THE DIGITAL GEOLOGICAL MAP OF KOSOVO AT A SCALE 1 : 100,000 (DGM 100) - MAP COMPILATION AND ASPECTS -

A. Knobloch [1], *E. Dickmayer* [1], *C. Legler*[1], *N. Peci* [2], *V. Pruthi* [3], *M. Sieste* [1]

Abstract

Beak Consultants GmbH compiled 15 digital geological map sheets for the whole territory of Kosovo at a scale of 1 : 100,000 (DGM 100). The geological and spatial information of the created maps is based on the digitalisation of the geological maps of former Yugoslavia 1 : 100,000 (GM 100), which have been printed between 1970 and 1984. Since these maps do not correspond to today's status of knowledge, it was necessary to update them to international standards – resulting in the compilation of the DGM 100. The project has been divided into two stages: During the first, the creation of the map concept, the unified legend and the compilation of test pilot map sheets was carried out. In the second step, all map sheets were compiled, based on the tested methodology, and finally linked to the GEO-Database Kosovo as Digital Geological Map. During the compilation of the map sheets, two main difficulties had to be managed: the first difficulty was to combine and unify the different map legends of the original maps to a new unified legend and to apply this created legend to the digital map representation process; the second difficulty originated from map sheet border inconsistencies, which had to be eliminated. The final geological maps are the most important base maps for all future geoscientific maps of Kosovo, for instance maps of raw materials, water supply, geological engineering, soils etc. Furthermore, the maps provide necessary information to local administration and help for territorial planning processes and particularly for the development of Kosovo.

Main Words

Geology, Unified Geological Legend, Map Compilation, Map Design, Regional Geological Units

Background

The Directorate of Mines and Minerals (DMM) – now the Independent Commission for Mines and Minerals of Kosovo (ICMM) – contracted the project "The Compilation of Geoscientific Maps of Kosovo" to Beak Consultants GmbH. In the first stage of the project (November 2004 to June 2005), a map concept including a unified legend and four pilot map sheets were compiled. In the second project stage (July 2005 to March 2006), 15 digital geological maps for the whole of Kosovo at a scale of 1 : 100,000 (DGM 100) have been created. The data is also provided in an easy-to-use database system, which makes it available to the ICMM employees via the GEO-Database Kosovo (GDK). The broader public can acquire base project information via the internet service: www.kosovo-mining.org.

[1] Beak Consultants GmbH, Am St. Niclas Schacht 13, D-09599 Freiberg, Germany
[2] Independent Commission for Mines and Minerals, Rruga Rr. Statovci 29, 10000 Prishtinë, Kosovo
[3] University of Prishtinë, Faculty of Mathematic and Nature Science, Department of Geology, Rr. Nëna Terzë 5, 10000 Prishtinë, Kosovo

Tasks and Objectives

The compilation of the presented Digital Geological Map at a scale of 1 : 100,000 (DGM 100) was a process that included a multitude of different tasks and objectives. The first phase of the first stage, from 1st November 2004 until 31st March 2005, included the complete procurement of the map base, all available geoscientific maps of Kosovo and adjacent territories, reports, documents and later, the compilation of the map concept. After the presentation of the map compilation concept for the DGM 100, it was decided to produce four pilot map sheets in the second phase of the first stage. Furthermore, the database had to be developed and designed in the course of the creation of the four pilot map sheets.

In the second project stage, Beak Consultants GmbH started with the compilation of the Digital Geological Concept Map (DGCM 100) and the Digital Geological Map (DGM 100) for the whole of Kosovo. According to the map concept, the different legends of the original geological maps (GM 100) were assigned to the new (unified) legend of the DGM 100. This work was continued by the re-attribution of each legend unit. By this, each polygon got assigned a colour of stratigraphy, a fill pattern of lithology and a fill pattern of alterations. This work was completed at the end of December 2005. In January 2006, the map legend and the map design for the map sheet printing at a scale of 1 : 100,000 have been programmed. In February 2006, the programming of the digital geological map with variable map scale / map extracts was completed. Now it is possible to print out any desired map extent in any required map scale with uniform map layout and a map legend that only lists the units that can be found on the map.

