THE GEOSCIENTIFIC MAP SET OF KOSOVO AT A SCALE OF 1 : 200,000

F. Müller¹, N. Burcham², E. Dickmayer¹, A. Knobloch¹, C. Legler¹

Abstract
At the moment, Beak Consultants GmbH is setting up a set of geoscientific maps for Kosovo at a scale of 1 : 200,000. Some of the maps are already completed (Map of Minerals, Hydrogeological Map), some are close to completion (Map of Morpho-Orographical Structures, Satellite Imagery Map, Map of Mineral and Thermal Water), some need further discussion (Tectonic Map) and some are still in compilation process (Geological Map, Metallogenic / Minerogenic Map, Soil Map). After completion, the map set will form an important basis for the economic development of the Territory as it provides a basis for investors, for state institutions and for geoscientific surveys and users in order to get a first overview of the resources and the potential of Kosovo.

Main words
Geoscientific Map Set, Geology, Raw Materials, Metallogeny, Hydrogeology

Background
Maps are the principal instruments of displaying geoscientific information and of providing this information to the different sectors. Geoscientific maps are very important for the ministries and for the municipal planning authorities, for the civil engineering and mining industry as well as for potential investors in the mining sector, and for many other users.

Beak Consultants GmbH started with the compilation of a geoscientific map set of Kosovo at a scale of 1 : 200,000. Some of the overview maps are already completed, some are close to completion, some need further discussion and some are still in compilation process. These maps represent the actual knowledge in Kosovo’s geology, raw materials, ground-water resources, soils etc. At the moment six maps are completed or are in preparation, respectively. Still in the process of compilation are the Geological Map of Kosovo and the Metallogenic / Minerogenic Map of Kosovo. It is intended to compile further maps at the same scale (Geohazard Map, Map of Construction Raw Materials etc.).

The Content of the Geoscientific Map Set at a Scale of 1 : 200,000
The Map of Minerals of Kosovo (MM 200)
The map is the first compilation of all so far known metallic and non-metallic mineral deposits and occurrences including solid hydrocarbons (lignite) of Kosovo. The map represents a clear overview and summary of all available information about minerals of Kosovo and forms a very important basis for the economic development. In the background of the map, the main geological formations of Kosovo are shown, which have been derived from the

¹ Beak Consultants GmbH, Am St. Niclas Schacht 13, D-09599 Freiberg, Germany
² Independent Commission for Mines and Minerals, Rruga Rrustem Statofci 29, 10000 Prishtinë, Kosovo
available maps and documents and from field observations. The mineral deposits and occurrences on the map are represented concerning their commodity group (solid hydrocarbon, metallic minerals, industrial minerals, construction minerals and aggregates, decorative and dimension stones, precious stones) by different colours; concerning their size (small, medium, large) by different symbol sizes, concerning their genetic type (magmatic, volcanogene, pegmatitic, hydrothermal, infiltration, metamorphic, sedimentary, placer, residual, water) by different symbol types; concerning their geological knowledge (reconnaissance, prospecting, general exploration, detailed exploration) by different symbol outline thickness; and concerning their mining activity (active, inactive). In addition, topographic features like main roads, railroads, rivers, lakes, main cities are shown on the map for better orientation, which have been digitised from the available topographic maps. The map also features two sketch maps showing, first, the main geotectonic units of the central Balkan Peninsula and, second, the main minerogenic units of Kosovo.

Inside the Serbo-Macedonia Minerogenetic Province, small-sized mineralisations of Sb and Fe can be found, whereas the Dinaric Minerogenetic Province is characterised by non-ferrous and ferrous metals, primarily. In the Vardar zone, particularly, large-sized Pb-Zn deposits are known, and in the Western Ophiolite Belt primarily podiform Cr-occurrences can be found. Essential magmatic processes are connected to the Oligocene-Miocene subvolcanic-volcanic calc-alkali event and to the Upper Jurassic ophiolite magmatism. Deposits, which are connected to the Middle Triassic rift magmatism (in connection with the opening of the Tethys ocean), and deposits of the Palaeozoic magmatism seem to be less important for the territory of Kosovo.

Lignite is of high strategic importance for the development of Kosovo. With 14,7 Mt, Kosovo possesses the world’s fifth-largest proven reserves of lignite. The lignite is distributed across the Kosovo, Dukagjin and Drenica Basin, although mining has so far been restricted to the Kosovo Basin.

