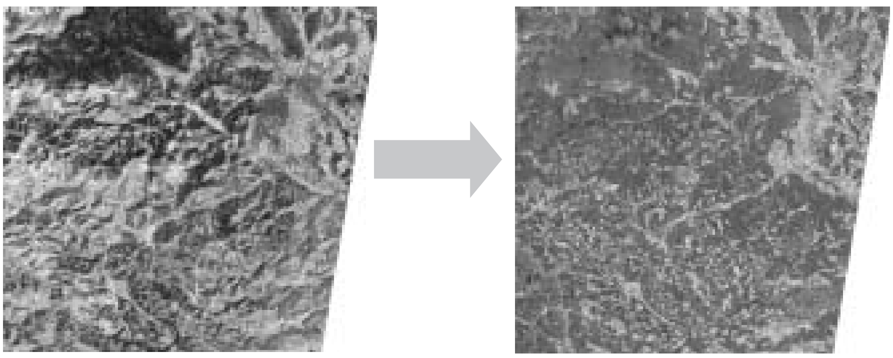

Figure 2. RGB to CIE L*a*b* transformation

Table 2. Portions of the variance, explained by factors with loaded variables (factor analysis)

| | All landslides | Fossile landslides | Dormant landslides | Creeping | Slides |
|---|---|---|---|---|---|
| **F1** | Slope & terrain roughness (22%) | Lithological properties & slope variation (26%) | Slope & terrain roughness (24%) | Lithological properties (23%) | Slope & terrain roughness (27%) |
| **F2** | Lithological properties (15%) | Slope & terrain roughness (19%) | Avrg. dist. waters & cover type diversity (14%) | Slope & terrain roughness (19%) | Lithologic diversity, curvature type & avrg. dist. geol. boundaries (16%) |
| **F3** | Average curvature & avrg. dist. waters (12%) | Cover type diversity & avrg. curvature (12%) | Cover type & orientation (12%) | Avrg. dist. waters & avrg. curvature (15%) | Lithological properties (14%) |
| **F4** | Cover type & orientation (10%) | Lithologic diversity & avrg. dist. tectonic elements (9%) | Lithological properties (10%) | Cover type & orientation (12%) | Cover type (10%) |
| **F5** | Lithologic & cover type diversity (7,5%) | Cover type (8%) | Avrg. dist. tectonic elements (8%) | Lithologic diversity & avrg. dist. tectonic elements (6,5%) | Avrg. curvature (7,5%) |
| **F6** | Avrg. dist. tectonic elements (6%) | Avrg. dist. waters (7%) | Curvature type (6%) | Curvature type (5,5%) | Avrg. dist. tectonic elements (6%) |
| **F7** | Curvature type (5,5%) | – | Lithologic diversity & avrg. dist. geol. boundaries (5,5%)- | – | – |
| **Sum** | **78,3%** | **80,2%** | **79,2%** | **80,4%** | **80,5%** |

landslide occurrence were defined. For the purpose of multivariate analysis, the area was subdivided into 78365 slope units, for which additional 24 statistical variables were calculated. In comparison with other multivariate statistical methods used, the factor analysis proved to be the most appropriate and reliable method for the landslide prediction. Table 2 is showing the portions of the variance, explained by various factors, that are represented by one or more variables. At the bottom, the total explained variance is shown.

After having combined all the spatial data, numerous models were developed, using the AHP method, with error ranging from 47 % to 3 %. Those that produced best results were then used to determine and locate the potentially hazardous areas and to draw the map of landslide risk. Figure 3 is showing the values of the weights of spatial factors in the most suitable models. The landslide risk-map was then used for assessment of hazard to the inhabitants and infrastructure (roads) on the tested area.

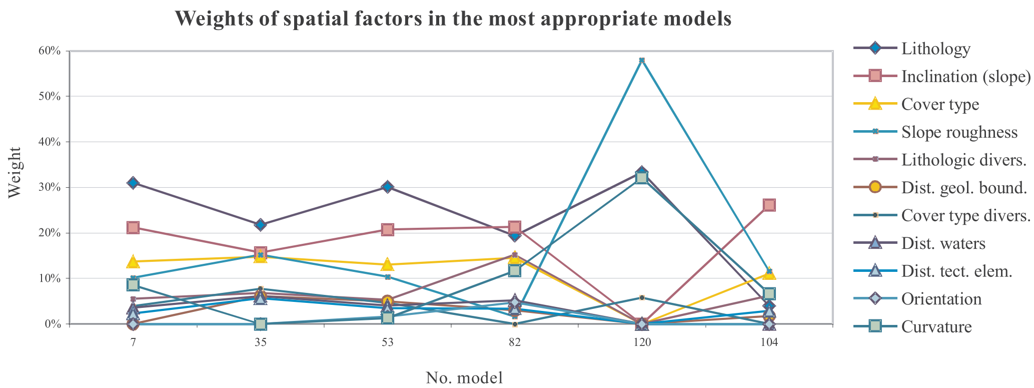


Figure 3. Weights of spatial factors in the most suitable models

## Conclusions

Regarding the results of the univariate statistics, the following influencing factors proved to have played an important role in landslide occurence: the steepness and the curvature of the slopes, the distance to the geological borders, the distance to the rivers, lithology, and the type of vegetation. It was shown that high-resolution multi-spectral satellite images could be successfully used for the spatial landslide prediction. The multivariate statistical methods, which take into account several spatial factors, showed better prediction power compared to the results of the individual factor prediction. They indicated in the case of landslide occurrence the primary role of slope, terrain roughness and lithology. Of importance are also the type of the land use, cover type and terrain curvature. Other spatial factors have smaller impact on landslide occurrence. In the study area, a relatively small percentage of the population (less than 3 %) inhabit the high risk areas. 20 – 25 % of the population live in areas considered to be landslide-prone. The creeping and sudden landslides (slides) represent the biggest threat to inhabitants. More than half of the roads cross the areas subjected to ground mass movement and 3 % of all roads cross the high-risk areas.

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GEOLOGIJA *46/2*, 373–378, Ljubljana 2003

# GIS-Based sensitivity analysis in site selection procedures for the disposal of hazardous wastes

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*Key words*: radioactive waste disposal, selection criteria, PCS, GIS

**Abstract**

Between 1999 and 2002, a multi-scientific working group on behalf of the German Federal Ministry of Environment was under way to determine scientifically founded criteria for a selection and rating procedure for the permanent disposal of radioactive wastes. The Federal Institute for Geosciences and Natural Resources (BGR) accompanied this process by developing a criteria-oriented Geographical Information System (GIS/FIS), titled "Geosciences and disposal of wastes (GEA)". In FIS GEA, 28 crystalline occurrences in Germany were exemplarily chosen for implementing the selected geo-scientific and socio-economic criteria for a future site selection and rating procedure. Currently, 17 crystalline occurrences have been evaluated and analysed. The results of the rating and weighting procedures implemented in a Point-Count-System (PCS) and its sensitivity analysis will be presented. The FIS GEA-application supports national or local authorities in their assessment of criteria-relevant information for a future site selection and rating procedure.

## Introduction

In 1998, the German government decided to phase-out the commercial use of nuclear power. This political intention and comprehensive negotiations with important German energy providers led to a consensus, which was signed on June 14, 2000. Since February 1999, the German Federal Ministry of Environment was under way to determine scientifically founded permanent repository criteria for a selection and rating procedure to specify one or more suitable area(s) for the permanent disposal of radioactive wastes. Its AkEnd-working group (Arbeitskreis Auswahlverfahren Endlagerstandorte) had the primary task to develop a transparent site selection procedure by accessing and evaluating geo-scientific and socio-economic criteria. These exclusive and suitable criteria should be used in the future site selection procedure to define an area of crystalline rock, salt or clay for the disposal of hazardous wastes in Germany. In order to ensure the transparency of this site selection procedure and thereby increase the acceptance within the population in Germany, the AkEnd-working group welcomed the participation of the population in every step of its predefinition of the criteria and selection procedure. Its work was completed at the end of 2002 (AkEnd 2002).

The Federal Institute for Geosciences and Natural Resources (BGR) accompanied this process by developing a criteria-oriented multi-layer Geographical Information System (GIS/FIS), titled "Geosciences and disposal of wastes (GEA)". In FIS GEA, 28 crystalline occurrences in Germany (Bräuer et al. 1994) were exemplarily chosen to apply specific geo-scientific and socio-economic criteria to a future small-scale site selection and rating procedure by using GIS. Currently, 17 crystalline occurrences (= investigation areas), all located in the Federal state of Saxony, have been evaluated and analysed. The results of the GIS-based selection procedure of these investigated areas, complemented by a sensitivity analysis, will be presented in this article.

## GIS-Methodology

The Geographical Information System FIS GEA comprises two key elements, the ESRI ArcGIS 8.2 environment, which has been used for all geo-processes and visualisation, and an ACCESS 2000 application for all the descriptive data or meta data and especially for the sensitivity analysis of each crystalline occurrence.

The advantages of a GIS-based data management for a future site selection and rating procedure, e.g. double-precision of all map layers or the transparent reproduction of all geo-processes for further verification, have been used to store and to geo-process geo-scientific and socio-economic criteria (see Table 1). The spatial information of the GIS-coverages are linked by a common item (IDENT) with the descriptive information stored in an ACCESS 2000 database. All spatial data are part of a topological model, consisting of geo-referenced coverages in the Gauss-Krüger coordinate system (Germany, zone 4), either digitised from published analogous sources (e.g. maps) or implemented from external spatial data provided by the authorities of the Federal Republic of Germany and of the Federal states, e.g. ATKIS – DLM25, DLM1000, DGM25 and raster data.

The object–oriented ACCESS 2000 application guarantees the integrity and security of both data input and data editing in a multi-user environment. The ACCESS 2000 application is composed of a descriptive data processing tool and a Point-Count-System (PCS), with an integrated sensitivity analysis. The PCS-tool, the linkage between the GIS (spatial information) and ACCESS 2000 database (descriptive information), enables the data representation and the weighting of the defined suitable criteria applied to each crystalline occurrence.

## Point-Count-System (PCS) and sensitivity analysis

The public acceptance for regions, areas or sites for the disposal of hazardous wastes is increasing with the transparency of a selection and rating procedure (Risolutti et al. 1999, AkEnd 2002). Therefore, a transparent rating/weighting methodology is an essential part of the FIS GEA-application, which is realised in the PCS-tool and its sensitivity analysis. Due to methodological reasons, FIS GEA applies not only AkEnd defined exclusive and suitable criteria, but various geo- and socio-economic criteria in order to provide incentives for further evaluations of GIS-based information in the case of small scale selection (less than scale 1:100 000) of suitable area(s) (see Table 1).

Based on the criteria-relevant geo-scientific and socio-economic information stored as geo-referenced map-layers (coverages) in GIS, the rating/weighting procedure includes two steps.

Table 1. Criteria-relevant subjects implemented in FIS GEA

| *exclusive criteria* | *suitable criteria* |
|---|---|
| distance to frontier of FRG | geology |
| seismicity | tectonics |
| future potential volcanic activity | hydrogeology |
| recent vertical crustal movements | seismic epicentres |
| water reservoir | population density |
| protected areas including national park, biosphere reservation | protected areas without national park, biosphere reservation |
| | mining areas |

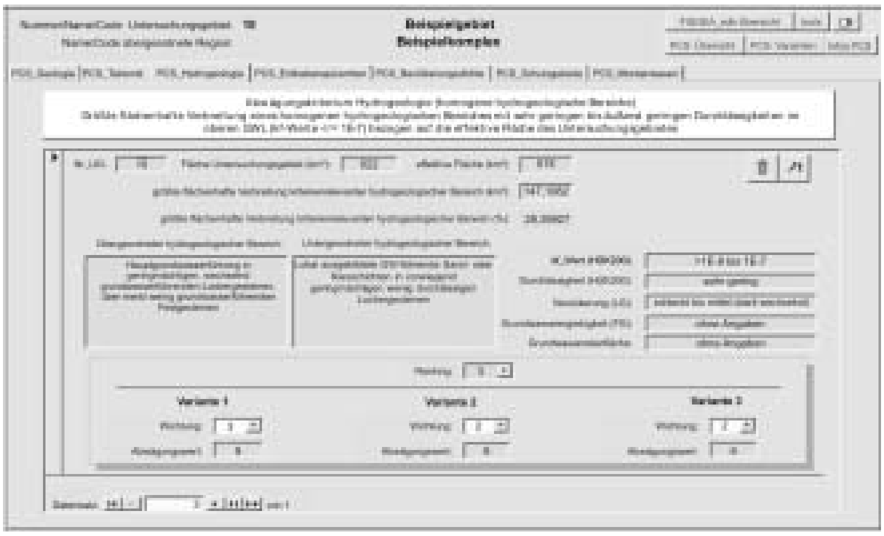

Figure 1. FIS GEA PCS-tool for the suitable criterion "hydrogeology"

The first step of the rating procedure is characterised by geo-processing of the six exclusive criteria in GIS, which leads to one or more positively remaining suitable area(s) within each investigation area. In the second step, these positively remaining suitable area(s) have to be geo-processed first according to seven suitable criteria and second, the spatial information of these GIS coverages have to be integrated into the PCS-application and complemented by descriptive data. The information of both sources provides the ranking and weighting data for each suitable area(s) in the PCS-tool and its sensitivity analysis (Maurer & Balzer 2002). The PCS-tool, the linkage between the GIS (spatial information) and ACCESS 2000 database (descriptive information), enables to specify the specific criteria-related queries and also a sensitive weighting of the applied suitable criteria to each crystalline occurrence in a user interface environment (see Fig. 1 for an example on the suitable criterion "hydrogeology", German version).

The calculation in the PCS-tool is exclusively based on the evaluation of the remaining one or more positive suitable area(s) within each investigation area, which will be weighted by using seven suitable criteria ($j$ = 1-7). These seven suitable criteria finally generate a suitability value ($P_j$). The suitability value ($P_j = R_j \times W_j$) for each suitable criterion is calculated from a specific parameter ranking value ($R_j$ = 1-10) and a specific parameter weighting value ($W_j$ = 1, 2 or 3). The ranking value ($R_j$) is associated with the maximum and minimum results of each specific criterion query defined in the PCS. The sum of all suitability values for each suitable criterion can be expressed as a suitability index $I$, see formula.

$$I = \sum_{j=1}^{7} R_j \times W_j$$

According to the number of suitable criteria and the minimum and maximum ranking and weighting values, the suitability index for each crystalline occurrence can range between 7 and 210 points. The calculated suitability indices allow the comparison of all investigated areas considering the suitability of a region, area or site for the disposal of hazardous wastes (see Table 2). Based on the suitability index ranges ($I$ = 7-210), three suitability classes have been defined to distinguish all investigated areas into site(s) of low, middle or high suitability for a disposal of hazardous wastes.

In order to assess the sensitivity of the rating system, three different weighting procedures have been implemented: the first emphasises the geo-scientific criteria, the second the socio-economic criteria and, finally, all criteria have been weighted neutrally (see Table 3). The sensitivity analysis has been performed in order to assess the influence of weighting of single or various geo-scientific or socio-economic criteria concerning the final suitability of the areas.

Table 2: Suitability index and suitability classes

| *suitability index (I)* | *suitability classes* |
|---|---|
| 7–74 | high (suitable) |
| 75–142 | middle (suitable) |
| 143–210 | low (non-suitable) |

## Case Study

The suitability index of all 17 considered crystalline occurrences of Saxony has been analysed and calculated for all three weighting procedures (see Fig. 2). The results show that the weighting procedure with a focus on socio-economic criteria (b) is producing the highest suitability indices. The same weighting procedures with an emphasis on geo-scientifically (a) or neutrally (c) weighted criteria show a heterogeneous distribution and almost no difference between the investigated areas. Five crystalline occurrences have been completely excluded by geo-processing of the exclusive criteria. The three different weighting procedures show,

Table 3.Weighting parameters of the PCS-tool

| ***suitable criteria*** | ***geo-scientific-emphasised weight (a)*** | ***socio-scientific-emphasised weight (b)*** | ***neutral weight (c)*** |
|---|---|---|---|
| geology | 3 | 2 | 2 |
| tectonics | 3 | 2 | 2 |
| hydrogeology | 3 | 2 | 2 |
| seismic epicentres | 3 | 2 | 2 |
| population density | 1 | 3 | 2 |
| protected areas without national park, biosphere reservation | 1 | 3 | 2 |
| mining areas | 1 | 3 | 2 |

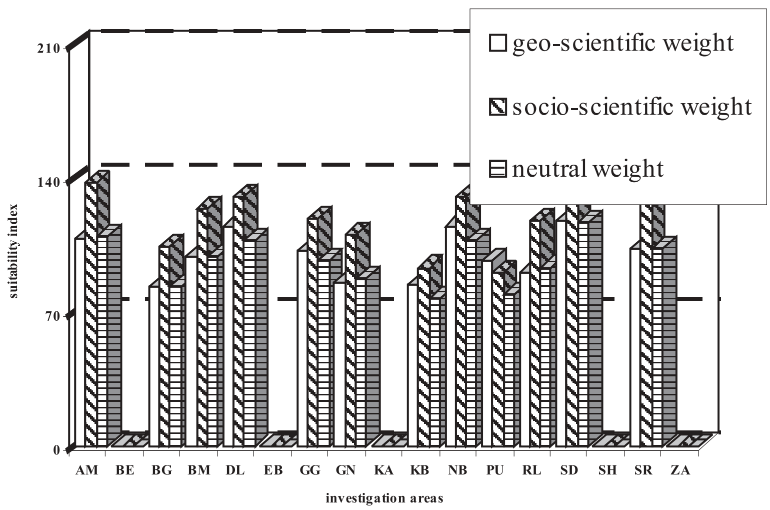


Figure 2. The suitability index of the crystalline occurences in Saxony

that the majority of the crystalline occurrences are characterised by a suitability class of middle degree. Only one investigation area with an emphasis on socio-economic criteria shows a high suitability index in the weighting procedure. The results of the sensitivity analysis can be presented in different digital suitability maps for the chosen crystalline occurrences.

## Conclusions

A GIS-based sensitivity analysis was established in order to test influences of the different weighting of geo-scientific and socio-economic criteria with respect to the suitability of different crystalline occurrences in a site selection and rating procedure. The sensitivity analysis is exclusively based on geo-processed spatial data and their complemented descriptive data of the FIS GEA-application, allowing to define suitable criteria and their implementation in a Point-Count-System. The analysis has shown that the majority of the crystalline occurrences are characterised by a suitability class of middle degree, independent from the chosen weight.

Therefore, the FIS GEA-application provides an intelligent system to support national or local authorities in their analysis and assessment of criteria-relevant information for a future site selection and rating procedure, irrespective of the host rock.

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GEOLOGIJA *46/2,* 385–390, Ljubljana 2003

# Developing a suitability model for potential vegetation distribution based on GIS

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*Key words*: suitability model, potential, vegetation map, spatial analysis, WOFE, GIS

**Abstract**

The growing problem of deforestation around the world will have serious consequences for life on our planet if urgent steps are not taken to remedy this situation. In order to reforest affected areas, it is first necessary to decide the areas most suitable to each type of forest. This can be determined by using suitability models based on a series of morphological and environmental variables (altitude, gradient, insolation, etc.), all of which have a bearing on the presence or absence of a particular type of forest in a particular area.

Our study involves the creation of a potential vegetation model based on the environmental variables that have a bearing on the existence of a particular type of forest at any given point of terrain. These variables can be represented on maps that are included in a spatial database together with a distribution map of existing forests. A potential vegetation map for each study area is then drawn up using the integrated mathematical and statistical functions of the database. Two potential vegetation maps are created, one using discriminant analysis combined with correspondence analysis, and the other using logistic regression combined with weights of evidence. The results for each method are then compared to the real distribution of the forests in the area of study.

## Introduction

When designing a reforestation project in order to reduce forest fragmentation and protect biodiversity in a particular area, the existing situation is a logical starting point. The surface area covered by each type of forest will be smaller than the original surface area since some of the forest will have been eliminated by artificial methods. Since reforestation projects are often based on working methods that are not entirely objective, they tend to give rise to different solutions depending on the technician who designed the plan. In a bid to eliminate this subjectivity, a number of authors have proposed the use of methodologies based on objective criteria for the development of suitability models for plant species (Van de Rijt et al., 1996; Felicísimo et al., 2002). These models take into account a series of physical and biological factors that have an impact on the distribution pattern of forests, among them lithology, altitude, gradient, temperature, rainfall, etc. All this information can be stored in a Geographic Information System (GIS) database, whose spatial analysis functions can be exploited to obtain distribution models based on objective methods (Felicísimo et al., 2002; Guisan et al., 1996).

In this study a potential vegetation model is created, based on the distribution of existing forests in the area of study and on the values of the morphological and environmental variables that have a bearing on this distribution. The proposed model was applied to the Liébana river basin in the northern Spanish region of Cantabria. This basin measures 629 km$^2$ and although its original forested area has diminished considerably (as in the entire Iberian Peninsula), it still contains autochthonous forests large enough to provide a representative sample.

## Database construction

The first stage in the development of the model was the creation of maps for the GIS cartographic database.

The basic primary information was as follows:

• Vegetation map drawn up by the Department of Earth Sciences of the University of Cantabria and containing 180 classes of vegetation, of which 18 are forest. Only 6 of these forests were included in the study as they are the only ones still large enough to provide a suitable sample. Their growth patterns are also influenced by climatic rather than edaphic factors.

• Lithological map drawn up by the Spanish Technological and Geomining Institute, and containing 19 lithological classes for the study area.

• Topographic map drawn up by the Geography Division of the Spanish Army, and containing elevation markings every 20 metres.

• Rainfall map created using rainfall data for the last five years obtained from the Spanish National Meteorological Institute.

The following maps were then derived from the topographic map:

• Altitude maps calculated using a Delaunay triangulation algorithm converted to a raster structure with 50–metre cells.

• Gradient map obtained from an altitude map using a second-order finite difference scheme (Skidmore, 1989) with a resolution of 50 metres.

• Potential insolation map obtained from the DEM (Digital Elevation Model) and that takes into account the amount of sun received by each gridded cell in accordance with the path of the sun and topographic occlusion. Time resolution is 15 minutes and spatial resolution is 50 metres (Fernández-Cepedal & Felicísimo, 1987).

• Map of distances between the sea and the mid-point of each 50-metre cell. These distances were recorded to take into account the influence of the continental ocean gradient.

All these variables have a potential bearing on the distribution of forests and are included in the GIS cartographic database that is used in the simulation.

## Development of a potential vegetation model using discriminant linear analysis

Discriminant analysis permits a series of observations to be classified into a number of previously defined classes. A linear combination is defined for each class that simultaneously maximises differences between means and minimises variances within classes (Fisher, 1936). This technique is widely used in fields such as taxonomy (Fisher, 1936), geology (Jordan et al., 1998), medicine (Mayer et al., 1998) and mining (Taboada et al., 2002), among others.

Each classification function provides a value for the cells in each class through the following formula:

$$S_i = c_i + \sum_{j=1}^{m} \lambda_{i,j} x_j$$

where $S_i$ is the value of the discriminating function for class $i$; $c_i$ is a constant, $\lambda_{i,j}$ is the coefficient for the $n^{th}$ variable in class $i$; $x_j$ is the value observed in the $j^{th}$ variable in class $i$ and $m$ is the number of variables.

Once the discriminating functions have been established, each cell is assigned to the class associated with the greatest discriminating value.

This is the method used in some geographic information systems and satellite image processing programs to obtain supervised classifications using information from each of satellite's spectral bands.

We applied the method to a sample of 3320 cells taken randomly from the forested areas. The independent variables taken into consideration were altitude, gradient, potential insolation, distance from the sea and rainfall. Lithology was initially excluded, as

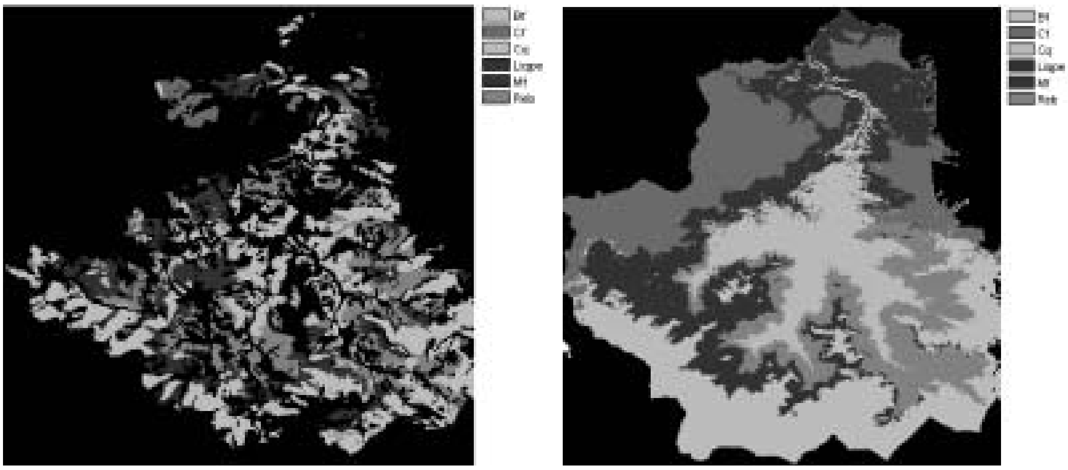

Figure 1. Distribution of existing forests (left) and potential distribution obtained using discriminant analysis, excluding lithology as an independent variable (right).

Table 1. Error matrices for the logistic regression (left) and discriminant analysis (right) models. The columns refer to actual forest and the rows to potential forest as determined by mathematical models.

| | 1 | 2 | 3 | 4 | 5 | 6 | E.C. |
|---|---|---|---|---|---|---|---|
| 1 | 20525 | 382 | 269 | 3998 | 32 | 2464 | 0.258 |
| 2 | 2881 | 2957 | 417 | 680 | 439 | 869 | 0.641 |
| 3 | 99 | 21 | 13666 | 100 | 377 | 2755 | 0.197 |
| 4 | 7132 | 359 | 752 | 9530 | 54 | 6476 | 0.608 |
| 5 | 342 | 934 | 2655 | 545 | 3986 | 1723 | 0.609 |
| 6 | 1956 | 21 | 2773 | 2570 | 1 | 8978 | 0.449 |
| E.O. | 0.377 | 0.367 | 0.334 | 0.453 | 0.185 | 0.614 | |

Kappa = 0.4688

| | 1 | 2 | 3 | 4 | 5 | 6 | E.C. |
|---|---|---|---|---|---|---|---|
| 1 | 23012 | 356 | 4 | 2807 | 0 | 866 | 0.149 |
| 2 | 2491 | 3354 | 16 | 211 | 255 | 477 | 0.506 |
| 3 | 5 | 28 | 13690 | 253 | 641 | 2623 | 0.206 |
| 4 | 5216 | 316 | 342 | 10390 | 30 | 3991 | 0.488 |
| 5 | 261 | 581 | 3217 | 260 | 3909 | 2230 | 0.626 |
| 6 | 1950 | 39 | 3263 | 3502 | 54 | 13098 | 0.402 |
| E.O. | 0.301 | 0.282 | 0.333 | 0.404 | 0.200 | 0.437 | |

Kappa = 0.5609

a non-quantitative variable. Figure 1 shows the potential vegetation map and the map showing the distribution of existing forests.

## Comparison with the logistic regression model

The logistic regression method has recently been used to generate potential vegetation distribution models (Felicísimo et al., 2002). It permits an estimation of the probability of the presence of a particular type of forest on the basis of the values of *n* explicative variables. These variables can be measured on any scale (nominal, ordinal, interval or ratio), in accordance with the following expression:

$$P(Y=1|\mathbf{x}) = \frac{\exp\left(b_0 + \sum_{i=1}^{n} b_i x_i\right)}{1+\exp\left(\sum_{i=1}^{n} b_i x_i\right)}$$

where $P(Y=1|\mathbf{x})$ is the probability of forest existence at point x, $b_0$ is a constant and $b_1$ to $b_n$ are coefficients for each explicative variable $x_1$ to $x_n$.

Results range between zero and one, indicating terrain-forest incompatibility and compatibility, respectively. As with the discriminant analysis method, the potential vegetation model is mapped by assigning to each cell the type of forest with the highest value on the corresponding suitability map.

Although it is not actually possible to test which of the models would result in better reforestation (it would mean waiting dozens of years for the forest to grow), we were able to test the validity of the model by analysing the extent to which the results matched the distribution of existing forests. Table 1 shows the error matrices and the Kappa index measurements (Rosenfield & Fitzpatrick-Lins, 1988) for the discriminant analysis and logistic regression models. It can be observed that the potential distribu-

Table 2. Error matrix and Kappa index for the logistic regression model and the weights of evidence method.

| | 1 | 2 | 3 | 4 | 5 | 6 | E.C. |
|---|---|---|---|---|---|---|---|
| 1 | 23117 | 394 | 480 | 5510 | 35 | 3132 | 0.2924 |
| 2 | 1870 | 2888 | 356 | 113 | 333 | 589 | 0.5303 |
| 3 | 21 | 7 | 12004 | 93 | 209 | 2291 | 0.1792 |
| 4 | 5185 | 343 | 709 | 8324 | 49 | 5116 | 0.5780 |
| 5 | 333 | 1024 | 3311 | 312 | 4225 | 1565 | 0.6077 |
| 6 | 2367 | 18 | 3668 | 3071 | 38 | 10572 | 0.4643 |
| E.O. | 0.2981 | 0.3821 | 0.4154 | 0.522 | 0.1358 | 0.5456 | |

Kappa = 0.4802

tion obtained using discriminant analysis provides a better match to the existing situation than the model obtained using the logistic regression method.

## Inclusion of lithology as a variable in the model. Analysis of correspondences

The inclusion of the lithology variable in the models deserves special attention; this is because, as a non-quantitative variable, it receives a different treatment from the other variables.

For the logistic regression model it is necessary to define C-1 dummy variables for the C lithology classes present. In our case, this meant adding a further 18 variables to the 6 existing variables. This can be problematic in some cases - for example, when using the Idrisi Geographic Information System (version Idrisi32), which can only manipulate a maximum of 20 variables. For this reason we used the SPSS program (version 10.1) to calculate the logistic regression model. Combining the six logistic regression models into a single map and assigning to each cell the forest with the greatest value for this cell, we obtained results which were a poor match to the existing forest distribution, as can be seen in the error matrix in Table 4.

Felicísimo et al. (2002) use the weights of evidence method to multiply the probability value for each cell by a constant that depends on the different lithologies for this type of forest. The constant is greater than one when the weights are positive, less than one when they are negative and zero when the value is minus infinite (i.e. when a certain kind of lithology is not present in the forest type in question). Table 2 shows the matrix error for this method. As can be seen, the match is better than that of the logistic regression model without the lithology variable.

To introduce the lithology variable into the discriminant analysis, real values were

Table 3. Contingency table for actual forest type and lithology, with first-dimension lithology scores.

| | FOREST | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| LITHOLOGY | 1 | 2 | 3 | 4 | 5 | 6 | Total | Score |
| 1 | 0 | 0 | 2 | 0 | 1 | 1 | 4 | –0.7812 |
| 2 | 0 | 2 | 14 | 0 | 1 | 0 | 17 | –0.7801 |
| 3 | 58 | 0 | 19 | 16 | 0 | 30 | 123 | 0.3276 |
| 4 | 55 | 3 | 84 | 53 | 3 | 81 | 279 | 0.1712 |
| 5 | 17 | 23 | 0 | 6 | 1 | 1 | 48 | –1.3657 |
| 6 | 0 | 0 | 0 | 0 | 7 | 0 | 7 | –3.0170 |
| 7 | 2 | 0 | 9 | 0 | 0 | 7 | 18 | 0.0078 |
| 8 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0.3870 |
| 9 | 39 | 9 | 14 | 57 | 0 | 27 | 146 | 0.2005 |
| 10 | 1402 | 35 | 638 | 479 | 99 | 837 | 3490 | 0.1777 |
| 11 | 556 | 12 | 428 | 505 | 0 | 462 | 1963 | 0.2911 |
| 12 | 70 | 0 | 27 | 83 | 2 | 18 | 210 | 0.3644 |
| 13 | 130 | 0 | 0 | 37 | 0 | 30 | 206 | 0.4353 |
| 14 | 70 | 190 | 256 | 10 | 118 | 22 | 666 | –1.4845 |
| 15 | 0 | 0 | 0 | 7 | 0 | 1 | 8 | 0.5877 |
| 16 | 21 | 34 | 19 | 0 | 76 | 20 | 170 | –1.9161 |
| 17 | 12 | 5 | 0 | 0 | 3 | 0 | 20 | –1.0161 |
| 18 | 0 | 0 | 0 | 0 | 11 | 2 | 13 | –2.4842 |
| 19 | 0 | 0 | 0 | 0 | 4 | 0 | 4 | –3.0170 |
| Total | 2442 | 313 | 1510 | 1253 | 326 | 1549 | 7393 | |

Table 4. Error matrix for model with lithology: discriminant analysis model with scored lithologies combined with correspondence analysis (left); logistic regression (right).

| | 1 | 2 | 3 | 4 | 5 | 6 | E.C. | | 1 | 2 | 3 | 4 | 5 | 6 | E.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 24119 | 362 | 5 | 2957 | 0 | 1098 | 0.155 | 1 | 20112 | 337 | 5521 | 9383 | 150 | 10891 | 0.566 |
| 2 | 1123 | 3252 | 16 | 19 | 238 | 133 | 0.319 | 2 | 6124 | 2880 | 121 | 718 | 423 | 596 | 0.735 |
| 3 | 9 | 57 | 13423 | 319 | 1036 | 3382 | 0.263 | 3 | 988 | 325 | 10272 | 232 | 1543 | 3209 | 0.380 |
| 4 | 5339 | 409 | 305 | 10357 | 56 | 4143 | 0.497 | 4 | 4723 | 563 | 2846 | 6149 | 1553 | 6916 | 0.729 |
| 5 | 70 | 546 | 3213 | 76 | 3069 | 700 | 0.600 | 5 | 44 | 489 | 486 | 13 | 1177 | 306 | 0.532 |
| 6 | 2275 | 48 | 3570 | 3695 | 490 | 13809 | 0.422 | 6 | 944 | 80 | 1286 | 928 | 43 | 1347 | 0.709 |
| E.O. | 0.268 | 0.304 | 0.346 | 0.406 | 0.372 | 0.406 | | E.0. | 0.389 | 0.384 | 0.499 | 0.647 | 0.759 | 0.942 | 0.596 |
| | | | Kappa = 0.5629 | | | | | | | | Kappa = 0.23 | | | | |

assigned to the different lithology classes in accordance with their capacity to discriminate the different types of forest through a correspondence analysis.

Correspondence analysis is a way of factoring categorical variables and representing them in a space that reflects their association in two or more dimensions (Greenacre, 1984). It tends to be used when a large number of rows and columns in the contingency table make it very difficult to understand associations between variables, but it can also be used to assign numerical values to categorical variables. The scores for the categories of one variable reflect their capacity to discriminate the other variable. Table 3 shows our contingency table, with an extra column added to record the scores for each lithology and forest type for the first dimension, which explains 68.8% of the variance (second dimension explains 16.3%). From these scores and the contingency table we can draw conclusions in regard to the relationship between both variables. Table 3 shows that lithologies 6 and 19, with very similar negative scores, are only present in forest 5.