Map Compilation

Existing and Used Data and Their Evaluation

With respect to the presented digital map sheets, 15 map sheets of former Yugoslavia (1970-1984) at a scale of 1 : 100,000 are available (GM 100) for Kosovo territory. Over a period a several years, different mapping teams have compiled and created them. Because of this, the map content and the shown standard of geological knowledge differ considerably when comparing one map sheet to another. One of the main problems in the compilation process of the DGM 100 was the lack of alignment of adjacent geological map sheets 1 : 100,000. The geological units or areas, which have been mapped, simply did not match together.

Procedure of Map Compilation

A revision of the existing geological maps 1 : 100,000 (GM 100) was indispensable. In the first steps, the GM 100 were digitised and implemented into the GEO-Database Kosovo (GDK) (as vector and textual data). The further map processing included the introduction of the unified legend (valid for all sheets) and the conversion of the single digital maps into a uniform map sheet system. Therefore, the assignment of single geological strata to regional geological units was based on the already developed regional geological model (concerning the geological history of the Balkan Peninsula and plate tectonics). It was created as “Conceptual Map” (DGCM 100 – digital geological concept map) without any field verification. Its intention was to identify contradictory and discrepant mapping of geological conditions. The verification and removal of discrepancies as well as boundary inconsistencies and the implementation of some field studies results was the objective of the last project step (DGM 100). Figure 1 shows the process of map compilation from the base (original) geological maps (GM 100) to the modern presented digital geological map (DGM 100).

Step 1 - Development of the unified legend for all map sheets

The Unified Legend

Methodology:
Development of a regional geological model, application of geological experiences, implementation of international standards

Step 2 - Finding the source - Intensive research for the existing GM 100

Original map sheets of the Geological Map 1:100,000 - GM 100

Methodology:
Research in archives and institutions in Kosovo and in foreign countries

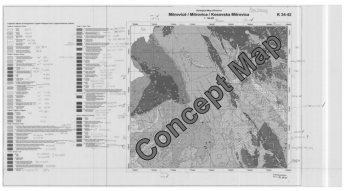
Step 3 - Digitalisation, translation of legends and implementation into GEO-Database Kosovo compilation of the Geological Map (GM 100) sheet-by-sheet, digital 1:1 copy of the GM 100)

Digitised map sheets of the Geological Map 1:100,000

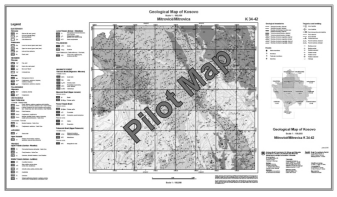
Methodology:
Capture of data - digitalisation

Step 4 - Development of pilot map sheets, re-attribution of the GM 100 legends and assignment of the mapping units according to the unified legend

The Digital Geological Concept Map 1:100,000 - DGCM100

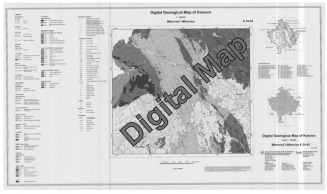


Methodology:
Desk studies and the first assignment of international standards



Step 5 - Removal of border inconsistencies, re-attributation

The Digital Geological Map 1:100,000 - DGM 100



Methodology:
Limited fieldwork with sampling and different investigations, application of the regional geological model, desk correlation and implementation of international standards

The first computerised seamless geological map of Kosovo at a scale of 1 : 100,000 !

Figure 1: Map Compilation Working Flow.

Data Processing and GIS

At the beginning, all old geological maps 1 : 100,000 (GM 100) that were available only as scans have been digitised and by this transferred into attributable vector format (polygon, line point). Some of the map sheets were in bad condition. A fortiori, their readability was restricted and their digitalisation was a difficult process. Therefore, digitalisation errors cannot be ruled out completely.

The selection of colours and fill patterns of the digitised GM 100 is based exclusively on the existing GM 100 to illustrate the relationship between the GM 100 and the digitised map sheets. The ESRI software tool "ArcGIS 8.3" was chosen as digitising program. The digitised maps and their factual data have been incorporated into the GDK system.