The most important hydrothermal lead and zinc mineralisations can be found in the northern and eastern part of Kosovo. They belong to the so-called Trepça Belt (Kopaonik) of lead-zinc mineralisations, which extends linear for over 80 km in northern and north-eastern Kosovo and includes numerous mined deposits and occurrences. The Trepça Belt is located within the Vardar zone. There, the possibilities of finding Pb, Zn and Ag of carbonate replacement type deposits (CRD) and interesting Au, Ag and Cu mineralisations connected with Cenozoic subvolcanic and volcanic rocks have to be checked and analysed. Five important Pb-Zn mines and numerous smaller deposits and occurrences do exist.

Nickel deposits and occurrences do appear in the centre of Kosovo and in the western part of the External Vardar subzone. The Golesh / Goleš massif hosts nickel deposits and occurrences, which originated from lateritic weathering of Jurassic ultrabasites. Nickel bearer are nickel-hydro-silicates of magnesium, iron and aluminium. The deposit of Cikatovë / Čikatovo is bound to the lateritic weathering zone of peridotite and weathered ore material, too.

The most important bauxite deposit is situated at the Grebnik mountain. More occurrences were found further south. The ore belongs to the group of ferro-bauxite. It originated from the hiatus of Upper Cretaceous sediments by lateritic weathering. The ore does have very high contents of Al₂O₃ and Fe₂O₃.

Kosovo does possess a variety of chromium occurrences. Essentially, they are connected to the Jurassic Western Ophiolite Belt. Noticeable is the fact that the Eastern Ophiolite Belt does contain only insignificant Cr mineralisations. The prospective areas for chromium are concentrated to the southern and south-western part of Kosovo (Gjakovë / Đakovica peridotite massif). These pods are small but of high grade. In Albania, genetically equal deposits
are known to contain enhanced levels of platinum group metals (PGM). Out of analogy reasons, it can be assumed that mineralisations can also be found at Kosovo side.

Indications of primary (hydrothermal) sulphide and oxide mineralisations of Cu, Fe, Mn in volcanogene-sedimentary series and liquid-magmatic impregnations of Ni, Cu, Fe, Ti in Middle Triassic and Upper Jurassic ultrabasitic complexes are worth an examination.

The most deposits and occurrences of magnesite do appear within the Vardar zone. Except for the deposit in the northern part of the Kamenicë basin, which is of sedimentary origin (strata-bound replacement of Cenozoic dolomites), all deposits and occurrences of magnesite originated from hydrothermal veins and are bound to serpentinised zones within the ophiolites. Kosovo possesses two magnesite mines at Goleš / Goleš and Strezovc. Both started as open pit operations and continued later on as underground mines prior to their closure.

Kosovo does have important deposits of kaolin in the Northeast of the country. A bentonite deposit is situated southwest of Karaçevë / Donje Karačevo and another important one around Drenovc / Drenovce. Both deposits are situated in the Kamenicë basin and are of Miocene age. Of high interest are occurrences of halloysite.

The Miocene and Pliocene clays are exclusively used for the production of bricks, mainly customary hollow bricks. Some clays are also usable as refractory clays, for the fabrication of ceramic products and as sealing material, too. Construction minerals, suited for the production of aggregates, are of increasing importance for the economic development of Kosovo. The most important carbonate hard rocks, marbles, silicate hard rocks, pyroclastic rocks, gravel and sand deposits and occurrences are represented on the map. The Kosovo Quarry Plan does provide a more detailed overview [1]. Of importance are dimension stones and stones for housing (e.g. white, black and red marble, gabbro, granite, gneiss, sandstone and travertine).

The Hydrogeological Map of Kosovo (HyGM 200)