The potential vegetation map is obtained by assigning first-dimension scores to each lithology variable and using this as a new quantitative variable in the discriminant analysis, together with the other variables (Figure 3). Comparing this error matrix model with the model without the lithology variable, we can observe that the errors are lower for four of the six forests. Of particular note is forest 2, with commission error falling from 50.56% to 31.98%.

## Conclusions

The use of a deductive method supported by statistical methods to create potential vegetation models reduces subjectivity and thus represents an important advance in reforestation project design methods.

These models are created using multivariate analysis methods, such as discriminant

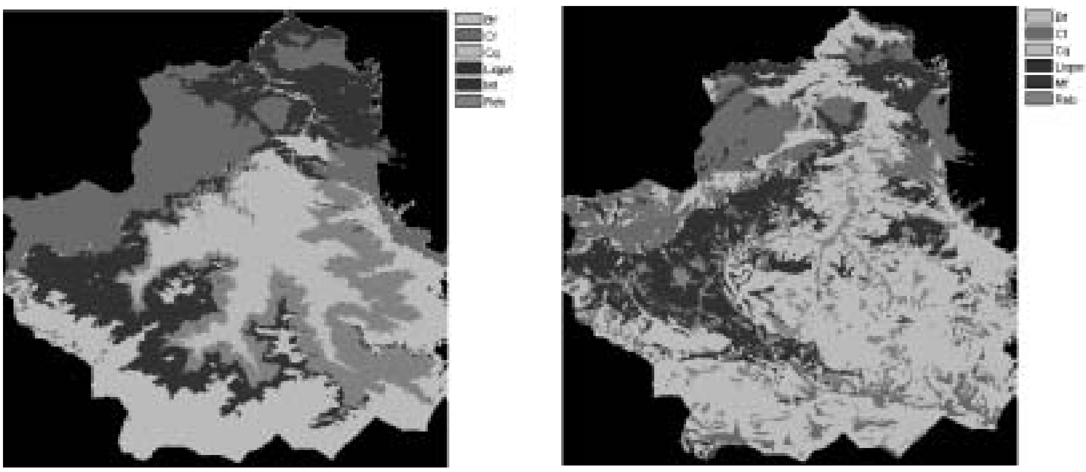

Figure 3. Potential maps including lithology as an independent variable: discriminant analysis model combined with correspondence analysis (left); logistic regression model (right).

analysis and logistic regression, which produce mathematical expressions associating independent variables with the dependent variable (in this case the forest).

When compared to the earlier logistic regression method proposed by some researchers, the discriminant analysis method combined with correspondence analysis produces a potential vegetation map that provides a better match to actual forest distribution. Matching results to existing distribution patterns is the only realistic way of corroborating results; the only other possibility would be to wait dozens of years for the forests to grow. The potential vegetation model only uses species which currently exist and in sufficiently large areas to provide a statistically representative sample, it not being possible, obviously, to take into account other poorly represented species or species which have already disappeared.

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GEOLOGIJA *46/2,* 385–390, Ljubljana 2003

# Application of remote sensing and GIS in Mt. Mangart landslide observation (Slovenia)

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*Key words:* landslides, radar interferometry, digital elevation models, satellite images, Mt. Mangart, Slovenia

**Abstract**

On 17 November 2000 a major landslide occurred on the slopes of Mount Mangart in the Upper Posočje region, Slovenia, as a direct consequence of extreme rainfall and assortment of several inconvenient circumstances. A research group was established immediately after the event to find possible causes of the landslide and monitor its consequences. As a part of these attempts also remote sensing and integration of remotely sensed data to GIS was used. In the paper usefulness of satellite images as one of the most convenient data source in natural hazard observation is demonstrated.

Satellite images were acquired within the "Space and Major Disaster" Charter, started just a few weeks before the event by the European Space Agency, the Centre National d'Etudes Spatiales and the Canadian Space Agency. Advanced image processing was performed carefully to analyze various aspects of the event. Before and after radar images were used to detect soil moisture and to observe the changes in water runoff. Optical images together with DEM were used for GIS analysis of areas affected by the slide. Land use maps, generated from processed imagery, proved to be highly useful for damage estimation.

## Introduction

The use of remote sensing is becoming increasingly frequent in environmental studies. In the 1970s and 1980s satellite images were mostly used in simple interpretations or as a map background (Merifield & Lamar 1975, Rib & Liang 1978). However, more recently there are almost no serious environmental studies that do not include advanced image processing and analysis. Remote sensing has been successfully applied to forest fires detection, flood monitoring, deforestation studies, co-seismic displacement monitoring, pollution tracking in the atmosphere and the sea, weather devastation observation, pollution prevention, desertification and erosion observation and many more (ESA 2001, Cracknell 2000, Sabins 1997, Dixon 1995).

One of the most important applications of satellite technology can be found in the case of natural disasters, where satellite images can be used to provide advance warning for specific hazardous events (Gens & Genderen 1996, Guo et al. 2001), to monitor the concerned, or for a quick evaluation of the damage and therefore support the deci-

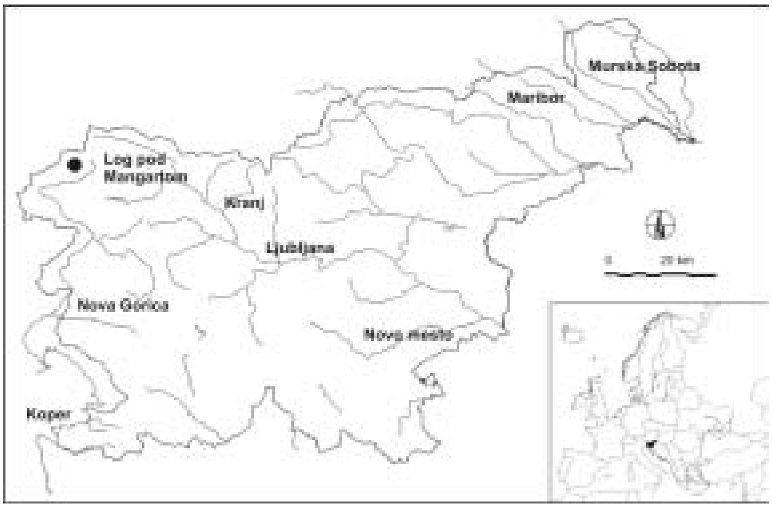


Figure 1. Location of the Mount Mangart landslide.

sion-making process in the rescue operations. Satellite and airborne imagery alone can offer an efficient contribution to natural resource management. Still, the most promising seems to be the application of remote sensing in combination with geographical information systems.

In the paper the use of remote sensing and geographical information systems in the Mount Mangart landslide observation is presented. A description of the "Space and Major Disasters" Charter is given, and details on image interpretation and analysis are described. Special attention is given to data integration and GIS modelling performed within the Mount Mangart landslide case study. At the end some general remarks and guidelines are presented.

## The Mount Mangart landslide

Following several weeks of heavy rainfall, a major landslide occurred on the slopes of Mount Mangart in North-western Slovenia in the night between 16 and 17 November 2000. The landslide hit the village of Log pod Mangartom, claimed seven dead and caused immense damage.

After weeks of continuous rain on 15 November 2000, a mass of morainic material and slope gravel moved down to the Predelica gorge, blocked the water flow of Mangart stream and stopped there for several hours. One day later, in the early morning of 17 November 2000, a major landslide occurred on the slopes of Mount Mangart (Figure 1). The landslide rested for several hours and became saturated from the waters of the Mangart stream supplemented by the heavy rain. This, together with the local dynamics, caused the ground material to become "liquefied". Within a few hours the slide was transformed into a debris flow – a fast moving mixture of water, soil and other material.

It is estimated that about 1,000,000 $m^3$ of various material flowed downwards along the bed of the Mangart stream, hitting the village of Log pod Mangartom, and finally flowing into the Soča river.

Both landslides were most probably influenced by the specific geological composition of the ground, the considerable seismological activity of the nearby area and the intense rainfall. The mountain ridge west of Mount Mangart is composed of massive Upper Triassic carbonate that is in areas interrupted by clastic rocks, and some poorly permeable Carnian calc stoneware. In the Pleistocene, over the stepped bedrock, poorly permeable grounding glacial sediments rich with silt were deposited over the dolomite gravel. The bedrock of the landslide, represented by a block of poorly permeable carbonate-clastic succession, is situated between the fault-bounded blocks of massive and bedded dolomite.

A direct triggering mechanism of the landslide and consequentially of the development of the debris flow was the intense rainfall. The landslide scar in the upper part of the slope exposed a cliff in the bedrock topography, probably produced by faulting. Considering the geological situation in the area, it seems that the fundamental trigger for the landslide was the poorly permeable bedrock combined with the extreme weather situation. Low permeability of the bedrock caused the concentration of water in diamicts and thus a rapid increase in material-rich water tension. The end of this process caused a rapid "liquefaction" of the first landslide material into an immense flow with almost no solidity at all.

## Satellite image interpretation

Shortly after the disaster a group of professionals was established in order to monitor the slide and propose solutions for its stabilisation. As the area was dangerous and further slides could occur at any time, the group relied on remote sensing techniques, both airborne and spaceborne. The actions to obtain and process satellite imagery started a few days after the landslide when the European Space Agency was contacted, and afterwards a request was made to the "Space and Major Disasters" Charter. The Charter was initiated following the UNISPACE III conference held in Vienna, Austria, in July 1999, by the European Space Agency (ESA) and Centre National d'Etudes Spatiales (CNES). The Canadian Space Agency (CSA), Indian Space Research Organisation (ISRO), and US National Oceanic and Atmospheric Administration (NOAA) joined the initiative later on. The Charter aims at providing a unified system of data acquisition and delivery to those affected by natural or man-made disasters. It was declared formally operational on 1 November 2000, less than three weeks before the events on Mount Mangart, and the landslide discussed in this paper was actually the first time it was activated.

After the problems which were to be analysed were defined, a plan of action was proposed by ESA and the Scientific Research Centre of the Slovenian Academy of Sciences and Arts. It was immediately submitted to the various space agencies for tasking satellites. In total 13 satellite images from 1992 to 2000 were utilised:

- five ERS (both ERS-1 and 2),
- two RADARSAT,
- four SPOT (two panchromatic and two multispectral), and
- two Landsat images.

In the analysis, an additional layer – a digital elevation model of Slovenia, produced using radar interferometry from ERS images and advanced modelling – was also used.

The first post event image, an ERS-2 scene, was acquired a week after the landslide. This was followed by two further acquisitions, the SPOT and RADARSAT images made during the second week. The images were supplemented by archive data taken under approximately the same conditions. All the necessary data and were distributed by mail as soon as possible. Nevertheless it took almost a month to gather all the necessary images. What suggests that in such cases electronic distribution would be highly desired and needed. After the images were received a visual inspection was made. The landslide was detected directly or indirectly in the images made after the event: ERS-2 (24 November 2000), RADARSAT (1 December 2000) and SPOT (29 November 2000).

Visual inspection was followed by geocoding and image interpretation. All scenes were georeferenced to the national system – that is the Gauss-Kreuger projection on the Bessel ellipsoid. Georeferenced satellite images were integrated into a GIS system, together with other already available referenced data (Landsat images, digital elevation model, etc.).

Within the project ERS images were used in two ways – to produce a digital elevation model and to observe the land properties at the time of the landslide. A digital elevation model for the area under investigation was made in the beginning of 2000, mainly to test the usability of ERS data in rough terrain and to support the observation of co-seismic activity after the 12 April 1998 earthquake (Oštir & Stančič 1999, Oštir 2000). In the area mentioned seven ERS-1 and 2 scenes were used from both the ascending and descending orbit. Partial elevation models and other height data sources, such as contour lines and a coarse digital elevation model with a resolution of 100 m, were used to produce a final digital elevation model InSAR DEM 25 (Oštir 2000, Podobnikar et al.

2000). The model has a resolution cell of 25 m; its overall accuracy is approximately 8 m, from better than 2 m in plains to more than 10 m in the mountains. Contemporary ERS images were used to observe land properties, mostly humidity in the time of landslide.

RADARSAT images, obtained in the frame of the Charter, offer very high spatial resolution (fine beam mode). They provided clearer results than ERS, despite the fact that the relief in the area of Mount Mangart is very steep and therefore causes severe problems to all radar satellites (layover and shadows) and considerably limits their use. The humidity observed on the RADARSAT image map is not as extensive as in the case of the ERS data. The reason for this lies in the fact that the second RADARSAT image was taken several days after the ERS image and that there was no significant rainfall in the meantime.

The interpretation of SPOT imagery gave a more detailed insight into the consequences of the disaster. Two panchromatic (21 August 2000 and 29 November 2000) and two multispectral (19 August 2000 and 29 November 2000) SPOT scenes were used to detect the landslide and to evaluate its impact on the natural environment. Figure 2 shows the scene acquired after the landslide. One can clearly see how the landslide changed the valley of Log pod Mangartom. The interpretation of SPOT images allowed us to obtain the most accurate information on the slide location and compare the situation before and after the event. However, as a consequence of the very low sun position in November (shadows were emphasised) the interpretation of SPOT data was not straightforward. In addition to the shadows the November image (Figure 2) contained snow in higher areas and the August image included some clouds.

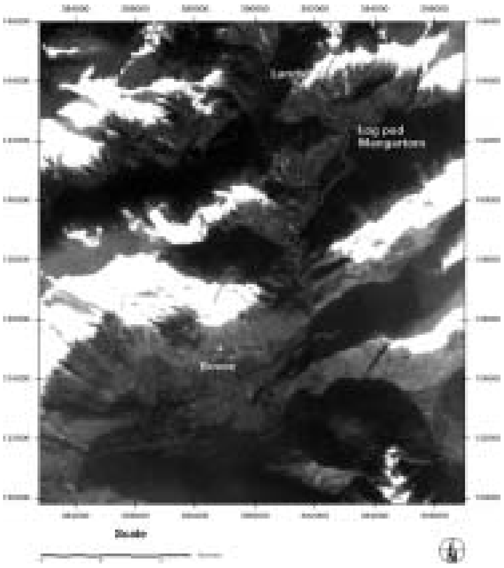


Figure 2. SPOT satellite map of landslide area (image was acquired on 29 November 2000).

### Remote sensing data integration and analysis

Image interpretation can offer useful information; however, it is often used merely as a data source for the GIS analysis. Therefore all available satellite images have been integrated within a geographical database, together with the digital elevation model and land use map. Initially, the exact location of the landslide and its direct area of influence were determined. Due to the high spatial and spectral resolution of the SPOT satellite images (panchromatic and multispectral) acquired on 29 November 2000, these images were used to isolate both areas.

The estimated total area of the landslide, i.e. the area of the slipped land, is 25.7 hectares. The additional area of destruction in the valley is therefore estimated to be 50.1 hectares, summing to the total direct impact area of 75.8 hectares.

As described before, a digital elevation model InSAR DEM 25 was produced for the area using ERS satellite images with interferometric processing (Figure 3). From the elevations also a slope map was produced. Average elevation, slope and terrain orientation were computed for the landslide and its impact area; the results are listed in Table 1. The landslide occurred at an average elevation of almost 1400 m, at a very steep slope (24%) facing south-east (161°). The standard deviations for both slope and orientation are small, showing that the landslide area is very homogenous. On the other hand the impact area lies much lower, on average at approximately 800 m. It is also modesty inclined (19%) and oriented to the south-west (224°). The impact area is rather heterogeneous, with standard deviations from two to more than three times larger than that for the landslide.

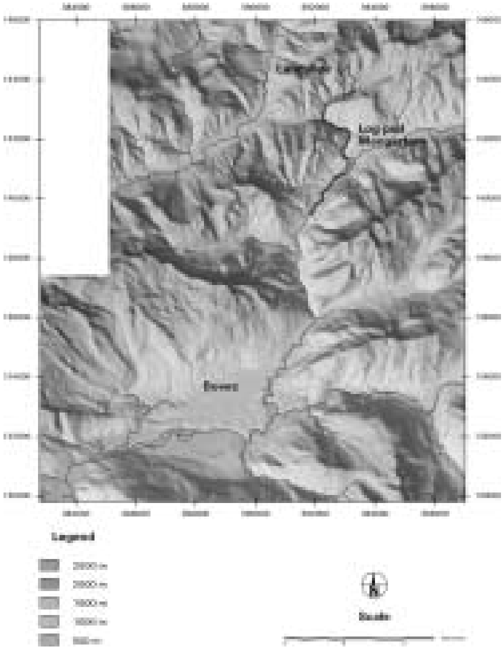

Figure 3. Digital elevation model of landslide area (InSAR DEM 25) produced from ERS images with radar interferometry and advanced modelling.

Table 1. Elevation, slope and orientation of the landslide and its impact area.

| | | Landslide | Impact area |
|---|---|---|---|
| Elevation (m) | Average | 1386 | 824 |
| | STD | 109 | 243 |
| Slope (%) | Average | 24 | 19 |
| | STD | 6 | 12 |
| Orientation (°) | Average | 161 | 224 |
| | STD | 25 | 83 |

Aside the digital elevation model, land use is amongst the most important natural environment variables. The land use map for the area of the landslide was produced from a combination of Landsat and SPOT images. Classical supervised image classification method has been used in order to obtain land use (S a b i n s 1997). The land categories were divided into ten classes: urban, built-up, individual houses, coniferous forest, deciduous forest, mixed forest, bushes, water, agricultural, and open. Additionally advanced post-classification techniques – such as elevation modelling and forest mixing – were also used. The estimated thematic accuracy of the produced land use map is approximately 90%.

A detailed analysis of the changes in the environment was carried out. Table 2 and

Table 2. Land use categories in respect to the landslide and its impact area.

| Class | Landslide area ha | % | Impact area ha | % |
|---|---|---|---|---|
| Urban | 0.0 | 0% | 0.0 | 0% |
| Build-up | 0.0 | 0% | 1.7 | 3% |
| Individual houses | 0.0 | 0% | 1.9 | 4% |
| Coniferous forest | 1.0 | 4% | 10.1 | 20% |
| Deciduous forest | 18.6 | 72% | 5.8 | 12% |
| Mixed forest | 2.2 | 9% | 5.4 | 11% |
| Bushes | 0.3 | 1% | 3.6 | 7% |
| Water | 0.0 | 0% | 4.0 | 8% |
| Agricultural | 0.0 | 0% | 9.4 | 19% |
| Open | 3.6 | 14% | 8.2 | 16% |
| Total | 25.7 | 100% | 50.1 | 100% |

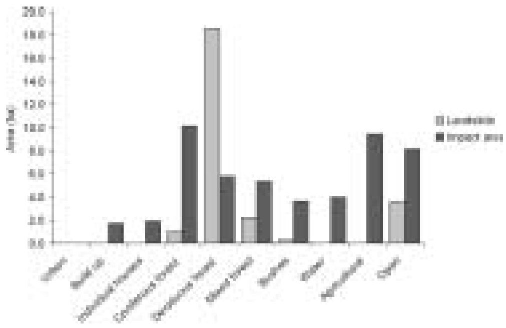

Figure 4: Land use classes destroyed by the landslide.

Figure 4 show areas that were destroyed by the slide in respect to land use. The landslide directly destroyed forests and a small amount of open areas, while other classes were not present. The impact area was more heterogeneous – forests covered almost half of it, but there was also a notable quantity of built-up land, individual houses and agricultural land.

## Conclusions

The disaster below Mount Mangart is a classical case used to show the value of satellite remote sensing. The landslide happened in late November 2000 after several weeks of heavy rainfall and had such extent that it can be clearly detected with the available satellite sensors. SPOT optical images offered a good illustration of the situation and could be compared with the archived data in order to evaluate the damage. Multispectral optical data was supplemented with radar images, acquired on four dates before and after the event. Due to the rough terrain, it was hard to directly detect the landslide and its consequences on radar imagery;

however, the high humidity in the area could be observed even several days after the event.

To evaluate the landslide consequences a detailed GIS analysis of the available satellite images and other data was made. The landslide has been identified on several post event images, most notably on the SPOT panchromatic image, which was used to outline both the landslide and its impact area. The total damage area was estimated to be almost 76 hectares – 26 hectares representing the surface of the landslide and 50 hectares the impact area. The landslide occurred on steep south-east facing slopes, at an average elevation of approximately 1400 m. With respect to slope, elevation and orientation the area affected in the valley was lower and more heterogeneous. The evaluation of land use showed that the landslide occurred mainly in areas covered by deciduous forest (almost three quarters of its surface). The impact zone was again more heterogeneous, half of it being covered with forests. There was also significant damage in agricultural land and built-up areas.

The Mount Mangart landslide study has proven the value of remote sensing technology for monitoring natural disasters and it has in particular proved the usefulness of the "Space and Major Disasters" Charter. It has shown that remote sensing can be used to estimate the damage and under suitable conditions also in rescue operations. In rescue operations the processing speed is critical and near real time data distribution is needed. In the case of damage estimation the processing speed is less important than the accuracy and quality of results. It has been proven, that remote sensing enables mapping and analysing topographic and land cover changes caused by a catastrophic event within a considerably short period of time. We also believe that with advanced simulations it can be used to determine hazardous areas and predict the triggering conditions. Satellite remote sensing may therefore be one of the most important steps in the development of an early hazard warning system.

## Acknowledgements

This project would not be possible without the "Space and Major Disasters" Charter. The authors would like to thank the European Space Agency, the Centre National d'Etudes Spatiales and the Canadian Space Agency for starting the Charter and providing most of the satellite images used in this project. Jerome Bequignon of the European Space Agency helped us to define the plan of action and Professor Bojan Majes of the Faculty of Civil and Geodetic Engineering invited us to contribute to his expert group. Adrijan Košir of the Scientific Research Centre of the Slovenian Academy of Sciences and Arts provided valuable interpretation on geological characteristics of the area.

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GEOLOGIJA *46/2,* 391–396, Ljubljana 2003

# Extracting NDVI temporal profiles of vegetation types in the Rižana spring catchment area from NOAA-AVHRR data using linear mixture model

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*Key words*: remote sensing, linear mixture model, NOAA-AVHRR, NDVI, NDVI temporal profiles, Rižana spring, Slovenia

**Abstract**

This paper presents methodology that was used to derive NDVI temporal profiles of the vegetation types in the Rižana spring catchment area. In the methodology the Landsat TM image was used for the classification of the area into vegetation cover classes and to determine proportions of classes within AVHRR pixels. According to the influence of the vegetation types on the water cycling process in the catchment area, six vegetation classes were defined (deciduous forest, grass, agricultural areas, shrub, coniferous forest and areas with no/sparse vegetation). This data and the NDVI data derived from AVHRR satellite images was then used in the linear mixture modelling that was applied to estimate the mean NDVI value of each vegetation class. The resulting temporal NDVI profiles of vegetation cover classes, with exception of class with no/sparse vegetation, are in general in agreement with the observed vegetation characteristics area.

## Introduction

Recharge of the aquifer is a dynamic process that depends on many factors. For accurate modelling of this process data is required that is distributed in time and space. One of the very important data are vegetation characteristics. Remote sensing data is a potentially very useful source of information on the state and development of a long range of vegetation and hydrological parameters (Sandholt et al., 1999). For vegetation monitoring from satellite platforms are common used vegetation indices. One of the most widely used is normalized difference vegetation index NDVI = (NIR-IR)/(NIR+R) (Rouse et al., 1973).

For describing spatial variability of vegetation in the catchment areas Landsat TM (30 m nominal spatial resolution) provides in general adequate data. But to monitor temporal dynamic of vegetation development Landsat TM, with its temporal resolution of 16 days, is often not sufficient. Especially if we have in mind that atmospheric conditions (cloudiness) at the time of the satellite overpass can make interpretation of satellite images impossible. On the other hand NOAA-AVHRR satellite system provides fine temporal resolution (daily frequency). But its coarse spatial resolution (nominal 1,1 km at nadir) is a huge limitation in many applications.

An ideal satellite system for observation of vegetation changes in catchment area would have spatial resolution of Landsat TM and temporal resolution of NOAA-AVHRR satellite system.

An approach towards this kind of system is a linear mixture model.

This paper presents methodology that was used to derive NDVI temporal profiles of vegetation types in the Rižana spring cathment area from Landsat TM and AVHRR images. Landsat TM image was used for classification of the area into vegetation classes and to determine proportions of the classes within AVHRR pixels. Linear mixture model based on multiple linear regression was then applied on the set of 21 AVHRR images to estimate the mean NDVI value of each vegetation class.

## Study area: The Rižana spring catchment area

Rižana spring is the most important water resource for water supply of the costal area of Slovenia. Its cathment area covers nearly 240 km$^2$ (Figure 1). The terrain is mainly hilly, with altitude ranging from 70 m to 1028 m. Very complex karst aquifer system was developed in limestones that cover most of the catchment area. Minor part of the area consists of flish sediments. According to the used classification most of the area is covered by deciduous forest, following by grass, agricultural areas, shrub, coniferous forest and areas with no or sparse vegetation (Table 1).

Table 1. Vegetation cover classes and theirs cover portions in the stuy area

| | vegetation class | cover portion (%) |
|---|---|---|
| R1 | no/sparse vegetation | 2 |
| R2 | grass | 19 |
| R3 | agricultural areas | 18 |
| R4 | decidious forest | 32 |
| R5 | coniferous forest | 10 |
| R6 | shrub | 19 |

## Satellite data

In the study one Landsat-5 TM image ((c) ESA, Eurimage, ZRC SAZU, 1992) taken on 18.8. 1992 and set of 21 images AVHRR (Advanced Very High Resolution Radiometers) - LAC images (NOAA Satellite Active Archive, http://www.saa.noaa.gov) were used. This set of images was selected from all available images for the studied period of two years (1992, 1993). Cloud contaminated images were rejected and in order to minimize scan angles effects only images where the study area is within 30° scan angle were selected.

On the AVHRR images only Sun angle correction and correction of panoramic distortion were applied. Neither atmospheric nor topographic corrections were performed on the used AVHRR and Landsat TM satellite images. Radiometric calibration was performed on all images and for the first two bands of NOAA 11-AVHRR images


Figure 1. Position of the study area, NOAA-11 AVHRR image, colour composition – RGB: Bands 1,2,4 (left) and Landsat TM image, colour composition – RGB: Bands 1,2,3 (right). Both images ware taken on 18.8.1992

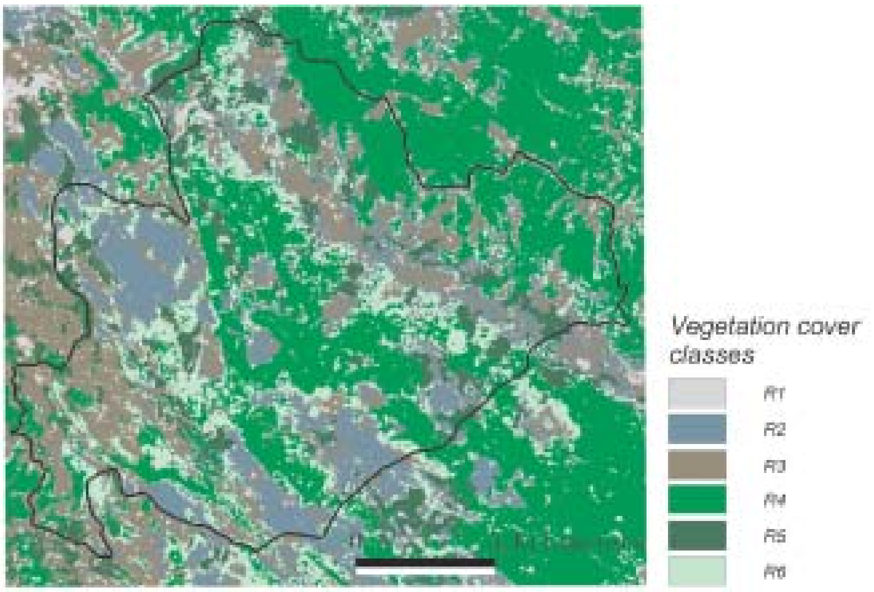


Figure 2. Classified study area

non-linear correction that accounts for sensor degradation was applied (R a o & C h e n , 1994).

All AVHRR images were coregistered to a Transverse Mercator projection (as the Landsat-TM image). Second order polynomial transformation and nearest neighbor resampling method were used. A georeferencing of AVHRR image was based mainly on the referenced points selected along the coastline.

## Vegetation cover classification

Vegetation cover classification was carried out by supervised classification based on maximum likelihood classifier. For the reference data CORINE Land Cover (H o - č e v a r et al., 2001) was used that covers part of the study area. According to the influence of the vegetation types on the water cycling process in the catchment area, six vegetation classes were defined. For each class more training areas (spectral classes) were selected (altogether 62) in order to incorporate variability within the class. After the classification smoothing with majority filter (3x3) was applied. The distribution of vegetation classes is shown in Figure 2.

## Spatial degradation of the fine resolution image

Used methodology of preparation of data for linear mixture model is based on the procedures presented by O l e s o n et al. (1995).

From the classified map a set of single class maps was determined. For each single-class map, a digital number (DN) 1 was assigned to each pixel that contains corresponding cover type. All other pixels were assigned a DN of 0.

Each single class map was then degraded to a spatial resolution approximating that of the AVHRR. With regards on the AVHRR point spread function (PTF), which defines the characteristics of the image of a point source formed by an optical system, convolution with a Gaussian filter was applied. This is similar approach to that used by M o r e n o & M e l i a , (1994), who modeled AVHRR PTF at nadir with two-dimensional Gaussian distribution. The standard deviation (σ) of the Gaussian distribution was defined with the expression (O l e s o n et al., 1995):

$$\frac{AVHRR\_pixel}{TM\_pixel} = 2.8\sigma$$

A series of new (filtered) class maps was created this way. Value of each pixel on these maps corresponds to the vegetation cover class proportion within an AVHRR spatial resolution pixel. These portions have been used in linear mixture model (as independent variables).

## Linear mixture model

Linear mixture modelling considers that the pixel's radiance results from the linear combination of the radiances of the elements composing the pixel multiplied by their respective proportion within the pixel. These base elements of the landscape are named endmembers (Kerdiles & Grondona, 1995). This assumption should be strictly true only for the original bands. However, studies of Kardiles and Gordona (1995) showed that linear combination of NDVI values implies only very minor inaccuracies. The linear mixture model in this study was formulated as:

$$NDVI_1 = f_{11} \cdot NDVI_{11} + ... + f_{1k} \cdot NDVI_{1k} + \varepsilon_1$$

$$\vdots$$

$$NDVI_n = f_{n1} \cdot NDVI_{n1} + ... + f_{nk} \cdot NDVI_{nk} + \varepsilon_n$$

The system of $n$ equations corresponds to the number of pixels and $k$ (independent or regressor variables) to the number of vegetation cover classes.

Using more general symbology, this set of equation can be expressed in matrix notation as $Y = X\beta + \varepsilon$
and

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ . \\ . \\ y_n \end{bmatrix}, X = \begin{bmatrix} x_{11} & x_{12} & . & x_{1k} \\ x_{21} & x_{22} & . & x_{2k} \\ . & . & . & . \\ . & . & . & . \\ x_{n1} & x_{n2} & . & x_{nk} \end{bmatrix}, \beta = \begin{bmatrix} \beta_1 \\ . \\ . \\ \beta_k \end{bmatrix} \text{ and } \varepsilon = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ . \\ . \\ \varepsilon_n \end{bmatrix}$$

Where $Y$ is a ($n$ x 1) vector of observation, $X$ is a ($n$ x $k$) matrix of the levels of the independent variables, $\beta$ is a ($k$ x 1) vector of regression coefficients and $\varepsilon$ is a ($n$ x 1) vector of random errors.

Multiple linear regression model was used to solve the set of equations. The least squares estimate of $\beta$ is (Montgomery & Runger, 1994):
$\hat{\beta} = (X'X)^{-1} X'y$
and the fitted model in the matrix notation is
$\hat{y} = X\hat{\beta}$

## Results

The mean NDVI temporal profiles of vegetation cover classes derived from AVHRR images are presented in Figure 3. Temporal profiles for two years show phases of vegetation cycle that are in agreement with known vegetation characteristics in the study area. In general low values of NDVI at the beginning and at the end of the year in the winter are shown. In the spring a green-up is observed. Very fast increase of NDVI values, that starts to increase in the middle of April and reaches the climax at the end of May and beginning of June. In the next phase in the summer period NDVI profile is relatively flat with gentle decrease until the end of August or beginning of September. After that phase in the autumn period NDVI profile drops fast and reaches low value, characteristic for the winter period, around the middle of November.

Extracted NDVI profiles for individual vegetation cover type show evidently separated profile of R4 (deciduous forest) that has far highest NDVI values in the spring and summer. Les evident characteristics of the others NDVI vegetation cover type profiles are:

- R5 (coniferous forest) profile has the lowest amplitude and relatively the highest value in the winter period,
- R2 (grass) profile has in average the lowest value.

• R6 (shrub) profile has relatively high amplitude similar to the R4 profile.

Exception is the profile of R1 (no/sparse vegetation) vegetation type that doesn't follow the characteristics of the other profiles. In general it has the lowest value, but very high amplitude, which makes it very difficult for interpretation. The reason for this is most probable low cover portion (2%) of that vegetation cover type in the study area.

## Conclusion

The study confirmed the potential of using linear mixture model for extraction of NDVI temporal profiles of vegetation cover types in Rižana catchment area and pointed out some characteristics of the used method.

Results are in general in agreement with the observed vegetation development cycle in study area. Study shows the ability of extracting NDVI temporal profiles for vegetation cover types that are spectrally separated and well represented in the mean of cover portion, which confirmed conclusions of Oleason et al. (1995). In this study it is the vegetation cover type R4 that satisfied mentioned criteria. Other vegetation classes' temporal profiles, with the exception of R1 profile, are of mixed quality and less separable but still in general in agreement with observation. Temporal profile of R1 that covers a very small part (2 %) of the study area is difficult to interpret and doesn't agree with expected results. This fact shows inability of linear mixture model to extract subpixel information for the vegetation classes that are not well represented in terms of cover portion within the study area.

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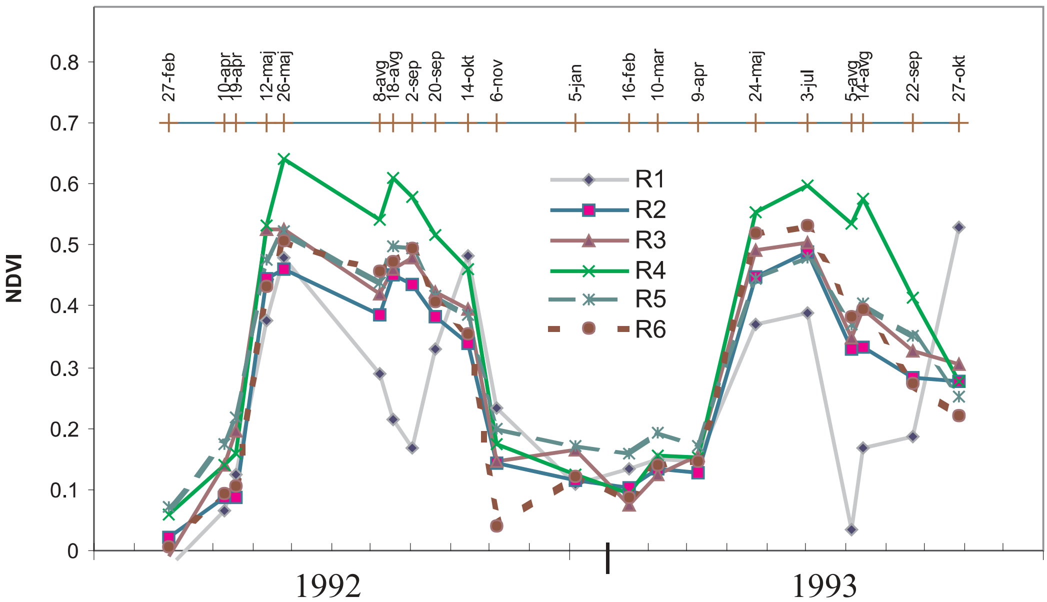


Figure 3. The mean NDVI temporal profiles of vegetation cover classes

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GEOLOGIJA *46/2,* 397–404, Ljubljana 2003

# New general engineering geological map of Slovenia

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*Key words:* Engineering Geological map, Slovenia, GIS
*Ključne besede:* Inženirskogeološka karta, Slovenija, GIS

**Abstract**

The new lithostratigraphic map of the entire Slovenia (in the scale of 1:250000) created by using the GIS method enabled the production of its derivative – engineering geological map (EG map). The goal of creating this map was to define the general engineering geological characteristics of rocks and soils that will be used for the general review of engineering geological conditions in Slovenia. The map also enables the planing of general interventions in Slovenia. The EG map was created by using the GIS method for merging the lithology units of Slovenia according to EG characteristics on three levels. The first one is the basic separation into soils, soft rocks and rocks. The second level is a more detailed separation on the basis of their origin and the third one on the basis of the composition, rock strength and particle size ranges. The first basic GIS layer determined the EG units merged with the database, giving the spatial and description data for each unit.

