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## IMPORTANT GEOLOGICAL AND MONTANISTIC SITES OF SLOVAKIA



ŠTÁTNY GEOLOGICKÝ ÚSTAV DIONÝZA ŠTÚRA MENTE ET MALLEO

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Periodical journal of the State Geological Institute of Dionýz Štúr is a biyearly presenting the results of investigation and researches in wide range of topics:

- regional geology and geological maps
- lithology and stratigraphy
- petrology and mineralogy
- palaeontology
- geochemistry and isotope geology
- geophysics and deep structure
- tectonics and structural geology
- geology of raw minerals deposits
- hydrogeology and geothermal energy
- environmental geochemistry
- engineering geology and geotechnology
- geological hazards and risks
- geoinformatics
- geotourism

The journal is thematically focused in the issues of the Alpine-Carpathian region.



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# IMPORTANT GEOLOGICAL AND MONTANISTIC SITES OF SLOVAKIA

## Content



COVER: *Left-up:* Lava flows of pyroxenic andesite with conspicuous columnar jointing in the area of the hill Štangarígeľ (pen-and-ink drawing by Vlastimil Konečný).

*Right-up:* A ceremonial visit to the Glanzenberg Hereditary Adit.

*Left-down:* A qualitatively exceptional sample (10 x 6 cm) of the emerald-green euchroite from the Ľubietová – Svätodušná deposit. The size of the euchroite crystals is up to 2 cm. Finding of 2003 (Photo: T. Bancík).

*Right-down*: Memorial Plaque commemorating a visit of Francis I, Holy Roman Emperor, spouse of Maria Theresa, to the Glanzenberg Hereditary Adit on June 7, 1751.

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# Preface

### Important Geological and Montanistic Sites of Slovakia

Since the restoration of the Slovak Geological Magazine issuing in 2013 there has been published wide spectrum of themes covering both basic and applied research in geology. However, the theme of geoheritage and geotourism has not been covered yet, despite the SGIDŠ workers have significantly contributed also to this booming sector of geological science. We could mention the publishing of important geological sites in the scope of the edition of regional geological maps. SGIDŠ has published several geological-tourist maps, for instance Cerová vrchovina Upland, Vysoké Tatry and Vihorlat Mts., Zemplín region. The specialists from our institute played a key role in establishment of Banská Štiavnica, Novohrad and Sapag geoparks. The SGIDŠ website presents to the society almost 500 important geosites of Slovakia, which were elaborated in collaboration with prominent geologists from Faculty of Natural Science CU University and then Geological Institute of the Slovak Academy of Science.

Nevertheless, despite the above activities, we have to admit, that due to the lack of the subject geology in the Slovak education system at elementary at elementary, but especially at high school since nineties of the previous century, we have experienced the down-warding trend in the geological knowledge level of the Slovak population. This is reflected also in declining number of students in geology and in degrading society perception of the environmental links among the compounds of the landscape – rocks, water, soil, atmosphere, and biota.

If we look back to history for a few centuries to millennia, we have always met geomorphosites, gems and the raw materials that have motivated the human population, and have significantly affected the course of human history. Just remember, for example, the routes of obsidian, amber, salt, copper, iron, silver, gold and the fortification networks built to protect them. This volume of SGM includes three contributions devoted to information system on geosites of Slovakia, exceptional minerals from our territory and Slovak mining road connecting historic mining towns.

Pavel Liščák & Dušan Kúšik

## LIST OF ACRONYMS

| | |
|---|---|
| a.s.l. | above sea level |
| BABB | Back-Arc Basin Basalt |
| BERG TU | Faculty of Mining, Ecology, Process Control and Geotechnologies of Technical University |
| E-MORB | Enriched Mid-Ocean Ridge Basalt |
| Fm. | Formation |
| GPS | Global Positioning System |
| HSCS | Heritage Sites and Collections Subcommission |
| HFSE | High-Field-Strength Elements |
| HSM | High-Sulphidic Mineralisation |
| IAG | International Association of Geomorphologists |
| ICG | International Commission on Geoheritage |
| IUGS | International Union of Geological Sciences |
| KI | Kubler Index |
| Mb. | Member (Beds) |
| MIAG | Magnesite Industrial Joint-Stock Company (*Magnesit Industrie Aktien-Gessellschaft*) |
| Mts. | Mountains, Mountain Range |
| NAPANT | National Park Nízke Tatry |
| NHM | Natural History Museum |
| NL | National Landmark |
| NNL | National Nature Landmark |
| NOŠ | New Drainage Gallery (*Nová odvodňovacia* štôlňa) |
| NP | National Park |
| n.p. | National Enterprise (*národný podnik*) |
| NNR | National Nature Reserve |
| NR | Nature Reserve |
| OIT | Ocean-Island Tholeiite |
| PF | Protected Finding |
| PIENAP | Pieniny National Park |
| PKB | Pieniny Klippen Belt |
| PLA | Protected Landscape Area |
| P-T | Pressure-Temperature |
| REE | Rare Earth Elements |
| SGIDS | State Geological Institute of Dionýz Štúr |
| SHRIMP | Sensitive High-Resolution Ion Microprobe |
| SIR | Slovak Iron Road |
| SMR | Slovak Mining Road |
| SNR | Slovak National Council (*Slovenská národná rada*) |
| SOP SR | State Nature Conservancy of the Slovak Republic (Štátna *ochrana prírody SR*) |
| SSPA | Small-Scale Protected Areas |
| š.p. | State Enterprise (*štátny podnik*) |
| TANAP | Tatra(s) National Park |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| VHJ RBMZ | Rudné bane Production Unit and Magnesite Plants |
| VSEGEI | Geological Research Institute (*Всероссийский научно-исследовательский геологический институт*) |

# 1. Information System of Important Geosites in the Slovak Republic

Pavel Liščák & Miroslav Antalík

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**Abstract:** Most of the Slovak geosites are not protected by law, but from a scientific and academic point of view many of them are extremely valuable geological objects, which should be maintained for future generations as geological heritage. Within the period of 2008 – 2011 in the scope of the project of Information system of important geosites in Slovakia a database of 480 geosites was elaborated at SGIDŠ. Later on, in 2014, the web application database was developed in the scope of the SGIDŠ project GEOIS. Each record of the database contains geological description of the site in detail, degree and the reason for its protection, location within the tourist map and the geological map at scale 1 : 50,000, graphic documentation in the form of photographs, drawings and contemporary postcards and references. The popular texts are provided both in Slovak and English.

**Key words:** geoheritage, important geosite, database.

## 1.1 Introduction

For the last 3 decades, there has been a continuously increasing interest for geological heritage, its assessment, protection and promotion, in various parts of the world. The European countries have carried out national geosite inventories as a basis for their geoconservation policy (Wimbledon & Smith-Meyer, 2012). Various international associations also developed guidelines for inventorying and managing geoheritage. This is the case of ProGEO – The European Association for the Conservation of the Geological Heritage (ProGeo, 2011) or the Global geosites inventory (Wimbledon, 1996; Wimbledon et al., 1999), launched by the International Union of Geological Sciences (IUGS), but unfortunately interrupted in 2003. The establishment of the Heritage Sites and Collections Subcommission (HSCS), as an integral part of the International Commission on Geoheritage (ICG) at the 35th International Geological Congress (Cape Town, South Africa) in 2016, has enabled the IUGS to take a leadership role in addressing geoheritage issues at world-wide scale. Nevertheless, world-wide, very few countries have completed a national inventory to date (see http://geoheritage-iugs.mnhn.fr/, accessed 19/01/2018). According to IUGS data among the European countries the national geoheritage inventories have been completed in Croatia, Czech Republic, Estonia, Finland, France, Iceland, Ireland, Italy, Lithuania, Spain, Slovakia, Switzerland, United Kingdom. Further countries with the national geoheritage inventories are Australia, Brazil, Canada, New Zealand, South Africa.

Also the International Association of Geomorphologists (IAG) formed a specific working group on Geomorphosites in 2001 (Reynard & Coratza, 2013), which deals with geomorphological heritage issues, in particular methodological ones. More in general, the World Heritage Convention, signed in 1972, allowed the classification of more than 180 geological sites (Migon, 2009), and the Geoparks initiative (Zouros, 2004) which started in 2000, allowed a better knowledge and evaluation of geoheritage at the regional scale.

Slovakia has developed a geosite inventory at a national level since the 1950s. The Slovak geoheritage has been inventoried and revised recently, recognising 480 geosites of national importance (Liščák et al., 2012).

## 1.2 Geological Setting of Slovakia (in brief)

Thanks to a varied geological structure and complex geomorphological evolution Slovakia is rich in geosites.

The Western Carpathians are mountain range with very complicated structural tectonical and geomorphological evolution. They are component of Alpine-Carpathian mountain system. In the Carpathian mountain range the rocks are present, which accrue in an immense time span of geological time from the oldest, dating back over 600 millions of years, until the youngest, which have been formed recently (river deposits, weathering scree, various debris, loams and other).

The geological map, regardless of the scale, reflects the age of the rocks emphasized by colour difference. Usually the oldest rocks are characterized by the darkest colours. The younger the rocks are, the brighter shades are used. The geological structure of our territory is made up of the Outer and Inner Carpathians separated by the Klippen Belt. The oldest rocks in the territory of Slovakia are metamorphosed rocks. Originally, they had been several kilometres thick sediments, which had deposited at the bottom of the primeval ocean, mainly in the period of older Palaeozoic and maybe even earlier (roughly in the period some 600 – 400 million years ago). In the wake of primeval Carpathians, these sediments had sunk to the depths of the Earth's crust; in the zone of the increased pressure and temperature they had turned into schists. At the same time part of these rocks in the zones with the highest temperature were melting, creating a magma, which after cooling and solidification created a colourful mosaic of granite (granitoid) varieties of rocks. In the subsequent movements of the Crust these rocks were uplifted and denuded thanks to deep weathering/erosion processes. To date, they form the central (core) parts of the Malé Karpaty, Považský Inovec, Tribeč, Strážovské vrchy, Vysoké and Nízke Tatry, Malá and Veľká Fatra, Žiar and Branisko Mts.; therefore we call them Core Mountains. The magmatic rocks were formed during the whole period of Palaeozoic, but mainly in the period of Younger Palaeozoic (350 – 300 million years). In the next period the territory of this primeval mountain range was peneplained and later submerged in the ocean. Carbonatic Mesozoic rocks (limestones and dolomites) deposited dominantly. These rocks were later folded due to pressure from the African Plate upon the European Platform and the secondary Carpathian Mountains evolved. After uplifts and sinks of the Crust blocks in the Tertiary period (Palaeogene) these rocks were, along with the older ones, uncovered. After their partial subsidence and partial peneplanation, sand, gravel and clay sediments deposited upon them within Young Tertiary (Neogene) seas, and freshwater lakes. The Neogene sediments have been preserved in depressions (lowlands and intermountainous basins). The movements of blocks along the faults were accompanied by an intense volcanic activity, the maximum of which fell within a period of approximately 10 – 13 mil. years. Some volcanoes were extinct merely one million year ago, the youngest had been extinct approximately 120,000 years ago (Putikov vŕšok). At the beginning of the Quaternary period (approx. 2.5 million years ago), a variable thick sheet of the Quaternary deposits of different types evolved on the above rocks, in the terrestrial environment exclusively. They are formed of weathering scree, in particular upon granitoid and carbonate rocks of the Slovak Core Mountains. Their flanks are covered by coluvial deposits. The southwestern part of Slovakia is typical of eolian Quaternary sediments of loess, loess loams and sands. Along the streams alluvial sediments – sands and gravels – have been deposited in the form of fluvial plains, alluvial cones and river terraces. In the Vysoké and Nízke Tatry, Veľká and Malá Fatra Mts., during the glaciation periods glacial sediments evolved. In several areas of Slovakia travertines have been formed along the faults.

## 1.3 Protection status of geosites in Slovakia

Nature protection in the Slovak Republic dates back to Medieval times and the feudal ownership of lands. The first protected territory in today's Slovakia was Kvetnica, a natural protected reserve in the glacial Velická Valley of the Vysoké Tatry Mts. The core part of the Vysoké Tatry Mts. became the first National Park in Slovakia, established in 1949. Recently, the protection of nature has been legally regulated through the Nature and Landscape Protection Act. A new executive decree to the act came in 2003 (Decree of MoE SR No. 24/2003 Coll.) implementing some of its provisions (technicalities of nature protection, list of protected species of biota along with their appreciation).

*Two larger areas of extraordinary geological significance are inscribed as* World Heritage Sites under the Convention on the Protection of World Cultural and Natural Heritage *(UNESCO).*

The first one is the "*Historic Mining Town of Banská Štiavnica (Chemnitz)*" and its vicinity, covering an area of 20,632 ha with a buffer zone (62,128 ha). It was inscribed on the List on 11th December 1993. The area contains several sites of international (world-wide and European) interest in the sphere of mining and metallurgy, both scientifically as well as for education. For instance, [mine] blasting with explosives was carried out here for the first time on 8th of February 1627 by the Tyrolean miner Gaspar Weindl, in the Daniel cross-cut of the Upper Bieber Gallery. This event was recorded in the protocol of the Banská Štiavnica Mining Court No.7 dated 1627: "official commission convinced themselves about the effects of the first mining blasting and found that the blast was successful, smoke dissipated and timber support was not damaged" (Durbák et al., 2002). In 1762, the world's first technical college of mining – the Mining Academy – was established in the area.

The second large territory on the UNESCO List are the "*Caves of the Slovak and Aggtelek Karst*". Within the territory of 56,650.57 ha and its buffer zone (86,797.33 ha) there are listed 712 caves and further karst objects, for instance the Ochtinská Aragonite Cave, Domica Cave, Gombasecká Cave and Jasovská Cave, Dobšinská Ice Cave. The Slovak part of this cross-border UNESCO World Heritage includes 4 territories: Dobšinská Ice Cave, Koniar Plateau, Plešivec Plateau, and neighbourhood of Silica and Jasov in Slovakia. The file of listed caves presents an exceptional example of ongoing geological processes and significant geomorphic features. Their main attributes are genetic and morphological diversity, variability of dripstone, exceptional density of representative types of caves in the temperate climatic zone and the occurrence of rare underground animals and archaeological finds.