The map is the newest presentation of the hydrogeological and hydrological conditions of Kosovo. The map represents a clear overview and summary of all available information about the water resources of Kosovo and forms a very important instrument for regional planning procedures. The hydrogeological classification has been based on the interpretation of the information shown on the available digital geological map of Kosovo at a scale of 1 : 100,000 [2]. Each unit is represented concerning their hydrogeological classification by different colours and concerning their lithology by different signatures. The units have been classified according to the type of porosity (intergranular porosity, fissured porosity, fissured and karstified porosity, double porosity, without porosity) and their permeability. The map also shows important data about certain and inferred directions of ground water flow in Kosovo, as well as areas with confined or artesian ground water. Furthermore, point data about the location of boreholes, observation wells, sampling wells, pumping wells, pumping stations and caves is represented on the map. On the hydrological side, the map does show the main springs of Kosovo, classified according to their discharge (small, medium, large), their development (developed, undeveloped) and their type (spring, mineral spring, thermal spring, thermomineral spring). The main surface water divides, rivers and lakes of Kosovo are also shown on the map. In addition, topographic features like main roads, railroads, rivers, lakes, main cities are shown on the map for better orientation, which have been digitised from the available topographic maps. The map also features two sketch maps showing, first, the mean annual rainfall distribution across Kosovo and, second, the mean annual air temperature distribution across Kosovo.
The Map of Morpho-Orographical Structures of Kosovo (MOM 200)
The map shows the main morphological and orographical structures of Kosovo. In the background of the map, a digital elevation model (DEM) is shown, which does have a ground resolution of 90 m per pixel and an accuracy of 1 m. The DEM was developed from the available SRTM (Shuttle Radar Topography Mission) data, which was taken during a NASA shuttle mission in February 2000 [3].
From a geographical point of view, Kosovo can be subdivided into two large, flat, regional units: The north-eastern part is referred to as Rrafshi i Kosovës / Kosovo basin, the south-western part as Rrafshi i Dukagjinit / Metohija basin. They are characterised by special climatic-geographical conditions. The border between Rrafshi i Dukagjinit and Rrafshi i Kosovës forms the surface water divide between the Adriatic Sea on the one side and the Black Sea and the Aegean Sea on the other side. Kosovo is surrounded by several high mountain ranges (far more than 2,000 m). The northern part is occupied by the Kopaonik mountains, which are characterised by abrasive activity. In the southern and south-western part of Kosovo, at the border to Macedonia, the Mali i Sharrit / Šar Planina mountains are located. The western part of Kosovo includes parts of the Alpet Shqipetare / Prokletije and the Mali i Moknes / Mokra Gora mountains. These areas are characterised by rocky material, high mountains and deep gorges. In the central part of Kosovo, western and north-western of Prishtinë / Priština, the mountain ranges Bjeshket e Çicavice / Čičavica and Golesh / Goleš, Carralevë / Crnoljeva and Milanovc / Milanovac are located, which are characterised by karstic forms, both fluvial and abrasive, rising to elevations of about 1,000 m.
The map is divided in geographical and landscape units (nature spatial units), respectively, based on the information shown on available different geographic-topographic maps of Kosovo. The borders of these units are main and tributary rivers and surface water divides. All units have been named in Albanian / Serbian language. Such a comprehensive presentation has not been available until now. The MOM 200 is a suggestion of the authors and shall stimulate the discussion since the delimitation of these units is very difficult.

The Satellite Imagery Map of Kosovo (SatIM 200)
The map shows a false-colour image of Kosovo as well as a three-dimensional view of the country. The image used for this map was generated from three LANDSAT 7 ETM+ bands, each sharpened with the panchromatic band to a ground resolution of 14 m. Band 7 (mid-infrared light) is displayed as red, band 4 (near-infrared light) is displayed as green and band 2 (visible green light) is displayed as blue. The coverage date is scene dependent (2000 ± 3 years) since the used scenes were taken at different time points. The three-dimensional view of Kosovo was compiled using the available SRTM data [4].
The false-colour satellite image represents the actual situation of the agricultural conditions, of the vegetation, of the geological background and of the morphological features by the different types of colours: Areas with a high heat transfer capability are red and violet coloured (constructional and urban areas), whereas areas with a low heat transfer capability are grey or black coloured (water reservoirs, lakes). Second, areas with a high vitality of vegetation are coloured green (forests), whereas areas without any vegetation are coloured red or black, respectively. Third, the geological main units with their main structures can be mapped from the image. Especially, the Cenozoic sediment basins, the distribution of ultramafic rock complexes, and furthermore tectonic features can be distinguished very well. At the moment, Beak Consultants GmbH is working on a new real-colour satellite map.
The Map of Mineral and Thermal Water of Kosovo (MMTW 200)

This map is the presentation of all known mineral and thermal water springs of Kosovo. The map gives a good overview and summary about these resources. The mineral and thermal springs on the map are represented concerning their usage (e.g. production of bottled water, balneotherapy, recreation and sport, local drinking water), their content of total mineralisation, their discharge, their temperature, and their main cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) and anions (HCO_3^-, CO_3^{2-}, Cl^-, SO_4^{2-}, OH^-). For better understanding of the geochemical classification, a PIPER plot of the water chemistry of the shown springs is printed on the map. Furthermore, the springs can be classified by using the plot of water temperature vs. electrical conductivity / total dissolved solids that is also shown on the map. An overview of all captured data of all on the map shown spring is provided by the table on the map (e.g. coordinates, spring type, discharge, temperature, electrical conductivity, pH, main ion composition, usage).