The digitised GM 100 was re-attributed according to the regional geological model and international standards – resulting in the digital geological concept map (DGCM 100). The transformation of the digital concept map (DGCM 100) to the digital map (DGM 100) was tested during the production of the four pilot map sheets. There, necessary automatic map creation tools have already been developed. The generation of the map legend for the DGM 100 was developed by using the "ArcObjects" package. It ensures that only the map items that are actually printed on the map extract are added as legend items, automatically. All polygon legend items are understood as linked three-layer objects. Every legend item is represented by an unique symbol and abbreviation. The programmed legend tool automatically creates the symbol, which comprises of:

- Fill colour (represents the stratigraphic position),
- Fill pattern (represents the lithology / petrography / genesis),
- Second fill pattern (represents the alterations),
- Rock abbreviation (indicating the rock age, the rock type with special descriptions).

In addition, on the map, all kinds of geological boundaries, different tectonic elements (anticline, syncline, folds, axis etc.), bedding and dip of bedding, foliation and dip of foliation, joint, cleavage, and biostratigraphic characteristics (flora and fauna) are illustrated.

For the representation of all information on the maps, the locally used reference system was used which is based on the Bessel 1841 Ellipsoid and the MGI Austria Datum. The data was projected using Transverse Mercator. The magnetic declination across Kosovo is 3.3° E, in average.

Unified Geological Legend

General Note

The numeric encryption of lithology, stratigraphy and alteration is the basic concept of the map. Because of this, the geological units shown on the map are categorised according to their geological age and their lithological and petrographical properties.

Stratigraphy

On the map, the sedimentary, para-metamorphic and metamorphic rocks are classified into erathem, system, series (section of system), epoch and stage. Their age and subdivision is reflected by a colour code (CMYK values), which is conform to the one used on the International Stratigraphic Chart [3]. The age of the rocks can also be identified by the assigned rock abbreviations.

Lithology

The following sedimentary rocks are distinguished on the DGM 100:

- **Unconsolidated sedimentary rocks (sediments)**: clay, mud, silt, sand, gravel, siliceous ooze, marl and carbonate sediments,
- **Consolidated sedimentary rocks (sedimentites)**: claystone, mudstone, siltstone, sandstone, conglomerate, chert, marlstone, undifferentiated carbonate rocks, limestone and dolomite.

On the map, the different sedimentary rocks / rock associations are illustrated by different fill patterns.

The following magmatic rocks are distinguished on the DGM 100:

- **Plutonic rocks**: granite group, granodiorite-granite group, syenite-monzonite group, gabbro group, essexite-theralithe group, alkaline group and ultramafic group.
- **Volcanic rocks**: rhyolite group, trachyte group, andesite group, basalt group, tephrite group, alkaline group, ultramafic group.

Separate colour codes and fill patterns were assigned to each group of magmatic rocks. The age of the magmatic rock cannot be identified by colour, but is presented by the rock abbreviation. The colours used for the few pyroclastic rocks coincide with the before-mentioned magmatic groups. Metamorphic rocks are illustrated by a simple fill pattern. Marbles and amphibolites are mostly very small layers or lenses. Because of this, these rocks are illustrated only by colour. Metamorphosed magmatic rocks are illustrated in the colour of adequate magmatic rocks with their specific fill pattern.

Alterations

A number of rocks have been a subject to secondary changes or alterations by a variety of processes like weathering, laterisation / bauxitisation, kaolinisation, silification, pyritisation etc. These alterations are highlighted by secondary fill patterns (beside the rock fill pattern). Metamorphism is a special type of rock alteration. Regional metamorphism and contact metamorphism can be distinguished. In the past, in Kosovo, metamorphic grades were only classified to a limited extent. Due to the lack of special metamorphic investigations, the fill pattern illustrating the metamorphic grading is not shown on the current version of the DGM 100.

Rock Abbreviations

The rock symbols on the map are used to identify the stratigraphic position, the genesis and the petrography of the mapped geological units. They are built up as abbreviations of the above-mentioned legend items. The minimum requirement for a rock symbol was the indication of the stratigraphic position. For magmatic rocks and metamorphic rocks, the use of the petrographic symbol was preferred. Some symbols are extended by additional information on genesis or other petrographic data, if necessary, in order to differentiate them. The formula for the rock symbol is as follows:

	structure	petrography features	rock	mineral	genesis	ERA/SYSTEM	Series	Stage	sub-series/sub-stage	*LOCAL NOTATION*
size:	3	3	1	2	3	1	1	1	2	2
indexed:	low	high	on line	on line	low	on line	on line	on line	high	on line