Under the Protection of Nature and Landscape Act (Law 543/2002 Coll. of 25 June 2002), § 17 Protected Areas and their Protective Zones, there are listed large-scale and small-scale areas of nature protection in the Slovak Republic. These are sites containing habitats of Community (European) importance and habitats of national importance, habitats of species of European importance, habitats of species of national importance and habitats of birds, including migratory species, on which protected areas, significant landscape features, natural habitats or nature objects, can be declared as protected areas:

a) protected landscape area (§ 18),
b) national park (§ 19),
c) protected area (§ 21),
d) nature reserve, national nature reserve (§ 22),
e) natural monument, national natural monument (§ 23, § 24 paragraph 3),
f) protected landscape element (§ 25),
g) protected bird area (§ 26).

The total area of 9 National Parks (protected buffer zones included) and 14 Protected Landscape Areas

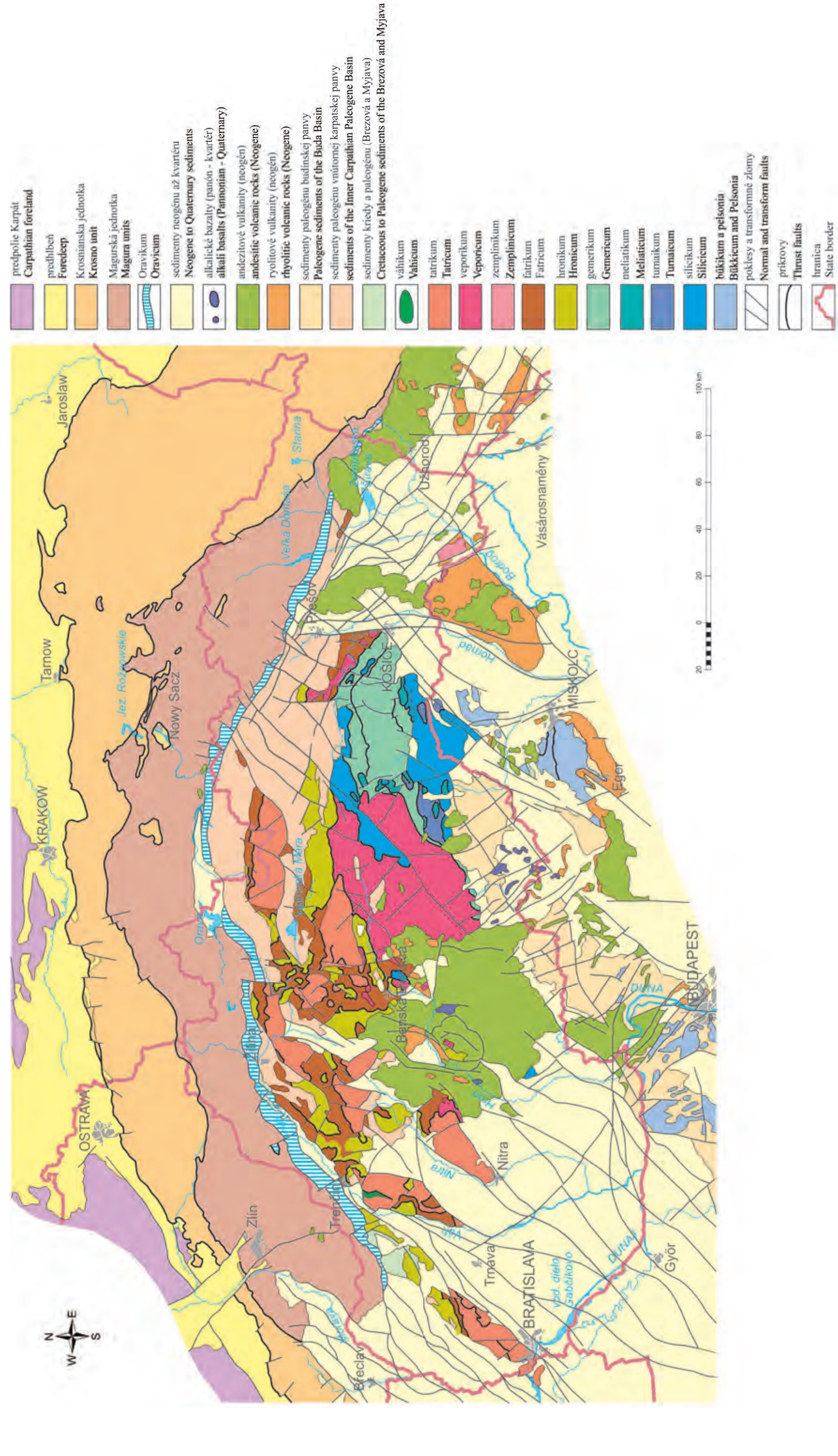


*Fig. 1.1 Tectonic scheme of the Slovak part of the Western Carpathians (Hók et al., 2014)*

Tab. 1.1 Nature protected areas in the Slovak Republic (as of December 31, 2018: source SOP SR) http://www.sopsr.sk/web/?cl=114

| Category | No. | Area of protected area (ha) | Area of protected buffer zones* (ha) |
|---|---|---|---|
| Large scale areas | | | |
| Protected Landscape Area | 14 | 522,581.5090 | - |
| National Park | 9 | 317,540.5726 | 262,591.3307 |
| Total | 23 | 840 471 | 262,591.3307 |

| Small-scale areas | | | |
|---|---|---|---|
| Protected Site | 172 | 11,015 | 2,425 |
| National Nature Reserve | 209 | 80,776 | 2,239 |
| Nature Reserve (including 2 private) | 384 | 14,222 | 301 |
| National Nature Landmark (without caves and waterfalls) | 11 | 59 | 27 |
| National Nature Landmark – caves | 44 | 0 | 3,055 |
| National Nature Landmark – waterfalls | 5 | 0 | 0 |
| Nature Landmark (without caves and waterfalls) | 217 | 1,525 | 207 |
| Nature Landmark – show caves | 45 | | 31 |
| Nature Landmark – other caves | 9 | | 261 |
| Total | 1097 | 107,599 | 8,545 |

*The protected buffer zone has normally a level of protection one level lower than the core protected area.

Tab. 1.2 Overview of protected areas in the Slovak Republic according to protection types and levels (as of December 31, 2018: source SOP SR)

| Protection level | Category | Area (ha) | % of the SR |
|---|---|---|---|
| Level 1 | "Open landscape" | 3,764,328 | 76.77 |
| Level 2 | Protected Landscape Areas and National Park buffer zones | 759,383 | 15.49 |
| Level 3 | National Parks, Protected area, and various buffer zones zones C | 268,150 | 5.47 |
| Level 4 | National Nature Reserves, Nature Reserves, Natural Nature Landmarks, Natural Landmarks and various buffer zones | 18,356 | 0.37 |
| Level 5 | National Nature Reserves, Nature Reserves, Natural Nature Landmarks, Natural Landmarks and various buffer zones | 93,183 | 1.90 |
| Level 2 – 5 | Legally protected areas classified by protection level | 1,139,072 | 23.23 |

(Tab. 1.1) represents 22.49% (1,102,713 ha) of Slovakia (4,903,500 ha). In addition 1097 small-sized protected territories (Tab. 1.1) under the 3rd to 5th levels of protection (see below) take up 2.25 % of the country.

The small-scale protected areas may exist within National Parks and Protected Landscape Areas. Within the existing Protected Landscape Areas there are 249 small-scale protected areas (SSPA) covering an area (included buffer zones) 12,689 ha (2.43 % of the PLA territory), 194 small-scale protected areas within National Parks (68,424 ha, 21.55 % of the NP territory) and 70 small-scale protected areas within buffer zones National Parks (2,487 ha, 0.95 %).

The nature protection level is divided into 5 categories where level 1 is general open landscape covering nearly 77% of the country, while levels 2 – 5 indicating the level of protection can be called legally protected areas (Tab. 1.2). Within the open landscape there are 584 small protected areas covering (included buffer zones) 32,475 ha (0.86 % of the area open landscape).

**Geological sites protection**

In the Nature and Landscape Protection Act geosites are not mentioned as such, but the act use the term geological objects at many places. The general provisions of this act, §2, point 2 states:

– section b: the ecosystem compounds rocks and raw minerals, morphology, soil, are identified beside the others; they are composed of various elements, which are plants and living animals, **rocks**, **minerals, fossils, morphology forms, soil types, lakes, springs, ponors, geysers.**

– section c: important landscape type is such a part of the territory, which creates a typical landscape or it contributes to its ecological stability; among the geological elements are **peatbog, cliff, gorge, block sea, sand dune** are stated.

In its further provisions, the Act distinguishes between territory and species protection.

**Territory protection**

As the geosite is not generally mentioned in the Act, it is necessary to see what sort of registred geosites exist within the system of protected sites. A rough estimate can be retrieved from the Database of Important Geosites of Slovakia (Liščák et al., 2012).

Tab. 1.3 Registered geosites (Liščák et al., 2012) within protected areas in Slovakia

| Category | Number of sites |
|---|---|
| Natural Park | 98 |
| Protected Landscape Area | 93 |
| National Natural Landmark | 26 |
| Natural Landmark | 47 |
| National Natural Reserve | 44 |
| Natural Reserve | 26 |
| Protected Areal | 1 |

However, this is not a complete list. For instance all caves and waterfalls are protected as (national) natural landmarks (see the text below) and some mining elements are protected as natural cultural landmarks.

## 1.4 Database of important geosites

The variegated geological setting of Slovakia offers numerous geosites which are predestined to become a component of the nature heritage in Slovakia. Some of the geosites are already protected under Law 543/2002 Coll. of June 25, 2002 on the Protection of Nature and Landscape as small-scale protected areas: National Natural Landmarks (NNLs), Natural Landmarks (NLs), National Nature Reserves (NNRs) and Nature Reserves (NRs). Many of geosites are protected within large-scale protected areas – National Parks (NPs) and Protected Landscape Areas (PLAs); some of them have been even declared by the Convention on the Protection of World Cultural and Natural Heritage.

There are already 3 geoparks operated in Slovakia (http://www.geopark.sk/en/geoparks-network-of-the-slovak-republic/), one of them – Novohrad-Nográd Geopark is one of the first cross-border (Slovakia/Hungary) geoparks out of the existing 120 geoparks across the world.

Yet, most of the stratigraphic and palaeontological sites are not protected by law. Moreover, the Slovak education system at elementary and high school lacks of the subject geology. The downwarding trend in the geological knowledge level of the Slovak population is reflected in degrading perception of the environmental links among the compounds of the landscape – rocks, water, soil, atmosphere, and biota. Therefore it was desirable to create a geosites database which should identify the geological peculiarities in our country, to recognize their recent physical status, to assess their scientific-educational value and, finally to give recommendations for geosites protection.

Within the period of 2008 – 2011 the State Geological Institute of Dionýz Štúr in Bratislava (SGIDS) solved a geological project **Database of important geological sites of the Slovak Republic.** The aim was to create an open file of the sites of geological heritage of the Slovak Republic.

At the project beginning a team of **main authors** (editors) was established for various special topics of geological sites, of which the number have reached 11. It was the task of the editors on the basis of their own erudition and the study of relevant literature, in particular of already issued Geological guides and Explanations to geological maps at the scale 1 : 50,000, and also on the basis of consultations with a broad community to propose a basic set of sites of the geological heritage of the Slovak Republic. A groundwork provided also publications devoted to these issues, mainly under the umbrella of PROGEO (Wimbledon et al., 1998), or others (Liščák et al., 2002, Jeleň & Galvánek, 2009).

By 31/12/2017 the database has included 480 sites, which are divided into 11 categories according to their thematic scope. The database affix is the Map of important geological sites which has been published on the SGIDS website https://www.geology.sk/maps-and-data/mapovy-portal/educational-geology/important-geological-sites/?lang=en. In order to attract a wider professional and amateur public information was issued on the project objectives in Enviromagazín No 5, Edition 2008/13 (Liščák, 2008) and a presentation poster was completed to the project; this poster was installed in the Slovak National Museum, in the framework of the exhibition “International *Year* of Planet *Earth*” which was hosted in the period of 2008 – 2012 by several nature museums across Slovakia.

The criteria for the geosites selection were as follows:

- representativeness and rarity,
- degree of site protection,
- visibility,
- accessibility of the site.

The following team of specialists from relevant geological organization took part in the project:

**61** Sites of Palaeozoic Metamorphites, labelled V- (**Prof. RNDr. Anna Vozárová, DrSc.****, co-author Ing. Zoltán Németh, PhD.*);

**19** Sites of Magmatites and Tectonics, labelled JM- (**RNDr. Ján Madarás, PhD.***);

**78** Mesozoic Sites, labelled RA-, V- (Assoc. Prof. RNDr. Roman Aubrecht, PhD.**, co-author Prof. RNDr. Anna Vozárová, DrSc.);

**18** Palaeogene Sites, labelled Np- (**RNDr. Alexander Nagy, CSc.***, co-author †Ing. Martin Kováčik*);

**17** Neogene Sites, labelled Nn- (**RNDr. Alexander Nagy, CSc.***, co-authors RNDr. Ivan Baráth, CSc.*, RNDr. Adriena Zlinská, PhD.*);

**88** Sites of Neogene Volcanites, labelled JL-, VK-, LS (**RNDr. Jaroslav Lexa, CSc.*****, co-authors †RNDr. Vlastimil Konečný, CSc.*, RNDr. Ladislav Šimon, PhD.*);

**37** Sites of Quaternary Sediments, labelled Y- (**RNDr. Martina Moravcová (Ábelová), PhD.***, in 2010 she was substituted by **Mgr. Martin Vlačiky, PhD.***);

**28** Sites of Historical Mining, labelled B-, P- (**RNDr. Daniel Ozdín, PhD.****);

**61** Mineralogical Sites, labelled DO- (**RNDr. Daniel Ozdín, PhD.****);

**39** Hydrogeological Sites, labelled HG- (**RNDr. Juraj Michalko, PhD.***);

**34** Geomorphological Sites, labelled P- (**RNDr. Pavel Liščák, CSc.***).

Note:

* SGIDS, State Geological Institute of Dionýz Štúr

** Faculty of Natural Sciences, Comenius University, Bratislava

*** Geological Institute of the Slovak Academy of Sciences

Several suggestions were received from the professional and amateur public; on the basis of these initiatives, there were added some sites in the database, for example the site Cígeľka – mineral water spring, Gelnica – extraction of Ag-, Cu-, Hg-ores, Čučma – Sb-Au-ore mining, NL (National Landmark) Sninský kameň – lava flow, NL Markušovský skalný hríb (Markušovce Stony Mushroom).