Kosovo does possess a variety of mineral and thermal water springs. Based on the current investigations, more than 50 locations have been verified so far. The measured spring temperatures vary from 10 to 50°C. Due to this, cold (<20°C), warm (20 to 35°C) and hot (>35°C) springs can be found. According to the measured / calculated values of the total dissolved solids (TDS), springs with low (<1 g/L), medium (1 to 3 g/L) und high (>3 g/L) degree of mineralisation do exist. Concerning the discharge of the springs, some springs do have a high discharge (far more than 100 l/min). The pH-values of the measured springs range only slightly between pH 6.2 and pH 7.4. The only exception to this is the pH-value of a spring in northern part of Kosovo with pH 11.4, which is unusual and of high interest.

Based on the field observations, many of the springs are gas containing. Generally, they contain carbon dioxide, sometimes also hydrogen sulphide. According to the chemical analysis results of the investigations, which have been made, most waters can be classified as (earth)-alkaline-bearing hydrogen-carbonate-waters. It is obvious, that almost all spring occurrences are connected to fault structures. Secondly, they can also be found in the parts of Kosovo where an increased geothermic gradient was measured (northern and eastern part of Kosovo). Only for few springs, the origin and genesis is not clear enough. In the future, additional springs could be found in the area of the Neogene volcanic complexes or in the range of the depth fault zones.

The Tectonic Map of Kosovo (TecM 200)

The map shows the main geological-tectonic units and main tectonic structures of Kosovo. Each formation has been delineated based on the information shown on the available geological maps [2][5]. Four types of thrust faults have been subdivided on the map. The main thrust faults are boundaries between tectonic units different in lithology, stratigraphic age and / or metamorphic grade. The second type of faults are thrust faults, which are spatially related with serpentinite bodies. The third type are thrust faults within a stratigraphic unit, in many cases forming a system of imbricated minor thrust faults. Back thrust faults, the fourth and youngest thrust fault type, are limited to areas where basement blocks have been moved onto Upper Cretaceous flysch sediments. Also shown on the map are major normal faults, fault zones, anticlines, synclines and high temperature shear zones.

The map also features two sketch maps showing, first, the main geotectonic units of the central Balkan peninsula and, second, the regional geological units and sub-units of Kosovo. For better understanding of the regional geological development, the map also shows a geological-tectonic cross-section across Kosovo.

The geotectonic units of Kosovo belong to the Mediterranean Alpine orogenic belt, which contains both Tethyan crustal elements like ophiolites as well as middle to high-grade metamorphic basement blocks of microcontinents and the
related marginal and platform deposits. The suture zone between the western oceanic elements and the blocks of continental crust in the east is built up by an extensive fold and thrust belt, which has been masked by postorogenic basin development and Cenozoic volcanic complexes.

The Digital Geological Map of Kosovo (GM 200)
The map shows the geology and tectonics of Kosovo. The geological formations have been delineated based on the information shown on older geological maps [5][6][7]. The map features a unified legend of the geological formations, which was applied all over Kosovo [2]. The legend comprises of a stratigraphic classification of the formation (colour), as well as a representation of the rock lithology / genesis / petrography / alteration (fill pattern). The classification of the geological formation concerning stratigraphy and lithology can also be derived from the rock abbreviation used on the map. Beside this, the map contains information about the main geological boundaries and the most important tectonic elements. In addition, topographic features like main roads, railroads, rivers, lakes, main cities are shown on the map for better orientation, which have been digitised from the available topographic maps. The map also features two sketch maps showing, first, the main geotectonic units of the Central Balkan Peninsula and, second, the regional geological units and sub-units of Kosovo. Altogether, this geological map 1 : 200,000 is the most important base for all further geoscientific thematic maps for Kosovo.

The area of Kosovo is characterised by a variety of geological formations. Among these are rocks ranging from old crystalline Proterozoic to youngest Quaternary age comprising sedimentary and magmatic rock types together with rather less frequent metamorphic rocks. Tectonic processes are of major importance for understanding the geological history. The following main units have been distinguished:

- Dardania massif (Dardanides, 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 regional structure on the map. It is based on local names.