Principally, the structure applied to the stratigraphic codes is based on the International Stratigraphic chart [3]. It consists of alphanumeric characters, denoting the era, system / epoch, series / sub-series, stage and sub-stage.
The following rules apply:

Era:	2 Latin capital letters on line, size 1 (e.g. NP, PZ)
System:	1 Latin capital letter on line, size 1 (e.g. K, N, Q)
Section Era / System:	Arab number on line, size 1 (e.g. 1, 2, 3)
Stage:	1 or 2 Latin low case letters on line, size 1 (e.g. cn)
Sub-Series / Sub-stage (Lower, Middle, Upper):	Arab number, indexed line high, size 2 (e.g. Nm^1)

(size 1: large, size 2: medium, size 3: small)

Lower case letters have to be used for Middle Triassic to Upper Cretaceous. New symbols were proposed for Lower Triassic (T1), for Berriasian (Kbe), for Palaeogene (E) and Neogene (N). Latin capitals in italics and size 2 (medium) denote local notes in the sense of facies, rock formations, lithostratigraphic and tectonic or even metamorphic units (e.g. *CVT* – Vardar Lower Cretaceous flysch trough). For a series of stratigraphic units, it was useful to include coded information on genesis or special morphological properties. This is expressed in lower case Latin letters, standing prefixed in front of the stratigraphic symbols. The letters have a size of 3 (small) and are placed at lower index level (subscript) (e.g. $_{ta}$Qh). Signs for rocks and additional signs for characteristic minerals, texture, structure and other petrographical details are placed in front of the stratigraphic symbols, i.e. prefixed. Abbreviations (e.g. for limestone (l), clay (c), conglomerate (g)) were used to clearly define the lithology. Lower case letters of the Greek alphabet express the lithology of magmatic (plutonic / volcanic) rocks. They have a size of 1 (large) and are on line. The symbols are orientated to the ones used on the QAPF-STRECKEISEN-Diagrams [4]. Palaeotypical rocks (e.g. diabase, porphyrite, quartz porphyry) do have the same sign like their reference rocks. The symbols for volcanoclastic rocks are similar to the before-mentioned explanations for volcanic rocks. In contrast, they are prefixed, i.e. are placed before the stratigraphic symbol. The sign does also carry a lower case Latin „v“. This letter is followed by a code for the magmatic origin of the respective effusive rocks. Generally, orthometamorphic rocks including migmatite / granulite are expressed by Latin capitals in italics (*A* – orthoamphibolite). Parametamorphic rocks are described in lower case italic Latin letters (*c* – marble). The symbols of metamorphic rocks are placed on line. Supplemental signs (mineralogical, petrographical, genetical features) can expand the lithology signs. Signs for minerals are denoted by lower case Latin letters in size 2. They are placed right behind the rock sign on line and are only valid in this combination. Multiple minerals are hyphenated (e.g. *s*q-cl). If necessary, all rocks can be further differentiated by adding signs for special petrographic features (e.g. serpentinisation, albitisation, hydrothermal alteration). Those signs will be expressed in lower case Latin letters of size 3 and placed before the actual rock sign as indexed line. Texture and structure (eyed, vitrophyric, fine-grained, massive) are also placed before the actual rock sign but are assigned on lower index line (subscript).

Sketch Map of Regional Geological Units

The area of Kosovo is characterised by a variety of geological formations. From a geotectonic point of view, Kosovo's territory can be divided into three main zones, from NE to SW:

- Dardania massif (DM), the Kosovarian part of the Serbo-Macedonian massif),
- Vardar zone (VZ), consisting of Internal Vardar subzone (IVZ), Central Vardar subzone (CVZ), and External Vardar subzone (EVZ) and
- Dinarides-Hellenides, subdivided into the Drinsko-Ivanjički element (DIE), East Bosnian - Durmitor zone (EBDZ), Ophiolite belt (OB) and Sharr-Korabi zone (SKZ).

Because of the differences in the portrayal of the distribution of the main tectonic zones and also because of their non-uniform, at times confusing names, Kosovo is given a modified nomenclature, which is presented on a sketch map on the DGM 100 (see Figure 2). It is based on local names. At the moment, it is the first step is to separate as many geological units as possible in order to recognise their individual characteristics. Later, these can be grouped together to form separate, superior units.