The basic data for each unit was stored in the GIS-database (serial number, the connection to the lithology unit, the name, short description, comprehensive description, the occurrence in Slovenia). The EG units were also stored in the database (the description of EG units, geotechnical characteristics, the foundation conditions, seismic characteristics). The map was further detailed by the creation of informational layers derived from the map. In this manner the map of rock strength, the map of possible land sliding, the map of weathering cover thickness estimation and the erosion map were produced. The GIS modelling method was used for the creation of these maps. For example, the map of possible land sliding was created regarding these informational layers: lithology structure, the thickness of weathering cover, the slope inclination and the hydrogeological conditions.

**Kratka vsebina**

Na novo izdelana geološka karta v GIS-u merila 1 : 250.000 teritorija Slovenije je omogočila tudi izdelavo izpeljanke – inženirskogeološke karte. Cilj izdelave inženirskogeološke karte je opredeliti splošne inženirskogeološke lastnosti hribin in zemljin, ki bodo služili za generalni uvid v inženirskogeološke razmere Slovenije. Poleg tega inženirskogeološka karta omogoča planiranje posegov v prostor v državnem merilu.

Inženirskogeološka karta je bila izdelana tako, da so bile litološke enote Slovenije s pomočjo GIS tehnologije med seboj združene po inženirskogeoloških lastnostih v treh nivojih. Prvi nivo je osnovna delitev v zemljine, polhribine in hribine, drugi že detajlnejši po načinu nastanka ter tretji po sestavi, trdnosti in zrnavosti. Tako so bile na osnovnem informacijskem sloju opredeljene inženirskogeološke enote, kateremu je bila pridružena baza podatkov, ki je za posamezno enoto podajala prostorske in opisne podatke.

Za vsako enoto so tako bili v GIS-bazi shranjeni osnovni podatki (zaporedna številka, povezava na litološko enoto, ime, kratek opis obsežnejši opis, razširjanje v Sloveniji) in inženirskogeološke lastnosti (opis inženirskogeoloških lastnosti, geotehnične lastnosti, pogoji temeljenja, seizmične lastnosti). Pri nadaljevanju dela je bila inženirskogeološka karta še detajlirana z izdelavo iz nje izpeljanih informacijskih slojev, ki so izrazili eno izmed pomembnih inženirskogeoloških značilnosti. Tako so nastali še karta trdnosti kamnin, karta podvrženosti plazenju, karta ocene debeline preperinskega pokrova in karta seizmičnih lastnosti tal. Za izdelavo teh kart je bilo uporabljeno GIS modeliranje. Tako je npr. karta podvrženosti plazenju nastala z upoštevanjem naslednjih informacijskih slojev: litološke zgradbe, debelina preperine, nagib terena in hidrogeološke razmere.

## Introduction

The production of the new lithostratigraphic map (Buser, 1999) in the scale of 1:250,000, dividing in great detail the Slovenian territory according to the lithological characteristic of its structure, also enabled the creation of an engineering geological map of the same scale as its upgrade. To this purpose, the lithological units were merged with regard to their relative engineering geological properties. In the preparation of the engineering geological map, two criteria were primarily used. The first one was the classification of the material composing the Slovenian territory into soils, soft rocks and rocks. The geomechanical characteristics of rock and its sensitivity to weathering greatly depends on its maturity and lithification. The second decisive criterion was the content of small clay fraction in rock structure. Rocks composed of clay as well as silt fraction are more susceptible to landsliding and other destructive processes.

In joining the rocks according to their similar engineering geological properties, it was necessary to take into account that the Slovenian territory is geologically very complex. A single lithologically homogenous rock is very rare. Most frequently, there is an alternation of different lithological variants, or the prevailing rock comes with inclusions, layers or veins of other rocks. This is the reason why it is not always possible to stick to the classifications set up in the extensive literature.

The purpose of engineering geology as a practical science is to offer an engineering geological map as an answer to a certain problem appearing in spatial development or in the preservation of the environment connected with such activities. The general engineering geological map, like this one, thus only presents the generalised engineering geological characteristics of an area. However, general engineering geological maps can also be produced for specific purposes. In such a case, rocks are categorised according to their engineering geological properties that are important for obtaining the answer sought. This part of the task, is the second step in the production of the engineering geological map of Slovenia.

## The processing of engineering geological data in the GIS environment

In the lithostratigraphic map, the 112 lithological units are represented by 4651 separated polygons. On the basis of the key which is described in more detail in the following chapter, each polygon was reclassified into new classes, indicating the engineering geological properties of rocks. The first part of the table (for soils), which was used for the reclassification from the lithostratigraphic map to the engineering geological map, is shown below:

Tab.1. Reclassification of the lithostratigraphic map to the engineering geological map

| ACAD_ ELEV | ID no. | EG mark | Decimal Class. | DESCRIPTION |
|---|---|---|---|---|
| 2 | 1 | ZEM-R | 111 | clay (Quaternary) |
| 13 | 1 | ZEM-R | 111 | brown clay, terra rossa and loam (Quaternary and Pliocene) |
| 14 | 1 | ZEM-R | 111 | clay and weathered material with chert (Quaternary and Pliocene) |
| 7 | 2 | ZEM-R | 112 | clay, peat (marsh sediments - Quaternary) |
| 8 | 2 | ZEM-R | 112 | clay, silt and weathered peat (marsh and lake sediments – Quaternary) |
| 9 | 2 | ZEM-R | 112 | clayey silt (continental and marsh loess – Quaternary) |
| 1 | 3 | ZEM-R | 113 | alluvium (pebble, sand, silt and clay – Quaternary) |
| 10 | 3 | ZEM-R | 113 | fluvial loose sediments in terraces (pebble, sand, silt and clay – Quaternary)0 |
| 5 | 4 | ZEM-P | 121 | diluvium (mainly clay with pieces of various rocks – Quaternary) |
| 3 | 5 | ZEM-P | 122 | talus (Quaternary) |
| 4 | 6 | ZEM-P | 123 | alluvial fan (gravel, pebble and silt – Quaternary) |
| 12 | 6 | ZEM-P | 123 | moraines – tuff (Quaternary – Pleistocene) |
| 15 | 7 | ZEM-K | 131 | clay, clayey silt with pebbles of flint and silicate rocks (Pliocene and Pleistocene) |
| 20 | 7 | ZEM-K | 131 | clay, silt and sand (Pliocene) |
| 19 | 8 | ZEM-K | 132 | sandy marl, clay and small pebbles (Lower Pliocene) |
| 21 | 8 | ZEM-K | 132 | sand and clay (Upper Miocene and Lower Pliocene) |
| 22 | 8 | ZEM-K | 132 | clayey marl, sand, pebble and clay (Upper Miocene) |
| 16 | 9 | ZEM-K | 133 | flint pebble, sand and silt (Upper Pliocene) |
| 18 | 9 | ZEM-K | 133 | pebble, and sandy clay (Middle Pliocene) |
| 6 | 10 | ZEM-A | 141 | mine tailings (anthropogenic recent sediments) |

Tab. 2. Frequency of appearance and the area that it covers in kilometres

| EG – mark | Description | Frequency of appearance | Area ($km^2$) |
|---|---|---|---|
| ZEM-R | soil (alluvium) | 533 | 3696 |
| ZEM-P | soil (on slope) | 305 | 601 |
| ZEM-K | soil (rocks with soil properties) | 203 | 1113 |
| ZEM-A | soil (anthopogenic) | 4 | 28 |
| POL | soft rocks | 303 | 1559 |
| KLA | clastic rocks | 782 | 2991 |
| KAR | carbonate rocks | 2093 | 8920 |
| MET | metamorphic rocks | 158 | 759 |
| MAG | magmatic rocks | 232 | 694 |

Each lithostratigraphic element, numbered by ACAD_ELEV, corresponds to a ID number according to the engineering geological map. In addition, the engineering geological unit obtained in this way is classified into the basic engineering geological class with regard to its engineering geological properties, i.e. obtains the appropriate decimal mark. Thus, in the table above, the engineering geological mark (EG mark) ZEM-R, means an engineering geological unit classified among soils (ZEM), alluvium deposits (mark R). The decimal classification 111, which has three levels, indicates that the engineering geological unit belongs among soils (first number), alluvium deposits (second number) and that it predominantly consists of clay (third number). The lithostratigraphic elements are divided into 9 classes with regard to their basic engineering geological characteristics. The following table gives the incidence for each class and the surface that it covers in kilometres.

## The brief description of the logical structure serving as the basis for the preparation of an engineering geological map

The basic engineering geological map determining the general engineering geological characteristic of the Slovenian territory is based on the key below. The key distinguishes between soils, soft rocks and rock (level 1).

The soils are further divided into alluvium soils (fluvial and stream alluvia), slope soils (diluvia, proluvia, slope alluvial fans and talus), rocks with soil properties and anthropogenic soils (man-made fills of large surfaces). Soft rocks have already been partially lithified, but their humidity, firmness and other geomechanical properties are still too low for them to be classified among rocks. Thus, they represent a class of their own. Rocks are divided into clastic, carbonate, metamorphic and magmatic rocks (level 2).

At the third level (level 3), the material is divided into three groups: geotechnically least appropriate, medium-appropriate heterogeneous material and geotechnically most resistant material. When there is an alternation of geotechnically different materials, the criterion for classification is the prevailing material.

Each lithological unit connected with ID AcadElev according to the original table is then classified by its engineering geological properties into the engineering geological class defined by the indication of ID no. (the serial number of the engineering geological group), engineering geological mark (generally classifying the material according to its engineering geological properties) and Dec.Cl. (decimal division of materials into classes), like it is shown above.

## Description of engineering geological units

The engineering geological map comes with general and detailed descriptions of the engineering geological characteristics. The general description of an engineering geological unit contains the following information:

A. NAME OF UNIT
B. LITHOLOGICAL AND EG DESCRIPTION OF THE ROCK
C. INCIDENCE IN SLOVENIA
D. CHARACTERISTIC TERRAIN MORPHOLOGY
E. DESCRIPTION OF THE STRUCTURAL DISCONTINUITIES OF THE ROCK

Tab. 3. The logical structure and the basis for the preparation of an engineering geological map

| BASIC CLASSIFICATION | | | | |
|---|---|---|---|---|
| Level 1 | Level 2 | Level 3 | EG mark | Dec.Cl. |
| SOILS (ZEM) | ALLUVIUM SOILS (and terrace sed.) | predominantly clayey soils | ZEM-R | 111 |
| | | marsh, lake soils (clay, silt, peat) | ZEM-R | 112 |
| | | alternation of different soils (pebble, sand, clay, etc.) | ZEM-R | 113 |
| | | pebble and sandy pebble | ZEM-R | 114 |
| | SLOPE SOILS | clayey – diluvial, proluvial | ZEM-P | 121 |
| | | gravely (with a clayey component) | ZEM-P | 122 |
| | | gravely (predominantly thick fraction), moraines | ZEM-P | 123 |
| | ROCKS WITH SOIL PROP. | clayey | ZEM-K | 131 |
| | | alternation of fine and coarse grain soils | ZEM-K | 132 |
| | | pebbly | ZEM-K | 133 |
| | ANTHROPO-GENIC SOILS | mine trailings – gangues | ZEM-A | 141 |
| | | mounds, soil barriers | ZEM-A | 142 |
| | | deposits of urban and other wastes | ZEM-A | 143 |
| SOFT ROCKS | | clayey, marly | POL | 201 |
| | | clayey, marly and limestone | POL | 202 |
| | | alternation of different materials (marl, sand, sandstone, conglomerate pebble, clay etc.) | POL | 203 |
| | | conglomerate with possible soil inclusions | POL | 205 |
| ROCKS | CLASTIC ROCKS | (slaty) claystones with inclusions of other rocks | KLA | 301 |
| | | marl and sandstone (flysch) with inclusions of other rocks | KLA | 302 |
| | | sandstones and conglomerates with inclusions of other rocks | KLA | 303 |
| | CARBONATES | stratified and cliff limestones | KAR | 401 |
| | | flat limestones | KAR | 402 |
| | | limestones and dolomites | KAR | 403 |
| | | dolomites | KAR | 404 |
| | | limestones with marls | KAR | 405 |
| | | limestones with inclusions of other rocks | KAR | 406 |
| | | limestone conglomerates and breccia | KAR | 407 |
| | METAMORPHIC ROCK | phyllites, schists and slate | MET | 501 |
| | | amphibolite and gneiss | MET | 502 |
| | MAGMATIC ROCK | diabase and other magmatic rocks with tuff | MAG | 601 |
| | | amphibolites, serpentinites, diaphthorites | MAG | 602 |
| | | tonalite, dacite, granodiorite | MAG | 603 |

F. WEATHERING
G. WEATHERING COVER
H. EROSION
I. TERRAIN STABILITY AND LANDSLIDE INCIDENCE
J. SUSCEPTIBILITY TO ROCKFALLS
K. HYDROGEOLOGICAL PROPERTIES
L. SEISMIC SENSITIVITY
M. CONSTRUCTION CONDITIONS

A detailed description of each engineering geological unit was also made. Part of the description for soils is given below as an example:

Soils – alluvium soils (ZEM-R)

111 predominantly clayey soils
112 marsh, lake soils (clay, silt, peat)
113 alternation of different soils (pebble, sand, clay, etc.)
114 pebble and sandy pebble

According to the EG classification, fluvial and stream alluvia are divided into four sub-units (111, 112, 113 and 114). The first includes sediments (of Quaternary or Pliocene age), mostly composed of clayey soils (111). It also includes terra rossa. They can be found in the basins of karst sinkholes, primarily in Dolenjska, at the margins of large basins, like the Drava and Mura basins, and in smaller patches also elsewhere in Slovenia. They form a flat or slightly undulating terrain. They are susceptible to erosion along waterways. They are impermeable to water and act as an insulator. Interference with them may be problematic due to their low bearing capacity and possible large differential subsidence. Deep slope and embankments require protective measures in order to ensure the stability of the excavation walls. If they are thick, they are appropriate for waste deposits. In case of an earthquake, a considerable increase in the seismic impact is expected.

## Upgrading of the engineering geological map

The next step in the preparation of the general assessment of the engineering geological properties of rock in the Slovenian territory was the creation of maps showing certain important engineering geological characteristics:

Thus, the following maps were derived from the basic engineering geological map:

– the map of rock classification according to rock strength properties,

– the map of rock classification according to stability or susceptibility to landsliding,

– the map with the assessment of the weathering cover thickness.

In the preparation of the above maps by means of GIS, other information layers were also used. Thus, the map of stability also took into account the following as input information layers:

– lithology

– the map with the assessment of the weathering cover thickness

– the hydrogeological map of Slovenia

– DEM (Digital Elevation Model)

Tab. 4. Weighting factors of information layers

| Influence factor | Percent of influence |
|---|---|
| lithology | 20% |
| weathering cover | 40% |
| slope inclination | 30% |
| hydrogeology | 10% |

We determined the influence factors for each information layer. For the stability map, they were the following:

The basic input data for the production of the derived maps were obtained by making an assessment of a certain engineering geological property for each lithostratigraphic unit, like shown in the following table and the keys attached:

Derived maps from the basic engineering geological map are shown below:

## Conclusion

The general engineering geological map in the scale of 1:250,000 was first used in searching for the location for the low radioactive waste deposit in Slovenia. Otherwise, it is not especially significant in construction and other local spatial development, however, it becomes important in spatial planning in a wider area and in understanding the engineering geological characteristics of the Slovenian territory.

Tab. 5. Assessment of an engineering geological properties

| Acad Elev. | ID no. | EG mark | Dec. class. | DESCRIPTION | Weathering cover – soil | Erosion | Rock strength | Stability/ lithology |
|---|---|---|---|---|---|---|---|---|
| 2 | 1 | ZEM-R | 111 | clay (Quaternary) | 1 | 1 | 2 | 2 |
| 13 | 1 | ZEM-R | 111 | brown clay, terra rossa and loam (Quaternary and Pliocene) | 1 | 1 | 2 | 2 |
| 14 | 1 | ZEM-R | 111 | clay and weathered material with chert (Quaternary and Pliocene) | 1 | 1 | 2 | 1 |
| 7 | 2 | ZEM-R | 112 | clay, peat (marsh sediments – Quaternary) | 1 | 1 | 2 | 1 |
| 8 | 2 | ZEM-R | 112 | clay, silt and weathered peat (marsh and lake sediments – Quaternary) | 1 | 1 | 2 | 1 |
| 9 | 2 | ZEM-R | 112 | clayey silt (continental and marsh loess – Quaternary) | 1 | 1 | 2 | 2 |
| 1 | 3 | ZEM-R | 113 | alluvium (pebble, sand, silt and clay – Quaternary) | 1 | 1 | 1 | 3 |
| 10 | 3 | ZEM-R | 113 | fluvial loose sediments in terraces (pebble, sand, silt and clay – Quaternary) | 2 | 1 | 1 | 3 |

| Weathering cover – soil (LEGEND) | |
|---|---|
| 1 | Soil, clayey, silty with weathered material properties |
| 2 | Soil, pebbly (gravely) with weathered material properties |
| 3 | Very thick and thick weathering cover |
| 4 | Weathering cover of medium thickness |
| 5 | Thin weathering cover |
| **Erosion (LEGEND)** | |
| 1 | highly erodable rocks |
| 2 | moderately erodable rocks |
| 3 | poorly erodable rocks |
| **Rock strength properties (LEGEND)** | |
| 1 | cohesionless soils |
| 2 | cohesive soils |
| 3 | soft rocks |
| 4 | soft and medium-hard rocks |
| 5 | hard |
| 6 | very hard rocks |
| **Stability (LEGEND)** | |
| 1 | very high possibility of the landslide appearance |
| 2 | high possibility of the landslide appearance |
| 3 | medium possibility of thelandslide appearance |
| 4 | moderate possibility of the landslide appearance |
| 5 | very low possibility of the landslide appearance |

Fig.1. Weathering cover map

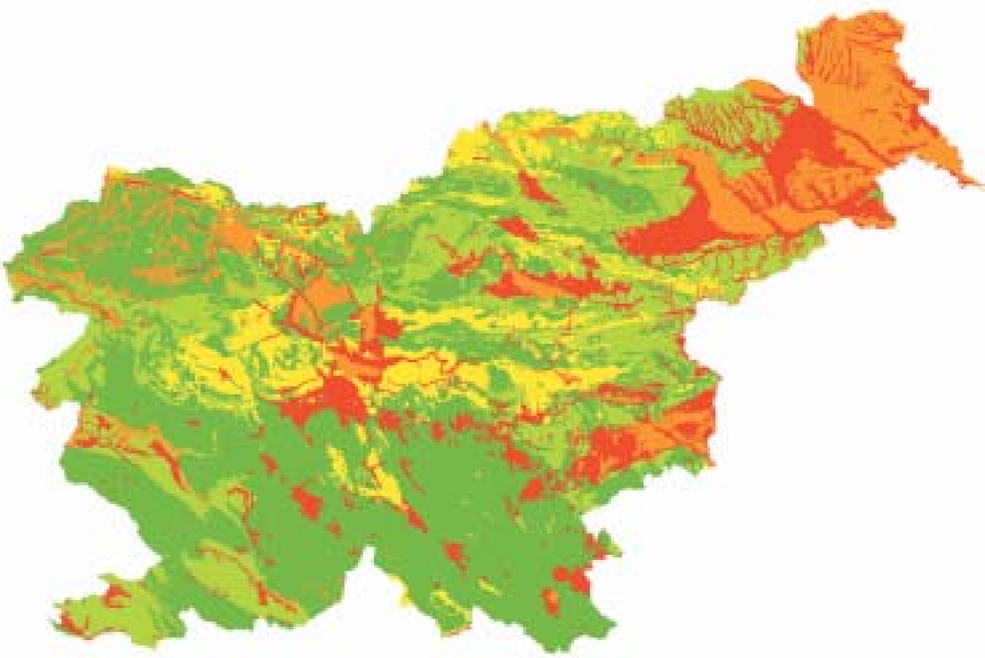


Fig.2. Erosion map

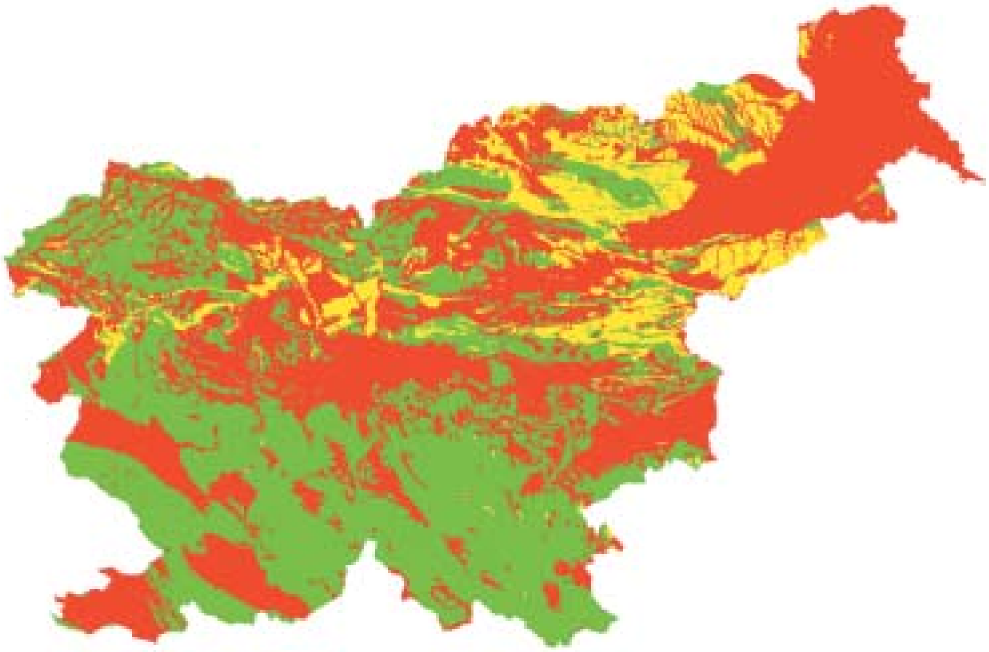


Fig.3. Rock strength properties map

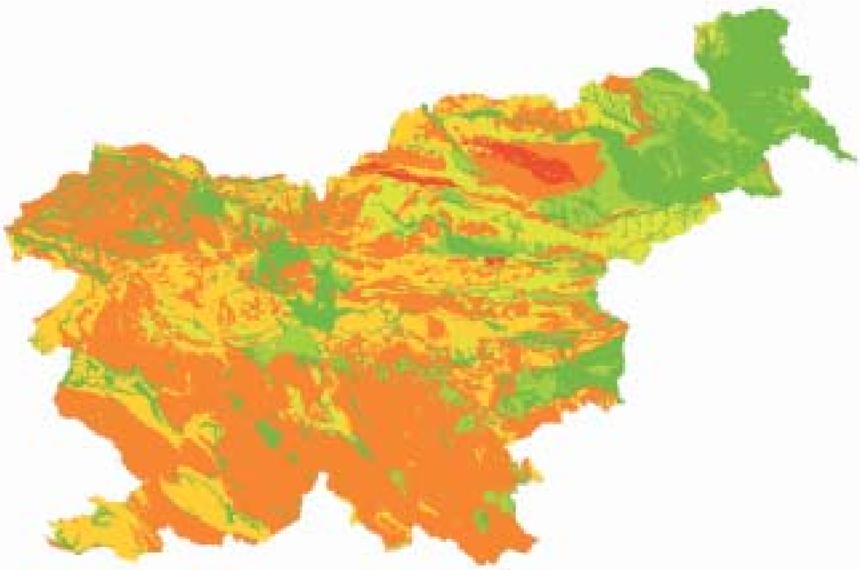
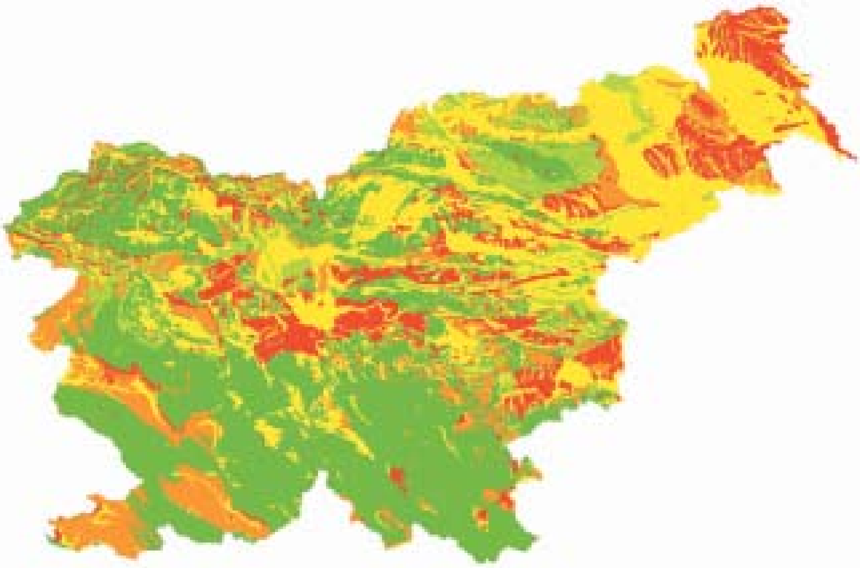


Fig.4. Stability map



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GEOLOGIJA *46/2*, 405–412, Ljubljana 2003

# Geotechnical and seismic microzonation map of the Bovec region

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*Key words:* earthquake, geotechnical map, map of seismic microzonation, GIS, post-earthquake restoration, Posočje, Bovec, Slovenia
*Ključne besede:* potres, geotehnična karta, karta seizmične mikrorajonizacije, GIS, popotresna obnova, Posočje, Bovec, Slovenija

**Abstract**

In 1998, the area of Upper Posočje in the north-west of Slovenia experienced the strongest earthquake in the 20th century in the Slovenian territory. There were no casualties, however, 4200 houses and other building were damaged. The Slovenian Government adopted an extensive plan of post-earthquake restoration, which was almost fully completed by 2003. In place of 160 buildings that suffered too much damage to be repaired new ones were constructed. A geotechnical map of wider Bovec area was produced to be used for planning, location selection and determination of foundation conditions. The geotechnical map was prepared on the basis of the existing geological map, which was additionally reviewed and supplemented on the field. This was added by the geotechnical field research data, including an overview of the existing documents on the foundation construction in the area concerned, engineering geological mapping and drilling of 20 boreholes in areas where the data on ground composition was insufficient. The geotechnical map was supplemented with GIS databases of the damage to buildings and the nature. For buildings for which foundation conditions were determined during restoration, a special database was additionally created. The data collected was also used for the preparation of the seismic microzonation map, which served as the basis for the static designing of seismically safe construction.

**Kratka vsebina**

Leta 1998 je bil na območju Gornjega Posočja v severnozahodni Sloveniji najmočnejši potres v dvajsetem stoletju na območju teritorija Slovenije. Smrtnih žrtev ni bilo, bilo pa je poškodovano 4200 hiš in drugih objektov. Vlada Slovenije je sprejela obsežen plan popotresne sanacije, ki je bil do leta 2003 skoraj v popolnosti zaključen. Namesto 160 objektov, ki so bili preveč poškodovani, da bi jih bilo mogoče popraviti, so se zgradili novi. Za planiranje, izbor lokacij in določitev pogojev temeljenja je bila izdelana geotehnična karta širšega območja mesta Bovec. Geotehnična karta je bila izdelana na osnovi obstoječe Geološke karte, ki pa je bila dodatno na terenu preverjena in dopolnjena. K temu so bili pridruženi podatki geotehničnih raziskav na terenu, ki so zajemali pregled obstoječe dokumentacije o izvajanju temeljenja na obravnavanem območju, inženirskogeološko kartiranje in vrtanje 20 vrtin na območjih, kjer je primanjkovalo podatkov o sestavi tal.

Postopek izdelave Geotehnične karte je bil naslednji. Najprej je bila digitalizirana geološka karta. Geološke enote na karti so bile nadalje združene ali deljene v inženirskogeološke enote, glede na geomehanske lastnosti tal. Drugi pomemben vhodni podatek za izdelavo Geotehnične karte so bili podatki o poškodbah objektov zaradi potresa. V alpskem svetu, kjer ni objektov so bile uporabljene ugtovljene poškodbe, ki so nastale v naravi zaradi potresa. Izdelana je bila karta poškodb, ki je v GIS aplikaciji združevala lokacije poškodovanih objektov z bazo popisa poškodb. Narejena je bila analiza velikosti poškodb v odvisnosti od sestave tal. Na osnovi korelacije med stopnjo velikosti poškodb in sestave tal so bili za inženirskogeološke enote dodatno opredeljene geomehanske lastnosti tal. Pri tem so bili posebno pomembni podatki o območjih, kjer teren gradijo slabo nosilna tla, ki so se ob potresu prikazala kot območja z najtežjimi poškodbami na hišah. Končno so bile inženirskogeološke enote s sorodnimi lastnostmi združene v nov sloj po podobnih geomehanskih lastnostih. Za vsako tako dobljeno združeno inženirskogeološko enoto posebej so bile določeni pogoji temeljenja. Rezultati GIS obdelave so bili pregledno prikazani v izrisih in izpisih: Karta velikosti stopnje poškodb na objektih in v naravi, Geološka karta, Inženirskogeološka karta Tabela pogojev temeljenja za inženirskogeološke enote in Karta seizmične mikrorajonizacije.

## Introduction

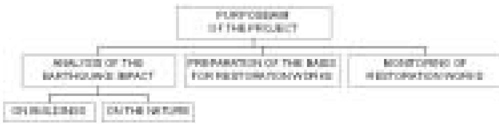
For the presentation and processing of all data the GIS technology was used.

The inter-disciplinary data collected was primarily used for three purposes:

– the analysis of earthquake impact,

– the preparation of the basis for the restoration works on the damaged buildings, and

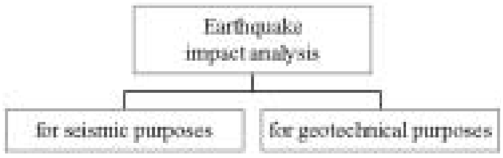
– the monitoring of restoration.



The analyses of earthquake impact were conducted for seismic and geotechnical purposes.

Seismologists used the data gathered to determine the seismic parameters of the earthquake (depth of earthquake, type of earthquake, definition of the tectonic structure in relation with the earthquake, seismic intensity, etc.).

The analysis of the geological-geotechnical data enabled the correlation of the impact of the damage to the nature and the buildings with the local geological conditions and geomechanical ground characteristics. The seismic and geotechnical analyses together were used for the preparation of a new seismic microzonation map.




## Maps and Databases

The data were organised in three groups:

– NATURAL CHARACTERISTICS OR NATURAL CONDITIONS,

– EARTHQUAKE IMPACT DATA, AND

– RESTORATION DATA (GEOTECHNICAL PART).

The spatial data were shown on digital maps, while the descriptive data were given in databases. The connections between the graphical representations and databases were made by means of ID numbers or identifiers.

In order to determine the natural characteristics, we amended the existing geological map of the Bovec Basin in the scale of 1:10,000, and we also used a more general

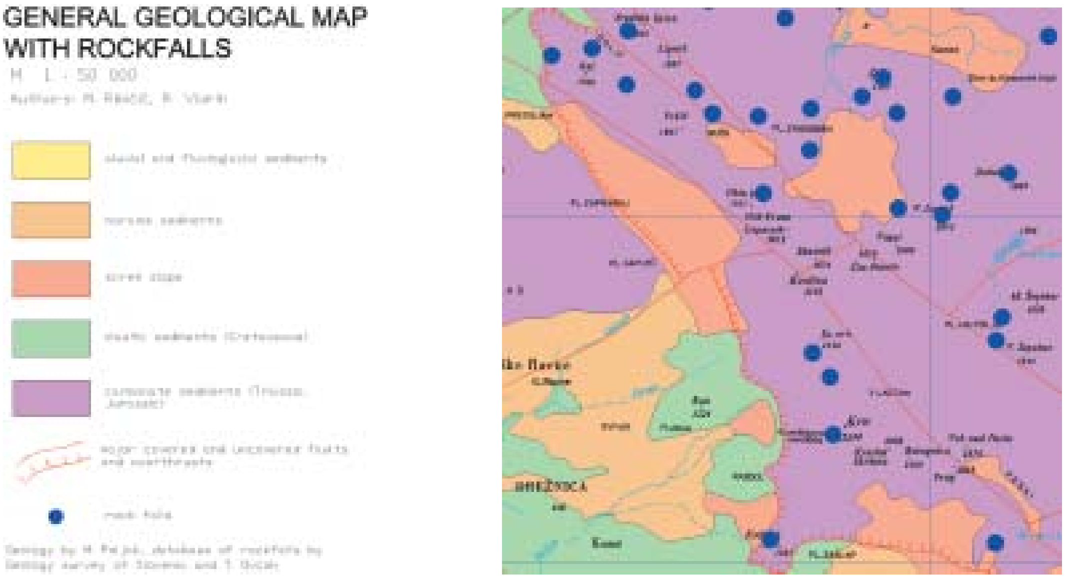



Fig 1. Section of Geological map of Upper Posočje in scale 1: 25,000.