The Metallogenic / Minerogenic Map of Kosovo (MetM 200)
This map is the most important geoscientific map for Kosovo. The map delivers the information for economic usage and for the strategic research of raw materials. Because of the already known and potential mineral resources, the mineral sector is one of the most promising sectors of the country. The map does show the spatial distribution of the deposits and occurrences of Kosovo, as well as their importance. The deposits and occurrences are categorised according to their commodity, their genetic type and size, their mining activity and their geological knowledge. In addition to the Map of Minerals (MM 200), this map also shows information about the time of mineralisation. In the background of the map, the main geological formations of Kosovo are shown, which have been derived from the available maps [2][8]. This information represents the main minerogenic controlling factor. Based on it,
minerogenic / metallogenic provinces, zones and districts are delineated and presented on the map. The map also shows prospective areas where further mineralisations could be located, also providing information on how this deposits and occurrences can be explored and found and whether exploitation would be economical or not. Indications for this could either be mineral indications (deposits and occurrences of metallic and non-metallic raw materials) and geochemical, geophysical and mineralogical indications, anomalies or alteration zones. The geochemical data was derived from the analysis results of detailed sampling of the different magmatic rocks and of selected minerals. After completion in the next year, the MetM 200 will belong to the primary sources of information about the assets of the territory. The map will find a broad application in all sectors of the public and private live of Kosovo and abroad. The map is a valuable instrument to govern the future development of Kosovo: attracting investors to the mining and subsequently following industries, and avoiding mistakes in infrastructure and land planning.

The Soil Map of Kosovo (SM 200)

This map is a comprehensive presentation of the soils of Kosovo. The delineated soils were digitised from the available soil map sheets at a scale 1 : 50,000 [9] and unified. The legend contains 101 legend units. On the map, soil types (e.g. regosol, rendzina, podzol, gley), soil species (Sandy soil, Loamy soil, Clayey soil), and soil substrata information (e.g. regosol on flysch, brownised diluvium, shallow brown soil on schists) is shown. The local geological conditions, particularly the lithology determine the distribution of the soils. In the great Neogene-Quaternary basins, primarily common brownised soils can be found. On Pliocene sediments, clayey-loamy soils occur and on Pleistocene and Holocene sandy environments are characteristic. In the areas with solid rocks, very different soils are known. In the territories of the Cretaceous flysch and the Jurassic ultramafites, regosol and rendzina occur. In the high mountains (Mali i Sharrit / Šar planina, Alpet Shqipetare / Prokletije), shallow brown soil on schist and metamorphic crystalline rocks are frequent. Ranker soil (without thin humus cover) and bare rock (without humus cover) are very endangered because of water and wind erosion.

In the future, it is intended to change the presented soil classification according to international standards. Because of the older map base, the presented soil map does not correspond with the actual Kosovo administrative border, at the moment. Because of this, the soil data shown on the map will be updated to whole Kosovo in the next project steps. The soil information was used for delineation of the construction raw material deposits for the Kosovo Quarry Plan (1 : 50,000) by Beak Consultants GmbH. For instance, information about the distribution of the sandy and gravelly alluvium as well as the distribution of Neogene clays is provided. Another important information taken from these maps is related to the formation of the confining beds for separate deposits (evaluation of the sandy, loamy and silty cover horizons for the sand-and-gravel deposits) and the cover horizons for the carbonate hard rocks etc.

Conclusions

At present, no other up-to-date map set at scale 1 : 200,000 than the presented one does exist for Kosovo. The geological and other geoscientific maps of the map set will be of immediate interest to the ministry of Environment and Spatial Planning, Ministry of Public Services, municipal planning authorities, relevant faculties of the University of Prishtinë / Priština, civil engineering industry, mining industry and many other users. The geoscientific maps of the map set are very important for Kosovo as well being the information base for geoscientific surveys, for the exploration and exploitation of raw materials and for the further compilation of different thematic maps. After completion, the map set
will form a very important tool for the economic development of the country as it provides a basis for investors, for state institutions and for geoscientific surveys and other users to get a first overview of the resources and the potential of Kosovo.

More detailed information about the data presented on the maps data can be found within the information system GEO-Database Kosovo or in the internet at www.kosovo-mining.org.

Literature / References


[8] Metallogenetic Map of Yugoslavia, 1 : 500,000 (printed 1983, 6 map sheets)