CVBK - Badofc/Kishinca Cenozoic volcanic complex
CVKB - Kopaonik/Belobërdë Cenozoic volcanic complex
CVMB - Majdan/Braine Cenozoic volcanic complex
CVMS - Mitrovicë/Samadrexhë Cenozoic volcanic complex
CVNK - Nosale-Kllokot Cenozoic volcanic complex
CVRB - Rogoznë/Bube Cenozoic volvanic complex
CBDU - Dukagjin Cenozoic basin
CBDG - Gjakovë Cenozoic subbasin
CBDP - Pejë Cenozoic subbasin
CBDS - Suharekë Cenozoic subbasin
CBKA - Kamenicë Cenozoic basin
CBKM - Moravë Cenozoic subbasin
CBKK - Kriva Rekës Cenozoic subbasin
CBKS - Strezofc Cenozoic subbasin
CBKO - Kosovo Cenozoic basin
CBPO - Podujevë Cenozoic basin
CBDR - Drenicë Cenozoic basin
CBMI - Mirushë Cenozoic basin
CPA - Pashtrik Upper Cretaceous syncline
CPG - Pagarushë Upper Cretaceous anticline
CCA - Carralevë Upper Cretaceous unit
CJE - Jezerka Upper Cretaceous unit
CKC - Kaçanik Upper Cretaceous unit
CZU - Zubin Potok Upper Cretaceous unit
CVT - Vardar Lower Cretaceous flysch trough
JBR - Brezovicë Jurassic ophiolitic complex
JGJ - Gjakovë Jurassic peridotite complex
JGO - Golesh Jurassic ophiolitic complex
JKZ - Koznicë Jurassic ophiolitic complex
JST - Strofc Jurassic ophiolitic unit
JLE - Leposaviq Jurassic ophiolitic complex
JRA - Rahovec Jurassic ophiolitic complex
TKO - Koritnik Triassic unit
TMO - Moknes-Alpet Shqipetare Triassic complex
TKR - Çiçavica Triassic unit
TKU - Kutlovc Triassic unit
MKO - Kolashin metamorphic unit
MSH - Sharr metamorphic complex
MST - Shtime metamorphic unit
MGA - Gadima metamorphic unit
MKC - Kaçanik metamorphic unit
MRU - Rugovë metamorphic unit
MNB - Novobërdë metamorphic unit
MKU - Kurolai metamorphic unit
MJK - Kopaonik metamorphic footwall unit
DA - Dardania massif (Serbo-Macedonian massif)