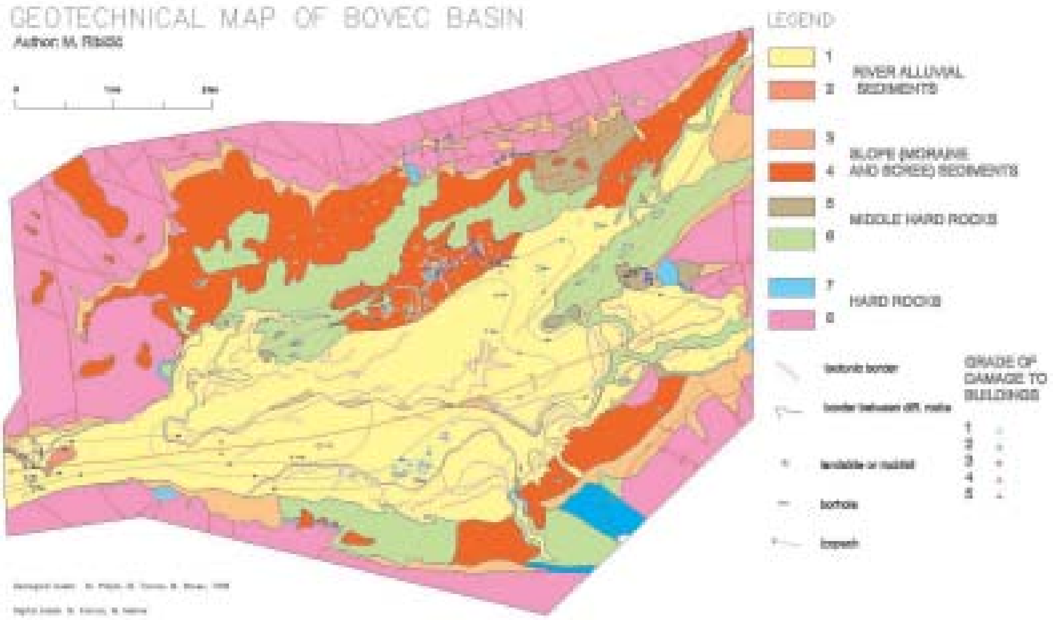



Fig. 2. Geotechnical map of Bovec basin

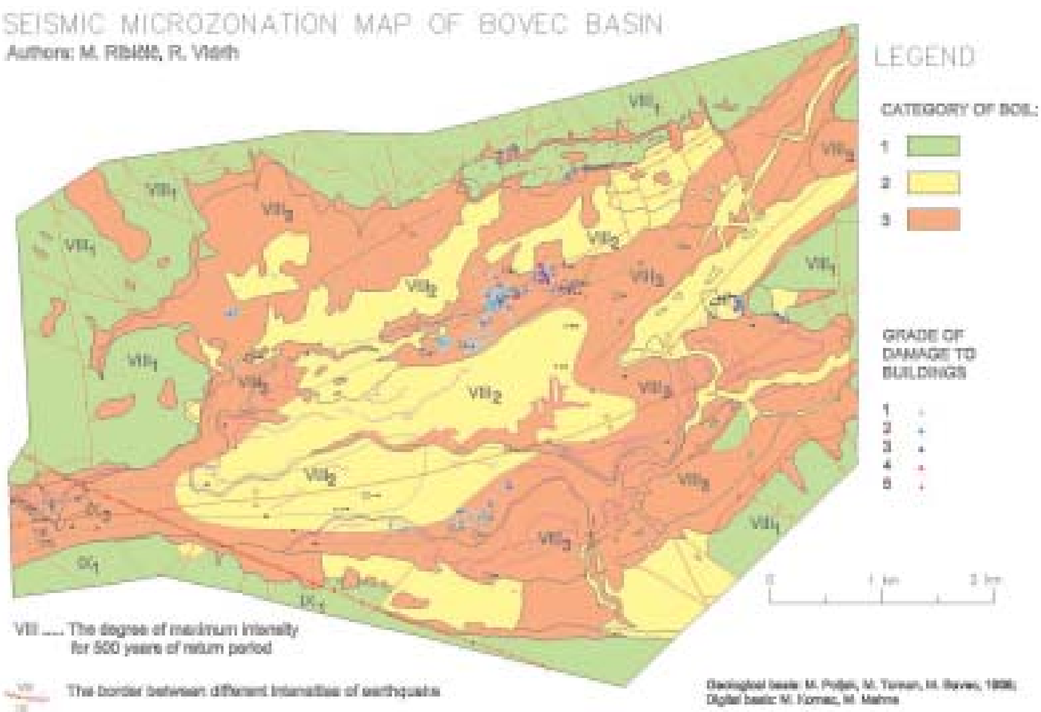
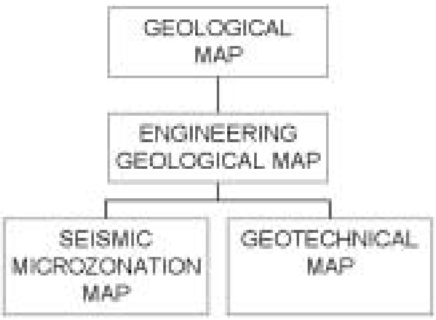



Fig.3. Seismic microzonation map of Bovec basin

map of the wider area in the scale of 1:25,000, added by the data on the probe boreholes and shallow excavations.

The procedure leading to the elaboration of the geotechnical map and seismic microzonation map as the final products was the following. First, the geological map was digitalised. Further, the geological units on the map were joined or divided to geological-engineering units according to the geomechanical and seismic characteristics of the ground. Another input data important for the preparation of both maps were the data on the damage to buildings due to the earthquake. In the Alpine region, where there are no buildings, the determined damage that the earthquake caused to the nature was used.




In the preparation of both maps, much aid was provided by the map of damage, joining the locations of the damaged buildings and the database of damage inventory. An analysis of the extent of damage in dependence on the ground composition was made.

On the basis of the correlation between the level of damage and the ground composition, the geomechanical and seismic properties of the ground were additionally determined for the geological-engineering units. Here, the especially important data were those referring to the low bearing capacity ground areas which the earthquake revealed as the areas with the worst damage to houses. At the end, the geological-engineering units with related properties were joined into a new layer according to their similar geomechanical or seismic characteristics. For each joined geological-engineering unit obtained in this way, the foundation conditions and the increase in the seismic level due to ground composition were determined.

Each map was added by a database describing the data captured.

| DATABASES TO MAPS |
|---|
| database to the geological map<br>database to the engineering geological map<br>database to the geotechnical map<br>database to the sesmic microzonation map |

The attributes of the database to the geological map and the attributes of the key to the geotechnical map are given as examples: The structure of the descriptive data base to the geological map:

| |
|---|
| Geological units (polygon)<br>– geological unit identifier<br>– description of the mapped geological unit<br>– age of rock<br>– type of rock |
| Layer stike and dip (point)<br>– layer strike and dip identifier<br>– type of layer strike and dip<br>– dip (angle)<br>– strike (angle) |
| Geological boundaries (lines)<br>– geological boundary identifier<br>– type of geological boundary |
| Structure units (lines)<br>– structure unit identifier<br>– type of structure unit<br>o axis of a normal large fold<br>o axis of a toppled fold<br>o axis of a metre fold<br>o axis of a covered fold<br>o axis of a plunging fold<br>o fault<br>o thrust<br>o cracks |
| Large landslide (polygon) |
| Rockfall – older (point) |
| Rockfall appearing during the earthquake (point) |
| Isolines of equal thickness of quaternary sediments (line) |

The maps were added by special databases formed within the data capture on the field:

| FIELDWORK DATABASES |
|---|
| database of damage to buildings<br>database of damage to the nature<br>database of boreholes<br>database of probe shafts<br>database of geotechnical foundation conditions |

The first database contained the inventory of the damage to buildings and the sec-

The database of the geotechnical key contained the following attributes. The right column shows descriptions for the geotechnical unit chosen as examples of the data contained in the database:

| Attribute | Example |
|---|---|
| ROCK CLASSIFICATION | cohesionless soil; slope sediments (moraine and scree) |
| ROCK FORMATION | glacier sediments |
| ROCK DESCRIPTION | till (loose moraine) appears as scree of poorly-rounded boulders of limestone |
| MORPHOLOGY | gentle to medium dip of slopes |
| PHYSICO-GEOLOGICAL PHENOMENA | subject to strong slope erosion; landslides on steeper slopes |
| WEATHERED MATERIAL | |
| thickness | 0.5 to 1.5 m |
| type | clayed gravel to clay with pebbles |
| USCS | GC – CL |
| EXCAVATION CATEGORY | |
| weathered material | II |
| rock | III |
| ASSESSMENT OF FOUNDATION AND CONSTRUCTION CONDITIONS | |
| description | ground of medium bearing capacity; requiring careful location selection and foundation |
| bearing capacity allowed | 200 to 250 kN/m$^2$ |
| adequacy assessment | less adequate; where possible, on larger area |
| groundwater | permeable to water; temporary groundwater above impermeable layers |
| slope inclination | 1 : 2 |
| applicability for building in | conditionally applicable |

The database of the damage to buildings:

| ATTRIBUTE | Example |
|---|---|
| ID NO. | 1745 |
| TYPE | residential buildings |
| ADDRESS | BOVEC, TRENTA, TRENTA 63 |
| OWNER | RUDOLF ANA |
| YEAR OF CONSTRUCTION | 1941 |
| YEAR OF RESTORATION | 1987 |
| NO. OF FLOORS | ground floor + 1 |
| FOUNDATION | no foundation |
| WALLS | stone |
| CEILING | wooden |
| ROOF | wooden |
| ROOFING | other |
| DESCRIPTION OF DAMAGE | The structure of the building has suffered much damage, partly due to the earthquake and partly because of its poor state and inappropriate construction method. |
| CATEGORY | 4 |
| DAMAGE LEVEL | 65.0 |
| Y | 403860 |
| X | 139619 |

ond one the inventory of the damage to the nature. In order to connect the database concerning the inventory of the damage to buildings with the abovementioned maps, we used the national house records, which contain the basic information on buildings, in particular spatial co-ordinates.

The database of the damage to the nature included the damage to the nature found after the earthquake, with the information being gathered by mapping in the field:

| ATTRIBUTE | Example |
|---|---|
| ID No. of the phenomena | 3 |
| Name | Mali Lemež – Šija |
| Time of triggering | 12.4.1998 |
| Place | LEPENA |
| Municipality | BOVEC |
| Y co-ordinate | 398130 |
| X co-ordinate | 128020 |
| Surveyed by | Beguš, Kočevar |
| Description and extension of the phenomenon | large rockfall |

The research on the field involved a large number of boreholes and probe shafts made next to the buildings. The following are two examples of records contained in the database of boreholes and shafts.

The database of boreholes:

| ATTRIBUTE | | Example |
|---|---|---|
| ID No. of borehole | | 9 |
| DEPTH | | 20 m |
| BOREHOLE | | G-3 |
| PLACE | | Žičnica |
| DATE | | August 1998 |
| PROCESSED BY | | M. Bavec |
| subreport – inventory of the borehole: | | |
| depth | AC | Description of soil |
| 0.2 | | humus |
| 1.8 | CI-CH | brown firm clay of intermediate to high plasticity |
| 2.1 | GC | brown clayey gravel |
| 9.1 | | borehole compacted lime breccia |
| 10.5 | | boulder of limestone |
| 10.6 | | boulder of sandstone |
| 14 | | grey marl (flysch) |

The database of shafts:

| Building ID No. | 17 |
|---|---|
| Place | BOVEC |
| Street | TRG GOLOBARSKIH ŽRTEV |
| House No. | 16 |
| Owner | Lilič L., Sivec F. |
| Depth | |
| 0.0 – 0.60 | man-made mound (GP, CL) |
| 0.6 – 1.00 | slightly silty gravel (GP) |
| Bearing capacity | 200 |
| Foundation | The building is founded shallowly, on strip footing 0.6 m under the height of the terrain, in incoherent soil |
| Structure | The foundation structure is made of 0.6-m strip footing, constructed of a composition of large rock singlets, poorly bound with concrete or fine sand |
| Assessment | The building has shallow foundations. The allowed bearing capacity of the ground corresponds to the freezing criterion. The foundation structure is of poor quality. |

ning and in the restoration or construction of new substitute buildings. The geotechnical map was used for envisaging the foundation conditions for building.

During the restoration, the geomechanical foundation conditions were determined for all new buildings. The above database of shafts was used for recording the data on the foundation conditions at individual locations.

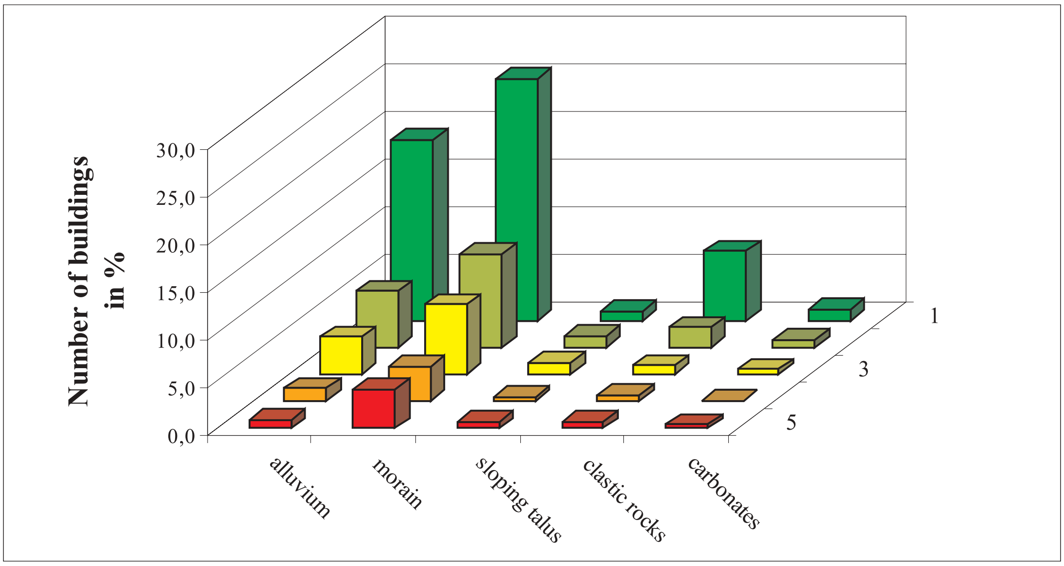
### The results and applicability of GIS in post-earthquake restoration

The results of the collected information on the geological structure and of the seismic and geotechnical conditions, produced by means of GIS technology (ArcInfo software) were useful during the whole period of restoration, both in the construction plan-

During the restoration, the seismic microzonation map served as a means of determining the basic seismic level and the impact of the ground composition on its increase or decrease, which is the basis for an expert in statics to be able to design seismically safe buildings.

We also created a GIS application which produced the foundation conditions and the seismic properties of the ground from the geotechnical and seismic map of the area of a selected building, i.e. of the location defined by the Y and X co-ordinates.

Besides, it was possible to make many useful analyses by means of GIS. Let us only present one of them. The chart below shows the number of damaged buildings in depen-




dence on the ground composition. It can be seen that the percentage of damaged buildings is the highest on the ground with the poorest geotechnical properties.

One can conclude that the use of GIS in post-earthquake research and restoration works proved to be successful, since at the beginning it required a clear and long-term concept of approach, and during the work it enabled a quick supply of information, much of which would have otherwise needed long processing, while with GIS it was immediately accessible.

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GEOLOGIJA *46/2,* 413–418, Ljubljana 2003

# Calculation of the moving landslide masses volume from air images

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*Key words:* landslide, remote sensing, GIS, aerial photography, landslide volume calculation, Slano blato, Slovenia
*Ključne besede:* plaz, daljinsko zaznavanje, GIS, letalsko snemanje, izračun volumna plazu, Slano blato, Slovenija

**Abstract**

The landslide Slano blato is of great dimensions, longer than 1 km and wider than 300 m. The movements of 10 m per day mostly happen in heavy rainy seasons and afterwards calm down, while the landslide progresses for a few 100 meters at the time. Because of the size and the inaccessibility of the landslide, common surveying was not possible. So the observation of the sliding masses movements was only possible by successive photography from a plane. For this purpose we carried out two special photo shoots with a special plane equipped for remote sensing. The existent snap shots from regular cyclic remote sensing prior to landsliding were also applied. On the basis of the snaps, TIN meshwork was created for each photo shoot separately. Geodetic maps in 1:2000 scale with contour lines 1 m apart were also produced for this purpose.

It is important to know the volume of the moving masses so we can determine which measures are significant for stopping the landsliding (mudflow) that threatens the village of Lokavec. As we had available data of the area size before landsliding, we could easily calculate the mass volume sliding by cross-sectioning the area of the two conditions at different times of aerial photo shoots. The problem in the calculation was the landsliding masses that joined the mudflow from the ground. These were the masses from the previous older slidings, known to had happened at least twice – 100 and 200 years ago. The volume of the old landslide was estimated with the help of geological evaluation which we used to access the depth of the slope base. Geological evaluation was partially based on field drilling and partially on presumption of the depth of weathering cover. The landslide depth data were interpreted with the help of two longitudinal sections and transverse sections each 25 m apart. We put the surface lines from each remote sensing on each cross-section and calculated the volumes of the landslide between two cross-sections. By means of this procedure we assessed that the volume of all the sliding masses was 684.000 $m^3$ (April, 2001). With regard to this and other parallel results we determined that we should stop the sliding before it gets to the village by draining and pushing the masses aside. Part of the masses was impossible to withhold on the slope (between 300.000 $m^3$ and 400.000 $m^3$), so it was removed by means of vehicles to the deposit.

It was confirmed that the calculation of the volumes with the help of remote sensing is a very suitable method for large landslides, but will only give the right results by detailed geological interpretation of landsliding.

**Kratka vsebina**

Plaz Slano blato je izrednih dimenzij, daljši od 1 km in širine do 300 m. Premiki na njem velikosti do nekaj deset metrov na dan se dogajajo po deževnih razdobjih in se zopet umirijo, ko plaz napreduje več sto metrov. Ker s klasičnimi geodetskimi meritvami zaradi velikosti plazu in nedostopnosti ni bilo mogoče spremljati premikov plazečih se mas, so bila dogajanja na plazu spremljana s pomočjo zaporednih slikanj iz letala. V ta namen sta bili izvedeni dve posebni snemanji s posebnim letalom za daljinsko opazovanje, uporabljeni pa so bili tudi obstoječi posnetki rednega cikličnega snemanja še predno se je plaz sprožil. Na osnovi posnetkov so bili izdelani TIN in GRID površine za vsako snemanje posebej in geodetske karte površine v merilu 1:2.000 z izohipsami na 1 m.

Za odločitev, kateri so nujni ukrepi za preprečevanje premikanja plazu, ki ogroža zaselek Lokavec, ki je neposredno pod plazom, je pomemben podatek, kolikšen je volumen premikajočih se mas. Ker je bila na razpolago prvotna površina terena pred plazenjem, se je izračun volumnov mas, ki so se "razlile" kot blatni tok preko prvotne površine, določil enostavno s presekom površin dveh stanj površine v različnih časih letalskega slikanja. Problem so predstavljale tiste plazeče se mase, ki so se vključile v blatni tok iz podlage. To so bile mase od starih plazenj, saj je poznano, da je bil plaz aktiven najmanj že dvakrat - pred dvesto in sto leti. Volumen stare plazine smo ocenili s pomočjo geološke ocene, s katero smo določili globino do hribinske podlage.Geološka ocena je temeljila deloma na terenskih vrtanjih, deloma pa na predpostavkah o debelini preperinskega sloja. Podatki o debelini plazu so bili interpretirani s pomočjo dveh vzdolžnih profilov in prečnih prerezov na razdaljah po 25 m. V vsak prerez so bile prenešene linije površin posameznih snemanj, dobljene s presekom med ploskvami površin in vertikalno ravnino prereza ter interpretirana linija podlage.. Volumni plazeče se mase med dvema profiloma so bili določeni s produktom polovice vsote ploščin preseka plazu med zaporednima presekoma in razdalje med presekoma. Po tem postopku je bil določen celotni volumen gibajočih se mas, ki je znašal 684.000 m3 (maja 2001). Ob upoštevanju teh in drugi vzporednih rezultatov se je pokazalo, da je za preprečitev prodora plazečih se mas do vasi Lokavec treba čim več mas zadržati z osuševanjem in odrivanjem na boke na plazu, tiste mase po oceni v količini med 300.000 do 400.000 m3 , ki ni mogoče zadržati na pobočju, pa odvoziti na deponijo.

Pokazalo se je, da je izračun volumnov s pomočjo letalskega slikanja za velike plazove zelo primerna metoda, ki pa da rezultate šele ob podrobni geološki interpretaciji dogajanj na plazu.

## Introduction

It is very probably in connection with the global climatic changes which, apart from dry periods, also brought extremely rainy seasons in recent years that four very large landslides have occurred in Slovenia after 2000, such as had not been observed for decades before that. Due to several reasons, we decided to obtain geodetic bases by aerial photography. These reasons were:

- inaccessibility of landslide bodies,
- large dimensions of landslides,
- requirements for quick acquisition of geodetic bases (implementation of urgent restoration measures),
- large displacements of soil masses in short time periods,
- comparison of the state before and after the triggering of landsliding,
- calculation of the volumes of the moving landslide masses.

We made air images of all four landslides on the same flight. One of these landslides was Slano blato, treated in this paper.

For landslides of extraordinary dimensions, like Slano blato, the calculation of volumes (volumes of moving masses, volumes to the base and potential volumes of new sliding) is important because it provides a basis on which answers of better quality can be given to the following questions:

- Is a final landslide restoration possible and sensible at all?
- Is it possible to restore it by regrouping the sliding masses?
- Is it sensible to remove a part of the landslide material?
- What masses may endanger the settled area under the landslide?
- What volumes of masses may move at the same time?
- What is the most probable sliding prognosis?

Only the calculation of the volume of potential and moving masses of the landslide material provides the basic answers specifying to which extent the works on a landslide would contribute to its stabilisation. The calculation also shows approximately what funds will be needed for landslide restoration.

Some basic data on the landslide:

- Location: Above Lokavec at Ajdovščina in Primorska
- Date of triggering: 18 November 2000
- Surface of the landslide: ~ 20 ha, length: ~ 1270 m
- Largest width: ~ 250 m, between 360 and 660 above sea level
- Largest progress: ~ 90 m/day

| | |
|---|---|
| • Rock in the base: | flysch (marl and sandstone) |
| • Composition of the sliding mass: | weathered flysch – clayey gravely soil |
| • Age of the landslide: | first reference dating 200 years ago |
| • Landslide restoration: | first performed in 1903, lasting for 17 years. |

In order to calculate the volumes of moving masses, aerial photographs were used as follows:

1. The original surface was taken from aerial photographs taken in 1998, before sliding,
2. The second shoot was carried out at the end of November 2000,
3. The third shoot was carried out in mid April 2001.

**Preparation of geodetic bases and calculation of volumes between different states of surfaces**

The preparation of the geodetic bases for the calculation of the volumes was carried out by the Geodetic Institute of Slovenia, which has an aeroplane for aerial photography and all the software needed for data processing.

The hardware used was:

- aerial photography equipment on the aeroplane with a RC30 aerial metric camera,
- analytical photogrammetric instrument Adam Promap,
- GPS receivers,
- PCs,
- electronic theodolite LEICA TCR 307.

The data gathered were processed by means of the following software:

- Adam System Software,
- AutoCAD,
- QuickSurf,
- Archos,
- KarTop,
- Polar.

The tests at comparative points showed that the error in the determination of the heights does not exceed two metres, which provided a satisfactory precision for the calculation of the volumes, in particular since it is known that landslide displacements of several metres in a short period are no exception.

The results of the geodetic processing which, in addition to aerial photography, also included the determination of new photogrammetric reference points by GPS measurements on the field as well as classical geodetic survey photography and the inventory of all buildings by entering house numbers, were the following products:

- a topographic map of the original state before landsliding of 1998 in the scale of 1:2000,
- a topographic map of the landslide state in November 2000 in the scale of 1:2000,
- a topographic map of the landslide state in May 2001 in the scale of 1:2000,
- TIN1998,
- TIN2000,
- TIN2001.

As examples of geodetic processing, the picture below presents TIN98 states before landsliding (yellow colour) and TIN2001 meshwork of movements in the upper part of the landslide (blue colour):

Fig. 1. TIN98 states and TIN2001 meshwork (upper part of the landslide Slano blato)

In the first step, we tried to calculate the changes in the volume over time due to the expansion of the landslide by simply determining the volume between two TIN meshworks. The checking of the data obtained showed unsatisfactory results, because the volume of the change in surfaces between two states did not provide a satisfactory answer about the sliding masses actually involved in landsliding. Consequently, we decided to calculate the volumes of the sliding masses in a more time-consuming way according to the profile method explained below.

### Calculation of the volumes of sliding masses

The calculation of volumes is a long and complex procedure which can practically not be performed by hand. The calculations were made by means of a computer with the software applications AutoCAD 2000, QuickSurf and Microsoft Excel. In order to transfer the data between AutoCAD and Excel, short programs were written in Visual Basic.

First, QuickSurf was used for constructing the planes of surfaces for each aerial shoot. These planes were cross-sectioned transversely against the slope at distances of approximately 25 m (right picture – presentation of the upper part of the landslide).

Fig.2. Presentation of the upper part of the landslide

We obtained three lines of states for each shoot. The fourth line, representing the depth of landsliding, was constructed for each case by means of the data gathered by probe wells and the interpretation of the geological structure, digitalised and transferred to the other three lines. The result was 51 transverse sections, with three of them being shown below as examples:

The procedure of calculating the volumes was the following:

- For each cross-section, the surface from the reference height was first determined for each of the three landslide states at different times and for the base by means of the Boundary and Area commands in AutoCAD.
- The data for the surfaces calculated in this way were transferred to Excel, where the calculation was continued.
- The surfaces were mutually subtracted for each case. The surfaces November 2000 and April 2001 were subtracted from the original surface (1998). We also searched for the difference between the state in April 2001 and the interpreted base. A negative difference between surfaces means that masses were carried away from the cross-section area, while a positive difference means that they were brought from elsewhere.
- The volume between two cross-sections was calculated by halving the sum of both surfaces and multiplying it with the distance between the two cross-sections:

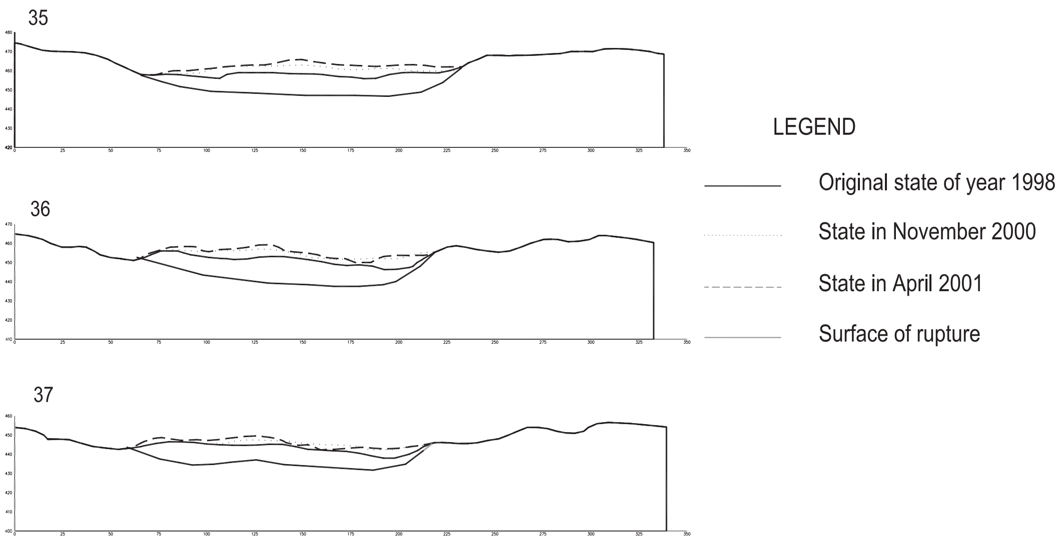


Fig.3. Transverse cross-sections

Tab.1. The results of the volume calculation

| Volumes ($m^3$) | 00–98 | 01–98 | 01–00 | 01–Pod |
|---|---|---|---|---|
| 1. upper part of the landslide and Slano blato | –35,876 | –61,190 | –25,313 | 144,800 |
| 2. upper channel | –12,714 | –25,716 | –13,002 | 42,742 |
| 3. “Blatno jezero” | 53,431 | 63,229 | 9,798 | 292,092 |
| 4. lower channel | 459 | 99,404 | 98,944 | 174,403 |
| 5. area above the waterfall | 0 | 10,274 | 10,274 | 24,344 |
| TOTAL | 5,300 | 86,001 | 80,702 | 678,381 |


• The results obtained were further used for drawing charts and for various summary tables and calculations.

$$Vk = \frac{p_k + p_{k+1}}{2} * d_k^{k+1}$$

$p_k$ k- cross-section
$p_{k+1}$ k+1- cross-section
$d_k^{k+1}$ distance between k- and k+1- cross-sections
Vk volume of k- area between two cross-sections

For easier understanding, the whole landslide was divided into five typical sections. The first “upper part of the landslide and Slano blato (1)” is the area of landsliding, from where all the sliding masses originate. In the area of “upper channel (2)”, these masses moving downhill become wet and turn into a mud mass, which continues its way as a mudflow. After long periods of heavy raining, the mudflow moves several hundred metres downwards, until it loses its energy within some days and stops for a few months. In the area of “Blatno jezero (3)” (“Mud Lake”), it spreads, thus producing a secondary accumulation of stagnating mud. When “Blatno jezero (3)” is full, the mud runs out along the “lower channel (4)” and starts to accumulate in the “area above the waterfall (5)”.

The calculations showed that 680.000 $m^3$ of material was involved in sliding until April 2001. Each movement of the sliding masses includes new amounts of landslide material, partly also from the base, like the remnants of old landsliding.

The basic question is what are the total masses that may get involved in landsliding over the long run. This is shown in the chart below, which presents the changes in the volume along the landslide. The chart and

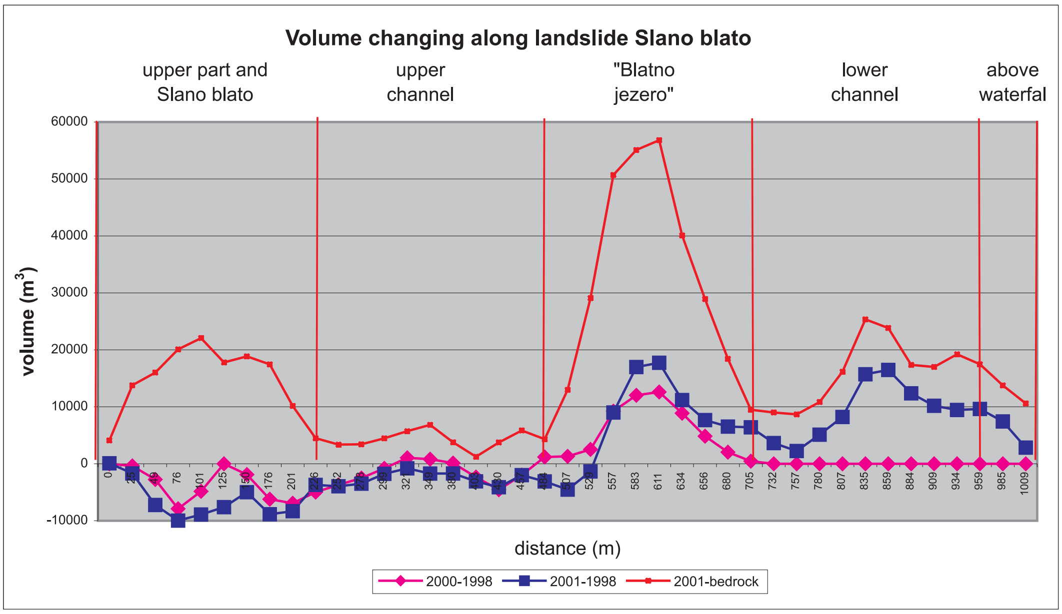


Fig.4. Volume changing along landslide Slano blato

the table above show that there are still potential large sliding masses in the base in the areas of the upper part of the landslide and of “Blatno jezero”. The “upper part” and “Blatno jezero” still contain around 150.000 $m^3$ and 290.000 $m^3$, respectively, and along the whole landslide there is around 680.000 $m^3$ of landslide material.

## Landslide restoration

The results of volume calculations of landslide masses indicate that successful landslide restoration is possible. Nevertheless, restoration will be time-consuming and financially demanding, taking several years.

The above volume analysis show that restoration measures should include:

• prevention of the sliding mass from becoming wet (draining),

• regrouping of the soil masses from the central landslide area to its sides with the aim of decreasing the sliding amount,

• carrying away of the sliding material in the amount of 300.000 $m^3$ to 400.000 $m^3$ to a deposit area.

The volume analysis also indicated that over time increasing amounts of mud masses get involved in landsliding. Consequently, any delay in restoration measures results in a more difficult and expensive restoration. The calculation of the movement until November 2000 thus showed that landsliding included ~50.000 $m^3$, while in April 2001 ~170.000 $m^3$ of material was already sliding. Approximately ~150.000 $m^3$ of unstable masses thus still remained in the upper part of the landslide. One-third to half of this material is already sliding. There are some additional sliding masses in unstable sides and the right part of the landslide.

Taking into account these and other parallel results, it turned out that in order to prevent the sliding masses from reaching the village of Lokavec as much as possible of the sliding masses should be retained in the upper and central parts of the landslide by draining and pushing the masses to the sides of the landslide, while the masses that cannot be retained on the slope – assessed to between 300.000 $m^3$ and 400.000 $m^3$ – should be carried away to a deposit area.

## Conclusion

It was shown that the calculation of volumes by means of aerial photography was a very appropriate method for large landslides which, however, only produces results after a detailed geological interpretation of the events in the landslide.

If a long-term extensive landslide restoration is not carried out, in a few years, the whole of this mass will also activate and begin to move downhill. In this case, the mudflow would reach the village of Lokavec.

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GEOLOGIJA *46/2,* 419–424, Ljubljana 2003

# Landslide mapping with the GIS

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*Key words:* landslide, morphology, GIS, landslide mapping, landslide map, landslide features, landslide description
*Ključne besede:* plaz, morfologija, GIS, kartiranje plazov, karta plazov, lastnosti plazov, opis plazov

**Abstract**

Any new technology allows an improved approach to the processing of expert data. The article describes how to make the recording of the data of engineering geological landslide mapping of the best possible quality by exploiting the possibilities offered by GIS. All input landslide data acquired during mapping, called landslide elements, were classified, as customary in GIS, into three groups: point, line and polygon elements. A list of the typical landslide elements noted in landslide survey was made for each group. Each element came with a description of its origin and appearance, the surveying method and the graphical representation in GIS. Additionally, a presentation of the landslide in three layers was introduced, historically reviewing the landslide. The first layer represented the past shapes before sliding, the second layer represented the recent signs of sliding and the third one (for old landslides) represented the shapes that arise after sliding. The graphical landslide data were connected with the attributes kept in the descriptive landslide database. The described approach involving the use of GIS considerably improves the quality of data capture in engineering geological landslide mapping. An example of a landslide map prepared according to the described system is attached to the article.

**Kratka vsebina**

Vsaka nova tehnologija omogoča izboljšan pristop k obdelavi strokovnih podatkov. V članku opisujem, kako čim bolj kvalitetno shraniti podatke inženirskogeološkega kartiranja plazu z izrabo možnosti, ki jih nudi GIS. Vse vhodne podatke o plazu, pridobljene pri kartiranju, ki jih imenujem elementi plazenja, sem razvrstil, kot je običajno za GIS, v tri skupine: točkovni, linijski in poligonski elementi. Za vsako grupo sem izdelal seznam tipičnih elementov plazenja, ki nastopajo pri pregledu plazu. Za vsak element podajam opis nastanka in pojavljanja, način zajemanja na terenu in grafični prikaz v GIS-u. Poleg tega uvajam prikaz plazu v treh slojih, ki plaz zgodovinsko obravnavajo. Na prvem sloju so prikazane reliktne oblike pred začetkom plazenja, na drugem sveži znaki in na tretjem (za stare plazove) dogajanja po končanju plazenja. Grafične podatke o plazu sem povezal z atributi shranjeni v opisni bazi podatkov o plazu. Opisani pristop z uporabo GIS-a zelo izboljša kvaliteto zajema podatkov pri inženirskogeološkem kartiranju plazu. K članku prilagam primer izdelane karte plazu po opisanem sistemu.