All the sites from basic file were dealt with simultaneously. The authors for the above defined topics compiled the relevant binding information to the sites selected. In many cases, it was necessary to invite experts from universities and academia – they entered into the project database as co-authors of individual sites. The sites were GPS documented and registered in writing. For most sites, photo documentation was carried out as far as possible in a uniform manner (RNDr. Ladislav Martinský) and at the most appropriate weather conditions, in close cooperation with the authors of the sites. Many field locations were amended on photo documentation from the archives of the authors, or the colleagues – geologists. A particularly significant contribution should be considered a photo documentation of minerals, which processed RNDr. Daniel Ozdín, PhD. using special photographic equipment and software. Mr. Pavel Staník from the Slovak Caves Administration, Liptovský Mikuláš, provided the original photographs of the cave underground spaces and decoration. RNDr. Jan Madarás, PhD. has included dozens of photos to sites from several topics. RNDr. Dušan Kúšik enriched the database in scans of postcards with mining motives, coming from his private collection. Many of the above photos are original. We have to draw the attention to pen-and-ink drawings of †RNDr. Vlastimil Konečný, CSc., whose compositions of volcanic sites are a combination of geological interpretation and the artistic expression of significant geological phenomena.

These logs have been transformed into an MS Access database containing 35 items. The database includes 480 1 : 50,000 slots, marked with an important geological location at the center of the slice, 480 slots from the digital geological map of Slovakia at a scale of 1 : 50,000 marked with a significant geological location at the center of the cut and 2,479 photographs, or pen-drawings and geological object schemes as well as the corresponding descriptions of the figures. The database also contains over 900 literary sources, which are quoted in texts for each site.

Tab. 1. 4 Representation of individual themes within the information system

| | |
|---|---|
| Palaeozoic | 61 |
| Magmatites and Tectonics | 19 |
| Mesozoic | 78 |
| Palaeogene | 18 |
| Sedimentary Neogene | 17 |
| Neovolcanites | 88 |
| Quaternary | 37 |
| Historical Mining | 28 |
| Mineralogy | 61 |
| Hydrogeology | 39 |
| Geomorphological Sites | 34 |

### 1.4.1 Localities of Palaeozoic

The file comprises the sites of metamorphosed rocks of various degree of polyphase metamorphosis (Fig. 2), which have been identified in the Gemericum, Hronicum, Fatricum, Veporicum and Tatricum palaeoalpine tectonic units of the Western Carpathians. The Gemericum unit the Hercynian Gelnica, Rakovec, Klátov, Štós, Ochtiná and Črmeľ tectonic units and their envelope formations. The Hronicum unit formed within the Neo-Hercynian period upon thickenned granitoid crust – it is represented by the Ipoltica Group. The Fatricum and Veporicum metamorphosed rocks were formed within the Neo- and Meso-Hercynian tectonic stage. Low metamorphosed rocks are typical for the Sourhern Veporicum. High-grade metamorphosed rocks are represented by ortho- and paragneiss and metabasics; some of them underwent later the process of diaphtoresis. Bezák et al. (1997) defined four main lithotectonic units in Tatricum, which originated during the Meso-Hercynian collision processes: lower prevailingly mica schist unit, middle gneiss unit, upper gneiss-migmatite unit, low-grade metamorphosed complexes in the uppermost part position.

V-01 Ochtiná, NNL Ochtinská aragonitová jaskyňa (Ochtiná Aragonite Cave), hosting rocks – Drnava Fm. of the Gelnica Group, Ordovician, crypto- to macrocrystaline aragonite. In the dark metapelites of the Drnava Formation, lenses of crystalline limestones (Middle Ordovician) occur. They were partly metasomatically altered into ankerite and siderite, which later being weathered into Fe-ochres at the surface. During prospecting for iron ores, in 1954, a cave was discovered by miners. They arose on faults along with the ankerite weathered into iron ochres. The latter were washed away by karst waters which dissolved the adjacent crystalline limestones and gave thus rise to free galleries and chamber-like spaces. In these spaces current forms of cave ornamentation consist of cryptocrystalline, microcrystalline and macrocrystalline aragonite. The calcite stalactites and stalagmites are present exceptionally. The aragonite forms various dendritic or shrub-like shaped formations, clusters, aggregates of crystals, sometimes drop-like forms and sinter crusts. Listed on the World Heritage List since 1995.

V-02 Gočaltovo – stratotype of Štítnik Fm., Southern Gemericum, crystalline dolomitic limestones, Permian.

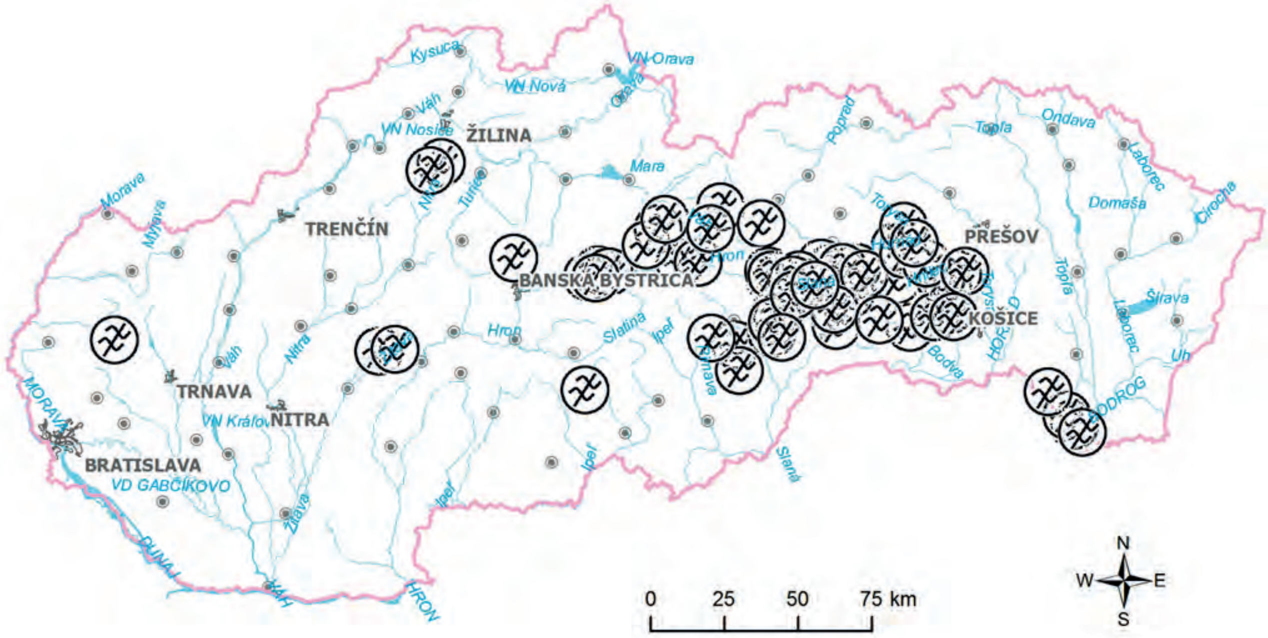


*Fig. 1.2 Distribution of the sites of Palaeozoic and metamorphosed Mesozoic in the Slovak territory*

Crystalline dolomitic limestones with interlayers of green-grey shale, which are dominant lithological member of the described site, represent lagoonal-offshore deposits. They are a component of the uppermost part of the Štítnik Formation. Characteristic is the excellently developed plan-parallel horizontal bedding. The carbonates are strongly influenced by the admixture of detritic grains of quartz, mica and infrequently also of plagioclase and heavy minerals. Rare is the stream-bed texture, which may indicate strong currents of near-shore platform (ebb and flow). Under microscope it is possible to observe manifestations of dedolomitization. There were found calcite pseudomorphoses after dolomite crystals and tiny enclosures of dolomite in them.

V-03 Dobšiná – abandoned quarry Biergarten – carbonates of Zlatník Fm., organodetritic massive carbonates, Carboniferous. The determination of the degree of alteration by exact methods was made on the basis of Kubler index (KI) and chlorite geothermometer. The KI values indicate the temperature of the regional metamorphosis in the range of 200 – 250 °C. The temperatures calculated empirically by method of chlorite geothermometer indicate the maximum metamorphic temperatures below 300 °C, within the interval of 250 – 290 °C (Vozárová in Liščák et al., 2011).

V-04 Ochtiná – abandoned quarry in carbonates and slates of Ochtiná Group, shaly carbonate facies, Visean-Serphukhovian.

V-05 Vyšný Hámor-Vyšná Maša – stratotype of Hámor Mb., abandoned quarry, conglomerate metasandstones alternating with micaceous and graphite shales, Pennsylvanian. The rock consists of cyclically alternating fine-grained, scarcely medium-grained conglomerate metasandstones, sandy and micaceous shales and black graphite shales. The thickness of cycles attains 10 m and more. Some cycles W of Dobšiná contain in their top part thin anthracite seams. Generally, the sediments are rich in quartz and clastic mica. Besides other clastic fragments there are different types of phyllites, metaquartzites, and scarce fine-grained granitoids, and lydites, basic and acid volcanics. $^{40}Ar/^{39}Ar$ cooling ages of clastic white mica proved 320 Ma of their source area (Vozárová & Frank, unpubl. data).

V-06 Stará Voda – lydites of Gelnica Group, arenaceous foraminifers of the family Psammosphaeridae or Saccamminidae in the lydites, Ordovician-Early Silurian. These flysch-type assemblages of aglutinated foraminifers indicate a deep-water turbidite character of sedimentation.

V-07 Zapálenica – Rudňany Fm., coarse-grained to bouldery polymict conglomerates exposed in several cliffs, Pennsylvanian. The basal coarse-grained Rudňany Formation sequence reflects the origin of Variscan collision suture. Delta-fan and near-shore coarse-grained to boulder conglomerates are characteristic lithotype. They contain detritic rock fragments from the all pre-Bashkirian North-Gemeric crystalline complexes. Black shales and grey sandstones with macroflora fragments are normal member of the upper part of this upward fining sequence.

V-08 Harnobis – type locality of Harnobis volcanogenic horizon, dacite effusions associated with pyroclastic tuffs and ignimbrites, Permian/Triassic. The Harnobis volcanogenic horizon, about 150 – 200 m thick, is a part of the Brusno Formation. It mostly consists of dacite effusions associated with pyroclastic tuffs and ignimbrites and scarce andesites. The latter ones, in the studied profile were only found as large redeposited fragments within metaarcoses. Zircon dating (in situ U-Pb SHRIMP) from the two samples documents the Cisuralian age of the Harnobis volcanogenic horizon, with concordia ages of 272.9 ± 5.9 Ma and 279 ± 4 Ma, respectively (Artinskian-Kungurian).

V-09 Nižná Boca – type locality of Nižná Boca Fm., situated within the buffer zone of NAPANT NP, cyclical fluvial-lacustrine siliciclastic sediments, mostly sandstones and shales, Pennsylvanian. It consists of cyclical fluvial-lacustrine siliciclastic sediments (mostly sandstones and shales) with distinct coarsening-upwards tendency. Macroflora from the upper part of the sequence on the locality Nižná Boca proved its Stephanian B-C age (Sitár & Vozár, 1973). Integral part of the Nižná Boca sequence are the dykes of dioritic porphyres.

V-10 Malužiná – stratotype of Ipoltica Group and Malužiná Fm., situated within NAPANT NP, alternating conglomerates, sandstones and shales, synsedimentary andesite-basalt volcanism, Permian. Generally the sediments of the Malužiná Formation originated in fluvial and fluvial-lacustrine/playa environment, at permanently semiarid/arid climate. They are made up of a thick sequence of red beds, consisting of cyclical alternating conglomerates, sandstones and shales. Lenses of carbonates, gypsum and calcrete/caliche horizons occur locally. Fining-upward cycles of the $5^{th}$ and $6^{th}$ order (thickness several meters), as well as the three regional megacycles of the $3^{rd}$ order (several hundred of meters), are most typical. An important phenomenon is the polyphase synsedimentary andesite-basalt volcanism (I. eruption phase within the 1th megacycle and II. eruption phase within the $3^{rd}$ megacycle) with continental tholeiitic magmatic trend. Basal parts of the all three megacycles consist of channel- and pointbar deposits, associated laterally and vertically with flood plain and natural levee facies. Upper part of the megacycles is characterized by a playa, scarce inland sabkha and ephemeral lake association.

V-11 Stráňanský potok Brook – stratotype of Stráňanský potok Fm., Tatricum, fine conglomarates to coarse sandstones, ?Cisuralian–Guadalupian. Based on lithological composition, superposition and correlation to other occurrences of analogous formations in the Western Carpathians, the Stráňanský potok Formation is ranged to the Permian, so far without biostratigraphic evidence. Fine-grained conglomerates and coarse-grained sandstones (even gravellites), locally comprising well rounded pebble material (10 – 15 cm in size) represent the most frequent lithofacies. Massive, graded-bedded and cross-bedded strata show repeated upward alternation. The beds are frequently separated one from the other by conspicuous erosive contacts. Sediments of the Stráňanský potok Formation are mineralogically and structurally immature. Pebble material in conglomerate beds consists of quartz, alkalic granites and adamelites, migmatites, quartzose and biotite gneisses, all with the Malá Fatra crystalline complex provenance. Composition of sandstone members belong to feldspar- and arkosic greywackes.

V-12 NL Biely potok Brook – profile through Early Triassic of Hronicum, transgression of Inner Carpathian Palaeogene. The Šuňava Member is the integral part of the Hronicum Unit. It consist of variegated shales, marls, calcareous sandstones, marly limestones, lumachelle and less frequent oolitic limestones. The shallow-water, littoral environment is documented by numerous sedimentary structures and external impressions and fragments of Lamellibranchiata and Crinoidea tests.

V-13 Zelená dolina Valley – Veporicum of Staré Hory Group – crystalline + sediments of Permian envelope, Northern Veporicum, ?Cisuralian, situated within the buffer zone of NAPANT NP ?Cisuralian. Braided stream deposits of the lower part of the Špania Dolina Formation are composed of graded bedded coarse-grained sandstones and sandy conglomerates with dominant feldspars and granitoid detritus. Frequent are erosive contacts on the base of beds and channel lag deposits. Isolated trough-cross bedded sequences are exposed.

V-14 Závadka I – polymict conglomerates of Rudňany Fm. in abandoned quarry, Pennsylvanian, Northern Gemericum. Basal boulder conglomerates of the Rudňany Formation unconformably overlap the low-grade complexes of the Rakovec Group. They contain detritic fragments which were derived from the both pre-Carboniferous crystalline complexes of the Northern Gemericum, the Rakovec and Klátov Group. $^{40}Ar/^{39}Ar$ muscovite cooling ages from orthogneiss boulder indicate Upper Devonian metamorphic event (385 ± 3 Ma.; Vozárová et al., 2005).