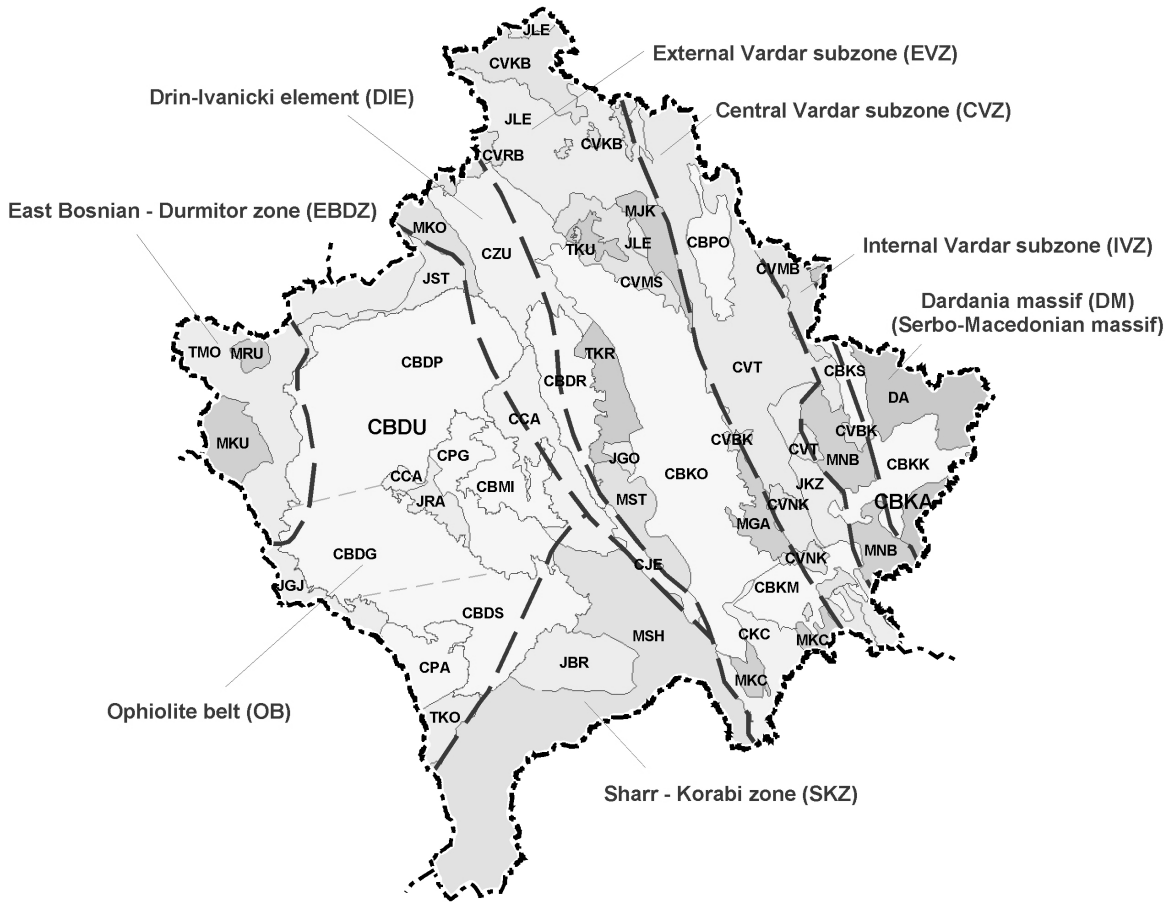


Figure 2: Regional Geological Units of Kosovo.

Conclusions

Maps are a subject to permanent change. The flood of new scientific insights results in a necessity to adapt the existing maps to these new findings in a fast and effective way. A digital map satisfies these demands the best. The presented 15 digital geological maps at a scale of 1 : 100,000 (DGM 100) have been created based on the digital implementation of the available and published geological maps at the same scale (GM 100). The DGM 100 represents the first attempt to introduce a uniform geological map at a scale of 1 : 100,000 in GIS-format for the whole of Kosovo. The DGM 100 can be understood as crucial column for the work of the future Kosovo geological survey. In the future, it is recommended to further perfect the presented maps since a couple of open questions still exists.

The creation of the digital geological map (DGM 100) has been done with only a limited knowledge of the territorial geological conditions and the geological outcrops since detailed geological mapping was not scheduled. It has to be noticed that the further completion of the geological map based on detailed field investigations is necessary. The removal of the existing map sheet border inconsistencies was only partly based on field investigations. In most cases, the elimination was based on logical and reasonable aspects in accordance with morphology, rock associations, tectonic, common superior stratigraphic units etc.

The primary goal of the created geoscientific maps is to provide a knowledge basis for investments into the mining sector of Kosovo. A major step for this is the further creation of a Metallogenic Map of Kosovo as part of the by Beak Consultants GmbH compiled map set 1 : 200,000 of Kosovo. The objective of this map set is helping to answer and follow raw material economical questions, particularly. Similarly, the creation of further thematic geoscientific maps will be possible, based on the map set itself.

Literature / References

[1] The Compilation of the Geoscientific Maps of Kosovo – The Digital Geological Map 1 : 100,000 – Description of the Map Compilation. – Beak Consultants GmbH, Prishtinë, March 2006, 175 p.

[2] Osnovna Geološka Karta SFRJ, 1 : 100,000, Beograd/Titograd/Skopje1970-1984, Geozavod Beograd/Geološki Institut Beograd, Zavod za geološka istraživanja SR Crna Gora, Geološki zavod Skopje.

[3] The International Stratigraphic Chart. - International Commission on Stratigraphy (ICS), Commission de la Carte Geologique du Monde, 2004.

[4] BGS Rock Classification Scheme Volume 1: Classification of Igneous Rocks. – British Geological Survey, Research report No. RR 99-06, 1999.