## Introduction

New technology, which GIS no longer is actually, also enables feedback. Those who master it can tackle the professional tasks that have been customary to date in a different way, from another aspect. In this way, new professional possibilities appear. The aim is not only to make data capture as appropriate for the GIS technology as possible, but to also improve the professional quality through a different aspect enabled by GIS.

Many experts have dealt with the use of GIS for landslides, so that there is a vast literature on various approaches and techniques. I have myself frequently used GIS in landslide mapping and thus discovered certain views and considerations that were new to me and which I hope will be at least partly new and useful to somebody else. My goal was not to develop a new system, but to create a useful method of landslide mapping.

## Landslide presentation in GIS

One of the usual techniques in GIS is that when a new spatial problem is being worked on each of the influential factors is presented in its own information layer. When mapping fossil landslides with more or less blurred shapes of sliding, one observes the geological and morphological forms that are or are not the signs of landsliding occurring in the past.

My work showed that the one of the most appropriate approach was the method in which information layers were divided into four groups:

1. original forms appearing before landsliding,
2. forms as the consequence of landsliding,
3. forms appearing after landsliding,
4. forms due to human activities.

The first group includes all morphological forms already existing before landsliding, like remnants of terraces, slope levelling, streambeds and similar features. The second group of information layers contains the forms appearing as the consequence of displacements during landsliding, which are later described in detail. The third group involves the forms that blurred or highlighted the shapes of landsliding, for instance the action of erosion on a landslide which subsequently eroded part of the landslide. Finally, the fourth group contains forms occurring during any landslide restoration or other human activities interfering with the surface of the area concerned.

All morphological forms for which it is not clear whether they arose due to landsliding are inserted in the information landslide layers. When, after the field processing and digitalisation of data, the information landslide layers are drawn separately, the previously hidden integral image of the landslide is clearly revealed. This is, naturally, only true of very large landslides which occurred in the geological history, but not of the smaller and more recent ones, most of whose characteristics can already be determined during mapping. However, I also use for these landslides the division to the forms before, during and after landsliding, because this makes their presentation much clearer. Sometimes such an approach shows that there have been several landsliding stages. In this case, the landsliding shapes are divided into information layers of individual landsliding stages. For a final determination whether a landslide is an old one, the morphological signs must be added by the geological signs of soil composition, pointing to a possible landsliding. Such signs are not treated in this paper.

The second basic characteristic of using GIS is that the graphical elements, in this case landslide elements, are presented as points, lines, polygons or bodies. The point elements may be sources, boreholes or measurements on a landslide. The line elements are all main scarps and cracks on a landslide. In time, the line elements of a recent landslide become blurred and rounded, and in old landslides they appear as ridges or steps. Then, it is frequently more appropriate to present them as plane units by polygons.

Plane units are the typical forms of different landslide areas occurring during the movement of the sliding masses down the slope. The typical plane forms are flat or undulating planes of characteristic shapes.

It depends on the rock in the base and its susceptibility to sliding how fast the initially distinct landsliding forms will disappear and become less and less recognisable. Another factor influencing the recognisability of landsliding is the size of the landslide and the dimensions of the displacements of the sliding masses. Very large landslides with extensive displacements remould the terrain to such an extent that the landslide shapes may remain visible even for several hundred years.

Only an assembly of several typical morphological forms with appropriate geological signs constitutes a reliable proof that there was a landslide in a certain place, while individual, although characteristic, forms could have occurred during other natural or anthropological events.

The point data are not important for landslide identification by itself. In the GIS presentation, they are used for marking water spring, measurement points, etc. In detailed mapping, point elements are used for the measurements of the morphological form characteristics, like the inclination of the terrain at a certain point. Below, point measurements connected with the line and polygon morphological forms are described in more detail.

### Line morphological forms

For landslide identification, line data as the remnants of landslide scraps and cracks are more important. In precise measurements, certain line elements can also be presented as polygons. The most typical line forms are shown in the following pictures of the characteristic landslide profile and ground plans:
Main scarp
Minor scarp
Right and left flank
Transverse cracks
Longitudinal cracks

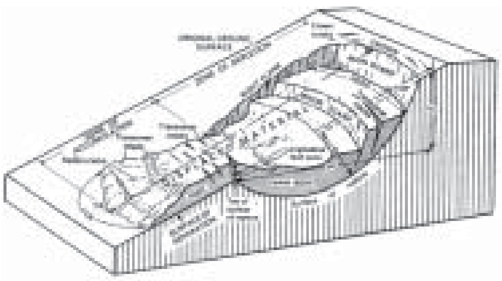
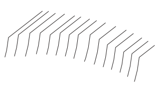


Fig. 1. Landslide terms (Cruden & Varnes, 1996)

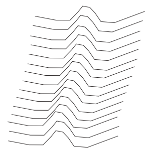
In the process of ageing, fresh cracks become increasingly blurred, the weathering rounds them, and erosion turns longitudinal cracks into ditches. Thus, with old landslides, the following forms are found instead of fresh cracks:
**The main scarp** is usually rounded and followed by a steep plane, ending in a more or less levelled terrain.

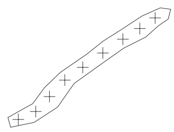
Appearance in the nature (sketch): Presentation in GIS:



**A longitudinal ridge** (left and right) is a remnant of the lateral flank in areas where the material on the sides was piled-up over the edge of the landslide. It is more frequent in the lower part of the landslide.

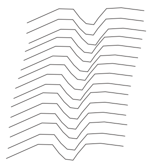
Appearance in the nature (sketch): Presentation in GIS:

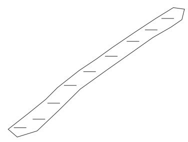




**A longitudinal ditch** (left and right) is also a remnant of the lateral landslide flank (left or right) which, after the slide, became lower than the displaced surrounding. It is often deepened by line stream erosion.

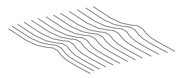
Appearance in the nature (sketch): Presentation in GIS:

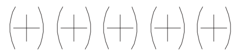




**Oblong concavity** appears in the form of a ridge which usually crosses the landslide transversely. Concavities may be of different dimensions – heights and widths. Ordinarily, they are the consequence of a step in the landslide whose edge later became blurred or plastic deformation of the sliding material. Concavity may also appear in a landslide when the landslide material with plastic behaviour gets compressed, raising the terrain.

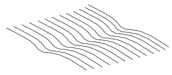
Appearance in the nature (sketch): Presentation in GIS:

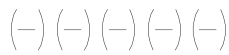




**Oblong convexity** usually appears when the landslide is moving, with the material opening up and deforms plastically (tensile stress). It may also be formed as the consequence of an uneven shape in the surface of rapture.

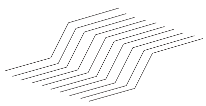
Appearance in the nature (sketch): Presentation in GIS:



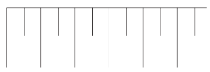


**A step** is a sharp transition of the terrain from a gentler slope to a steeper one. It differs from a concavity by the sudden change in the inclination. The form of a step is similar to the edge of a terrace. In the field, both inclinations are measured and the point values of the measurements are given. During landsliding, a step may also appear as a sliding surface in the very body of the landslide. One of the opportunities for it to form is also when the rock in the base on which the material is sliding locally changes its direction from a gentler inclination to a steeper one.

Appearance
in the nature (sketch):



Presentation in GIS:



In the mapping of line morphological forms, the line shapes that probably appeared due to sliding are added by the line shapes that had existed before sliding (displaced paths, stired terraces, boundaries of changes in the vegetation, etc.) and those that formed after sliding (erosion ditches, new waterways, etc.).

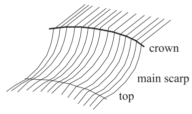
As far as the forms appearing after sliding are concerned, we are interested in the extent to which they have covered up the signs of sliding. The natural signs are primarily connected with erosion, frequently with the carrying away of the landslide material, and the anthropological signs are mostly connected with farming, afforestation, remoulding of the terrain by a bulldozer, etc.

## Plane morphological forms

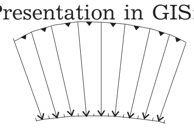
The most reliable evidence of landsliding in the past can be obtained by analysing plane forms. When mapping or identifying old landslides, I found many other characteristic plane shapes, with some of the most frequent being presented below:

**The main sliding surface** appears under the crown and represents the slide of material along the main scarp. This movement is usually the largest one in the body of a landslide. With fossil landslides, the main sliding surface is one of the most distinct features showing that sliding has occurred in the past. In old landslide identification, a distinct lack of soil volume is recorded in this part.

Appearance
in the nature (sketch):

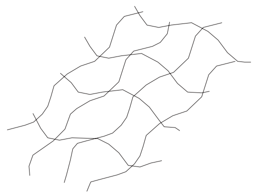



Presentation in GIS:

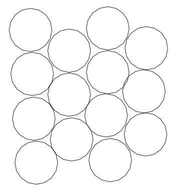


**An undulating surface** as a very frequent sign of old landsliding appears when the landslide material has plastic properties. When moving down the slope, the sliding material becomes compressed or expands, with various irregularities in the form of the landslide material and the wet masses in the landslide body finding their expression in plastic deformations of the material.

Appearance
in the nature (sketch):

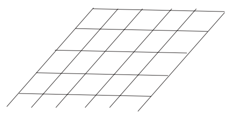


Presentation in GIS:

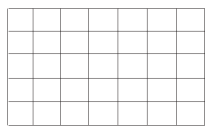


**A horizontal or an inclined plane**, on the other hand, normally appears in areas where the sliding is even and regular. It may be a remnant of original levelling before sliding.

Appearance
in the nature (sketch):

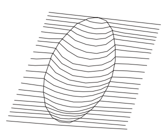


Presentation in GIS:

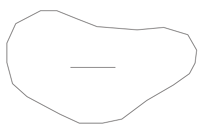


**A concavity** is a round or elliptical depression appearing in a landslide. It often contains water or becomes marshy. It is formed on the upper part of the landslide as a lack of the material that slid or due to the uneven movement of the landslide, with the sliding mass being of such a material that can get plastically deformed.

Appearance
in the nature (sketch):

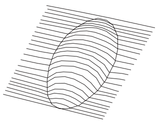


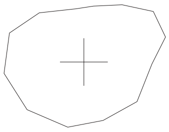
Presentation in GIS:



**A convexity** is round or elliptical and looks like a small hill on the landslide. It points to a local accumulation of masses in the landslide, primarily in its toe.

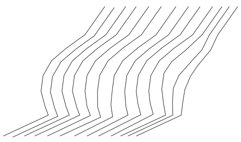
Appearance in the nature (sketch): Presentation in GIS:

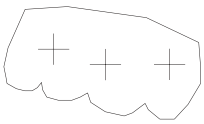




**The zone of accumulation** appears in the area where the shear resistance of the ground increases largely, thus stopping the sliding masses, although they are still under pressure of the higher sliding masses. Due to the slowing down of the landslide, the pressures in the landslide directed towards the slope result in the accumulation of material and even in the rising of the surface in the area of zone of accumulation. The latter are typical of the toe of the landslide.

Appearance in the nature (sketch): Presentation in GIS:

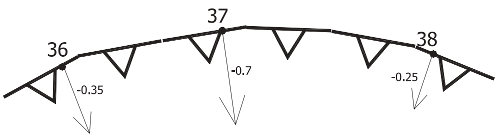




## Landslide measurements

When determining the characteristics of line and plane units mostly of an active landslide, it is sensible to also perform point measurements, which provide additional information on the characteristics of the forms: Main scarp, minor scarp or new scarp:

Height of vertical displacement – presentation:

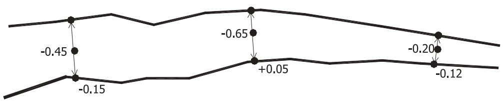



36 .... ID No. of point, → direction of movement, –0.35 vertical movement in meters

Right and left flank:
Height of vertical displacement (upwards or downwards), horizontal displacement, expansion to the sides – presentation:


Transverse cracks and longitudinal cracks:

Openness and depth of cracks – presentation:

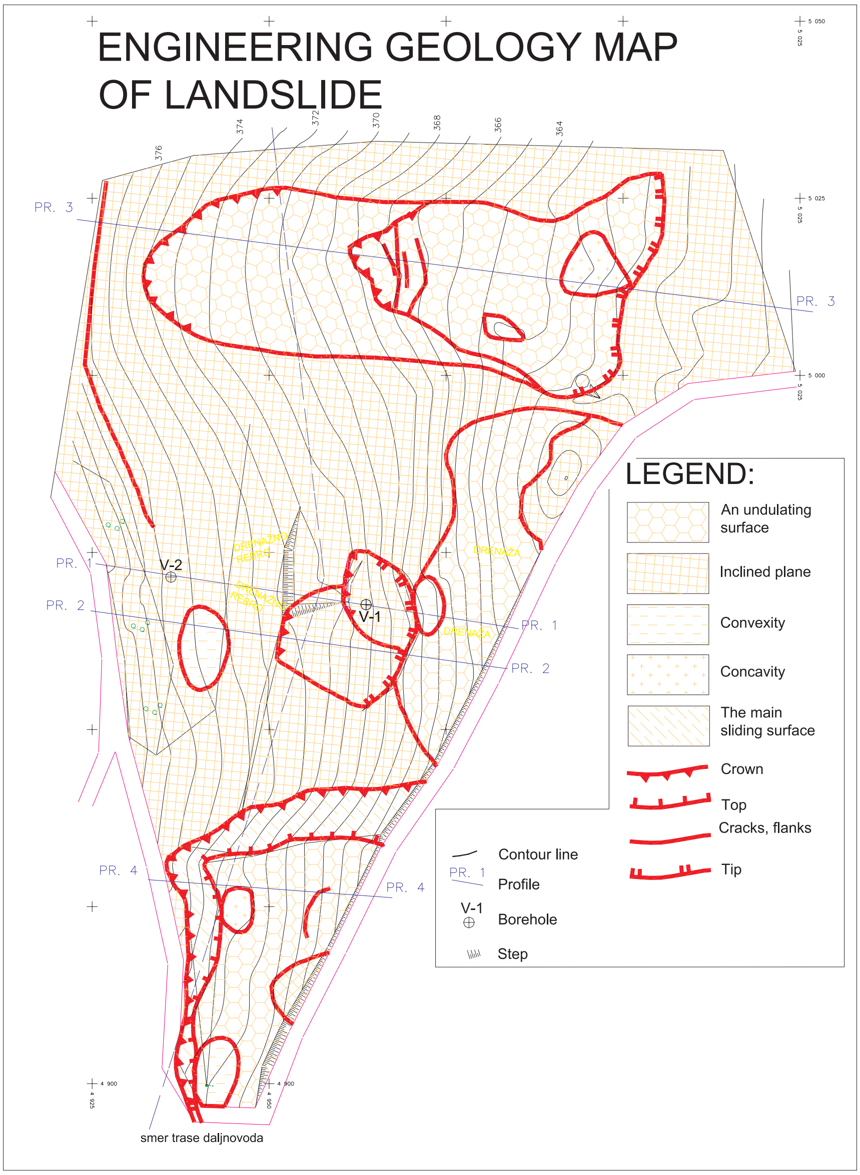



Similarly it can be presented also next landslide elements (units):

| | |
|---|---|
| Longitudinal ridge: | height of ridge |
| Longitudinal ditch: | depth of ditch |
| Step: | inclination of terrain above and under the step |
| Main sliding surface: | inclination of the sliding surface |
| Undulating surface: | distance between two concavities or convexities |
| Inclined plane: | inclination of the inclined plane |
| Convexity: | depth of convexity |
| Concavity: | height of concavity |
| Zone of accumulation: | height and superposing of the zone of concavity |

## Conclusion

When mapping old landslides, one no longer encounters fresh signs of landsliding, primarily expressed as lines, but blurred consequences of sliding which mainly appear as plane morphological forms. According to the procedure described in the paper, GIS is used to present these forms in separate information layers, thus supplying new information on landsliding, which is shown in the following picture.

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GEOLOGIJA *46/2,* 425–428, Ljubljana 2003

# GESTCO GIS and DSS – A GIS solution to assist with decision making for the geological storage of $CO_2$ from fossil fuel combustion

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*Key words:* GESTCO GIS, DSS, $CO_2$, geological storage, GIS

**Abstract**

This project aims to determine whether the storage of $CO_2$ underground, such as is taking place at the Sleipner West Gas Field, North Sea, can become a practical industrial solution to major $CO_2$ emissions into the atmosphere from large point sources such as power plants. If this is a practical proposition it could make an impact on the enhanced greenhouse effect caused by man emitting $CO_2$ into the atmosphere.

As part of the project a dedicated Geographical Information System (GIS) and a Decision Support System (DSS) have been developed. The GIS enables the user to view and analyse the large amounts of data collected, whilst the DSS enables emission – source – storage scenarios to be planned and cost evaluated. A webGIS was also set up to enable the project partners to view the progress of data collection and to assist with data checking.

## Introduction

Following the Kyoto climate conference in 1997 a consortium of 8 European national geologic surveys launched a project in 2000, spanning 3 years, which has studied the technical and economical feasibility of wide-scale application of $CO_2$ storage in the subsurface. This EU project was entitled "European Potential for Geological Storage of Carbon Dioxide from Fossil Fuel Combustion" (acronym GESTCO).

The EU Kyoto objective implies a reduction of 8% (relative to 1990) of the greenhouse gas emissions. This amounts to a reduction of approximately 600 million tonnes per year of $CO_2$ between 2008 and 2012. Power generation has the largest individual contribution of $CO_2$ emission and this amounted to 950 million tonnes in 1990. As nearly all fossil fuel power generation occurs at major facilities there is potential for CO2 capture and sequestration.

The GESTCO project has aimed to make a major contribution to the possibilities of reducing $CO_2$ emissions into the atmosphere by investigating whether geological storage of CO2, as is taking place at the Sleipner West Gas field, is a viable method capable of wide scale application. The GESTCO project

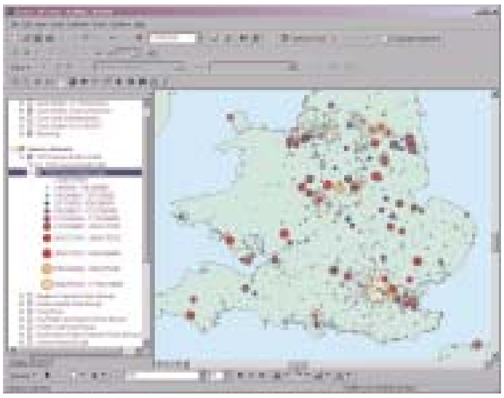

Figure 1. View of UK CO2 sources in the GIS

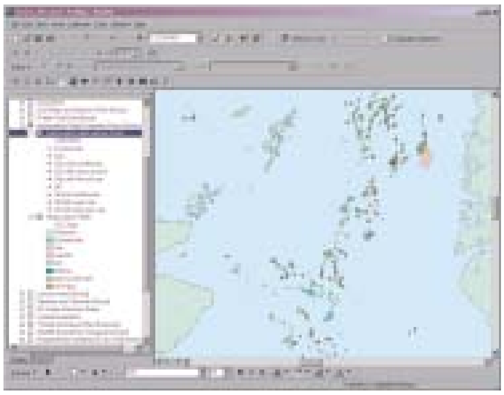

Figure 2. View of Hydrocarbon Field sinks in the North Sea

aims to provide documentation and data to show that for emission sources in key selected areas there is sufficient geological storage capacity.

A large amount of data has been collected from the participating countries (Belgium, Denmark, France, Germany, Greece, Netherlands, Norway and the UK) for use in the GIS and the DSS. An inventory of major $CO_2$ sources has been made and this data will be combined in the GIS with information on potential underground $CO_2$ sinks and potential $CO_2$ transport routes. Four main types of underground storage sites have been investigated, these being onshore/offshore saline aquifers, low enthalpy geothermal reservoirs, deep methane-bearing coal beds and abandoned coal and salt mines, and exhausted or near exhausted oil and gas fields. The participating countries have also researched several case studies. The DSS, developed through customisation of ESRI's ArcMap® using VBA, provides the tools for evaluation and comparison of the costs and economic risks of realistic combinations of $CO_2$ emission sources, transport possibilities and storage capacities for various scenarios input by the user, it takes into account all cost relevant parameters for sequestration, transport and storage of the $CO_2$.

## GESTCO GIS

The objective for the GESTCO GIS was to produce a Geographical Information System that would incorporate the wide range of data provided by the project partners and allow the partners and end-users meaningful access to the data. The GIS allows users to simultaneously view one or more layers of data including the location of the $CO_2$ sources and possible $CO_2$ sinks, it will also enable the user to perform extensive on screen analysis on all the available data. Geoscience datasets included in the GIS comprise aquifer injection points and aquifer area location, hydrocarbon field injection points and hydrocarbon field locations, coal mines, coal field and coal field injection points as well as the locations of the $CO_2$ sources, existing pipelines and pipeline terminals. Many other datasets have also been provided to enhance the capabilities and information held within the GIS, for example geological, tectonic zone and ecosystem data.

### *$CO_2$ Sources*

The $CO_2$ sources database was built by EcoFys from data provided by the project partners. The database incorporates a large amount of data including information on the location, emission and sector (power, chemical etc). The data is then converted into shapefile format for visualisation within the GIS as a point dataset with scale rendering to give users an immediate view of the size of emissions.

### *CO2 storage (sinks) datasets*

These datasets, which include the aquifer injection points, hydrocarbon field injection points and coal field injection points were collated from data provided by each partner. The data incorporates information on the storage capacity for $CO_2$, depth, pressure and porosity of the sink. The hydrocarbon field injection points database was built by TNO whilst the other datasets were provided as shapefiles by each partner and merged into single datasets by the British Geological Survey (BGS).

To provide access to additional information, held within the websites of the Geological Surveys involved, along with other websites, links to external websites have been set upwithin the GIS.

The GIS, which has been developed using ESRI's ArcGIS®8.2 software, uses ArcMap, whilst the datasets, which were initially provided in shapefile or Excel format, are stored within a personal geodatabase which uses Microsoft Access. The personal geodatabase enables the storage of all the datasets in a single location which makes transfer of the GIS data from one location to another much easier. This is a very important requirement for the GIS, as well as the DSS, as it is necessary to ensure the systems are easily transferable to the project partners and the end users on completion of the project. To assist in the ease of this transfer process the GIS has also been set up using relative pathnames which ensures that the GIS will always pick up the location of the datasets.

There has been some customisation of the GIS to allow users, who are unfamiliar with the GIS environment, to use the system more effectively. This customisation has taken place using ESRI ArcObjects within the VBA environment. The main customisation has been to develop a selection tool that will allow users to select from within the datasets based on the $CO_2$ emissions or $CO_2$ storage capacity. This tool also allows the user to save their selection as a new shapefile should they wish to keep it for further analysis.

Copyright information is also a feature of the GIS. Users must agree to abide by the copyright of the data before the GIS will open fully and there is also the ability to access the copyright information from within the GIS should users wish to read it again.

*Case study data*

Many case studies have been carried out for the project and the data from these has been included in the GIS. As this data has been provided in many different formats and is specific to particular case studies this data has not been merged into single datasets as with the general GIS datasets. There are many maps and diagrams that have been provided for the case studies, as it is highly useful to be able to view such maps, diagrams and seismic profiles, from within the GIS, hyperlinks have been set up. This enables the user to click on a feature with the hyperlink tool and view any maps or documentation associated to the feature.

*GESTCO WebGIS*

It was decided that the best way to allow the project partners and end-users to monitor the progress of the data collection was to set up a web-based GIS system. The GESTCO webGIS was developed using ESRI's ArcIMS® software, which allows the easy dissemination of GIS data over the internet. The webGIS does not have the full functionality of the GESTCO GIS, however it does allow users to view the datasets on screen and perform simple queries on the data. The webGIS also became a very useful resource towards the end of the project when it was used by the project partners to do the final checks on the data they had provided in the preceding 3 years.

## GESTCO DSS

As part of the project The Netherlands Institute of Applied Geoscience TNO, one of the GESTCO participants has developed a decision support system. This DSS calculates costs and economic risks of realistic combinations of $CO_2$ emission sources, transport possibilities and storage capacities for each of the selected areas.The DSS is founded on ArcView®8.2 extended with Spatial Analyst. The end user interfaces with ArcView®8.2 and defines a removal scenario by selecting a $CO_2$ source and a storage location (sink).

After scenario composition, Spatial Analyst will determine the least costly transport route. For this ArcView®8.2 is fed with data which expresses costs related to pipeline construction; costs determined by aspects like land use, elevation, artificial and natural barriers, existing pipeline corridors are added in grid format so that Spatial Analyst can take these into account when searching for the optimal route.

Once the scenario is completed with an optimal routing between sources and sink, calculation models will kick in and evaluate remaining technical and economical aspects of the problem definition: the costs for $CO_2$ separation at the source is calculated, the size of the $CO_2$ flow in time from source(s) to sink is used to calculate the needed dimensions of pipelines and the number of compression stations along the route. Storage models will evaluate the chosen sink on volumetrics (pore volume, compressibility, sweep efficiency) and injectivity behavior (fluid mobility, injection rate, number of needed wells). These calculation models are implemented outside ArcView®8.2 and coupled as Dynamic Link Libraries.

When all calculations are finished, the results are gathered within ArcView®8.2 and the whole scenario evaluation will be presented to the end user in numbers and graphs. And, of course, the chosen route is geographically mapped. The end user will get an answer on whether it is technically possible to separate, transport and store an amount of $CO_2$ over time and how much such a scenario will cost.

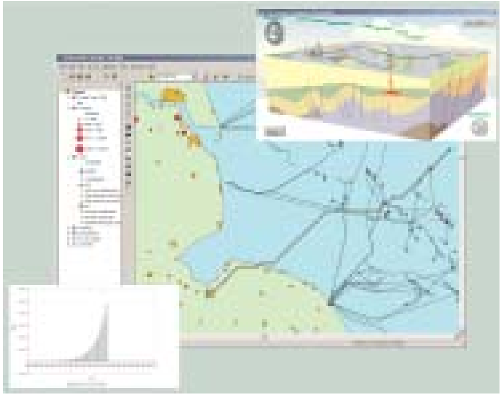

Figure 3. Gestco DSS

## Conclusions

This project has enabled the development of two highly useful systems that should prove invaluable in the decision making process with regards to possible $CO_2$ sequestration.

The data collected is a valuable resource and the GIS provides the best interface for accessing and viewing the data. The DSS has been the vehicle that comprises many of the geoscientific and economical study results that were gathered during the GESTCO project. Although it should be viewed upon as a prototype, it is already being used in other projects. Several assumptions and simplifications were made for the sake of implementation. As with many DSS systems the results of a scenario run will not result in deadly accurate figures. The results should be applied as selection criterion for many different scenario runs. The DSS aims however to provide insight in the power of costs that are at hand when dealing with $CO_2$ sequestration.

It is the intention to continue to develop and maintain these systems within future projects relating to $CO_2$ sequestration.

## Acknowledgments

The authors would like to acknowledge the project co-workers from GEUS (Geological Survey of Denmark), BGR (Federal Institute of Geoscience and Natural Resources Germany), BGS (British Geological Survey), BRGM (Geological Survey of France), GSB (Geological Survey of Belgium), IGME (Institute of Geology and Mineral Exploration Greece), NGU (Geological Survey of Norway), NITG-TNO (Geological Survey of The Netherlands) and EcoFys Environment and Energy for the work done to provide the data included in the GIS and DSS.

This paper was produced with the kind permission of the Director of the British Geological Survey.

GEOLOGIJA *46/2,* 429–434, Ljubljana 2003

# SMART oilfield GIS: Application of GIS for economic and environmental monitoring of oil and gas fields

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*Key words:* SMART, oilfield application, GIS

**Abstract**

TNO-NITG has recently developed an extensive exploration and production (E&P) database system, thereby providing a practical and very cost-efficient alternative to the systems existing on the market. Two different approaches were taken: one using licensed software with built-in components, and another using open source software. In this article the merits of both approaches are discussed.

## Introduction

With ever growing possibilities in data gathering, processing speed and storage capacity, the amount of information that can be derived from oil or gas field data has grown enormously over the past decades. A few vendors developed software systems capable handling these complex data streams and their relationships. However, due to the complexity of matters to deal with, they are expensive with respect to the costs of their license and maintenance. At the same time these systems suffer from the 80-20 syndrome: only 20% of the functionality is used while the remaining 80% contributes to the total product costs. This jeopardizes the effectiveness of the users' software investments.

TNO-NITG, being the National Geological Survey of the Netherlands, has developed an E&P database and GIS application that can compete with this off-the-shelf software in functionality and speed. At the same time TNO-NITG žs system is cost-effective with respect to development costs, maintenance and customisation. It is a flexible, scalable solution for managing a wide range of information on exploration and production activities of a company, as well as environmental monitoring data. Two national oil companies have already been using this new E&P database system.

## System Design

The distinguishable features of the systems are the open source and modular structure. Thanks to these, the system is highly customisable to meet the requirements of a particular client and it is easy for the customer to maintain the software.

The E&P system includes three main modules:

- E&P Data Manager (the core database management module)
- E&P Reporter (intelligent tool for data mining and flexible reporting)
- E&P Spatial Modeller (E&P GIS)

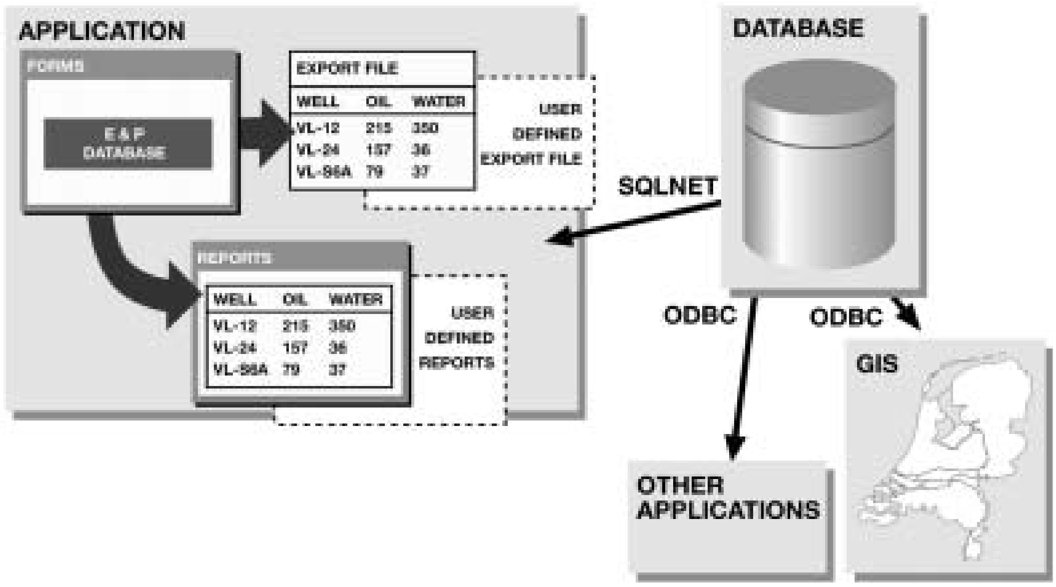


Figure 1. E&P Data Manager

## E&P Data Manager

The E&P Data Manager (Figure 1) module includes:

- E&P DATABASE management system with POSC-compliant database model
- E&P FORMS for data input and analysis
- E&P REPORTS for creating standard reports of company activities

The most important component of the E&P Database management system is the TNO-NITG's E&P data model, which comprises all aspects of the E&P enterprise. The TNO-NITG model is based on a subset of the Petrotechnical Open Software Corporation's (POSC) Epicentre data model, which allows users to store and extract all forms of data and metadata related to E&P: seismic, petrophysical, geological, reservoir engineering, well, borehole, facility, pipeline, rock and fluid sample, and field data.

An added benefit is that the database can be easily integrated with other software. Users can thus get hold of any relevant E&P data when performing supplementary analyses or drafting reports on particular topics. The types of data that might be of interest for such purposes are statistics or facts and figures about hydrocarbon production and contouring.

The system also incorporates an authorisation function with respect to users. They are assigned specific roles for specific groups of data. This distributes the responsibility for the import and quality control of the groups of data among various users. The E&P database manager is responsible for the referential and application data, and therefore also for the user roles

## E&P Reporter

TNO-NITG has extended the E&P database's functionality by incorporating Oracle Discoverer into the system. Being an intelligent tool for data mining and flexible reporting, the new E&P module is of particular interest to geo-scientists and production engineers involved in the analysis of oil and gas field performance (Figures 2, 3,4).

The module gives the E&P database a number of additional advantages relative to other oilfield management systems. For example, a new report can be created via dialogues similar to those in Windows Explorer. This makes it quite simple for an oil specialist to create a new report tailored to personal requirements and spares the user from having to learn the complex relational data-

**WELL STRATIGRAPHY**

Page Items: Area name: TA-58 ▾ | Wellname: [illegible] ▾

| | Top Depth | Bottom Depth | Thickness | Stratunit nm | Age | Stratunit Par nm |
|---|---|---|---|---|---|---|
| 11 | | | | Seal | | Average water saturation |
| 12 | | | | Seal | | Average Porosity |
| 13 | 1178 | 1208 | 30 | T2-Sand | Paleocene | Average Porosity |
| 14 | | | | T2-Sand | | Average water saturation |
| 15 | | 1247 | 69 | T-Sand | Paleocene | PorosityFeet |
| 16 | | | | T-Sand | | Porosity feet |
| 17 | | | | T-Sand | | Net feet |
| 18 | | | 69 | T-Sand | Paleocene | HC feet |
| 19 | | | | T-Sand | | Estimated liquid |
| 20 | | | | T-Sand | | Average water saturation |
| 21 | | | | T-Sand | | Average Porosity |
| 22 | 1219 | 1247 | 28 | T1-Sand | Paleocene | Average Porosity |
| 23 | | | | T1-Sand | | Average water saturation |

Figure 2. Analysis of well geology

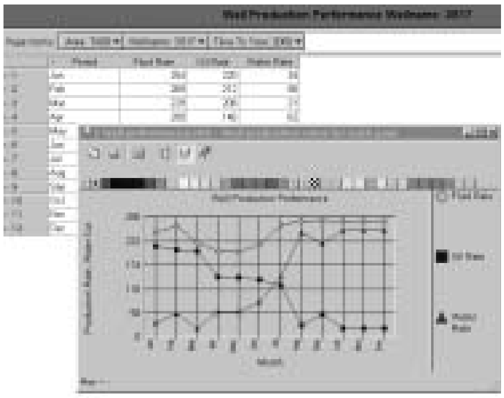

Figure 5. Well productivity analysis by means of E&P Reporter

**TOTAL THICKNESS OF STRATIGRAGHIC UNITS PER WELL**

Page Items: Area name: TA-58 ▾ | Wellname: 35131 ▾

| | Stratunit nm | Layer thickness |
|---|---|---|
| 1 | Seal | 54 |
| 2 | T-Sand | 39 |
| 3 | T1-Sand | 9 |
| 4 | T2-Sand | 9 |

Figure 3. Netto sand thickness calculations per well

**Monthly Oil Production per Field**

Page Items: Abbr of the area: BS ▾

| | Date | Wellname | Oil Production |
|---|---|---|---|
| 90 | **Sep-1992** | SS062 | 669 |
| 91 | | Z20 | 959 |
| 92 | | Z25 | 1,092 |
| 93 | | Z151 | 512 |
| 94 | | Z181 | 928 |
| 95 | | Z19 | 309 |
| 96 | | | **Sum: 4,459** |
| 97 | **Oct-1992** | SS062 | 701 |
| 98 | | Z19 | 346 |
| 99 | | Z181 | 959 |
| 100 | | Z151 | 530 |
| 101 | | Z25 | 1,153 |
| 102 | | Z20 | 855 |
| 103 | | | **Sum: 4,544** |

Figure 4. Monthly Field Production Report

base structure. Once a report has been produced it can be shared with other colleagues.