V-15 Závadka II – polymict conglomerates of Krompachy Group exposed in cliffs, Cisuralian, Northern Gemericum. The basal part of the Permian sequence, the Knola Formation, contains mostly poorly sorted polymict conglomerates of variable thickness, with angular pebble material reflecting the composition of the underlying rock complexes. These coarse-grained sediments unconformably overlap different parts of both pre-Carboniferous rock complexes (the Klátov and Rakovec), as well as irregularly eroded surface of the Pennsylvanian formations. The Knola Formation sediments represent fossil mudflows, partly reworked by alluvial deposits, indicated by stream channel deposits.

V-16 Nálepkovo – fine-laminated basic tuffites of Sykava Fm., Rakovec Group, Northern Gemericum. The rocks are well foliated, with foliation planes oriented parallel to former sedimentary lamination. The foliation planes are strongly deformed by a system of the Alpine crenulation cleavage. The metasediments of the Sykava Formation are unconformably covered by the Rudňany Formation polymict conglomerates (Pennsylvanian).

V-17 Hnilčík – u Zajaca – metabasalts of Sykava Fm., Rakovec Group, in abandoned quarry, ?Silurian-?Devonian, Northern Gemericum. The metabasalts were originally built up by subaqual basaltic lava flows E-MORB/OIT signature. They represent a relic of the back-arc basin oceanic crust in the initial stage of opening, which was followed by the subduction-related metamorphic processes in the supra-subduction tectonic regime.

V-18 Grajnár – metabasalts and black phyllites of Zlatník Fm. in abandoned quarry, ?Pennsylvanian, Northern Gemericum, situated within the buffer zone of NAPANT NP. Generally the volcanoclastics dominate over effusive forms. The volcaniclastics represent a range of mixed varieties, with variable admixture of non-volcanic detritus. According to their chemical composition, the volcanics of the Zlatník Fm. correspond to tholeiitic basalts with affinity to BABB type. Black shales form the underlier of the volcanogenic horizon. The grade of metamorphism reached PT conditions corresponding to the boundary of lower-temperature greenschist facies. Alpine shortening associated with thrust faulting caused the emplacement of the Zlatník Fm. rocks over the Permian sediments. The younger down slip fault uncovered the violet-coloured Permian strata.

V-19 Kolínovce – violet slates of Permian and Palaeogene transgression (Borové Fm.), Northern Gemericum. Sedimentary sequences of the uppermost part of the Petrova Hora Fm. are exposed in the slope. They consist of violet-red and red-brown claystones, siltstones, with local layers of redeposited volcanoclastic material and irregularly distributed thin layers of carbonate claystones and carbonates. Frequent are carbonate and chlorite nodules. Carbonate layers of variable thickness are light-pink or grey-pink and mineralogically correspond to dolomite limestones partly enriched with Mn. The shale sequence originated in playa environment. Parallel-layered thin patches of sandstones reflect a regime of low-energy streamflows. In several levels, interference wave ripples are cropping out. The uppermost shale member of the Petrova Hora Fm. is discordantly overlain by basal, coarse-grained sediments of the Central Carpathian Palaeogene sediments (Borové Fm.).

*Fig. 1.3 Kolínovce, Krompachy Group – Petrova Hora Formation is represented by intense coloured violet shales, shales with interlayers and laminae of very fine-grained sandstones. The formation is conspicuously schistosed and affected by Alpine cleveage filled up with carbonate-chlorite veinlets – detail view (Photo J. Vozár)*

V-20 Krompachy – volcanites of Petrova hora Fm. in abandoned quarry, Cisuralian, Northern Gemericum. In the abandoned quarry trachyandesites, basaltic trachyandezites and rhyodacitic ignimbrites of the Petrova Hora Fm. are exposed. The polyphase volcanic activity reflects synsedimentary tectonics. Generally, the volcanites correspond to calc-alkaline/alkaline, peraluminious/metaluminious magmatic series. Chemical composition of the Petrova Hora volcanites indicates postorogenic A2-type magmatic suite. U-Pb (SHRIMP) zircon age data proved the Kungurian-Artinskian (272.4 ± 7.3 Ma; Vozárová, unpubl. data).

V-21 Ružín Defilé – In the roadcut section along the Ružín Dam the Upper Cretaceous NW-SE thrust fault structures can be studied, composed of the Northern Gemeric Črmeľ anticlinorium rock complexes on the one side and the Veporic Sivec synclinorium rock complexes on the other side. The macrostructures and their filling are predominantly penetratively deformed to form scales within a SW dipping cleavage system, which resulted in a monoclinal transportation of the formations. The structure is characterized by the tectonic contact of the Jurassic sequence of the Veporic type Mesozoic envelope of the Čierna Hora Massif and the epimetamorphosed Mississippian suite of the Northern Gemeric Unit. The Mississippian Črmeľ Formation consists of siliciclastic turbidite sequence associated with metabasalts and their metavolcaniclastics and lenses of carbonates in its upper part, metamorphosed in the greenschist facies conditions. The Čierna Hora envelope sequence is represented by the Jurassic, predominantly carbonate sediments. Dominant are Lias, cherty, marly and siliceous metacarbonates and pastel coloured radiolarian and cherty crystalline metacarbonates, corresponding to Dogger. The carbonate Jurassic complexes are in the tectonic contact with granitoids of the Bujanová Complex along the thrust fault at the SE limb of the Sivec synclinorium.

V-22 Jasov – metarhyodacites of Jasov Fm. in abandoned quarry, Guadaloupian, Bôrka nappe, situated within Slovenský kras NP. The Bôrka Nappe comprises a variable, discontinuous and tectonically intensively segmented package of the Alpine metamorphosed sedimentary-volcanic rocks of the Permian-?Jurassic age. The Jasov Fm., as its part, consists of a complex siliciclastic metasediments with smaller metarhyodacite bodies, usually cropping out as a separate partial thrust outlier of the Bôrka Nappe. These associated acid volcanites correspond to calc-alkaline, peraluminous magmatic series. Chemical composition of the Jasov Fm. volcanites (REE and HFSE) indicates postorogenic A2-type magmatic suite. U-Pb (SHRIMP) zircon dating proved the Wordian age (266 ± 1.8 Ma; Vozárová et al., unpublished data).

V-23 Štós – metasediments (metasandstones and metasiltstones) of Štós Fm., Southern Gemericum. The Štós Formation rock complex overlies tectonically the Drnava Formation of the Gelnica Group and is unconformably overlapped by Permian continental sediments. It is dominated by fine-grained metasandstones, metasiltstones with very often plan-parallel horizontal sedimentary lamination, and chlorite-muscovite metapelites. Sedimentary structures indicate a distal turbidite environment. The total thickness of the Štós Formation is estimated at ca. 500 – 800 m. Biostratigraphic age evidence is still lacking. Relics of overturned or isoclinal folds are preserved within outcrop. Slaty cleavage (axial-plane cleavage) is dominant feature.

V-24 Helcmanovce – tuff-porphyroides of Drnava Fm. in abandoned quarry, Gelnica Group, Cambrian – Ordovician, Southern Gemericum. The low-grade crystalline basement of the Southern Gemeric Unit (Inner Western Carpathians) consists mainly of siliciclastic deep-water turbidite sequence associated with huge mass of redeposited rhyolite/dacite volcanics and their volcanoclastics, latter preserved at the locality Helcmanovce. Method of U-Pb (SHRIMP) zircon dating (Laboratory of VSEGEI, Sankt Petersburg) applied to metavolcanic/metavolcaniclastic rocks of the Drnava Formation gave 463.9 ± 1.7 Ma average concordia ages. The geochemical data are compatible with an orogenic geodynamic setting (magmatic arc in the active continental margin). Dominant rhyolite-dacite metavolcanites/metavolcanoclastics belong to the peraluminous, calc-alkaline high-K magmatic series.

V-25 Stará Voda II – metarhyolites a metarhyolite tuffs of Vlachovo Fm., Gelnica Group, in cliffs and talus sediments, Cambrian, Southern Gemericum. The acid to intermediary metavolcanites and their metavolcaniclastics are represented mostly by vitreous/vitroclastic varieties, in which phenocrysts/crystalloclats constitute ~ 1/3 of the rock volume. Among the phenocrysts, magmatically corroded high-temperature quartz is dominant, associated with less microperthitic K-feldspars and Na-Ca feldspars ($An_{05-15}$). The K-feldspars often form the sanidine type phenocrysts. In intermediary affinity varieties, the magmatic biotite in relics is present. Based on the $SiO_2$ vs. $Zr/TiO_2$, the Vlachovo Fm. metavolcanites/metavolcaniclastics are concentrated mostly between rhyodacite/dacites and rhyolites. They are classified as calc-alkaline, peraluminous magmatic suite.

V-26 Pača – metarhyodacite tuffs of Drnava Fm., Gelnica Group, Middle Ordovician, Southern Gemericum. The rhyolite-dacite metavolcanites and their metavolcaniclastics are represented mostly by blastofelsitic varieties, in which phenocrysts/crystalloclats constitute approximately 1/3 of the rock volume.

V-27 Dolina Idy Valley – metasediments of Bystrý potok Fm., Gelnica Group with apophyses of Gemeride granites in abandoned quarry, Middle Ordovician, Southern Gemericum. The S-type Early- to Middle Permian Gemeric granite apophysis penetrate the low-grade metapelites of the Bystrý potok Formation of the Cambrian-Ordovician Gelnica Group. The newly formed biotite crystals reflect metamorphic heating on the contact of the granitoids and metapelites. The granitoids apophyses are younger than system of penetrating cleavage in metapelites.

V-28 Vyšný Klátov – amphibolites of Klátov Group in roadcut, Northern Gemericum. The Klátov Group, as a part of the Northern Gemericum basement, is dominated by amphibolites, associated with minor gneisses, serpentinized spinel peridotites (altered to antigorite serpentinites and their hydrothermal-metasomatic derivatives) and very rare Ca-silicate rocks.

V-28a Nižný Klátov – amphibolites of Klátov Group, in operating quarry, Northern Gemericum. Pebbles from this already metamorphosed complex, which were found within Moscovian conglomerates (the Rudňany Formation), indicate the pre-Carboniferous age of the Klátov Group rock complex. Its metamorphic evolution was polystage, from eclogite to amphibolite facies and to the retrograde stage, reaching P-T conditions of the low-pressure greenschist facies.

V-30 Súľová – railway cut, apical body of Gemeride granites, Cisuralian-?Guadaloupian. Metasandstones with intercalations of black phyllites are exposed along the road-cut. Basically, it is a complex of turbidite sediments, that belong to simple sandstone – shale lithofacies.

V-30a Podsúľová – metasediments of Vlachovo Fm., Gelnica Group, in roadcut, Cambrian-Ordovician, Southern Gemericum. Complex of the coarse-grained metagraywackes and microconglomerates associated with turbiditic relatively finer-grained metasediments represents relics of submarine slumping bodies.

V-33 Šebeková – upper metaconglomerates of Rožňava Fm. associated with rhyodacite volcanites, exposed in cliffs, Cisuralian, Southern Gemericum. The whole Rožňava Formation is subdivided into two regional larger cycles, with conglomerate strata at the base of each. Sedimentary structures of stream channel deposits are dominant, with distinct unimodal transport system. Both conglomerate horizons were associated with rhyolite-dacite subaerial volcanism.

V-34 Ostrá skalka – oligomict metaconglomerates of basal part of Rožňava Fm., exposed in cliffs, Cisuralian, Southern Gemericum. The Permian sedimentary complex represented by the Rožňava Formation conglomerates is generally characterized by a high content of mineral mature detritus, mainly by presence of quartz and metaquartzites pebbles. The oligomictic conglomerates are indistinctly stratified.

V-35 Krokava – metasediments of Slatvina Fm. altered into garnet-biotite hornfelses with granite apophysis, Southern Veporicum and contact with Northern Gemericum. In the road cut near the village Krokava the two-mica granites/granodiorites are exposed. Geochemical characteristics of the granitoids are calc-alkaline with affinity to normal I/S types. Rb/Sr isochrone indicates the age of the granitoids ranging from 392 to 382 Ma (Cambel et al., 1988), U/Pb method of zircons 350 Ma (Bibikova et al., 1988) and finally K/Ar method of micas suggest the age of 93 – 94 Ma. Along the road cut, in the complex of garnet-biotite hornfels decreasing P-T conditions of thermic metamorphism from amphibolite to greenschist facies may be observed. The climax of the contact – thermic metamorphism determined by garnet-biotite thermometer reached maximally 563 °C (Vozárová & Krištín, 1989). Nearly gradual transition into the black schists of the Slatvina Formation can be followed.

V-36 Predajnianske Čelno, Kelemen`s Tunnel – National Technical Monument – metarhyolites in Ľubietová crystalline, ?Guadaloupian-Lopingian, Northern Veporicum. Based on the age dating and their chemical composition the Kelemen Tunnel volcanites are correlated with the Harnobis volcanogenic horizon from the Brusno Formation.

V-37 Predajnianske Čelno – polymict conglomerates of Predajná Fm., Northern Veporicum. The sedimentary structure of the Predajná Formation boulder polymictic conglomerates indicates an upper part of alluvial-fan environment. Regional transition to piedmont basin deposits is evident.

V-38 Volchovo Valley – metavolcanites and metaarcoses of Brusno Fm., exposed in cliff, Mississippian Northern Veporicum, situated within the buffer zone of NAPANT NP. The magmatic zircon concordia age from the metavolcanites of the Volchovo Valley was confirmed to be Lower Carboniferous – 358.7 ± 3.9 Ma. In the assemblages of the analysed grains inherited zircon cores were identified with the Lower Cambrian concordia age – 516.7 ± 8.6 Ma. These results determine the low-grade crystalline complex in the Volchovo valley as the Variscan rock basement.

V-39 Dikula Valley – Mesozoic envelope sequence of Veľký Bok and its tectonic contact with Carboniferous sediments of Hronicum, situated within NAPANT NP. The Nižná Boca Formation sediments are characteristic of numerous repeating small fining-upward sedimentary cycles, consisting of fine-grained conglomerates, sandstones and shales. Abundant graded-bedded sandstones, channel bedding structures, as well as the layers rich in coalified plant detritus indicate a fluvial-lacustrine delta association. Sequences of well bedded fine-grained sandstones, mudstones and shales of grey and black colour correspond to lacustrine facies development. The whole rock complex of the Nižná Boca Formation was overthrusted upon the Early Cretaceous overfolded cover of the Northern Veporicum Unit.