As Discoverer reports have an Excel-like interface, their contents and layout can be easily customised by users, including field geologists and production engineers. The extremely flexible report construction tools allow for in-depth data mining that employs the end-user's professional expertise. Moreover, the use of dynamically updated graphics significantly simplifies the analysis of production and geological data. All in all, the module has proved itself to be an effective tool for data quality control. Finally, the module can export the E&P data to a large number of external formats (incl. ASCII, Excel and HTML) enabling more sophisticated oilfield analysis using advanced computer simulators (Figure 5 & 6).

### E&P Spatial Modeller (Oilfield GIS)

The GIS module stores information about oil and gas fields as a collection of thematic layers that can be linked together by geography. It is able to visualise the geo-referenced data stored in the E&P database and automatically update the information each time while opening a new session. Moreover the module enables selecting geographically (interactively on the screen) and updating the environmental and field operation data whenever it is necessary (Figure 7).

The module allows mapping both technical and environmental data as well as studying relationships between contamination and

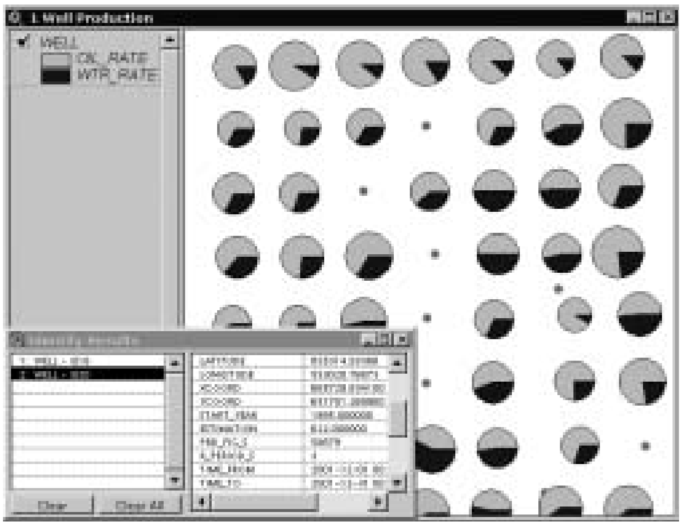


Figure 6. Well map showing oil/water production rates. *The radius of the circles is proportional to the fluid production rate for each well. The exact data on a particular well can be obtained by clicking at it with a mouse.*

facilities (Figures 8-9). Furthermore, multispectral satellite and airborne images integrated into the GIS module can provide a company with independent information on environmental changes in the production area (Figure 10). The integrated Web-technologies make the Oilfield GIS a perfect tool both for environmental self-audit within the company as well as for reporting on the environmental performance to the government or public.

## Prospect development towards SMART E&P

The approach discussed above is based on extensive use of conventional, licensed software components. However, not every E&P company has the same set of requirements with respect to the complexity of the analysis wanted, the software development budget and the like. With the growing amount

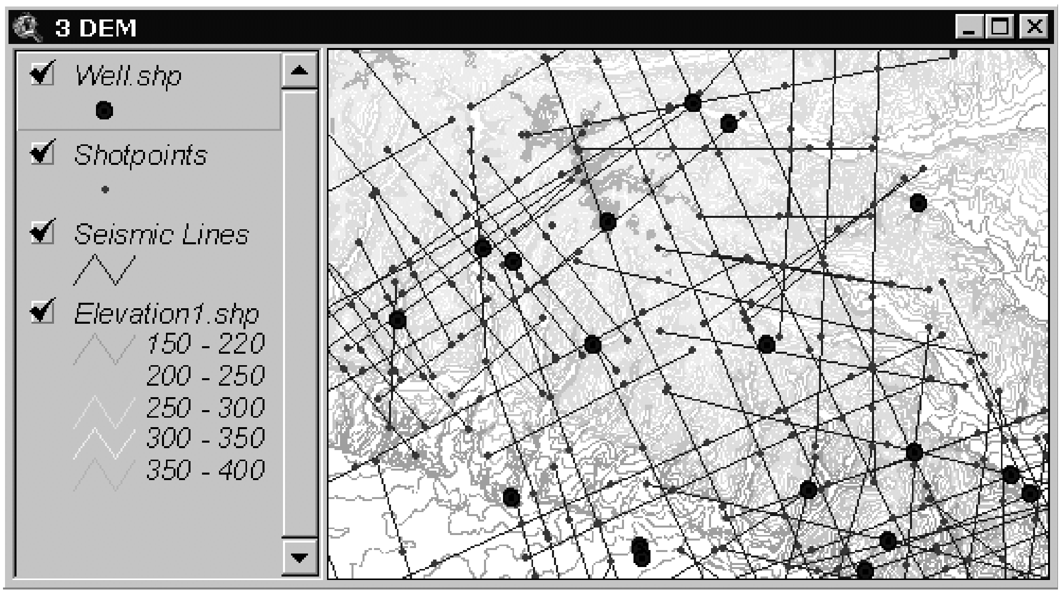


Figure 7. Well map combined with a few survey maps as well as digital elevation model (DEM)

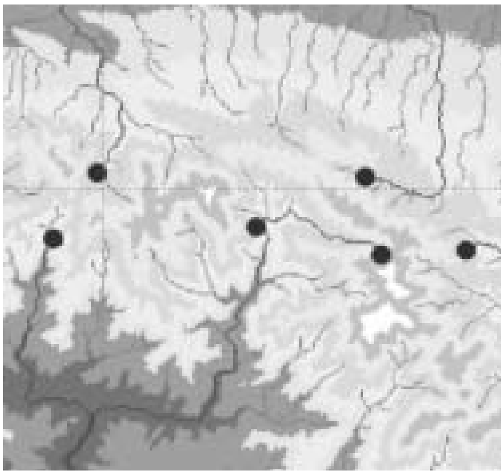

Figure 8. Defining surface water streams that can be potentially effected by oil spill from the wells

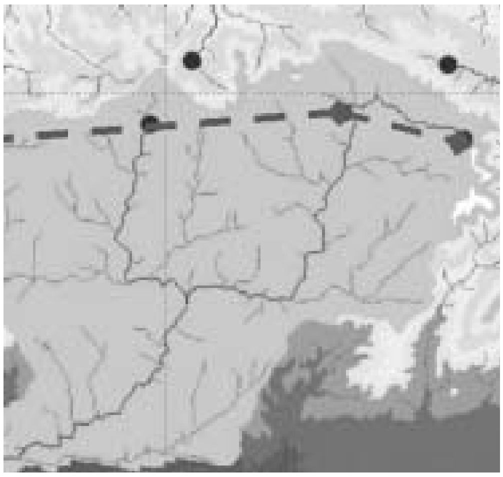

Figure 9. GIS modelling of potential environmental risks from pipelines

of open source software projects, other software customisation and implementation approaches came within reach. The TNO-NITG solution comprises a template CORE E&P database whose generic data model is applicable throughout the oil and gas industry and easy to customise (Figure 11 & 12).

SMART E&P is a trajectory that involves local people in customisation, maintenance, and upgrading of the CORE E&P database system. In this approach the software is to be developed in mixed teams of TNO-NITG consultants and trainees using open source software for the database, the GIS and the application server. When desired, the use of licensed software like Oracle and ESRI is also possible.

In the course of time, TNO-NITG's involvement decreases to zero, while the level and involvement of the local trainees increases. In this way, former trainees can do the maintenance, future customisation and training completely on their own. As the result, both the responsibility for data and the

Enhancement scenarios on TNO-NITG's CORE E&P database

| | Open source software |
|---|---|
| Development by TNO, including training | **SMART E&P** |
| Development exclusively by TNO | **CUSTOM E&P** |

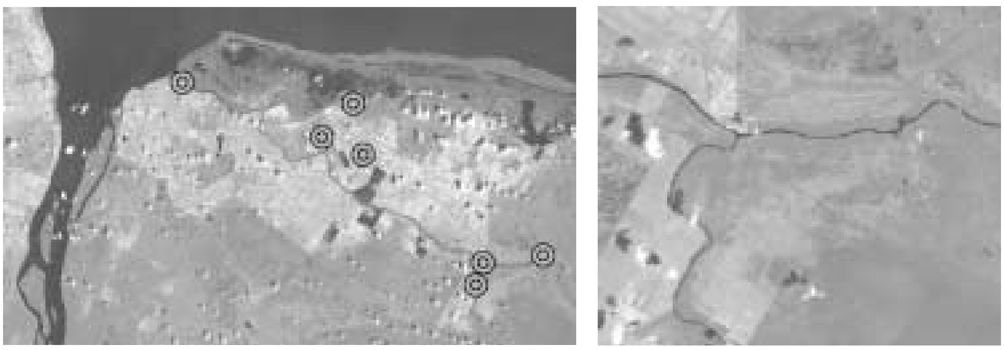

Figure 10. Environmental management by means of GIS and remote sensing

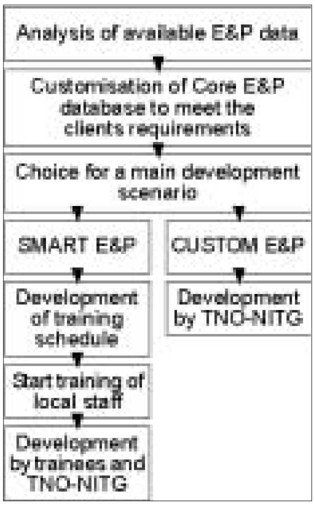


Figure 11. Workflow diagram

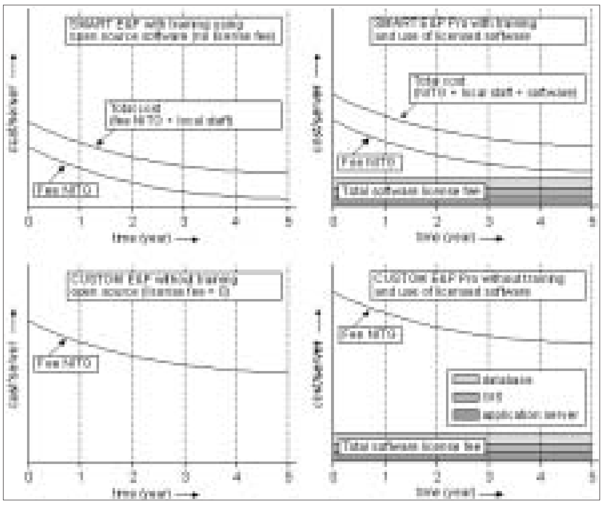

Figure 12. Cost trend for the four enhancement scenarios on TNO-NITG's CORE E&P database. *Note that the costs of the customisation of the CORE E&P database are not included.*

means to transform this data into crucial information are in the hands of their owner – the client.

The proposed scenarios are listed in Table 1, while a schematic project workflow is illustrated in shows cost trends for development and maintenance for the different scenarios.

## Conclusion

The modular structure of the E&P database allows a customer to select only necessary elements of the application and customise them according to his particular needs. This significantly enhances the efficiency of the investments into the software. Moreover all modules of the standard E&P System are based on conventional software components, such as Oracle Server, Oracle Discoverer and ARC GIS (ESRI). Thus the licenses existing in a company can be used.

Alternatively a Smart solution can provide similar functionality using open source software components. This cuts license costs, however can increase expenditures for development and implementation. This disadvantage can be compensated by involvement of less costly, though not less professional personnel on a client site. The local personnel granted the E&P application source would be capable to further maintain and extend the core application.

GEOLOGIJA *46/2,* 435–438, Ljubljana 2003

# GeoHazardView: Interactive presentation of geological hazard maps

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*Key words*: Geological hazard map, GIS, East Asia, Japan

**Abstract**

This paper presents an interactive method of showing geological hazard maps and other related information using the software developed at the Geological Survey of Japan. The main purpose of the software is to easily provide information about geological hazards. In this paper, the region of interest is East Asia. The software provides a good alternative to viewing geological hazard maps and other related information in paper form. It incorporates spatial and a-spatial data to interactively present the time, locations and extent of occurrence of geological hazards and other related information. Queries for a particular hazard information like number of casualties, magnitude and location of earthquake epicenters, names and locations of volcanoes erupted in a particular year can be easily done. Simulations of the occurrence of a particular geological event like the spread of volcanic ash during major volcanic eruptions can also be shown. The new software is named GeoHazardView.

## Introduction

Studying geological hazard is very useful in mitigating the loss of human lives and properties brought about by the occurrence of the phenomena. Geological hazard maps are generally used to provide information about the occurrence of the geological hazards in the past and their potential occurrence in the future. The maps are used by planners and policy makers for national and regional development to minimize the potential waste of resources committed for development and the loss of human lives due geological hazard occurrence.

Information obtained from the conventional geological hazard maps are not always sufficient to provide the users with their data needs. The difficulty of presenting more relevant information in geological hazard maps in conventional paper forms is due to the limited physical space available in this format. Printing more information in this paper maps has the tendency of confusing rather providing more information to the users. Furthermore, these kinds of maps provide little opportunity for the users to make queries for additional information. Geological hazards generally have important temporal attributes. Presenting these attributes in the map, like the sequence of volcanic eruptions in a region or the frequency of the occurrence of earthquake in a particular area during a particular period of time is very difficult. Presenting these kinds of information very clearly requires the printing of a series of maps.

The conversion of maps into digital format and the linking of the maps' information to other related data in a GIS is very advantageous. Through this, the information on the maps can be easily accessible to policy makers or users for decision making and other application such as education, research and exploration (Champati, 2000). This paper shows a system of presenting geological hazard map in East Asia in an interactive way using a GIS software. The paper version of the map was published in 2002 (Kato, 2002). The software was developed at the Geological Survey of Japan to interactively present geological hazard information and to manage and maintain the geological hazard database. Important information can be easily queried using the software and simulation of important geological hazard phenomena can be easily shown on-screen. The software is called GeoHazardView.

## The Software

The GeoHazardView software was written using the Microsoft Visual C++ programming language at the Geological Survey of Japan. The main purpose of the software is to inform the user about geological hazard. It is designed to be user friendly and can be operated in a "straightforward point and click operation". Users who don't have technical knowledge of geology can easily use the software. Considering the dynamic nature of the geological hazard, the software can also be used to manage and update GIS based geological hazard information database.

The types of geological hazard handled by the software are volcanic, earthquake, tsunami and landslide hazards. Figure 1 shows the flowchart of the GeoHazardView software. It shows the major components of the software and the different decision nodes and possible software courses of actions depending on the decision path chosen by the user. The software uses unique database formats for its spatial and a-spatial information. They can however be converted to other formats compatible to the mainstream GIS softwares.

The software uses the geological map of East Asia as the base map. Geological hazard information are spatially referenced together with the map. Spatial queries can also be done using the base map. Important geological hazard symbol displayed over the base map can be easily double clicked to extract more information about the hazard symbol.

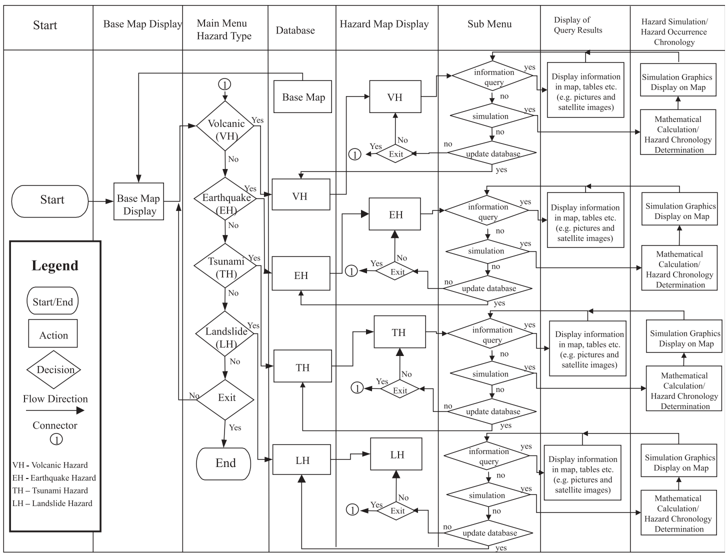


Figure 1. The flowchart of the GeoHazardView software.

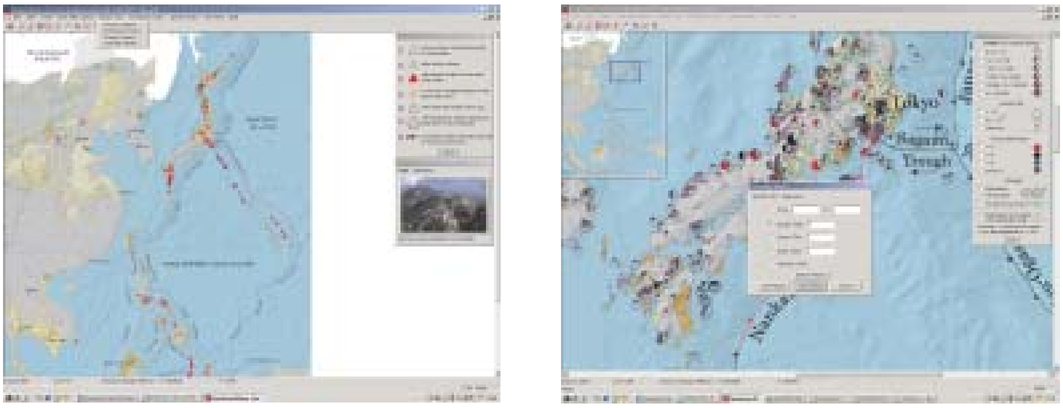


Figure 2. GeoHazardView in volcanic hazard mode.

### User Interface

The user interface of the software is typical of a GIS software running under Windows operating system as shown in Figure 2. The tool bar includes buttons to control the zoom factor, zoom box and panning of the hazard map. The choices for the geological hazard types, information queries and other important features of the software can be found on the menu bar. The legends of the hazard maps are also interactive. Figure 2 shows the volcanic hazard map. The figure shows an interactive legend where symbols on the legend can be clicked to show the locations of the volcanoes on the map represented by the symbol. Viewing the simulation of the ash distribution from the major volcanic eruptions in the region can also be done using the legend. The picture of a volcano can also be viewed by pointing the mouse on the volcano's location on the map. Double clicking the location will result in the display of the information of the volcano including its enlarge picture and satellite image if they are available.

### Information Queries

Interacting with the geological hazard database is possible using the software. Queries for a particular hazard information like number of casualties, magnitude and location of earthquake epicenters, names and locations of volcanoes erupted in a particular year can be easily done. Search parameters can be defined using search dialog boxes to extract the needed information in the database. The result of the query can be readily shown on the map and pictures and satellite images can be viewed on-screen. Figure 3 shows an example of a dialog box used for extracting information in the geological hazard database. The figure shows the search for earthquake epicenters with magnitude greater than 7.00. The result of the operation will be shown on tables and the earthquake epicenters will be highlighted on the hazard map. The date of hazard occurrence query is also possible using the software. Through this, the location of the hazard occurrence on the map in a chosen date will be highlighted.

### Hazard Occurrence Chronology

One of the most important features of the GeoHazardView software is its capability to show the geological hazard occurrence chronology on the spatial context. It can be set to automatic mode to continuously show locations of hazard occurrence in a chosen range of years in the past. The continuous increment of years will also show changes of the locations of the hazards on the map. The speed of the hazard occurrence chronology show can also be adjusted. Figure 4 shows an example of the show. The volcanoes erupted on the year 1821 are highlighted on the hazard map. The detailed information about the volcanoes that erupted on that year can be easily

Figure 3. Querying geological hazard information in GeoHazarView.

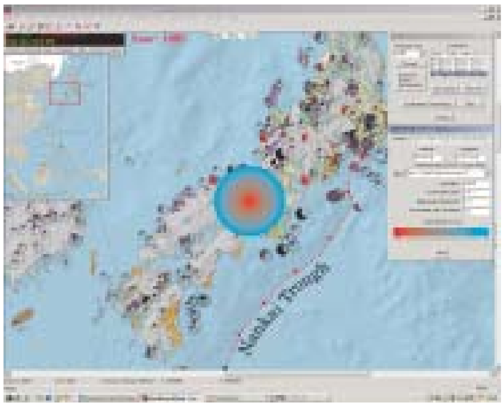


Figure 4. Geological hazard occurrence chronology show.

viewed by choosing the volcano on the list on the dialog box on the right side of the screen. The Figure also shows the epicenter of the Kobe earthquake on January 17, 1995. The details of the earthquake information including the earthquake magnitude scale are shown on the dialog box on the right side of the screen.

## Summary

The interactive presentation of the geological hazard map using GeoHazardView software provides a good alternative of viewing geological hazard maps and other related information in paper form. The ease by which geological hazard information can be obtained and the ability of the system to present information in the spatial context makes the software very useful to a wide range of users. It can be an important source of information for land use planners and policy makers and a good teaching material for elementary and high school science classes. The software will be continuously improved adding additional important features in its future versions.

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GEOLOGIJA *46/2,* 439–444, Ljubljana 2003

# Comparison of the CORINE Land Cover data and Agricultural Land Use Monitoring Data as a basis for groundwater vulnerability mapping in the Peca border region

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*Key words:* groundwater vulnerability estimation, CORINE, GIS

**Abstract**

In the article the land use data analysis as a basis for groundwater recharge area protection and vulnerability estimation in the region of Peca is represented. The area is positioned on the Karavanke mountains border region between Slovenia and Austria. Preliminary results of Slovene part are presented in the article.

This paper wants to show usefulness of CORINE Land Cover (CLC) and major differences in results between CLC and more detailed data of Agricultural Land Use Monitoring (ALUM). Differences between results of both datasets are minor on first level of categorization especially when it comes to two most prevailing categories, but much bigger on next levels of more detailed nomenclature. Some categories are even not detected by CLC dataset.

By both methodologies on first level of nomenclature forest is far prevailing land use category covering 78 (CLC) and 81 % (ALUM) of the area followed by agricultural land with about 16% (CLC) and 17 % (ALUM). Differences important for groundwater vulnerability study occurred in artificial areas with 2 % (CLC) and 3,9 % (ALUM) surface.

## Introduction

In the recent past natural resources became important not only as natural and economical wellness but also as an integral part of the environment that must be protected from the anthropogenic influences. Among them water resources are of paramount value. To study and prepare the data for groundwater vulnerability land use analysis is important part of the estimation process.

Land use reflects a complex correlation between natural (slope, altitude, exposure of slopes of the surface area), historical (such as characteristics of settling, economic conditions in the past, land ownership situation...), and socioeconomic factors. It constantly changes, which is reflected in the changing of land categories or/and their relative proportions (Gabrovec & Kladnik, 1997).

The land use study has been performed in the border Karavanke mountain region of Peca between Austria and Slovenia. The main goal of the land use analysis has been to prepare data for vulnerability mapping of the carbonate aquifer of Peca and its wider area in east Karavanke region. The aquifer represents a major and very important drinking water source for area on both sides of the border. Due to its karstic characteristics it is considered to be very vulnerable and land use is an important indicator of its potential pollution sources.

## Geographical Settings

The area belongs to Alpine region and is positioned on the Karavanke mountains border region between Slovenia and Austria. It partly lies in three municipalities Črna na Koroškem, Mežica and Prevalje. On its west it is limited by river Koprivna, on south the border of the area follows river Meža, the most important river in the area, up to north to Poljana and further on to the Austrian-Slovene border crossing at Holmec.

It covers 64 km$^2$ and shows big topographical differences on short distances. It is mostly mountainous except of northeastern and south plain parts. Altitude reaches the highest point in Peca mountain crest on 2125 meters (Kordeževa glava) and the lowest on 435 meters in east part. An average altitude is 998 meters. Average slope value is 25`, but there are big differencies betweeen individual parts. The highest slope values are in Peca mountain crest and also in south near settlement Žerjav, where they reach even 50`. Plain surface is present in east and northeast of the area, which is also suitable for agriculture. The rest of the surface is covered mostly by forest.

There are 10 settlements, except of Mežica with 3656 inhabitants, all minor villages. Alltogether there are about 5230 inhabitants (MOPE, 2002).

## Data

We decided to use CORINE Land Cover (CLC) as basic dataset for whole region and Agricultural land use monitoring data (ALUM) for comparison and reference data set.

*CORINE Land Cover Slovenia (CLC)*

The CORINE Land Cover (COoRdination of INformation on the Environment) programme was established by the European Commission in 1985 aiming at »gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the European Community«. The aim was therefore to create for the first time in Europe a spatially referenced Land Cover database following a single standardized methodology (European Commission Phare Programme, 2000).

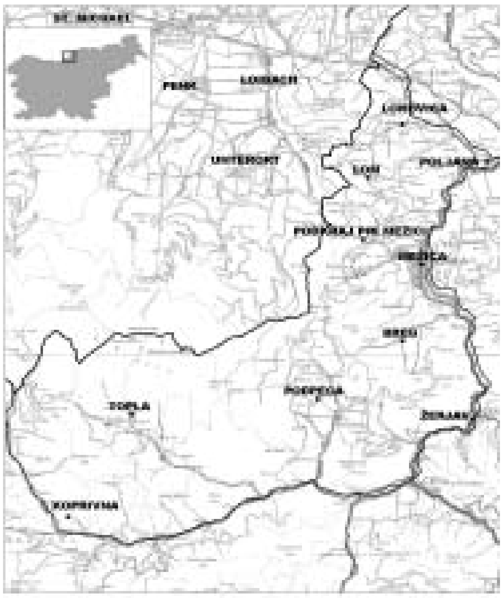


Figure 1: Area of interest

CLC Slovenia is a digital land cover database of the country; consistent and comparable with the other land cover databases in the Phare countries (Petek, 2002).

The most frequent domain of CLC data usage appeared to be environmental, land and spatial planning, followed by general mapping. It is also used in many other specialized areas (nature conservation, water management, soil, air, meteorological and geological studies). CLC data are often used for the enhancement of existing models or the development of new ones. In combination with other data sets constitutes a very important input to integrated environmental analysis, evolution studies, evaluation of pressures and trend analysis (European Commission Phare Programme, 2000).

CLC nomenclature is divided into three levels:

- First level: 5 headings
- Second level: 15 headings
- Third level: 44 headings

*Agricultural land use monitoring data (ALUM)*

Ministry of Agriculture, Forestry and Food of Republic of Slovenia made the dataset. The objective was the creation of a database of agricultural land use, including the definition of data maintenance and methods of application for specific assignments imposed to the Ministry of Agriculture, Forestry and Food. It also includes the addition of agricultural and forest land use to parcels in the Land Cadastre database. The merging of the Land Cadastre data layers with the data layer of land use will make possible the administrative control of subsidy applications for subsidies based on agricultural land area. The acquired land use data will also be applied in creating the Farm Register, the Permanent Plantation Cadastres (vineyards, orchards, olive groves and hop fields) and in other assignments related to the implementation of the agricultural policy.

The methodology divides land use into 7 main categories on four levels, but focusing on agricultural land, which is the main disadvantage of the methodology for many users. Agricultural land is divided into four levels and is very detailed while other categories are considered »less important« and are divided only into three or two levels.

In our area agricultural land is divided on all four levels, while other categories are not divided into any subcategories.

## Other data sets

In the past there were several different approaches and methodologies to land use surveys in Slovenia. The basic source in undertaking land use studies used by most authors in the past was the data maintained by the Surveying and Mapping Authority of Slovenia. The data are assembled on the basis of cadastral records showing current situation in all the cadastral municipalities. But considering the fact that the data is not updated regularly it is obvious that it does not show up-to date situation. This is the main disadvantage of the data. Land use is recorded on a parcel. The dominant use of the parcel is the one the database collects no matter the fact that there are mixed categories in most of parcels. The second most used database is statistical data maintained by Statistical office of Slovenia. In our opinion these two datasets do not meet needs of the study.

## Methodology

GIS tools (Arc View 3.1.) were used. The method of intersecting or overlaying layers was chosen. Some basic descriptive statistic analysis were obtained for determination of locations, percentages and sizes of individual land categories. Datasets have been geocoded and put in digital cover polygon format.

## Analysis and Results

*CORINE Land Cover Slovenia (CLC)*

In the area of Peca there are three major land use categories of CLC present:

- Artificial surfaces
- Agricultural areas
- Forests and semi-natural areas

Wetlands and Water bodies categories are not defined.

The categories of first level categorization are presented in the figure 2.

On the second level they are divided into seven land use categories:

1.1. Urban fabric
1.2. Industrial, commercial and transport
2.3. Pastures
2.4. Heterogeneous Agricultural areas
3.1. Forests
3.2. Shrub and/or herbaceous vegetation associations
3.3. Open spaces with little or no vegetation

On the third level they are divided on the following categories:

1.1.2. Discontinuous urban fabric
1.2.1. Industrial or commercial units
2.3.1.Pastures
2.4.2. Complex cultivation
2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation
3.1.1. Broad-leaved forest
3.1.2. Coniferous forest
3.1.3. Mixed forest
3.2.2. Moors and heath land
3.3.2. Bare rock
3.3.3. Sparsely -vegetated areas

Table 1. Table of proportions and sizes of CLC categories

| Classification 1st level | Classification 2nd level | Classification 3rd level | Area [km$^2$] | Share [%] |
|---|---|---|---|---|
| 1. Artificial surfaces | 1.1. Urban fabric | 1.1.2. Discontinuous urban fabric | 1,22 | 2 |
| | 1.2. Industrial, commercial and transport | 1.2.1. Industrial or commercial units | 0,06 | < 0,1 |
| 2. Agricultural areas | 2.3. Pastures | 2.3.1. Pastures | 5,33 | 8,3 |
| | 2.4. Heterogeneous Agricultural areas | 2.4.2. Complex Cultivation | 0,12 | 0,18 |
| | | 2.4.3. Areas principally occupied by agriculture, interspersed with significant natural areas | 5,32 | 8,32 |
| 3. Forests and semi-natural areas | 3.1. Forests | 3.1.1. Broad leaved forest | 2,39 | 3,7 |
| | | 3.1.2. Coniferous forest | 30,04 | 47 |
| | | 3.1.3. Mixed forest | 12,66 | 19,8 |
| | 3.2. Shrub and/or herbaceous vegetation associations | 3.2.2. Moors and heath land | 5,16 | 8,1 |
| | 3.3. Open spaces with little or no vegetation | 3.3.2. Bare rock | 0,46 | 0,7 |
| | | 3.3.3. Sparsely vegetated areas | 1,18 | 1,8 |

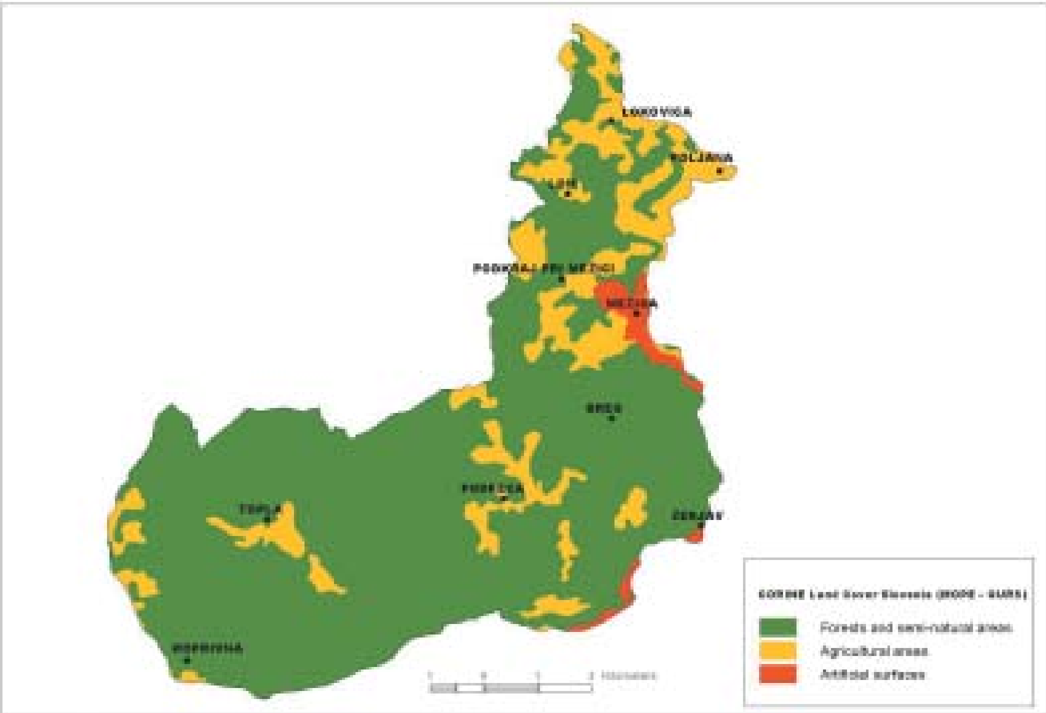


Figure 2: CLC Slovenia (MOPE-GURS, 2002) - Categorization on 1st level

It is obvious that forests and semi-natural areas with 51,88 km$^2$ or 81,16 % are the most prevailing category. Forests, mostly coniferous and less mixed and broad-leaved forests, cover more than 70 % of the area. Moors and heath land cover another 8 %. Sparsely vegetated and bare rock areas are present in Peca mountain crest with 2,5 %.

Agricultural areas cover almost 17 % or 10,76 km$^2$, most of it pastures and so called areas principally occupied by agriculture, interspersed with significant natural areas (together 16 % of the area), complex cultivation is less present.