V-40 Spišské Bystré – transgressive conglomerates and sandstones of Borové Fm., Palaeogene, overlying alternating Permian sandstones, siltstones and shales of Malužiná Fm., exposed in cliffs. Sediments of the Malužiná Formation belonging to the upper part of the 1st megacycle are exposed in the left flank of the valley. They are of typical red-violet colour. The layers of fine- to medium-grained sandstones alternate with mudstones and shales, representing alluvial environment. The shales associated with massive silty mudstones with considerable contents of small carbonatic spots (pedogenic horizons) represent the playa/ephemeral lakes environment.

V-41 Šimonov vrch Hill – abandoned quarry, rhyodacite tuffs of Tŕňa Fm., Pennsylvanian, Zemplinicum. Thick and relatively regular layers of volcanoclastics are interlayered by thin laminae of shales, rich in clastic mica. The volcaniclastics were redeposited into lacustrine environment, which is documented by well preserved horizontal lamination as well as by the scarce relics of ostracod shells.

V-42 Malá Bara – South of Černochov – abandoned quarry, red-violet claystones and siltstones of Černochov Fm., Permian, Zemplinicum. The Černochov Formation is represented by a complex of monotonous violet-redbrown, vaguely schistose mudstones and pelites. It is the youngest lithostratigraphic unit of the Late Palaeozoic envelope sequence of the Zemplinicum crystalline basement. This monotonous playa association is unconformably overlain by light-grey quartzose conglomeratic sandstones, quartzose arenites and subarkoses of the Lower Triassic Lúžna Formation.

V-44 Branisko – amphibolites and in left slope gneisses of Patria Crystalline, Northern Veporicum. The fundamental feature of the geological environment of the Branisko crystalline complex is gneisses-amphibolites basement, penetrated by several generations of granitoids, and its Permian-Lower Triassic envelope.

V-45 Valley North of Kluknava – Eocene/Oligocene transgressive conglomerates and sandstones of Borové Fm. overlying mylonitized Crystalline of Lodina and Miklušov complexes and Guadaloupian sediments of Predajná Fm. Along the roadcut, between the villages Kluknava and Víťaz in the Dolinský potok valley, crystalline rocks of the Lodina Complex are exposed, which belongs to the lowest lithostratigraphic unit of the Veporicum in the Čierna Hora Mts. It is dominantly composed of refolded and monoclinal (SW dipping), scaly, diaphtorised paragneisses with sporadic bodies of amphibolite, schists and phyllonites, latter derived from these rocks. In the northeastern continuation of the Dolinský potok valley, the tectonic contact of the Lodina Complex and the Miklušovce Complex, the middle lithostratigraphic unit of the Čierna Hora crystalline basement, is exposed. The Miklušovce Complex consists of diaphtorised migmatites, which contain intrafolial leucogranite bodies. Along the NW-SE fault, in the vicinity of Dolina settlements, the Permian sediments of the Predajná Formation are preserved in the tectonic contact with the crystalline rocks of the Miklušovce Complex along the NW-SE fault. These composed Variscan and palaeo-Alpine structure is overlapped by basal sediments of the Central Carpathian Palaeogene.

V-46 Ružín – Malá Lodina – postkinematic intrusives of biotite granodiorites of Bujanová and Miklušov Complexes, Northern Veporicum. Granitoids of the Bujanová Complex represent the uppermost crystalline unit of the Veporic basement in the Čierna Hora Mts. They are postkinematic intrusives and penetrate the fold structure consisting of different crystalline schists. K/Ar method proves the wide time span of ages, from 387 to 295 Ma, while latter could also reflect the Alpine rejuvenation processes. Based on chemical composition they belong to peraluminous S-type granitoids. Different type of blastomylonites derived from these rocks within the Alpine NW-SE shear zones.

V-47 Sopotnica Valley– metaarkoses and volcanites of Brusno Fm. in Čierna Hora Mts., Cisuralian, Northern Veporicum. The Permian sequence as the basal part of the envelope at the SE margin of the Čierna Hora crystalline basement is represented by the Brusno Formation with the Harnobis volcanogenic horizon.

V-48 Veľké Uherce – Early Triassic quartzose metasandstones of Lúžna Fm. overlying metasandstones of Brusno Fm. with dykes diorite porphyrites, Cisuralian, Hronicum. In the NE margin of the Rázdiel part of Tribeč Mts. formations of the Permian-Mesozoic sediments whose lithological content and metamorphic recrystallization show close links with the Mesozoic Veľký Bok sequence and the Permian Ľubietová Group from the Northern Veporic Unit. The Lower Triassic sediments of the Lúžna Formation overlain the Permian Brusno Formation as well as the pre-Triassic erosive relics of the Predajná Formation. The Lúžna Formation sediments are mostly represented by quartzose metasandstones, associated with fine-grained oligomictic metaconglomerates in its basal part. Characteristic is fining upward trend, with thin intercalations of red shales in the uppermost part. Plan-parallel lamination and low-angle cross lamination are the most frequent sedimentary structures. The Permian sediments of the Brusno Formation are represented by the light-grey, strong foliated metaarcoses. At the northeast part of the Rázdiel, the Veporicum Permian-Lower Triassic sedimentary sequence tectonically overlie the Tatricum Permian envelope.

V-49 Settlement Píla pri Žarnovici – sediments of Nižná Boca Fm. with dykes of diorite porphyrites, Pennsylvanian, Hronicum. The Nižná Boca Formation is a regressive clastic sequence with distinct tendency of upward coarsening. Numerous repeating upward fining sedimentary cycles is the most typical feature. The modal cycle evolving from medium- to fine-grained sandstones to siltstones and claystones is frequent in the lower part of the sequence. In the upper part it commences at the base with coarse-grained sandstones (even conglomerates in some places) and passes gradually across medium- and fine-grained sandstones to siltstones and claystones. Tabular strata with graded bedding and horizontal planparallel lamination are most frequent among sandstones. At the left side of the road cut the thin dyke of diorite porphyrite is visible.

V-50 Lošonec – andesite-basalts of Malužiná Fm. in abandoned and active quarries, Ipoltica Group, Lopingian. There are several varieties of andesite-basalts uncovered in the quarries: fine-grained to aphanitic, amygdaloidal-porous, porphyric, locally breccias filled with barite, calcite, chlorite and epidote, less frequently veins with Fe-Cu mineralization. Locally, especially in the peripheral parts of the quarry, there were found lava breccias, mostly in the basal parts of the flows. Numerous flows with thickness of 0.5 to 1.5 m (sheeted lavas), are observed to considerable distances. Fluidal structures, mainly in porous, amygdaloidal, but also fine-grained and porphyritic varieties are not rare and were documented in individual lava flows. Volcanoclastics are mostly ashes, sands, shots, and only quite sporadically lapilli of size max. 2 cm were found. They are less represented with respect to effusive bodies.

V-51 Brusník – Chvalová – Bodvaszilaš sandstones and polymict conglomerates of Brusník Fm. in abandoned quarry, Permian-Early Triassic, Turnaicum. The Werfenian Formation of the Turnaicum Unit is represented by a complex of variegated Bodvaszilas sandstones and shales. The Turnaicum Unit represents a rootless nappe composed of several partial units emerging from the tectonic underlier of the Silica Nappe. The Bodvaszilas Member sediments contain characteristic bioturbation structures (e.g. *Diplocraterion paralellum*), as well as sedimentary fluvial channel structures (graded bedding, high energy planparallel lamination). Fine-grained sediments are rich in clastic mica. The underlying Permian Brusník Formation polymict conglomerates are preserved in outcrops along the roadcut, in prolongation to the Brusník village.

V-52 Kazimír – Late Carboniferous envelope polymict conglomerates of Čerhov Fm. overlying crystalline basement, Zemplinicum. The Čerhov Formation overlies unconformably the crystalline basement which is documented from numerous drillhole data and the composition of detritus. Dominant lithofacies are polymict conglomerates and sandy conglomerates, with grain-supported structure and well-rounded pebble material. Minor gray sandstone layers with black shale intercalations occur. Conglomerates are interpreted as a braided-river deposits. The dating – Westphalian D – Stephanian A (Upper Moscovian) – is based upon microflora assemblages (Planderová et al., 1981).

V-53 Margecany – Margecany Fault Line – The Margecany shear zone forms the eastern imbricated boundary between the Northern Gemericum and the Veporicum of the Čierna Hora Mts. At the Margecany road cut is possible to observe from the NE to the SW direction the following lithotypes: a) chloritic-muscovite phyllonites of gneisses belonging to the uppermost basement complex (the Bujanová one) of the Čierna hora Mts. They are typical s-c tectonites containing lens-like and/or veinlet quartz segregations; b) approx. 25 m wide zone of diaphtorised garnet-amphibole gneisses and granodiorite protomylonites of the same complex; c) fine-grained metaconglomerates and metasandstones intercalated by graphitic schists of the Pennsylvanian Hámor Fm. Margecany shear zone has NW – SE direction and generally moderate (50°) dip to SW. Symmetrically penetrative cleavage belongs to axial plane set of regional NW-SE fold structure of the region. This relationship is visible at mentioned (b, c) lithotypes of the outcrop. The zone has however a complex polyphase development, with thrust fault, strike-slip and normal fault movements.

V-54 Košická Belá – bouldery conglomerates of Rudňany Fm. in cliffs, Pennsylvanian, Northern Gemericum. In the valley E of the Košická Belá village, bouldery metaconglomerates of the Rudňany Fm. are exposed (Pennsylvanian). In contrast to the occurrences in the northern part of the Slovenské rudohorie Mts., they are affected by very distinct flattening deformation, which is the result of shearing along the Ľubeník – Margecany line.

The composition of the boulder metaconglomerates reflects the direct underlier – rock complexes of the Črmeľ Group. Detritic material related to the other pre-Carboniferous complexes of the Northern Gemeric basement units is secondary. Metaconglomerates have a distinct NE vergency, dipping to SW. Local differences reflect different mechanical properties of particular lithotypes.

V-55 Vlachovo – fold in metagreywackes of Vlachovo Fm. (known as "Andrassy`s Cave"), Furongian. Gently asymmetric fold, with the N-S orientation and distinct western vergency was formed in the metagraywackes of the Vlachovo Formation. Dipping of the axial plane is to the SE. Expressive cleavage, parallel to the axial plane is significant phenomenon. The opinion about age of the origin of this fold is not unambiguous up to present. According to Lexa & Schulmann (2003) its origin was connected with the Jurassic subduction processes related to the closure of the Meliata Ocean.

V-57 Kamenná Poruba – type profile of siliciclastic sediments of Kamenná Poruba Fm. in forest road cuts, ?Guadaloupian-?Lopingian. The variegated siliciclastic Permian deposits S and SE of the Kamenná Poruba (the Kamenná Poruba Formation) are overlain by the Lower Triassic quartzose sandstones. They show subhorizontal position, dipping northwestwards at 5° – 15°, which is in a striking contrast comparing to the upright Permian sediments of the Tatricum (the Stráňanský potok Formation), with repeated north-vergent overthrust faults. The cyclical sedimentation is represented by two large cycles (each ranging to 500 m in thickness, based on the surface occurrences and borehole KV-1) and by repeatedly alternating one above another smaller cycles. Conglomerates-sandstones-claystones/carbonate shales are varicoloured, from lightgrey, greenishgrey to violet, violet-red and red colour. Mineral composition of sandstones corresponds to arkoses and arkosic wackes. Among pebble material in conglomerates fragments of granitoids, gneisses, low-grade metamorphic rocks (phyllites, muscovite- and hematite metaquarzites, quartzose metagraywackes), acid and intermediary to basic volcanites, were distinguished. The sediments are characteristic of only diagenetic alteration, with calcite, illite, quartzose, ferruginous, and scarcely anhydrite/gypsum cementation. Dolomite-evaporite shales contain also the authigenic albite crystals.

V-58 Valley of Ipoltica – stratotype of Ipoltica Group and Malužiná Fm., natural exposures of three megacycles of Malužiná Fm., Cisuralian-Guadaloupian-Lopingian, situated within the buffer zone of NAPANT NP. Along the Ipoltica Valley, sequences of all three megacycles of the Malužiná Formation can be observed. The whole succession consists of upward fining sequences, in the order of megacycles as well as in the other type of smaller cycles. The complex of strata reflects different facies of a fluvial environment. A typical cycle starts with conglomerates or conglomeratic, coarse-grained sandstone grades over an erosional surface. Unbedded, lens-shaped gravel-sandstone bars and channel lag deposits may be distinguished. The upper part of cycles is characterised by silty or shaly overbank deposits with intercalations of thick cross-bedded sandstones (crevasse deposits). Wavy and lenticular bedding as well as very often intensive bioturbation are typical structures of overbank sediments. Horizons of dolomitic or pelosideritic concretions occur on some levels. In the uppermost part of megacycles, monotonous red shales and muddy siltstones accumulated, with varying admixtures of fine-grained sandstones.

V-59 Heľpa – Permian phyllites, metabasalt tuffs and metabasalts of Predná Hoľa Complex, overlain by Early Triassic envelope sequence and Hronicum sediments, Nižná Boca Fm., situated within the buffer zone of Muránska planina NP. Phyllites, metabasalts and metavolcaniclastics of the Predná hola complex were folded together with their Permian-Mesozoic envelope sequence during the Alpine tectogenesis. Complicated thrust/fold system and following shear movements and faulting highly reduced both the Predná hoľa rock complexes as well as its Permian-Lower Triassic envelope sequence.

V-61 Dobšiná – Foederata – metamorphosed Mesozoic, Southern Veporicum. The metacarbonates of the Federáta Group were formed from the carbonate protolith of the Steinalm, Wetterstein, Raming and Gutenstein limestones facies in the low-temperature ($T_{Cal}$ = 354 – 476 °C, $T_{Ab-Or}$ = 329 – 453°C) and low- to medium pressure conditions of the greenschists facies (0.3 – 0.5 GPa) during the Cretaceous orogenesis.

V-63 Vyšná Maša – metacarbonates, Southern Gemericum. The metacarbonates of the Southern Veporic Federáta Group were formed from the carbonate protolith of the Middle Triassic limestones facies in the low-temperature (T = 350 – 380 °C), and medium pressure conditions of the greenschists facies (0.8 – 0.9 GPa)

V-65 Bukovec – flyschoid sandstones of the upper part of Gelnica Group exposed in cliffs, Silurian-Devonian, Gemericum. Rocks in this locality demonstrate a strong tectonization and plastic recrystallization due to the south-vergent Variscan tectogenesis in the Carboniferous. Younger (Lower Cretaceous) north-vergent Alpine structures have distinctly lower ductility and penetrate older plastic ones.