Artificial surfaces of only 1,28 km$^2$ or 2% with two subcategories are detected: discon-

Table 2. Table of proportions and sizes of ALUM

| 1st level | 2nd level | 3rd level | 4th level | Area [km$^2$] | Share [%] |
|---|---|---|---|---|---|
| 1. Agricultural land | 1.1.Arable land | | | 0,45 | 0,7 |
| | 1.2.Areas under permanent cultures (permanent crops) | 1.2.1.Viticulture land | 1.2.1.1.Vineyards | 0,001 | < 0,01 |
| | | 1.2.2.Orchards | 1.2.2.2.Extensive orchards | 0,5 | 0,8 |
| | 1.3.Meadows and pastures | 1.3.1.Intensive meadows | | 4,96 | 7,76 |
| | | 1.3.2.Extensive meadows | 1.3.2.2.Other extensive meadows | 2,87 | 4,5 |
| | 1.4.Other agricultural areas | 1.4.1.Overgrown areas | | 1,42 | 2,2 |
| | 1.5.Riparian overgrowth and forest hedges | | | 0,3 | 0,47 |
| 2.Forest and other overgrowth areas | | | | 49,74 | 77,8 |
| 3.Built-up areas and related surfaces | | | | 2,49 | 3,9 |
| 5.Dried open areas with special vegetation | | | | 0,02 | 0,03 |
| 6.Open areas with little or no vegetation | | | | 1,04 | 1,63 |
| 7.Water | | | | 0,13 | 0,2 |

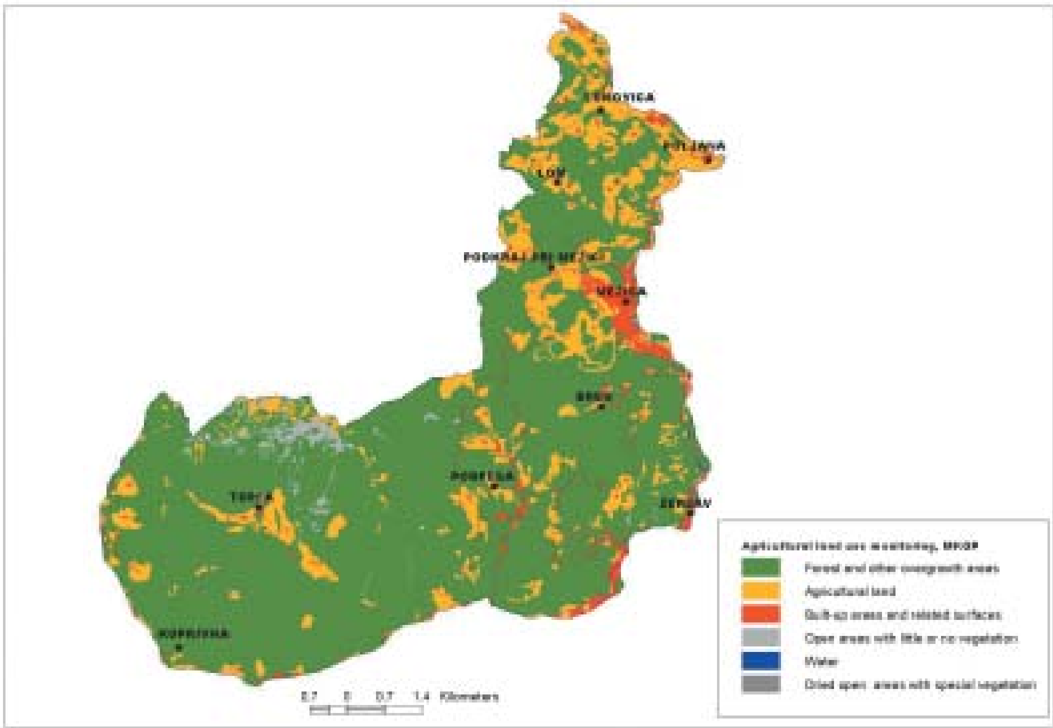


Figure 3: ALUM map of the Peca area (Ministry of Agriculture, Forestry and Food of Slovenia, 2002)

tinuous urban fabric and industrial or commercial units.

*Agricultural land use monitoring data (ALUM)*

In the area of Peca there are six major land use categories of ALUM present:

1. Agricultural land

2. Forest and other overgrowth areas
3. Built-up areas and related surfaces
4. Dried open areas with special vegetation
5. Open areas with little or no vegetation
6. Water

In the investigated area agricultural land is divided on all four levels, while other categories are not divided into any subcategories. The categories of agricultural land are:

1.1. Arable land
1.2. Areas under permanent cultures (permanent crops)
1.3. Meadows and pastures
1.4. Other agricultural areas
1.5. Riparian overgrowth and forest hedges

On the third level they are divided on the following categories:

1.2.1. Viticulture land
1.2.2. Orchards
1.3.1. Intensive meadows
1.3.2. Extensive meadows
1.4.1. Overgrown areas

On the fourth level they are divided on the following categories:

1.2.1.1. Vineyards
1.2.2.2. Extensive orchards
1.3.2.1. Other extensive meadows

Prevailing category is forest and other overgrowth areas covering 49,74 $km^2$ or 77,8 % of surface. The category does not have any subcategories.

Agricultural land covers 10,5 $km^2$ or 16 %. Prevailing subcategories are meadows and pastures (three quarters of agricultural land), followed by overgrown areas. Subcategories present are arable land, areas under permanent cultures (vineyards, extensive orchards), meadows and pastures (intensive pastures and extensive meadows), other agricultural areas (overgrown areas) and riparian overgrowth and forest hedges.

Agricultural land is followed by built-up areas and related surfaces covering almost 2,5 $km^2$ or 3,9 % of surface. Open areas with little or no vegetation cover Peca crest area of 1 $km^2$ or 1,63%. Other two categories present are dried open areas with special vegetation with 0,02 $km^2$ or 0,03 % and water with 0,13 $km^2$ or 0,2 % of the area.

## Conclusion

It is widely predicted that CORINE Land Cover (CLC) database usefulness is bigger on international and state level, but less on regional and local level in cases when small areas with particularities are analyzed. In comparison with more detailed land use categorization (ALUM) obtained and provided by Ministry of Agriculture, Forestry and Food of Slovenia relatively big differences between results of the two databases occurred. A relevant comparison is not even possible due to different nomenclature, mapping scale, area of the smallest unit etc. By both datasets forest is far prevailing land use category covering more than three quarters or 78 % (ALUM) and 81 % (CLC) of surface followed by agricultural land with about 16 % (ALUM) and 17 % (CLC) %. The differences are also present in artificial areas. It is covered by 3,9 % (ALUM) and 2,1 % (CLC). No major differences in proportions of two most prevailing land cover categories (forests, agriculture land) on first level can be found but big differences are present when it comes to subcategories on lower levels that cover smaller parts of surface (settlements, roads, dump sites…). Some of the categories are even absent (CLC does not detect any water bodies). In general we can so far conclude that CLC database is appropriate for land use analysis on regional level as well but mostly in certain specific cases when for instance the region is shared by two states and no other common methodology for both states exists. We can also say that the CLC data show quite realistic picture of the area land use main characteristics. But however for more detailed picture it is necessary to use more detailed data. On the base of the results we can so far conclude that Peca aquifer and also its wider area (Slovene part) is at the moment not endangered in greater scale.

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GEOLOGIJA *46/2,* 445–450, Ljubljana 2003

# Novi atlas geotermalnih virov v Evropi

## New Atlas of Geothermal Resources in Europe

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*Ključne besede*: geofizika, geotermalni viri, Evropa, Slovenija
*Key-words*: Geophysics, Geothermal resources, Europe, Slovenia

**Kratka vsebina**

Naftna kriza leta 1973 je povzročila hitro naraščajoče zanimanje za geotermalno energijo kot ene izmed morebitnih nadomestil fosilnih energetskih virov. To je zahtevalo solidno poznavanje njenega nastanka, eksploatacije in praktične izrabe. Evropska komisija za raziskave in razvoj v Bruslju je ta vir energije podpirala, vendar je bilo zato potrebno veliko osnovnih podatkov za praktično realizacijo. Zadnje raziskovalno delo predstavlja novi *Atlas geotermalnih virov v Evropi,* kjer je prikazana tudi Slovenija. Poleg kart temperatur v raznih globinah, opisov geoloških, hidroloških in fizikalnih svojstev kamnin, je zastopana z opisom geotermalnih virov na dveh najbolj obetavnih območjih. To sta jugozahodni del Panonskega bazena v severo-vzhodni Sloveniji in Krška kotlina v njenem vzhodnem delu.

**Abstract**

The oil crisis in 1973 caused rapidly increasing interest in geothermal energy as one of the eventual substitutes for fossil energy resources. This interest required a solid knowledge of the origin, exploitation and practical use of geothermal energy. European Commission for Research and Development in Brussels has supported this source of energy, however, for the practical realization was necessary a large amount of fundamental data. The last research work is presented with the new *Atlas of Geothermal Resources in Europe* with Slovenia included as well. Slovenia is therefore presented with description of geothermal resources in the two most promised areas besides the temperature maps in different depths, and descriptions of geological, hydrological and physical characteristics of rocks. These areas are the southwestern part of the Pannonian basin in northeastern Slovenia and the Krško basin in the eastern part.

Preteklo leto je izšel *Atlas geotermalnih virov v Evropi* urednikov S.Hurter-jeve in R.Haenela z *Leibniz-ovega inštituta uporabnih znanosti Zemlje* iz Hannovra (Nemčija). Koordinacijo je izvajal *Deželni urad za raziskave tal*, pravtako iz Hannovra, tiskala pa je firma *Lovell Jones Ltd.* iz Oxfordshire-a (Velika Britanija). Atlas je objava urada *Evropske komisije (EC)* za uradne publikacije iz Luxemburga. Format Atlasa je 32 x 47 cm, obsega 91 strani teksta s tabelami in 89 dvostranskih kart in profilov. Delo je na področju geotermalnih raziskav velik skupni dosežek 156 geoznanstvenikov iz 31 evropskih držav. Kljub temu, da naj bi to delo izšlo že preje, smo ga zaradi finančnoorganizacijskih težav dobili šele septembra leta 2002. V njem je sodelovala tudi Slovenija z ekipo petih strokovnjakov raznih področij geologije, hidrogeologije in geofizike.

Pri raziskavah geotermalne energije je pomembno poznavanje razdelitve temperature pod površjem. Takó je zbiranje zanesljivih temperaturnih podatkov pogojeval program Evropske komisije *Geothermal Energy Research and Development* od njegovega zametka v letu 1975 dalje, ki je nastal kot posledica naftne krize leta 1973. Rezultati so bili zbrani v *Atlasu podzemeljskih temperatur v Evropski skupnosti*, katero je uredil Haenel (1980). Karte so obsegale temperature do globine 5 km. Države, ki jih je atlas zajel, so bile Belgija, Danska, Francija, Italija, Nizozemska, Velika Britanija in Zahodna Nemčija. To je bil uporaben dokument ne le za strokovnjake, ki jih zanima geotermalna energija, temveč tudi za industrijo nafte in plina, rudarstvo, družbe za vodooskrbo in geološke inštitute.

Omeniti moramo še prve podatke o površinskem toplotnem toku Evrope v *Predhodni karti toplotnega toka Evrope* (Čermák in Hurtig, 1977) in kmalu za tem še v *Karti toplotnega toka Evrope* (Čermák & Hurtig, 1979). Že na prvi karti so bile na severnem delu nekdanje Jugoslavije na obrobju Panonskega bazena vrisane izolinije izmerjene gostote toplotnega toka.

Leta 1988 je izšel prvi *Atlas geotermalnih virov v Evropski skupnosti s Švico in Avstrijo* (Haenel & Staroste, 1988). Kasneje pa so objavili še obsežni *Geotermalni atlas Evrope* (Hurtig in sodel., 1992). V njem je poudarek na temperaturnih kartah do globin 5 km in na gostotah toplotnega toka za celotno Evropo. Tu se je prvič pojavila tedanja Jugoslavija (Ravnik s sodel., 1992) in v njenem okviru tudi Republika Slovenija z do takrat zbranimi podatki v tabelah in na ustreznih kartah.

Sedanji Atlas je skupno s prvim *Atlasom geotermalnih virov* (Haenel & Staroste, 1988) dopolnjen še s poročili novih trinajstih držav. Vključeni so še podatki za Belorusijo, Bosno in Hercegovino, Hrvaško, Islandijo in Ukrajino. Norveška nima geotermalnih virov, kot so definirani v tem Atlasu. Finančno podporo je Evropska komisija dodelila večini evropskih držav, tudi Sloveniji. Finska, Rusija in Švica so se financirale same, medtem ko so Belorusija, Hrvaška in Ukrajina prostovoljno prispevale le temperaturne podatke. Strokovnjaki iz Srbije s Črno Goro, Makedonije in Turčije pa so skušali dobiti podporo v svojih državah. Za triletni potek vseh priprav je Evropska komisija dala na razpolago okoli 1,1 milijon evrov sredstev (Hurter & Haenel, 1998).

Atlas 2002 kaže rezultate večletnega dela in je poskus predstaviti podatke geotermalnih virov Evrope na primerjalni osnovi tako znotraj kot tudi zunaj državnih meja. Podaja pregled ugotovljenih geotermalnih virov v skoraj vseh državah Evrope, predstavlja pa razširjeni atlas urednikov Haenel-a in Staroste-jeve (1988). Oba atlasa prikazujeta oceno geotermalne energije, ki bi jo lahko ekonomično izrabljali takoj ali v bližnji prihodnosti. To je temeljni dokument za nadaljnje raziskave geotermalne energije v času, ko zahteve za zmanjšanje negativnih učinkov na okolje postajajo vse ostrejše. Obravnava tudi one količine teh virov, ki še niso v eksploataciji, ampak jih bodo z izboljšano tehnologijo in pri ugodnih ekonomskih pogojih še izkoriščali. Atlas obsega za vsako posamezno državo splošni tekst, tabele in karte. V tabelah so zbrani podatki o termalnih izvirih, o gostoti toplotnega toka in o izvedenih geotermalnih inštalacijah. Glavni del pa predstavljajo po štiri karte v opisu geotermalnih vodonosnikov: globine do vodonosnika, temperatura na vrhu vodonosnika, debeline vodonosnika in njegovi geotermalni viri ali rezerve.

Pri opisovanju geotermalnih nahajališč uporabljamo nekatere točno določene pojme. *Geotermalne vire (resurse)* nekega področja, ki so nakopičeni v kamninah in tekočinah pod Zemljino površino, bi lahko pridobivali v bližnji bodočnosti, dočim so njihove *zaloge (rezerve)* izkoristljive takoj. Številčno jih izračunamo po enotnih enačbah Evropske skupnosti s pomočjo temperatur, globin in prostornin podzemnih vodonosnikov ter toplotnih kapacitet kamnin in vode. Poleg teh podatkov, ki so prikazani na kartah, so za temeljitejše razumevanje predstavljeni še geološki profili, ponekod tudi s podatki o efektivnih poroznostih, prepustnostih, slanostih podtalnih voda ter z njihovimi piezometričnimi višinami.

Vsekakor ima določitev geotermalnih virov neko prehodno vrednost in jo je treba občasno dopolnjevati glede na tehnološki razvoj, politične okolnosti, okoljevarstvene ozire in socialno politiko.

Za oceno potencialov geotermalne energije je poleg podzemeljskih temperatur potrebno tudi poznavanje količine prenešene toplote na površino v enoti časa in na enotno površino, to je *gostote toplotnega toka*. Razen tega so za možnosti ekonomske izrabe geotermalne energije koristne hidrogeološke, litološke in stratigrafske značilnosti kamnin skupno z njihovimi toplotnimi parametri, t.j. geotermičnim gradientom, toplotno difuzijo, specifično toploto ali toplotno prevodnostjo kamnin in tekočin v njih in vsebnosti izotopov. Vse te podatke posredujejo razne geofizikalne raziskave v vrtinah (karotaža) in laboratorijih, dopolnjenih s hidrogeološkimi, geokemičnimi in inženirsko-geološkimi preiskavami.

Glavna načina prenosa toplotne energije na površje Zemlje sta *kondukcija* in *konvekcija*. Velikost *konduktivnega* prenosa toplote določa gostota toplotnega toka, ki kaže tudi na višino podzemeljskih temperatur, vendar je tak način zelo neučinkovita oblika transporta toplote na površino. *Konvektivni* prenos toplote pa oskrbijo podzemne tekočine, predvsem voda. Ta je zaradi svojih specifičnih lastnosti (mobilnost, visoka specifična toplota) najbolj pomemben za izkoriščanje geotermalnih nahajališč. Konvektivni način prenosa toplote je omejen na globoke prelome, vulkanska območja in na robove tektonskih plošč.

Atlas 2002 obsega posodobljene podatke, vendar se nekatere, v prejšnjih atlasih veljavne informacije, v tem Atlasu ne pojavljajo več. Za popoln pregled vseh znanih geotermalnih podatkov je potrebno zato ustrezno upoštevati še vse dosedanje atlase (1980, 1988, 1992). Skrbna spremljava teh podatkov omogoča razviti in izboljšati izrabo in izdatnost doslej uporabljenih virov. S primernim modeliranjem, izkoristljivostjo virov in ustrezno optimizacijo tehnologij pri zajetju na površju, lahko dobimo več energije brez povečevanja števila vrtin. To je važno, kajti posebno vrtine predstavljajo največji strošek geotermičnih naprav.

Atlas pa olajšuje tudi identifikacijo geotermalnih razmer možnim partnerjem za mednarodne skupne projekte v regijah s podobnimi geološkimi razmerami, kar vzpodbuja Evropska komisija. Informacije v Atlasu ne nadomeščajo detajlnih lokalnih študij, čeprav objavljene karte sicer dopuščajo primarno oceno geotermalnega potenciala v smislu njegove tehnološke in ekonomske življenjske dobe.

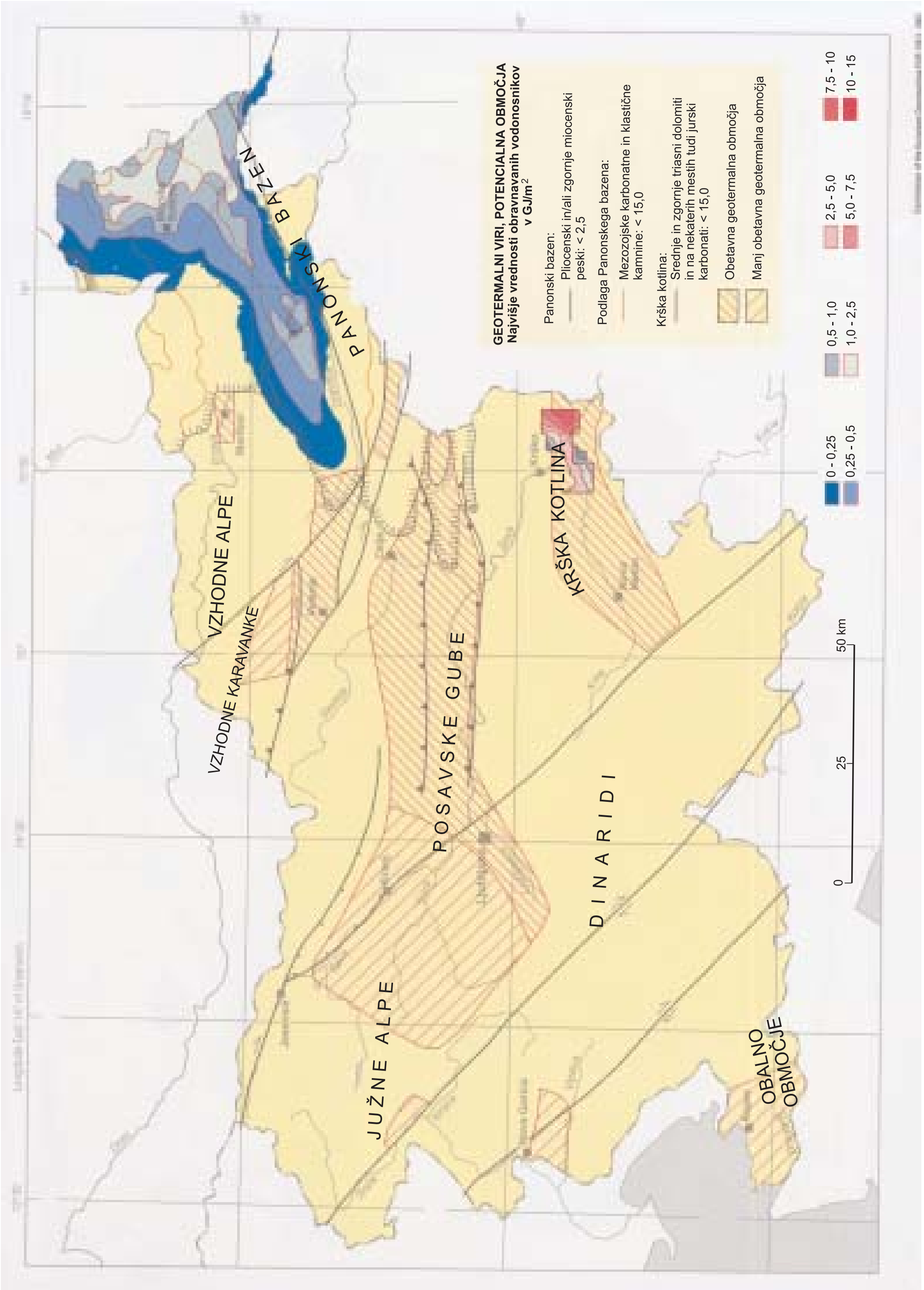
Osnova za oceno geotermalnih virov v Atlasu 2002 je model eksploatacije geotermalne tekočine z dvema vrtinama (dublet): po eni prihaja geotermalna voda na površje, po drugi pa navadno isto, toda ohlajeno vodo na 25 °C vračamo nazaj v geotermalni vodonosnik. Vendar ta Atlas ni pripomoček za določitev lokacij vrtanja za geotermalne instalacije. Bolj služi za omejitev perspektivnih ozemelj za nadaljnje raziskave in nakazuje številne možnosti za uporabo različnih geotermalnih naprav, toplotnih izmenjevalcev in toplotnih črpalk.

Geotermalno energijo izrabljamo lahko z različnimi tehnologijami, ki v glavnem vključujejo vrtanje in črpanja geotermalne vode iz globin. Perspektivna je tehnologija HDR (angl. *Hot Dry Rock* = vroča suha kamnina) kot ena uspešno razvijajočih se sistemov EGS (angl. *Enhanced Geothermal System* = ojačani geotermalni sistem). Tàko je na primer nahajališče Soultz-sous-Forêts v francoskem delu Renskega jarka.

V Evropi je doslej geotermalno instaliranih že okoli 1000 MW električne in preko 8000 MW toplotne moči za ogrevanje, rekreacijo in balneologijo, za industrijske procese in v poljedelstvu. Vendar stremijo k povečanju teh kapacitet, nižanju obratovalnih temperatur za ekonomično izkoriščanje in k razširitvi produkcije električne energije hidrogeotermalnih virov tudi na nevulkanskih območjih.

Slovenija je v Atlasu 2002 predstavljena s kratkim splošnim tekstom, spiskom meritev gostot toplotnega toka, preglednico naravnih termalnih izvirov, geotermalnih instalacij in z najbolj značilnimi geotermalnimi kartami in profili. Kot eden od rezultatov dosedanjih raziskav pa so na priloženi karti (slika 1) prikazani geotermalni viri in njihova potencialna območja.

Na kartah geotermalnih parametrov je opazno njihovo naraščanje v smeri proti severovzhodu in delno proti vzhodu. Temu so vzrok geološke in tektonske posebnosti na prehodu od Vzhodnih Alp in Dinaridov na območje Panonskega bazena. Za prvo področje so značilne nizke gostote toplotnega


GEOTERMALNI VIRI, POTENCIALNA OBMOČJA
Najvišje vrednosti obravnavanih vodonosnikov v GJ/m²
Panonski bazen:
Pliocenski in/ali zgornje miocenski peski: < 2,5
Podlaga Panonskega bazena:
Mezozojske karbonatne in klastične kamnine: < 15,0
Krška kotlina:
Srednje in zgornje triasni dolomiti in na nekaterih mestih tudi jurski karbonati: < 15,0
Obetavna geotermalna območja
Manj obetavna geotermalna območja
0 - 0,25
0,25 - 0,5
0,5 - 1,0
1,0 - 2,5
2,5 - 5,0
5,0 - 7,5
7,5 - 10
10 - 15
0
25
50 km
PANONSKI BAZEN
VZHODNE ALPE
VZHODNE KARAVANKE
POSAVSKE GUBE
KRŠKA KOTLINA
DINARIDI
JUŽNE ALPE
OBALNO OBMOČJE

toka in s tem pogojene tudi nizke podzemeljske temperature, na drugem pa vladajo razmeroma visoki toplotni tokovi in s tem v zvezi povišane temperature. To je še jasneje razvidno v Atlasu 2002 na preglednih geotermalnih kartah celotne Evrope.

Zaradi take situacije in še ne preiskanih delov Slovenije smo na detajlnih kartah in profilih naše države pokazali le dvoje najbolj preverjenih in značilnih geotermalnih lokacij. Obe ležita vzhodno od meridiana petnajstih stopinj vzhodne dolžine, to sta Štajerska s Pomurjem in Krška kotlina. So pa še druga, sicer posamezna, toda ekonomsko uspešna geotermalna nahajališča (Topolšica, Laško, Rimske toplice, Dobrna, Zreče, Snovik, Podčetrtek, Rogaška Slatina, Dolenjske toplice, Medijske toplice in druga). Osrednji del Slovenije je sicer potencialno zanimiv, vendar je še premalo raziskan.

Pregled geotermalnih razmer v Sloveniji, kot ga kaže Atlas 2002, daje osnovo za nadaljnji razvoj tega energetskega vira. Vzhodna Slovenija je sicer sposobna razvijati geotermalna nahajališča tako, kot jih izvajajo pri podobnih geotermalnih pogojih v večini Evrope. V zadnjih desetih letih so razvili tudi izrabo nizkoentalpijskih virov geotermalne energije. Ti so uspešni zlasti tam, kjer ni večjih geotermalnih nahajališč in se jih uporablja za ogrevanje ali razne industrijske procese. Zato bi se bilo treba tudi pri nas osredotočiti na plitvo geotermijo z raznimi tehnologijami, ki jih uspešno razširjajo v Švici, Avstriji, Nemčiji, na Švedskem in v ZDA.

## Zahvala

Avtorja sva hvaležna Duški Živanović za pomoč pri obdelavi slike.

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GEOLOGIJA *46/2,* 451–458, Ljubljana 2003

# Poročanje ali dokazovanje: jezikovni problem ali kaj več

## Reporting or argumentation: is there more to it than a linguistic problem?

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*Ključne besede:* vloga razmišljanja v geologiji, neracionalni in racionalni miselni procesi, jezikovni in logični način prikazovanja, logične zmote
*Key words:* Geology as a way of thinking, irrational and rational processes, linguistic and non-linguistic modes of representation, fallacies

**Kratka vsebina**

Prispevek je racionalna diskusija o problematičnem razmišljanju in o jezikovnem prikazu v dveh znanstvenih objavah. Postavljena je na računalniško-informacijski opredelitvi področja mehkih znanj, kjer je glavni in bistveni problem razmišljanje in na teoriji znanstvenega raziskovanja, kjer ima disciplinirano razmišljanje posebno mesto. Problematično razmišljanje raziskujem in odpravljam na stratigrafskih primerih z uporabo formalnega kritičnega razmišljanja. Na raziskovanih primerih sem ugotovil odsotnost oziroma nepoznavanje jezika znanosti nasploh. Posledica tega je prizadeta resničnost in s tem veljavnost spoznanja oziroma resnicotropičnost raziskovanih stratigrafskih besedil.

**Abstract**

The contribution is a rational discussion on problematic thinking and linguistic representation in two papers. It is based on soft knowledge delineation as in computing and information science and on the theory of scientific research. In both cases good and disciplined way of thinking is a crucial process. The difficulties of the stratigraphic parts of the papers are analysed and rectified by applying formal critical thinking. The analysis revealed the omission of acknowledging the language of science in general. As a consequence, the seeking for knowledge which should be truthtropic, and the truthfulness function of the texts are not corroborated in the investigated stratigraphic texts.

### Uvod

Drugi in moji primeri kažejo, da kolegi debato razumejo kot kritiziranje in napad na njihovo delo in osebo z vsemi posledicami, ne pa kot debato o celovitosti raziskovalnega postopka in o širšem, apriornem okolju (motivacija in vedenje raziskovalcev, kultura in organiziranost v raziskovalni organizaciji, vpliv družbe) ter o tem, da so rezultati raziskovanja in njihova veljavnost proizvod obojega (prim. Kourany, 1998). Zato tukaj ponovno trdim, da je slednje razumevanje debate pravilno.

Ta nepravilni miselni model kolegov predstavlja, poleg še drugih miselnih modelov, prav nič malenkostno oviro do uspešnosti naše znanosti. Senge (1990) je lepo pokazal na vpliv miselnih modelov na človekovo uspešnost. Predvsem pa je nepravilni miselni model onemogočil sleherno racionalno diskusijo, za katero menim, da je v znanosti in v raziskovalni organizaciji del adaptivnega učenja in vzajemnega razvoja (koevolucije). Zgradil je celo nepremostljive pregrade in pripomogel k fragmentiranosti, ki je segla vse do posameznika in njegovega izključevanja in celo do diskreditacije z argumenti proti človeku. Sam sem, v svojih sicer maloštevilnih razpravah, vedno želel oviro obiti tako, da sem poskušal ustvariti interaktivno diskusijo. Kljub temu je bilo le redkokdaj mogoče vzpostaviti komunikacijsko sporočanje, da na sporazumevanje kot višjo obliko komunikacije sploh ne pomislim, in to vedno samo z istimi kolegi. Med poskušanjem prodreti v ozadje te izkušnje sem dojel tisti del teorije, ki govori o tem, kako zelo je interaktivna diskusija odvisna od udeleženčevega razumevanja. Drugače povedano: odvisna od razumevanja, omejenega z globoko usidranimi miselnimi modeli, takimi kot je na primer v Andersenovi pravljični prispodobi Cesarjeva nova oblačila.

Kljub temu moje mišljenje ostaja enako, saj nimamo moralne pravice, obrniti se stran od orodij znanosti kot sta racionalna diskusija in kritično razmišljenje (prim. Jelen, 1996). Prav tako nimamo moralne pravice zatajiti – niti enkrat, kaj šele trikrat in se greti pri ognju – logike (v ožjem in širšem pomenu) raziskovalnega in znanstvenega dela ter veljavnosti spoznanja. Če to storimo, potem »znanost nima nobene pravice več razlikovati svojih teorij od fantastičnih in poljubnih stvaritev poeta« (Reichenbach, citiran v Poppru (1972)). Če to storimo, razdejamo še poetovo iskanje smisla in še dlje, samo načelo *zōon logikon*, kakor so stari Grki imenovali človeško bitje, tj. načelo, ki iz káosa ustvarja notranje urejen svet. Zato Popper (1979): »Naša glavna skrb v filozofiji in znanosti bi morala biti iskanje resnice.« (Opomba: mišljena je korespondenčna resnica, tj. resnica, ki je v skladu s stvarnim svetom). In tako je od starih Grkov naprej (prim. Sarton, 1980).

V tem diskusijskem članku se z racionalno diskusijo še enkrat odzivam na ujetost v naše nepoznavanje znanstvenoraziskovalne teorije, to pot člankov »Litološke značilnosti terciarnih plasti na Kozjanskem« (Aničić et al., 2002) in »Dacitic glassy lava flow from Trlično at Rogatec, Eastern Slovenia« (Kralj, 2002), Od formalnih in neformalnih napak v prvem članku bom razpravo omejil na problematični stratigrafski fragment članka, ne bom pa razpravljal o problematičnem stanju litostratigrafije, litostratigrafske korelacije, biostratigrafije, biokorelacije in kronostratigrafske korelacije. V drugem članku avtorica v stilu »hitrega potega« opravi s problemom starosti vulkanizma v vzhodni Sloveniji in pri tem sledi problematičnemu stratigrafskemu fragmentu v prvem članku ter doda še nove napake.

V vseh primerih, ki jih bom izbral, gre za problematična stanja, s stališča tistega dela znanstvenoraziskovalne teorije, ki obravnava miselno dejavnost. Stratigrafija in znanstvenoraziskovalna metodologija sta moji področji proučevanja, predvsem pa stratigrafija terciarja vzhodne Slovenije, zato ne prestopam mej pravila *noblesse oblige* (pisati samo o temah, ki jih obvladaš), čeprav sem opazil problematična stanja tudi drugod v članku.

Da bi se izognil naivnostim in napakam vsakdanjega razmišljanja, bom, kot to ponavadi storim, poskušal najprej ugotoviti, kaj vidim in kako to vidim z višjega relevantnega gledišča obstoječega znanja.

## Postavitev problema

Če uporabim računalniško-informacijsko izrazoslovje, potem lahko trdim tako, da geološke discipline in poddiscipline sodijo med področja »mehkih znanj«. To pomeni, da področja ne dopuščajo zanesljivih in natančnih rešitev nalog in da je preveč možnosti za različne interpretacije in za subjektivno presojo (Gerlič, 1990). Na teh področjih torej, povedano zopet v računalniško-informacijskem jeziku, ne obstaja toliko problem programiranja rešitev nalog, temveč je problem predvsem v razmišljanju (Gerlič, 1990). Če nadaljujem v tem smislu, potem je potrebno povedati, da umetna inteligenca za reševanje nalog iz mehkih področij uporablja sposobnosti, ki jih ima živa, naravna inteligenca: sposobnost sklepanja, sposobnost presoje, sposobnost odločanja ob nepopolnih in nezadostnih informacijah in zmožnost pojasnjevanja svojega razmišljanja (Gerlič, 1990). Vlogo naštetih sposobnosti v raziskovalnem procesu, ki so jo razvijali raziskovalci na različnih znanstvenih področjih, so in še naprej proučujejo kognitivne znanosti, z namenom odkrivati splošna načela razmišljanja v pridobivanju in uporabi znanja (npr. Meystel & Albus, 2002). V naši raziskovalni dejavnosti ta načela ne bi smeli tako romantično-naivno zamenjevati z običajnimi, vsakdanjimi miselnimi operacijami. Na primer, pri miselni operaciji preoblikovanja enega predmeta ali sestave predmetov v drug predmet (sklep, rezultat) ne gre za splošno prehajanje od ene miselne vsebine na drugo, ampak za prehod po načelu logične konstrukcije (Šešić, 1962).

Predmet proučevanja kognitivnih znanosti je tudi jezikoslovje. V jezikoslovju kognitivne znanosti iščejo zakonitosti uporabe simbolov in sekvenc simbolov, tj. besed in stavkov, ki jim dajejo lastnost smiselnega pomena – semantično informacijo. O pomenu teh zakonitosti v naravoslovnih znanostih je že 1854 spregovoril Boole takole: »Resnično, le v zelo redkih primerih je v naravoslovnih znanostih mogoče sklepanje izraziti brez tega doumevanja jezika.« Za manj poseben in manj formalen primer naj navedem Škarića (1999), ki piše. «To me še posebej radosti, ker sem imel s Slovenci vselej dobre izkušnje. Njim namreč ni tuje, če se jim pove nekaj urejenega in logičnega ... Še več, če opazijo nelogičnost in nepopolnost, se mrščijo in negodujejo.« Po drugi strani pa mi je neki Anglež, ki pozna slovenski jezik tako dobro, da lahko prevaja iz slovenščine v angleščino, zaupal svojo izkušnjo, da se v Sloveniji izražamo neurejeno in logično slabo. Kakorkoli je že, oba, Škarić in ta Anglež, govorita o urejenem in logičnem prikazovanju tudi v manj formalnem okolju. Za pravilno razumevanje izjav obeh je potrebno razumeti, da se poslužujeta splošnega jezikovnega (= smiselno) in ne terminskega pomena logike. Če že vsakdanje življenje dopušča ohlapno in neurejeno, situacijsko cik-cak, osebno obarvano, nesmiselno in celo sleparsko prikazovanje, bi moralo biti znanstveno prikazovanje prosto teh stranpoti, kajti komunikacijska funkcija znanstvenega prikazovanja ni ista kot je pri običajnem, vsakdanjem prikazovanju, ker mora smiselno in verodostojno prikazati koncepte, njihovo formulacijo, argumentacijsko strukturo itd. To pa zahteva posebno disciplino v prikazovanju kompleksne strukture znanstvenega mišljenja (predmeti – misli – besede) (Šešić, 1962). Žal pa vedno znova ugotavljam, da največkrat ne razlikujemo med obema.

Nadalje, v samem vrhu med kriteriji, ali je neka dejavnost raziskava ali ne, je objektivnost. V tem smislu je objektivnost kompleksen in zahteven pojem. Pred raziskovalca postavlja mnoge tehnološke in etične zahteve in ne samo zahtevo po citatu, kot bi si mislili. Že pred leti sem opozoril na to, da moramo, če resnično želimo našo dejavnost imenovati raziskovanje, in to znanstveno raziskovanje, poznati teorijo raziskovalnega in znanstvenega dela (Jelen, 1993). Naštevanje, kaj bi raziskovalec že moral vedeti o metodologiji svojega dela, bi bilo podpiranje indolence. Glede na postavljeni problem pa je vendarle potrebno našteti nekaj tehnoloških in etičnih zahtev. Nekatere tehnološke zahteve, ki se nanašajo na miselno dejavnost: jasnost, specifičnost, zanesljivost, natančnost, bistvenost, skladnost, poglobljenost, širina, kompletnost, ustreznost, logičnost. In nekatere etične zahteve: poštenje, verodostojnost, stvarnost in pozitivnost v naravnanosti in izvajanju raziskave. Zgolj dajanje citata ni zadostna objektivnost.

## Ugotovitev problematičnih stanj

V članku Litološke značilnosti terciarnih plasti na Kozjanskem na strani 230 piše (besedilo A): »Eno od še vedno čisto nerešenih geoloških vprašanj Kozjanskega sta časovno razdobje in vulkanska intenzivnost v času zgornjega oligocena in spodnjega miocena. Predori andezita, dacita in riodacita ter njihovih tufov datirajo večji del v daljše obdobje spodnjega oligocena (kiscellija). Avtorja osnovne geološke karte Rogatec (Aničić & Juriša, 1985a) prikazujeta na Kozjanskem in na sosednjem Hrvaškem Zagorju zvezni vulkanizem v obdobju od srednjega oligocena do spodnjega miocena (kiscellij in egerij), medtem ko Buser (1978) na listu Celje dopušča možnost oziroma prikazuje dve ločeni vulkanski fazi in sicer obe v oligocenu. O dveh vulkanoklastičnih sekvencah znotraj oligocenskega klastičnega paketa v vzhodni Sloveniji poročajo tudi Jelen in sodelavci (2001). Prostor Savsko-Celjske tektonske cone, kamor umeščajo ozemlje južno od Rogaške Slatine, po njih pripada drugi sekvenci (med sivico in govškimi plastmi) s časovnim razponom med vrhnjim kiscelijem in spodnjim delom zgornjega egerija. Prva sekvenca, ki zajema Smrekovški bazen in prostor severno od Rogaške Slatine pa na čas med zgornjim eocenom in oligocenom.« Na isti stani še piše: »Točnega odgovora na to vprašanje ni dala tudi ta študija, z veliko verjetnostjo pa se nagibamo k dvema ali celo več vulkanskim fazam (sl. 3). To zagovarjamo z različno mineraloško in kemično sestavo magme na posameznih izdankih (tabela 1)«.

Jezikovni izraz besedila A je videti neproblematičen. Marsikoga bo prikaz in njegova namenska komunikacijska funkcija celo pritegnila, saj izkazuje tako imenovano »poetično« komunikacijsko funkcijo. Toda raziskovalca mora zanimati predvsem resničnostna funkcija. Če najprej preverim resničnost stavkov, ugotovim, da stvari, ki jih opisujejo, ne obstajajo, torej so stavki neresnični. Nato ugotovim neprepoznavanje formalnega sklepanja, odsotnost presoje in na koncu zmedo v pojasnjevanju razmišljanja.

V istem članku na straneh 228 in 230 nadalje piše (besedilo B). »Na žalost profil Plohov Breg, kljub odlični odkritosti, ni zvezen. V njem je skrit daljši hiatus, ki zajema celotno obdobje eggenburgija, ottnangija in karpatija ter precejšen del badenija, kar pomeni, da so bili na Kozjanskem v neogenu posamezni predeli, kot je ta med Podčetrtkom in Virštanjem, tudi 5 – 6 miljonov let okopneli.«

Besedilo B odkriva, na kako slabi logiki je postavljena stratigrafska vsebina članka. Miselna vsebina besedila je nesmiselna.

Izbrane faktične napake v članku Litološke značilnosti terciarnih plasti na Kozjanskem naštevam po zaporedju strani. Stran 215 (besedilo C): »Gre le za rupelijsko stopnjo, ki so jo zaradi značilnega razvoja pri Kiscelliju, nedaleč od Budimpešte, prvotno poimenovali kiscellijska formacija, nato pa kiscellijska stopnja, kot spodnji del oligocena v razvoju Paratetide (Báldi & Báldi–Beke 1985, Báldi 1986)«; stran 220 (besedilo D): »Kiscellij (spodnji oligocen)...« in besedilo E »Po svojih litoloških značilnostih in po podobnosti foraminiferne favne, ki ji daje morski značaj, je sivica podobna kiscellski glini na Madžarskem. Med foraminiferami so stratigrafsko pomembne *Tritaxia (Clavulinoides) szaboi*, *Almaena ex. gr. osnabrugensis*, *Vaginulinopsis gladius* in *Planularia kubiryii* (Rijavec 1978, 1984 in Rijavec v Buser 1979 ter v Aničić & Juriša 1985b)«; stran 226 (besedilo F): »Egerij (zgornji oligocen in spodnji miocen)« in (besedilo G) »Okolje sedimentacije je bilo večji del morsko, na kar sklepamo po številnih fosilnih ostankih, med katerimi so za biostratigrafsko razčlenitev najpomembnejše foraminifere *Bathysiphon taurinensis*, *Bulimina elongata*, *Ammonia beccarii*, *Glomospira charoides*, *Spiroplectamina carinata* ...«

Faktične napake so hude logične napake.

V uvodu članka Dacitic glassy lava flow from Trlično at Rogatec, Eastern Slovenia piše (besedilo H): Tertiary volcanic rocks outcropping in the Rogaška Slatina and Rogatec area form a part of a widespread volcanic complex which extend discontinuosly from the Smrekovec Mts. towards the southeast along the Donat transpressive zone (Fig. 1). The age of volcanism is not solved yet, although recent tectonostratigraphic and biostratigraphic studies (Jelen et al. 2001) indicate the existence of two Tertiary volcanic sequences: the lower, and the upper (Upper Oligocene - Egerian) volcanic sequence. Both sequences have entirely submarine character as evidenced from nannoplankton and plankton foraminifera fauna found in the underlying interstratified, and overlying fine-grained clastic sediments. Lavas and high-level intrusive bodies in the Smrekovec Mts., and in the Rogaška Slatina and Rogatec areas, both seem to belong to the lower volcanic sequence.« V zaključkih pa Kralj (2002) piše (besedilo I): «Comparison with the chemical composition of Smrekovec andesites suggests that the rocks probably do not belong to the same volcanic complex, displaced by tectonic activity.«

»Poteg« je bil tako hiter, da je slika stratigrafije povsem popačena in stratigrafska semantična informacija prazna, navedeni zakjuček (besedilo I) pa protisloven s propozicijo v uvodu (besedilo H).

### Razrešitev problema: odprava problematičnih stanj

Iz trditve, da je geologija s svojimi disciplinami in poddisciplinami mehko področje, sledi, da je v geologiji zelo pomembno razmišljanje. Ker pa, kadar je beseda o tem, ne samo da neomajno trdimo, da je geologija znanost, ampak tudi, da je geološko kartiranje znanost, bi bilo logično, da se pri raziskovanju, preiskovanju, iskanju ali kartiranju ali karkoli že počnemo v imenu znanosti, poslužujemo tistega razmišljanja, ki je značilno za vse znanosti, tj. razmišljanja, ki si prizadeva iskati logičnost in resničnost oziroma veljavnost spoznanja – resnicotropično razmišljanje. V tem miselnem procesu je od dela tega procesa, kjer je dejavna misel, pomembnejši tisti del, ki ga imenujejo miselna dejavnost. V tem zadnjem pa je zelo pomembno sklepanje, tj. preoblikovanje enega predmeta ali sestave predmetov v drug predmet (zaključek, rezultat). V znanosti bi morali propozicije strogo utemeljiti – dokazati. Torej v znanosti nimamo opraviti s poročanjem (besedilo A), temveč s strogim utemeljevanjem. Jelen in sodelavci (2001) poskušajo biokronološko strogo utemeljiti kronostratigrafsko propozicijo, seveda v okolju, ki ga dopušča razširjeni izvleček; tako ni bilo mogoče prikazati preverjanja izhodičnih propozicij. Med raziskovanjem pa zaradi finačnih ovir Jelen in sodelavci niso mogli izvesti popolne, tj. vključno fizikalne verifikacije, ki bi omogočila izpeljati zakonski stavek. V majhnem delu so jo izvedli Odin in sodelavci (1994). Novo spoznanje je torej doseženo po temeljnem induktivnem vzorcu (Polya, 1968), ki daje sklepanju Buserja (1979) in posledicam tektonostratigrafskega modela (Jelen et al., 2001) resničnostno funkcijo večje verjetnosti. Nasprotno pa Aničić s sodelavci (2002) ni in ni mogel demonstrirali svoje propozicije o položaju vulkanskih sekvenc na časovni lestvici, ker je uporabil nepravilen raziskovalni postopek, zato, kot pravi, »Točnega odgovora na to vprašanje ni dala tudi ta študija ...« »Različna mineraloška in kemična sestava magme na različnih izdankih« samo podpira prikazovanje in sklepanje Buserja (1978, 1979) ter biokronološko utemeljevanje Jelena in sodelavcev (2001), ne demonstrira pa nobenega položajnega odnosa ali položaja vulkanskih faz na časovni lestvici in zato ostaja samo pri ugibanju. Njegova razprava o tem vprašanju je zato bolj literarno esejistična kot znanstveni prikaz. Zaradi neresničnosti stavkov je razprava tudi zavajajoča. Aničić & Juriša (1985a) ne »prikazujeta na Kozjanskem in na sosednjem Hrvaškem Zagorju zvezni vulkanizem v obdobju od srednjega oligocena do spodnjega miocena (kiscellij in egerij)«, ampak od prehoda srednji/zgornji oligocen do zgornjega egerija, sledi krajša prekinitev v najvišjem delu zgornjega egerija, prekinitvi pa ponovna krajša vulkanska faza v začetku burdigalija $M_1^2$. Višek vulkanizma prikazujeta v egeriju. V Tolmaču za list Rogatec (Aničić & Juriša, 1985b) pa v nasprotju s svojim prikazom na karti pišeta: »Del andezitnega tufa severno od Rogaške Slatine je verjetno srednjeoligocenske starosti.« Zato se mi postavlja vprašanje, od kod Aničiću s sodelavci (2002, str. 230 in sl. 2, 3) zdaj podatek, da »Predori andezita, dacita, in riodacita ter njihovih tufov datirajo večji del v daljše obdobje spodnjega oligocena (kiscellija)«? Če ga ni utemeljil, ga je mogoče napačno prepisal (glej prvi odstavek na str. 7) iz razširjene kratke vsebine (Jelen et al. 2001)? V razpravi na str. 230 sploh ne upošteva članka Petrice s sodelavci (1995), čeprav ga citira drugje v članku. Petrica s sodelavci (1995) datira vulkanoklastite v Trobnem Dolu v najvišji del spodnjega egerija, medtem ko ga Aničić s sodelavci (2002) na sl. 3 brez dokazovanja uvršča v kiscellij, na sl. 2 pa neurejeno v kiscellij s pripisom v oklepaju »del egerijske starosti«. Pri tem pa kiscellij na sl. 3 napačno označi s simbolom $Ol_2$, kar naj bi pomenilo, da je kiscellij kronostratigrafski ekvivalent chatiju, tj. zgornjemu oligocenu. Za problematično razumno sklepanje navajam: kar sta prikazovala Aničić in Juriša (1985a, 1985b), Aničić s sodelavci (2002) postavlja kot vprašljivo: »Eno od še vedno čisto nerešenih geoloških vprašanj Kozjanskega sta časovno razdobje in vulkanska intenzivnost v času zgornjega oligocena in spodnjega miocena.« Hkrati pa brez citata piše »Predori andezita, dacita in riodacita ter njihovih tufov datirajo večji del v daljše obdobje spodnjega oligocena (kiscellija).« Kaj pa je potem z manjšim delom, ki ga na sl. 3 prikazuje kakor egerijskega in eggenburgijskega? Ali z uvodno izjavo podvomi tudi v svoj prikaz na sl. 3, pri tem pa pri sklepanju ne zna presoditi Buserja (1978, 1979), Petrice s sodelavci (1995) in Jelena s sodelavci (2001)? Prikaz spominja na pisanje »o vsem in o nobenem«.

Nadalje v besedilu A neurejeno in neresnično piše, »medtem ko Buser (1978) na listu Celje dopušča možnost oziroma prikazuje dve ločeni vulkanski fazi in sicer obe v oligocenu.«. Buser (1978) ne »dopušča možnost« in tudi ne »prikazuje dve ločeni vulkanski fazi in sicer obe v oligocenu«, temveč jasno loči srednjeoligocenske in spodnjemiocenske vulkanske kamenine. V Tolmaču lista Celje pa Buser ( 1979) piše: »Pri Dramljah nahajamo med govškimi plastmi nekaj deset metrov debel horizont andezitne vulkanske breče (θ), ki se menjava s tufom in izlivi lave (opomba: Buser (1979, str. 33-35) govške plasti uvršča v spodnji del miocena) ... Te vulkanske kamenine se že makroskopsko bistveno razlikujejo od oligocenskih piroklastitov. Miocenske vulkanske kamenine so ...« in še »skladi katijske stopnje na območju Posavskih gub niso razviti in tako obstaja diskordanca med rupelijem in akvitanijem. Tako nismo nikakor upravičeni, da bi govške plasti uvrščali v oligomiocen ...«

Tudi Jelen in sodelavci (2001) so v besedilu A citirani neurejeno in neresnično. Najprej, naj ponovno poudarim, da v citiranem razširjenem abstraktu ne poročamo, temveč poskušamo strogo dokazati. Prav tako ne uporabljamo pojma »prostor Savsko-Celjske tektonske cone« in v ta prostor ne »umeščamo ozemlje južno od Rogaške Slatine« in po našem niti prostor Savsko-Celjske tektonske cone niti ozemlje južno od Rogaške Slatine ne »pripada drugi sekvenci (med sivico in govškimi plastmi) s časovnim razponom med vrhnjim kiscellijem in spodnjim delom zgornjega egerija. Prva sekvenca, ki zajema Smrekovški bazen in prostor severno od Rogaške Slatine pa na čas med zgornjim eocenom in oligocenom.« V razdelku Druga vulkanoklastična sekvenca smo napisali takole: »Druga sekvenca vulkanskih klastičnih kamenin se na površini diskretno pojavlja severno v TTE B2, v kompleksno zgrajeni desnozmični Savsko-Celjski tektonski coni (prim. Fodor et al., 1998). Od Peračice preko Tunijškega gričevja v Savinjsko dolino in naprej južno od Rogaške Slatine na območje Ivanščice na Hrvaškem je odložena med morsko laporno glino (sivico) in med govške plasti. V B1 v govških plasteh in v B2 v morski laporni glini južno od Savsko-Celjske tektonske cone se pojavlja v sledeh razen pri Trobnem Dolu. Tudi ta sekvenca razdeli siliciklastično zaporedje Savsko-Celjske tektonske cone v dva dela.« in »Kronostratigrafski položaj druge vulkanoklastične sekvence v najzgornejšem delu NP 25 (vrhnji oligocen) določajo ...«. V oddelku Prva vulkanoklastična sekvenca pa pišemo: Prva vulkanoklastična sekvenca se na površini razteza v terciarni tektonostratigrafski enoti (TTE) B1 ob Donački transpresivni coni (prim, Fodor et al. 1998) in južno od nje: od Smrekovškega bazena preko območja severno od Rogaške Slatine na Hrvaško v Čakovsko antiklinalo in naprej v Srednjemadžarsko tektonsko cono. Ta vulkanska sekvenca razdeli eocensko karbonatno in oligocensko siliciklastično zaporedje v dva dela ...« in »Masovni pojav vrste *Reticulofenestra ornata* z akcesornima vrstama *Transversopontis fibula* in *Orthozagus aurens* pod vulkanoklastično sekvenco postavlja začetek le-te najkasneje v čas NP23. Naj dodatno opozorim, da v našem razširjenem izvlečku nismo nikoli pomešali med vulkanoklastično sekvenco in siliciklastičnim zaporedjem, prostorom oziroma ozemljem in vulkanoklastično sekvenco ter kronostratigrafskim razponom siliciklastičnih zaporedij in kronostratigrafskim položajem vulkanoklastičnih sekvenc, kakor se je to storilo Aničiću.

Za vzpostavitev neproblematičnega stanja v besedilu B je potrebno pojasniti, da se hiatus, zveznost in odlična odkritost v profilu Plohov Breg postavljajo v nemogočo zvezo. Nadalje, da je miselna vsebina stavka »V njem je skrit daljši hiatus, ki zajema celotno obdobje eggenburgija, ottnangija in karpatija ter precejšen del badenija, kar pomeni, da so bili na Kozjanskem v neogenu posamezni predeli, kot je ta med Podčetrtkom in Virštanjem, tudi 5 – 6 miljonov let okopneli« nesmisel. Časovni obseg vrzeli namreč ni mogoče enačiti s časom trajanja erozije. In napačno je trditi, da je v njem skrit hiatus, saj ga nakazuje kotna diskordanca.

Faktične logične napake kažejo na inkoherenco (nepovezanost) članka s stratigrafskim sistemom. Izjave v besedilu C se ne skladajo s stratigrafsko teorijo, stratigrafsko nomenklaturo in tudi ne s citatoma. Imenovanje druge kronostratigrafske enote enostavno ne bi bilo potrebno, če bi šlo za rupelijsko stopnjo. Značilen razvoj pri Kiscelliju ni narekoval postavitev nove stopnje. Nadalje, kiscellij ni kronostratigrafska stopnja v Paratetidi, ampak v Centralni Paratetidi. Vzhodna Paratetida in Zahodna Paratetida imata drugačno kronostratigrafsko razdelitev oligocena. Zgodovinski vpogled pokaže na nasledji nesmisel: v času, ko je bila kiscellijska stopnja imenovana, je bila kronostratigrafska razlika med kiscelijsko in rupelijsko stopnjo še večja kot je danes. Nadalje, kiscellijska stopnja ni bila imenovana po kiscellski formaciji, še več, termin, navajam, »kiscelijska formacija« nikoli ni obstajal. Obstaja in obstajal je samo termin Kiscelli Agyag Formáció (angl.

Kiscell Clay Formation), ki pa ne obsega celotnega, navajam, »spodnjega oligocena v razvoju Paratetide«. Báldi (1986) v podpoglavjih 1.1. in 1.2. uporablja zaporedje besed drugačnega smiselnega pomena »Early Kiscellian Formations« in »Upper Kiscellian Formations«. Niti Báldi & Báldi-Beke (1985) niti Báldi (1986) pa se v obeh navedenih delih nista ukvarjala s poimenovanjem kiscellijske stopnje. Nadalje (besedilo D), kiscellija in spodnjega oligocena kronostratigrafsko ne moremo enačiti, prav tako ne spodnji egerij z zgornjim oligocenom (besedilo F), zato naj še enkrat pogleda v Röglovi (1996, 1998) objavi in v Jelen in sodelavci (2001, 2002)). Glede podobnosti med slovensko »kiscellsko glino« in madžarsko kiscellsko glino (besedilo E) pa kolikor vem še ni nihče izvedel primerjalne analize, zato se o podobnosti med njima samo govori. Drugačen korelativni kronostratigrafski položajni odnos med madžarsko Kiscellsko glino in slovenskimi neformalnimi oligocenskimi litostratigrafskimi enotami pa sta postavila Jelen in Rifelj (2001, 2002). Na tem mestu pri Aničiću s sodelavci (2002) pogrešam dva citata: 1) kdo je prvi ugotavljal podobnost med obema glinama in 2) kdo je prvi prišel do velikega odkritja, da foraminiferna favna daje sivici morski značaj.

Besedili E in G sta zelo hudi logični zmoti. Našteti taksoni nimajo nobenega biostratigrafskega pomena in nobene biokronostratigrafske vrednosti. Stratigrafska raziskava, ki temelji na tako težkih logičnih zmotah in zmedi v pojasnjevanju svojega razmišljanja, ne proizvede veljavnega znanja in samo prenaša stratigrafsko zmedo iz preteklosti v sedajnost.

Zanimivo je, da v članku Dacitic glassy lava flow from Trlično at Rogatec, Eastern Slovenia (Kralj, 2002) avtorica sledi problematičnemu stratigrafskemu fragmentu v članku Aničiča in sodelavcev (2002) in napravi še dodatne napake. Stavek v besedilu H »The age of volcanism is not solved yet, although recent tectonostratigraphic and biostratigraphic studies (Jelen et al. 2001) indicate the existence of two Tertiary volcanic sequences: the lower, and the upper (Upper Oligocene - Egerian) volcanic sequence.« je propozicija, ki je lahko resnična ali neresnična in je zato semantična informacija prazna. Oziroma, v nasprotju s slovničnim stavkom, propozicija ne pove ničesar. S tem avtorica izkaže nezmožnost pojasnjevanja svojega stratigrafskega razmišljanja in tudi presojanja. Enostavno ne gradi ekspertne mreže podatkov in domnev (kar hkrati predstavlja nespoštovanje zahtev iz tehnološke in etične objektivnosti), ki bi jo pravilno vodila do sklepa in pravilno zadostila komunikacijski funkciji znanstvenega članka, če že hoče opraviti z vprašanjem starosti oligocenskega in spodnjemiocenskega vulkanizma v vzhodni Sloveniji. Poleg tega je zadnji del stavka neresničen (glej zgoraj pri odpravi problematičnega stanja v besedilu A). Nespoštovanje zahteve po citiranju povzroči še druge nejasnosti. Iz čigavih podatkov o nanoplanktonu in planktonskih foraminifer sledi, da »Both sequences have entirely submarine character ...« Če to sledi iz v besedilu H edinega citiranega dela, tj. Jelen et al. 2001, potem je argument neveljaven, ker navedeni avtorji mikropaleontološko niso raziskovali teles vulkanoklastičnih sekvenc, temveč samo prehode. Nejasen je tudi stavek »Lavas and high-level intrusive bodies in the Smrekovec Mts., and in the Rogaška Slatina and Rogatec areas, both seem to belong to the lower volcanic sequence.« v besedilu H. Če propozicija ponovno izhaja iz Jelen et al. 2001, potem je neresnična (glej zgoraj pri odpravi problematičnega stanja v besedilu A). Če pa je to avtoričina domneva, potem je v nasprotju z njeno domnevo v besedilu I. V logiki pa so nasprotja vedno pogubne okoliščine, ker nasprotujoče si propozicije v istem logičnem sistemu ne morejo biti istočasno resnične. Seveda pa prikazovanje mnenj in možnosti že od Aristotela naprej ni področje znanosti (Sarton, 1980).

## Zaključne misli

Pisanje o problemu starosti oligocenskega in spodnjemiocenskega vulkanizma v vzhodni Sloveniji v člankih Litološke značilnosti terciarnih plasti na Kozjanskem in Dacitic glassy lava flow from Trlično at Rogatec, Eastern Slovenia spominja na v znanosti že poznan način, h kateremu se zatekajo, ko zagovorniki čutijo, da je morda njihov koncept ogrožen. Svoj koncept rešujejo po naslednji metodi treh korakov: najprej trdijo, to (novi koncept) je nemogoče. Človek, ki ga predlaga je neumen. Po nekem času omehčajo svoje stališče in pravijo, to (novi koncept) je mogoče, vendar to v tem primeru ne drži popolnoma. Čez nekaj časa sledi tretji, zadnji korak, to (novi koncept) je tako, vendar smo to mi že zdavnaj vedeli. Vse tri korake sem že dvakrat doživel. Najprej se je metoda treh korakov pripetila zelo visokim izmeram odsevnosti vitrinita v Murski depresiji, drugič pa določitvi zgornje eocenske starosti soteškim skladom pri Socki in Dobrni. Izgleda, kot da v tem primeru oba članka začenjata pri drugem koraku. Torej ta, iz literature že poznana metoda treh korakov, drži. Drži pa tudi, da mora biti sleherni znanstveni koncept »ogrožen«, saj ga je potrebno poskušati v strogi znanstveni analizi - kakor želite - preveriti ali falsificirati (Popper, 1972). To pa je vprašanje znanstvenoraziskovalne metodologije in pravilnega napora.

Oba članka zrcalita vsesplošno zelo slab odnos do stratigrafije in še posebno do stratigrafske paleontologije. Ne zavedamo se, da obe stratigrafija in stratigrafska paleontologija gradita hrbtenico geološkim raziskavam, saj urejata raziskovane procese in dogodke v ordinalni red. Brez njiju bi bili le kup neurejenih podatkov.

V primeru predmeta te diskusije moram na koncu opozoriti še na dvoje. Po moji zaznavi je pri nas logično problematično stanje, ko se resnica neke trditve presoja po osebi, ki jo je izrekla, večinoma prisotna. Prisotno je celo tako, da se trditev vrednoti po izražanju, ki ugaja.

## Zahvala

Ko sem rokopis odložil, sem začutil, da je ponekod jezikovno, a drugod zopet vsebinsko šibak. Zahvaljujem se recenzentu prof. dr. Simonu Pircu za popravke in predloge za odpravo teh pomanjkljivosti. Seveda pa je moja krivda, če nisem znal sugestije najbolje uresničiti.

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# Poročanje ali dokazovanje: jezikovni problem ali kaj več?

## Odgovor

Podpisani smo od uredniškega odbora Geologije prejeli kopijo sestavka kolega dr. Bogomirja Jelena, v kateri slovensko geološko srenjo seznanja in poučuje, kako se pišejo znanstvene razprave in kot primer »zavajanja javnosti« navaja članka Litološke značilnosti terciarnih plasti na Kozjanskem (B. Aničić, B. Ogorelec, P. Kralj in M. Mišič; Geologija, 2002, 45/1, 213-246) ter Dacitic glassy flow from Trlično at Rogatec (Eastern Slovenia) (P. Kralj, Geologija, 2002, 45/1, 139-144).

Tega »razmišljanja« smo omenjeni avtorji zares veseli, saj smo izvedeli, da naše geološko znanje seže le do vznožja Boča in Bohorja, ki izstopata ob robu raziskanega prostora Kozjanskega, in na žalost ne do Keplerjevega vesolja, s katerim se spogleduje cenjeni kolega. Zato se očitno ne moremo, dr. Jelen pa kot vse kaže niti ne želi, da bi se o določeni strokovni problematiki pogovorili strpno in na ustreznem znanstvenem nivoju. V sestavku si dr. Jelen pravzaprav predava sam sebi o metodah znanstvenega dela in o raziskovalni etiki, v resnici pa je sestavek oz. njegov drugi del pisan na žaljiv in mestoma nestrpen način. Zato bo tudi naš odgovor precej direkten, saj mora biti, čeprav sprva na njegovo poročanje niti nismo nameravali reagirati.

V »racionalnem miselnem procesu«, kot avtor pojmuje svoje razmišljanje in ki izhaja iz ene njegovih številnih znanstvenih paradigem, nam očita vrsto netočnosti, ki pa niso podprte z dokazi. Ob kopici skovank domačega in tujega besedja se spretno skriva zmedenost stavčnih zvez, osebno pa zavist in nenazadnje strah. Pri tem pa nam pravzaprav ni jasen namen njegovega pisanja. Razen, da se dr. Jelen s svojim razmišljanjem postavlja nad slovensko geološko znanost in nad veliko kolegov, ne samo podpisanih, ki jih očitno podcenjuje. Istočasno pa ne dopušča oziroma je bogokletno, da se s tematiko terciarja na slovenskem ukvarja še kakšen od domačih geologov, katere on za to ni posvetil. Očitno smo avtorji obeh navedenih člankov z njihovo objavo zagrešili hud znanstveni prekršek. Kaj bo šele po objavi geološke karte Kozjanskega v merilu 1:50.000, ki je tik pred tiskom?

Na nekaterih mestih se v svojem poročanju kolega dr. Jelen spretno zateka k metodi rumenega tiska, npr. »čeprav sem opazil problematična stanja tudi drugod v članku«, brez dokazov, samo namig, tako da se bralcu nehote zdi sporno celotno besedilo obeh člankov. Tudi v njegovem članku je opaziti kar nekaj napak in nedoslednosti, npr. nenavajanje avtorjev citatov v seznamu literature, mestoma napačno pisanje imen fosilov ter nestrokovno citiranje med besedilom. Vendar to omenjamo le mimogrede, nenamerno, saj se včasih tudi vrhunskemu znanstveniku kaj zapiše ali spregleda.

Žal so se naši predlogi in želje pred desetimi leti, ko smo načrtovali skupno objavo o geologiji Kozjanskega in ki naj bi ta prostor zajela celovito že v okviru geološke karte II izjalovili, saj kolega dr. Jelen ni želel sodelovati z »amaterskimi regionalnimi geologi«, prav tako pa v sodelavo po začetnem strinjanju kasneje ni privolila tudi kolegica H. Rifljeva. Zato smo težišče prvoimenovanega »spornega« članka kasneje prestavili na litološke in petrološke značilosti namesto na celovit razvoj neogenskih plasti na Kozjanskem, kar je razvidno že iz njegovega naslova in izrecno obrazloženo tudi v uvodu. Smo bili pač domači in ne uveljavljeni mednarodni strokovnjaki.

Kolegu dr. Jelenu smo bili nekateri »dobri« le toliko, da smo mu na Kozjanskem in v Halozah razkazali profile in pomembne golice ter mu s tem skrajšali »pot do znanosti in zvezd«. Naj tu omenimo, da ga je prvoimenovani avtor samo na profil Plohov breg vodil štirikrat z eminentnimi tujimi in domačimi strokovnjaki. Slednje, le teh je blizu deset, je dr. Jelen kasneje skoraj po pravilu »izločil« iz svojega znanstvenega tima, ko je iz njih izvlekel željene informacije. Pri tem tudi pozablja, da mu je prav prvoimenovani avtor, še v fazi OGK I, nakazal na osnovi dolgoletnih terenskih raziskav številne nerešene probleme terciarja na Kozjanskem in v Halozah (še posebej mejo med spodnjim in zgornjim oligocenom, posebej problem spodnjega in zgornjega egerija ter problematiko starosti terciarnega vulkanizma). Dr. Jelen zavestno uporablja tudi metodo, da zamolči tiste podatke in literaturo, ki mu iz različnih razlogov ne ustrezajo, zato npr. v svojih objavah vedno zataji članek kolegov J. Pavšiča in B. Aničića Nanoplanktonska stratigrafija oligocenskih in miocenskih plasti na Plohovem bregu pri Podčetrtku (1998, Razprave IV. razr. SAZU, 39/2, 55-79). V tem članku je prvič v vzhodnem delu Slovenije dokazana oligocenska in miocenska starost plasti na osnovi nanoplanktona.

Na žalost nas dnevne naloge priganjajo in podpisani nimamo niti dovolj časa, niti smisla za metafiziko znanstvenih paradigem. Zato bomo zelo veseli in željno pričakujemo dokončno rešitev vseh paleontoloških, stratigrafskih, petrografskih, tektonskih, medgalaktičnih in drugih problemov terciarnih plasti v severovzhodni Sloveniji, s kartami, stolpci in drugo dokumentacijo, ki nam jih bo podal kolega dr. Jelen s timom renomiranih tujcev. Tako bomo domači raziskovalci vedeli, kje smo izgubljeni v vesolju. Do takrat pa naj za dr. Jelena velja že kar udomačen rek o podobarju Apelu in kopitarju.

*Bogoljub Aničić*
*Bojan Ogorelec*
*Polona Kralj*
*Miha Mišič*

# Navodila avtorjem

GEOLOGIJA objavlja originalne znanstvene razprave in strokovna poročila iz geoloških in sorodnih ved. Njen osnovni namen je seznanjati domačo in tujo strokovno javnost s sprotnimi stanji geološke nacionalne vede v Sloveniji in z dosežki tujih geologov v svetu. Rokopisi prispevkov naj praviloma ne bodo daljši od 25 računalniško izpisanih strani, v kar so vštete tudi slike, tabele in table. Le v izjemnih primerih (natisi habilitacijskih, doktorskih in magistrskih del) je možno ob predhodnem dogovoru z uredništvom tiskati tudi daljše prispevke.

GEOLOGIJA od leta 2000 izhaja praviloma dvakrat letno v obsegu 20 do 25 avtorskih pol. Vse prispevke recenzirajo domači in tuji vrhunski strokovnjaki. Avtorji so dolžni njihovo pisno mnenje upoštevati ter svoje prispevke po potrebi tudi dopolniti.

V želji, da bi z našimi izsledki v slovenski geološki vedi seznanjali čimširši krog strokovnjakov po svetu, je večina prispevkov v GEOLOGIJI objavljena razen v slovenskem tudi v angleškem oziroma nemškem jeziku. Prispevke, ki obravnavajo snov v slovenske geologije, morajo avtorji pripraviti vsaj v tretjini celotne vsebine za objavo v slovenskem jeziku kot povzetke. Za prevode poskrbijo avtorji prispevkov sami, uredništvo opravi le jezikovne popravke.

Prispevke oddajte uredništvu v enem izvodu pisno in na disketi ali CD-ROMU. Pisci prispevkov naj imena citiranih avtorjev med besedilom prispevka in pri naštevanju literature pišejo brez presledkov med črkami. Imena avtorjev naj samo podčrtajo ročno z rdečim svinčnikom, razpiranje bo uredila tiskarna. Imena fosilov (rod in vrsto) pa naj pišejo poševno. Vse drugo bo uredilo uredništvo.

Naslovi prispevkov naj bodo kratki in praviloma ne presegajo 12 besed. Če je prispevek napisan v slovenskem jeziku, mora biti njegov naslov preveden tudi v angleški oziroma nemški jezik. Poleg avtorjevega polnega imena in priimka naj bo podan tudi njegov naslov. Vsebine oziroma kazala pri normalno dolgih prispevkih ne objavljamo.

Kratka vsebina oziroma abstract naj ne presega tisoč tiskovnih znakov. Pri slovensko napisanih prispevkih mora biti kratka vsebina napisana v slovenskem in angleškem oziroma nemškem jeziku.

V literaturi naj avtorji prispevkov praviloma upoštevajo le tiskane vire, rokopise naj navajajo v izjemnih in nujnih primerih z navedbo, kjer so shranjeni. V seznamu literature navajajte samo v prispevku omenjana dela. Med besedilom prispevka citirajte samo avtorjev priimek brez inicialke njegovega imena (inicialko navajajte samo, če je več avtorjev z istim ali enakim priimkom), v oklepaju pa navajajte letnico izida navedenega dela in po potrebi tudi stran. Če navajate delo dveh avtorjev, izpišite med tekstom prispevka oba priimka (npr. Pleničar & Buser, 1967, 152), pri teh ali večih avtorjih pa napišite samo prvo ime in dodajte et al. z letnico (npr. Mlakar et al., 1992). Literaturo navajajte po abecednem redu.

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Primer citirane knjige:

Flügel, E. 1978: Mikrofazielle Untersuchungsmethoden von Kalken. – Springer Verlag, 454 pp., Berlin.

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