V-66 Guľapalag – metarhyolite tuffs of Gelnica Group exposed in cliffs, Ordovician-Silurian, Gemericum. The locality Guľapalag presents the Lower Paleozoic rocks of the Gemeric Gelnica Group, manifesting a higher grade metamorphic recrystallization (620 – 640 °C) and tectonization in the plastic state as well.

V-67 Rakovec – gabbros and diaphtorites of Rakovec Group, exposed in cliff, Devonian, Gemericum. Eclogitized gabbro outcropped on eastern slopes of the altitude point Ostrá south of the village Rakovec in the Spiš-Gemer Ore Mts. (tectonic unit Gemericum) represents a relic of magmatic chamber from the boundary zone of continental crust and the mantle (~35 km).

*Fig. 1.4 Dobšinský potok Brook in the right slope of the valley forest road at the altitude of 574-575 m a.s.l. – Foederata Group, Middle Triassic: thick-bedded metamorphosed limestones of grey colour arranged in the road-cut into oblique fold (Photo J. Vozár)*

### 1.4.2 Localities of magmatites and tectonics

The sites of magmatites, dominantly granitoids, are located mainly in the central parts of the Core Mountains. The granitoids of the Gemericum tectonic unit (Gemericum granites) of the S type are present in the form of smaller bodies intruding the Old-Palaeozoic low metamorphosed volcanosedimentary formations. Compared to Variscan granitoids of the Western Carpathians they are enriched in volatile elements B and F and trace elements Rb, Sn, Li, Nb, Ta, W and Mo. In the Veporicum and Fatricum tectonic units there is a variety of granitoids. Among the Neo-Hercynian rocks granite and quartz porphyries, their tuffs and tuffites and porphyroids, leucocrate granites to granodiorites, locally porphyric and aplitic, biotite tonalites to granodiorites are present. The Meso-Hercynian collisional granitoids include leucocrate aplitic granites to aplites, leucocrate granites, biotite and two-mica granites to granodiorites, porphyric biotite granites to granodiorites, porphyric biotite and two-mica granodiorites to granites, hybridic granodiorites to tonalites. The theme involves also diorites, serpentinites and hornblendites.

The present structure and essential tectonic division of the Western Carpathians reflect the ongoing Neo-alpine tectonic processes, which have started by the end of Palaeogene and have taken place during the Neogene and Quaternary periods. However, the manifestations of the older tectonic stages – Palaeo-alpine and Neo-Hercynian ones – have not been completely wiped out. In addition to the magmatic sites, the theme 2 includes the most significant sites of these tectonic stages (Fig. 1.5).

JM-01 NNR Velická dolina Valley Večný dážď (Eternal Rain) (Fig. 1.6) – megaxenolith of metamorphites, situated within TANAP NP. In the crystalline granite core of the High Tatras the metamorphic rocks and migmatites of gneiss character are relatively rare. The highest incidence of such rocks amidst the granitoid rocks occurs in the form of sunken block, from both sides limited by faults, at the bottom of the Velická dolina Valley above the Velické pleso Tarn.

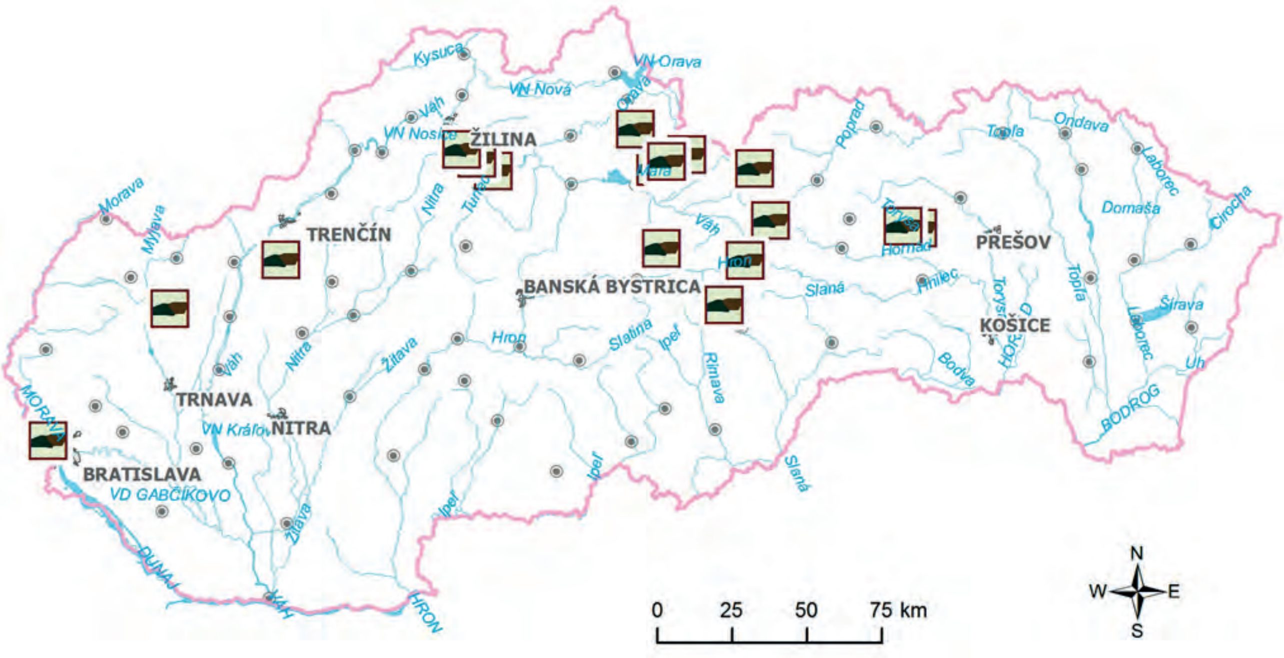


*Fig. 1.5 Distribution of the sites of magmatites and tectonics in the Slovak territory*

*Fig. 1.6 General view of the central part of Velická dolina Valley from cirque-moraine glacial Velické pleso tarn (Panoramatic photo: J. Madarás)*

JM-02 Západné Tatry Mts. – Baranec – tectonic nappe outlier of "Upper Unit" of magmatites and highly-metamorphosed rocks upon "Lower Unit" – low- to medium metamorphosed rocks, situated within TANAP NP. In the crystalline core of the Western Tatras, in the massif of their third highest peak – Baranec (2,184 m), a complex of gneisses to migmatites and amphibolites appears in the position of a tectonic outlier atop the underlying mica schists. Two lithologically and metamorphically different units show the presence of a nappe structure in the crystalline area of the Západné Tatry Mts. In the overburden of the gneiss-migmatite complex there are younger – Hercynian granitoids of the Tatry core.

JM-03 Západné Tatry – Bystrá – highly-metamorphosed rocks of "Upper Unit" upon granitoids of Tatry Pluton, situated within TANAP NP. In the crystalline core of the Western Tatras, in the massif of the highest peak – Bystrá (2,248 m), atop the granitic rocks there occur quite diverse sets of metamorphic rocks – gneisses to migmatites and amphibolites. The metamorphic rocks in the Bystrá massif are relics of metamorphic mantle of older rocks into which younger granitic magma had penetrated (intruded).

JM-04 Vikartovce Fault – neotectonically active fault, contact of Permian rocks of Kozie chrbty Mts. with Palaeogene Fms. of Hornádska kotlina Basin. Vikartovce fault is a unique example of neotectonic (Quaternary) fault activity of the southern foothills of the High Tatras – horst structure of the Kozie chrbty Mts. The activity of the fault resulted in a very recent geological past in a change in the watershed between the two main streams in the High Tatras region – Poprad and Hornád.

JM-05 Muránska planina Plateau – quarry Muráň – Muráň Fault – tectonic contact of Stolické vrchy Mts. Crystalline (Muráň orthogneiss) with Triassic carbonates (Wetterstein dolomite) of Muráň Plateau along Muráň Fault, situated within Muránska planina NP. In a quarry behind the village of Muráň there is exposed a direct contact of two diametrically different rock units: Mesozoic carbonates (dolomites) of the Muráň Plateau Silicicum and Early Palaeozoic schists (Muráň orthogneiss) of the Kohút Veporicum zone. The contact zone contains tectonic clay; it represents a fault plane of one of the most important faults in the Western Carpathians – Muráň fault.

JM-06 NNR Hrdzavá dolina Valley – Muránska planina Plateau – tectonic outlier of Crystalline and Veporicum unit envelope below carbonatic rocks of Muráň Nappe, situated within Muránska planina NP.

JM-07 Kráľova hoľa – Kráľova skala – Nízke Tatry Mts. (Fig. 1.7) – an example of extreme tectonic deformation of Nízke Tatry Mts. Crystalline (mylonitisation) and

*Fig. 1.7 Outcrop of gneiss at the ridge Kráľova hoľa, towards Stredná hoľa (Photo: J. Madarás, 2010)*

transtension Palaeoalpine tectonics, situated within NAPANT NP. The cliffy top of the Kráľova skala is formed by dark grey to dark green medium-granular, locally coarser-granular granodiorites and tonalites of the Kráľova hoľa zone (complex) – partial nappe of Veľká Vápenica. The rocks show a typical platy to thick-bedded jointing along the systems of extension subhorizontal mylonitic foliation planes. The rock cliffs of Kráľova skala and below the top of Kráľova hoľa are periglacial frost cliffs, which were formed due intense frost (cryogenic) weathering and material displacement. This weathering had reached the greatest intensity in the cold Pleistocene glacial periods. Some cliffs underwent further development (especially frost weathering along transverse cracks) associated with the creep downslope movements (solifluction), which separated them from the rock wall; there have been created single rock towers reaching up to 10 m in height. At their foot frost debris and cryoplanation terraces have developed.

JM-08 Kľačianska Magura – Malá Fatra – Northern tectonic termination of the Turčianska kotlina Basin is an example of neotectonic activity and well-preserved facetted slopes, which evolved due to rapid tectonic uplift of Tatricum crystalline of Malá Fatra Mts. (Massif of Kľačianska Magura) along the Lipovec fault in opposite to the Tertiary sediments in the Turčianska kotlina Basin.

JM-09 Zuberec – Milotín – tectonic "enigma" – huge (several tons) reworked granitoid block enclosed in rocks of Inner Carpathian Palaeogene. In the village of Zuberec, amid soft claystone – sandstone sediments of Early Tertiary (Palaeogene) age, there is a large boulder of resistant granitic rock of Younger Palaeozoic (Permian) age. Its origin is considered as exotic, being outside the current granitoid rocks in the area. The granite is probably the rest of the geologically older ridge made of crystalline rocks, which by the end of Mesozoic and Early-Tertiary separated marine basins of the Inner Carpathians from the marine environment of the Outer Carpathians and the Bohemian Massif.

JM-10a,b Highway tunnel Višňové (a) – Dubná skala (b) – complete cross-section through Malá Fatra Mts., situated within Malá Fatra NP. In the period of 1998–2002, an exploratory gallery of a future motorway tunnel Višňové – Dubná Skala was driven in the length of 7480 m. The gallery runs across the entire mountain massif, therefore it has provided a complete geological section through the core mountain range of Malá Fatra. The profile through granitoid rocks is 6081 m long. These rocks and their petrographic and tectonic diversity can be studied in Dubná Skala quarry, located close to the Eastern tunnel portal.

JM-11 Veľký Inovec Mts. – Považský Inovec – the deepest naturally exposed part of Western Carpathian crust – Crystalline and envelope sequence of Infra-Tatricum. Thanks to the intense uplift and erosion on the hill spur Veľký Inovec (1,042 m a.s.l.), mica schist and gneisses are exposed; they are probably the deepest levels of Western Carpathians crystalline, which are accessible to direct examination. The tectonic block is affiliated to Selce Tatricum (Infra-Tatricum) of the crystalline core of the Považský Inovec Mts.

JM-12 Dobrá Voda Depression – Malé Karpaty Mts.– seismically the most active area in Slovakia in 20$^{th}$ Century; the last strong earthquake in Slovakia in year 1906 with epicentre intensity I0 = 8.5° MSK 64 and magnitude $M_0$ = 5.9, situated within PLA Malé Karpaty.

JM-13 Pass Čertovica – Nízke Tatry Mts. – mylonites in Crystalline – contact of two basic tectonic units – Tatricum and Veporicum; course of Čertovica fault line, situated within NAPANT NP. Čertovica line represents a surface projection of the the contact of two main tectonic units of the Central (Inner) Western Carpathians – Tatricum block fundament and overlying Veporicum unit. The contact zone of the tectonic units is visible above the saddle Čertovica and is characterized by strong tectonic deformation and broken (mylonitized) crystalline rocks.

JM-14 Bystrá dolina Valley – Trangoška – Nízke Tatry Mts. – ductile (plastic) deformation of highly-metamorphosed rocks of Tatricum Crystalline of Hercynian age (cca 330 Ma), situated within NAPANT NP.

JM-15 Rejdová – Hlboké – Valley of Slaná River – Stolické vrchy Mts. – profile through Crystalline along Zdychava fault line – an example of various deformation levels of crystalline rocks – granitoids along significant regional fault line.

JM-16 Kamenistá dolina Valley – dolina Valley Hrončok – Kyslá – Veporské vrchy Mts. – Pohorelá tectonic line – contact of granitoids of Vepor Pluton Kráľova Hoľa Complex with schists of Hron Complex, situated within PLA Poľana.

JM-17a,b Highway tunnel Branisko – complete cross-section through Branisko Mts.; a) Eastern portal Palaeogene flysch complexes, overlying crystalline highly metamorphosed rocks of the Patria Complex (hornblende–biotite gneisses); b) Western portal – Palaeogene flysch complexes overlying Permian rocks of Korytné Fm.

JM-18 Tunnel Sitina – first double-tube highway tunnel in Slovakia, two-mica granodiorites, mica schists, gneisses of the Bratislava Massif. With a length of almost 1.5 km the motorway tunnel Sitina is the first two-tube road tunnel in Slovakia. It passes across the southern termination of the Small Carpathians in Bratislava and it was driven in particular in the granitoids of Hercynian age.

JM-19 Žiarska dolina Valley – abandoned gallery for iron and silver ores – profile through Early Devonian Crystalline – orthogneisses migmatites, amphibolites and granitoids – of the Západné Tatry Mts., situated within TANAP NP. The old mine adit in the mouth of the Žiarska dolina Valley, probably dated back to the beginning of the19$^{th}$ Century, with a length of over 500 m, is the only one preserved mining gallery in the Západné Tatry Mts. It is situated in the lens of amphibolites of Early Palaeozoic age in the Western Tatras crystalline.

### 1.4.3 Mesozoic localities

The theme deals with the dominant carbonates sites accross the Slovak part of the Western Carpathians. These kinds of rocks are evolved in the Klippen Belt and in the Palaeoalpine tectonic units (Fig. 1.8).

**The Klippen Belt** represents complicated narrow tectonic zone, extended from Podbranč through Považie to Orava region, where it submerges beneath the Neogene sediments of the Orava Basin. It crops out on the Polish territory and in the Pieniny area it enters the Slovak territory again. Further in the SE direction it is buried beneath the volcanic complexes of the Vihorlat Mts. and near the Beňatina Village it crosses the Slovak-Ukraine borders. Recent shape of Klippen Belt is the result of mainly Tertiary destruction of Meso-Alpine fold-nappe system.

Into the structure of the Klippen Belt s. l. there were dragged, besides the Klippen Belt s. s., also the units from the adjacent original sedimentation area. These are affiliated mainly to the Klapy, Manín and Haligovce tectonic units.

In the Klippen Belt s. s. the Late Triassic, Jurassic and Early Cretaceous carbonatic formations of various klippen sequences form the morphological and structural klippens of metre to kilometre dimensions. Their evolution was of polyphase character, the last significant tectonic movements occurred between Badenian and Sarmatian. The Middle and Late Cretaceous flysch-like and marly formations formed originally the overlier of older klippen formations. Recently they are squeezed into or pulled out from normal stratigraphic successions and strongly tectonized. By this way they form the encircling environment of individual klippens – the so-called Klippen Cover.

The **Palaeoalpine tectonic units** comprise the whole-crust units as well as a system of near-superficial nappes. The crustal tectonic units – Tatricum, Veporicum, Gemericum and Zemplinicum are built up with crystalline basement and incorporated fragments of Hercynian tectonic units, as well as the cover formations of the Upper Palaeozoic and Mesozoic. The Palaeoalpine near-superficial nappe units comprise the nappe system of Fatricum, Hronicum, Meliaticum, Turnaicum and Silicicum.

RA-01 NL Beckovská hradná skala (Beckov Castle Cliff) – profile through Triassic–Ladinian. The Beckov castle-rock hill represents the erosion remnant of Hronicum, which is cut from the west by the Považie Fault, bordering the Považský Inovec mountain range. The preserved bed succession consists of three groups of sediments. The lower group is represented by Steinalm Limestones which are shallow-marine deposits of carbonate shelf spread in the whole area of Hronicum. This carbonate shelf was disintegrated into the system of basins and platforms due to the Late Pelsonian rifting.

RA-02 Belianska dolina Valley – Belianska dolina Valley is one of the most famous in Veľká Fatra mts. It starts at the village Belá-Dulice and its closure is below the hill Borišov (distance 15,6 km along a green tourist trail). From the north the valley is limited by massif of Lysec, in which several tributaries are encarved – the most spectacular is Šindolná Valley. One of the most enjoyed touristic attractions of the Veľká Fatra Mts. represents a complete profile of the Šiprúň Sequence of the Veľká Fatra Tatricum. The lithostratigraphic profile covers a period from Ladinian till Albian-Cenomanian (Ramsau Dolomite, Došná Mb., Carpathian Keuper, crinoidal biosparites, crinoildal limestones, Allgäu Beds, radiolarian limestones, Calpionella limestone, black cherty limestones, Poruba Mb.

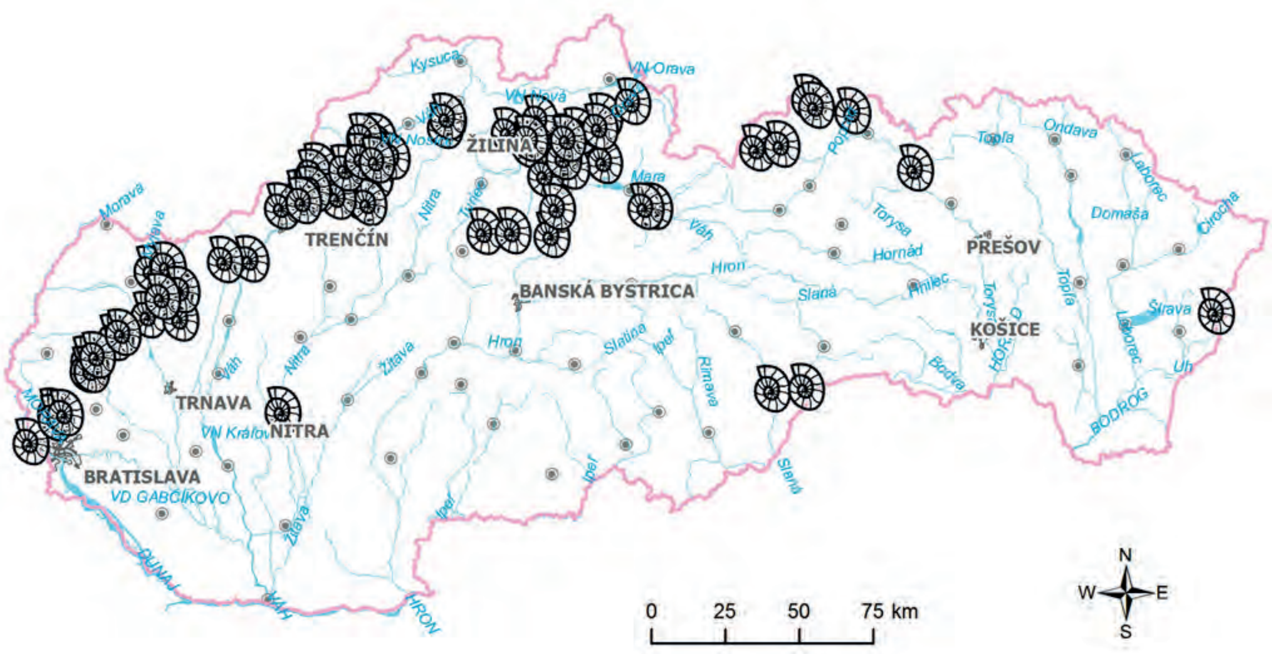


*Fig. 1.8 Distribution of the sites of Mesozoic in the Slovak territory*

RA-03 Podtureň – Lunz Mb., type profile, alternating sandstones and dark profile through grey shales, Carnian.

RA-05 Ždiar, roadcut – type profile of Carpathian Keuper, Norian. Between the Podtúreň Village and the town of Liptovský Hrádok, an abandoned quarry is located, with the best preserved Hronic Lunz Beds; the section has 50 m in thickness. The Lunz beds in this area are more than 300 m thick, which is the largest thickness of these beds recorded in the Western Carpathians. They are typical of alternating sandstones and dark-grey shales.

RA-06 NNR Prielom Dunajca (Dunajec Breakthrough) – Klippen Belt, Jurassic–Cretaceous, situated within PIENAP NP. The most valuable parts of the Pieniny Mts. were declared a National Park (PIENAP) in 1967. It is the smallest national park in Slovakia covering an area of 222.44 $km^2$. The PIENAP territory is characteristic of klippe and karst relief with remarkable concentration of surface and underground karst phenomena. Among them very spectacular are river gorges which have been formed thanks river erosion. The largest one is the Gorge of Dunajec, which starts on our territory near Červený Kláštor and it continues eastwards till Lesnica. The Dunajec River incised within the Mesozoic (dominantly Jurassic, less Cretaceous) formations of the Klippen Belt. The meandring fluviokarst gorge is of so-called antecedent nature (incised into the territory with continuous uplift); geological structure was another factor.

RA-07 NL Devínska hradná skala (Devín Castle Rock) – Jurassic – profile through Permian to Jurassic of Tatricum of the Malé Karpaty Mts. The Devín castle hill is built by basement phyllites, Upper Permian terrestrial clastics, Lower Triassic quartzites, Middle Triassic dolomites and Lias limestones from E to W. The western cliff wall is formed by Middle Lias biodetritic (crinoids, belemnites, brachiopods) breccia limestones with angular clasts of the underlying dolomites. The limestones intrude deeply into the Triassic basement forming fissure fillings and neptunic dykes, pointing to an extensive erosion and faulting before the Lower Jurassic transgression. The Devín Succession is a sedimentary cover of the pre-Alpine basement of the Bratislava Nappe overlying the subautochthonous Borinka Unit.

RA-08 NNR Vršatské bralá (Vršatec Cliffs) – fossil fauna, geomorphology, Jurassic–Early Cretaceous, situated within Biele Karpaty PLA. The group of main Vršatec Klippen is the largest in Slovak territory and in the entire Pieniny Klippen Belt (PKB). The cliffs are situated above the Vršatské Podhradie village, NW of the Ilava town. This locality consists of two tectonic blocks that belong to the Czorsztyn Unit: the Vršatec Castle Klippe and the Javorník Klippe. They are formed by a succession of the Middle Jurassic-Lower Cretaceous carbonates that are capped by the Upper Cretaceous marls. Importantly, this locality exposes relatively thick, coral-dominated biohermal deposits, which are missing or very rare in other Jurassic successions of the PKB.

RA-09 NR Červenokamenské bradlo (Červený Kameň Klippen) – amonite fauna, Jurassic, situated within Biele Karpaty PLA. Dissected klippe of Červený kameň thrones over the village of the same name. In 1966 and 1986 it was declared Nature Reserve. Immediatle to the main monolith a higher cliff is located, westwards a smaller cliff which passes into distinct ridge called "Chinese Wall". The territory is made of weathering-resistant Czorsztyn Limestone of Jurassic age encompassed within Late Cretaceous envelope – Púchov Marl.

RA-10 NR Kozinská – Klippen Belt, Jurassic, type profile of the Orava Unit, situated within the buffer zone of Malá Fatra NP. A klippe which forms two hills north of the Zázrivá Village in Orava territory of Slovakia belongs to the Orava Unit. It is the type klippe of the unit defined by Haško (1978). The klippe represents a false anticline. In fact it is a reversed dish-like syncline. Along with the Kysuca-Pieniny Unit, the Orava Unit is the most deep-water unit of the Pieniny Klippen Belt (according to the stratigraphic development even the deepest one). The entire klippe is cut by the Zázrivka Creek into two parts.

RA-11 Skladaná skala – Allgäu Mb., Jurassic, type profile in abandoned quarry, thin-bedded marly limestones. The site represents a unique complex exposure of the occurrence of the Allgäu Fm. in the Western Carpathians. More than 80 meters high artificial outcrop (quarry) represents distinctly thin-bedded grey speckled limestones with positions of grey marls. Typical for this type of limestone is the presence of variously large and varied shapes of dark grey to black spots, which are oriented mostly parallel to the stratification.

RA-12 Liptovská Osada – NL Triasový útes (Triassic Cliff) at Liptovská Osada, Raming and Korytnica Limestones in abandoned quarry, massive biohermal Ladinian Raming Limestones, overlain by dark, bedded organodetritic Korytnica Limestones of Early Carnian age. Situated within the buffer zone of NAPANT NP.

RA-13 NL Dogerské skaly (Dogger Cliffs) – Ždiar Fm., deep-sea (bathyal) lithofacies of the Zliechov Sequence of the Krížna nappe. The Dogger sequence consists of red and green radiolarian limestones to radiolarites. Situated within the buffer zone of NAPANT NP.

RA-14 NL Meliatsky profile (Meliata Profile) – stratotype of Meliata unit, Triassic-Jurassic, bank of the Muráň river, about 220 m long and locally up to 25 m high natural outcrop. The base of the section begins with thick white crystalline Honce Limestone (most probably metamorphosed Steinalm Limestone) of the Lower Anisian. In the upper part, the red shaly intercalations of the Žarnov Fm. are present. Above the white crystalline and red Anisian limestones, radiolarites of various colours (predominantly red) follow in the section (Ladinian). Their contact with the underlying limestone is, however, covered by debris and soil. Between the variegated radiolarites and the overlying units, a sharp contact occurs in the form of a thin intercalation of greenish claystone (0 – 7 cm). It is followed by an olistostrome layer (6 m in the upper part of the outcrop) composed of lithoclasts of grey, grained and cherty Carnian limestones (10 – 30 cm size), also an angular block of the red radiolarite (20 x 10 cm in size) was found. The olistostrome is locally strongly squeezed with a minimum content of matrix, resembling a coarse nodular limestone. Above the carbonate olistostrome, the content of dark calcareous shales increases (10 m) with decreasing quantity of the limestone olistoliths. In some of them, Carnian and Norian conodonts were found (Kozur & Mock, 1973; Mock in Mello, 1975). Deposition of the grey calcareous shales in the upper part of the section gives way to a huge complex of non-calcareous claystones, in places with thin layers of grey and greenish-grey radiolarites. They contain radiolarian assemblages of Middle Jurassic-Early Oxfordian age.

RA-15 NL Litmanovský potok Brook – pyritized amonites in the bank and on the bottom of the creek, which originate from black and dark-grey claystones and spotted marlstones ("fleckenmergel") and pelocarbonates, Jurassic. In the Litmanovka Brook in Litmanová, there are scattered pyritized ammonites, which originate from black and dark-grey claystones and spotted marlstones ("fleckenmergel") and pelocarbonates (Nemčok et al., 1990). These rocks are rich in pyritiyed, mainly ammonite macrofauna. The thickness of the beds is up to 10 m. The whole formation is a component of the Klippen Belt.

RA-16 NR Pod Pajštúnom – olistolith cliff, Lias limestone of Borinka type. Several tens of meters thick body of brecciated Ballenstein-type limestones occurs among turbiditic sequences of the Korenec Fm. This consists of alternating shales marlstones and sandstones to sandy limestones, the turbiditic nature of which is indicated by the presence of almost complete Bouma intervals. Limy mud-supported intra- and dominantly extraclastic brecciated limestones deposited from cohesive mud to debris flows form probably the channel filling in these more distal zones of the Borinka halfgraben in comparison with the quarry Prepadlé. Mass-flows in channels could carry large megaolistoliths (more than 100 m in diameter) of Triassic carbonates.

RA-17 NR Rochovica – profile through Kysuca section of the Klippen Belt, Jurassic-Cretaceous. The Rochovica section is located near Žilina in NW Slovakia. The section in the "Kysuca Gate" narrows was cut by the Kysuca River penetrating from the north into the Váh River Valley across a large klippe of the Kysuca Unit (Rochovica is one of the type sections of this unit). The klippe is limited by thrusted Palaeogene flysch complexes of the Outer Carpathian Magura Unit from the north, and by Upper Cretaceous shales of the Manín Nappe from the south. Uppermost Tithonian – Lower Albian Majolica-type limestone sequence is exposed both on the foot of the Rochovica Hill, in a local road escarpment between Rudinka and Vranie villages and in erosive terrace of the Kysuca River. This is the best exposed area of the Pieniny Limestone Formation in the Kysuca Unit.

RA-18 Orava Castle, NL Hradné bralo (Castle Rock), – profile through Orava section of Klippen Belt, Jurassic. In the tectonically complicated section, following lithostratigraphic units can be distinguished from the base: spotted marly limestones with ammonoids (Allgäu Fm.: Upper Sinemurian), greenish-grey limestones (Korinec Fm.: Pliensbachian), pale grey weakly spotted limestones with belemnites (Upper Pliensbachian), red pseudonodular limestones (Adnet Limestone: Toarcian), green and red silicites and siliceous limestones (Aalenian–Oxfordian), red nodular limestone (Czorsztyn Lst. Fm.: Kimmeridgian) and pale grey micritic limestone (Pieniny Lst. Fm.: Tithonian–Berriassian).

RA-19 NNR Zádielská tiesňava – canyon in limestones, Triassic, Silicicum unit, situated within Slovenský kras NP (Fig. 1.9). Typical karst canyon with a length of about 4 km. At the bottom the width reaches from 20 to 100 m, the depth of the incision is up to 300 m. The canyon cut through the Triassic sandstones and dolomites. In the medium section of the valley there is a remarkable rock cliff – Cukrová homoľa (Sugar Loaf), enjoyed by climbers. In the upper part of the canyon there are several exsurgences and numerous caves (Mišík, 1976).

*Fig. 1.9 National Nature Reserve Zádielska tiesňava – Zádiel Gorge, mouth of karst canyon (Photo J. Madarás)*

RA-20 NR Klape – profile through Klape Unit of Klippen Belt, Early Jurassic. The klippe Klape is made of almost exclusively Jurrasic rocks; their lithostratigraphy was described by Began (1987). This klippe is encompassed by marly/flysch complex (Nimnica Fm.). Accounting for inverted position of the flysch sequences as well as that no direct contact between Jurassic of the klippe and the Albian flysch has been observed, we are not sure, whether these two lithologies represent a continuous sequence. The enigma lies in explanation of the Klape Klippe within the flysch sediments.

RA-21 NNR Tlstá – fold of Tlstá, dominantly Gader Limestone of Middle Triassic, situated within Veľká Fatra

NP. Tlstá Hill is one of the dominants of the western part of the Veľká Fatra Mts. The massif is made of Gader Limestone. The type profile is situated in the Vápenná dolina Valley on the western flanks of Tlstá (blue tourist trail up to the summit of Tlstá). The Gader limestone is very pure; therefore it is prone to karstification process. In the massif of Tlstá there are numerous caves: Mažarná, Biela, Stĺpová, Textorisovej, Havranova, etc.

RA-22 NNR Tiesňavy – Choč Nappe, Triassic – Vrátna dolina Valley – profile through Choč Nappe, situated within Malá Fatra NP. Almost the entire Vrátna dolina Valley is situated within the dolomites of the Choč nappe which thanks to selective weathering create bizzare turret-like objects; some of them were accordingly named, for instance Monk, Camel etc. After crossing the narrow gorge at the left side we can see the deposits of the rock fall. At the closure of the gorge there is Reifling Limestone and the last cliff is dolomite again. Its alternation with dolomites proves for existence of several structures of probably inverted folds. Just behind a brook, below the Middle Triassic dolomites, Neocomian marly limestones of the Krížna Nappe are exposed.

RA-23 NNR Borišov — profile through the Krížna Nappe, Triassic–Cretaceous, situated within Veľká Fatra NP. The Borišov Hill in the Veľká Fatra Mts. is one of several peaks here which are formed of Jurassic Mraznica Formation (Krížnea Ostredok, Ploská, Lysec). From the lithology point of view the rocks are grey, dark-grey marly limestones, marlstones and marly shales.

RA-24 NR Veľká Lučivná – profile through the Tatricum envelope unit, Cretaceous, situated within Malá Fatra NP. The ascent of the Veľká Lučivná Valley starts in the Gutenstein Formation represented by Middle Triassic dark-grey to black thick-bedded Gutenstein (Annaberg) Limestones (1 km). Than the valley splits and we continue the ascent to the right and we pass into the Ramsau Dolomite of Middle-Younger Triassic. The Ramsau Dolomite is irregularly stratified in prevail, the thickness of the beds fluctuates in the range of 2 to 120 cm. The dolomite is compact, fine-grained, the colour is pale-dark-grey.

RA-25 NNR Choč – Veľký Choč – profile through the Choč Nappe, Triassic. The top of the Veľký Choč Hill represents a fault outlier of the Choč Nappe, which has received its name from this very site. This nappe was overthrust from south or south-east some 90 million years ago. Thanks to erosion and denudation it has been preserved in the form of tectonic outliers, solely. The fundament for the Triassic rocks of the Choč Nappe create the Cretaceous rocks of the Krížna Nappe.

RA-26 NNR Prosiecka dolina Valley, gorge, profile through the Choč Nappe, Triassic. The middle and upper sections of the canyon are dry, the stream flows here through obscure underground spaces (Gross et al., 1993). The mid-part of the valley is more open, which is due to exposure of Reifling Limestone and rather soft Lunz Beds. Atop of them and dolomites there are horizontal or slightly N-dipping overthrusted Gutenstein Limestones of the medium digitation, which build up the rocky cliffs here. The Reifling Limestones and Lunz Beds are sporadically uncovered on the surrounding flanks. The most picturesque part of the canyon is its closure, carved again within Gutenstein Limestone of the upper digitation.

RA-27 NNR Haligovské skaly – (Haligovce Cliffs) – profile through the Haligovce unit of the Klippen Belt, Jurassic-Cretaceous, situated within PIENAP NP. Very rich in surface and karst forms in Pieniny Mts.are Haligovské skaly (Haligovce Cliffs) – a stony wall north of the Haligovce Village. They are very intense dissected due to combined erosion-denudation process supported by karstification. The surface karst forms are present like schrattens or lapies, rock needles and towers; quite unique is the stone gate and bridge. The underground karst is present in the form of caves. Up to now there have been studied and registered 23 of them. The largest one is the Axamitka Cave, dwelled already by Paleolithic man. It is formed within Middle Triassic to Jurassic rocks of the Haligovce Sequence. Among the other caves we may note Jazvečia jaskyňa (Badger Cave), Ježovka (Hedgehog Cave), Skrývačka (Shelter Cave), Zbojnícka jaskyňa (Robber Cave), Cave Emmental, Lebka (Skull) and numerous smaller caves.

RA-28 Bzince pod Javorinou – profile through the Nedzov Nappe. Jurassic – Cretaceous sediments of the Nedzov Nappe in the northern part of the Čachtické Karpaty Mts. occur in form of narrow lenses or more or less continuous stripes. In the quarry, their intensive fold-and-thrust deformation is visible, with general dip to the south or southeast, which is typical for them. In the left part of the quarry, grey, pale-grey, brownish to pink bedded limestones occur, locally slightly crinoidal. In the most strongly folded limestones there are claystone layers, locally with pyrite. The limestones are biomicrites to biosparites. Directly above the quarry in the crinoidal varieties, foraminifer *Triasina hantkeni* can be found. According to the lithological character and the Late Triassic age, the limestone can be named as Dachstein Limestone.

RA-29 Nitra – Pyramída+Zobor – Early Triassic quartzstones and Lias limestones of Tatricum in natural outcrops, situated within Malé Karpaty PLA Ponitrie. A complex development of the Lúžna Formation (Tatricum) is very well exposed on rocky cliffs of the Zobor Hill above Nitra. The bottom part of the profile is made of fine- to medium-grained quartzites with planar cross-bedding. The thickness of the formation is estimated to 200 – 300 m.

RA-31 NR Kršlenica – organodetritic and reef limestones of Veterník Nappe – Triassic, situated within Malé Karpaty PLA. Anisian thin-bedded nodular cherty Reifling Limestones are covered by thin organoclastic Raming Lst. and by very thick (800 – 1000 m) Wetterstein fore-reef complex. A nice section of the latter is situated on the S slope of the Kršlenica Hill. It enables to study the prograding of the Cordevolian carbonate platform over an intraplatform basin. Fore-reef material consists of dolomitized fine grained carbonate debris (2 – 20 mm) with huge reef limestone blocks (l – 40 m in diameter), diminishing upwards. Intercalations of brown-gray micritic limestone with crinoid ossicles occurring in the middle part of the section indicate a transgression episode. The upper part of the section consists of true reef limestones. The reef core is built by calcisponges, hydrozoans, stromatoporoids and codiacean algae. Corals occur in the back-reef facies.

RA-32 Plavecký Peter – Ježovka – Abandoned quarry, Lunz (Reingraben) Beds, Opponitz Lst. Fm., Hauptdolomit, “Dachstein” Lst. Fm. and Rhaetian Norovica Fm. of Havranica Nappe, Norian, situated within Malé Karpaty PLA. Upper Triassic sequence of the Havranica Nappe attains a thickness of about 1200 m. It consists of Lunz (Reingraben) Beds, Opponitz Lst. Fm., Hauptdolomit, “Dachstein” Lst. Fm. and Rhaetian Norovica Fm. Southern end of the quarry below the Buková Dam exposes the uppermost part of the Hauptdolomit. Dolomite layers are of more or less cyclic nature. Lower part of the beds contains dolomite clasts, organic debris and foraminifers (*Agathammina austroalpina, Angulodiscus* sp., *Frondicularia* sp.).

RA-33 Chtelnica – Černík – glauconite limestones with ammonites – Sinemurian. The site is situated within Malé Karpaty PLA. The locality belongs to one of the highermost nappes of the Hronic group, the so-called Nedzov Nappe. It is formed of Triassic, Jurassic and lowermost Cretaceous (Valanginian) sedimentary rocks. Lower Sinemurian deposits with ammonite fauna are exposed at two places, approximately 30 metres one from another, separation of the two outcrops is due to local tectonics. The first one is in the road-cut on the right side of the road from Chtelnica village to local dam NW of the village. The second one is on the afforested slope above this road.

RA-34 Podbranč – onset of Klippen Belt, active Podbranč quarry yield untypical section of the Kysuca Unit of the Klippen Belt, Jurassic, Cretaceous/Neogene transgression. The outcrops situated on the three levels of the still active Podbranč quarry yield untypical section of the Kysuca Unit of the Klippen Belt. This section offers unique possibilities for detailed bio-sequence, and isotope stratigraphic investigation. The preliminary biostratigraphic framework is based mainly on calpionellid distribution (Reháková 1995) supplemented by calcareous nannofossils, calcareous dinoflagellate-, planktonic foraminifer-, radiolarian-, as well as ammonite- and aptychi zonations.

RA-35 Trstená – Halečková – In the old abandoned quarry, a part of the Pieniny Succession (deep-water sequence of the Pieniny Klippen Basin) is visible in tectonically overturned position. The uppermost part of the quarry contains Fleckenkalk/Fleckenmergel-type facies (former Supra-Posidonia Beds – Bajocian). In the basal part of the quarry radiolarites of the Pieniny unit can be seen, Cretaceous.

RA-36 Bradlo – Hrombaba – organodetritic limestones of the Brezová Group in natural outcrop, Senonian. Bradlo is the highest hill of the Brezovské Karpaty Mts. Its top is composed of Široké Bradlo Limestones (Upper Campanian-Lower Maastrichtian), which are the best exposed at Hrombaba locality, situated east of the Bradlo summit. The limestones represent coarse-grained organodetrital limestones to conglomerates, fine-clastic limestones – calcarenites, organodetrital limestones with orbitoids and grey marls to marly limestones. They are exposed in a natural cliff on the top of the ridge.

RA-37 Rohatá skala – limestones of the Choč Nappe – profile from Lias to Neocomian, situated within Strážovské vrchy PLA. Variegated, pink, white and reddish coarse- and fine-grained massive crinoidal limestones, in places with randomly scattered nodules of red and brownish cherts, are exposed in an abandoned quarry near the road between Belušské Slatiny and Mojtín in the Strážovské vrchy Mts. The brachiopod fauna points to the Middle Lias age (up to Pliensbachian). The limestones belong to the Choč Nappe (Hronicum Unit).

RA-38 Nosice – exotic conglomerates of the Klapy unit, Albian. Nimnice – Dam of Youth and Spa. Some of the technical data on the dam are on the panel. This 500 m long and 35 m high gravity dam creates a reservoir of 36 millions m$^3$ of water. It was founded within formations of the Klippen envelope. The right wing of the dam is founded in terrace sediments of the Váh River, the dam itself rests upon Middle Cretaceous marly shales. During the excavations works for the dam a mineral water was met with a content of carbon dioxide. As such water is highly aggressive against concrete special measures had to be taken – the foundation base was covered by basalt cubes and these were sealed with asphalt.

RA-39 Liptovský Hrádok – in the abandoned quarry, Lunz Fm. of the Choč Nappe is uncovered, Norian. In the quarry, Upper Triassic Lunz Fm. of the Choč Nappe is uncovered. The Lunz Formation, a characteristic member of the Choč cover nappe, is of Carnian age and attains a thickness of up to 300 m. Turbiditic nature of this siliciclastic sequence is revealed by lamination, convolute bedding, slump structures, wave and oscillation ripple marks, hieroglyphs and plant debris. The Lunz Fm. represents probably a humid climatic event in otherwise arid carbonate platform Triassic succession of the Choč Nappe.

RA-40 Silická Brezová – profile through Late Triassic of Silica Nappe, In the quarry, Upper Triassic Lunz Fm. of the Choč Nappe is uncovered. The Lunz Formation, a characteristic member of the Choč cover nappe, is of Carnian age and attains a thickness of up to 300 m. Turbiditic nature of this siliciclastic sequence is revealed by lamination, convolute bedding, slump structures, wave and oscillation ripple marks, hieroglyphs and plant debris. The Lunz Fm. represents probably a humid climatic event in otherwise arid carbonate platform Triassic succession of the Choč Nappe. Situated within Slovenský kras NP.

RA-41 Štepnická skala – Jurassic of the Czorsztyn unit of Klippen Belt. Štepnická skala is a klippe on the hill with the same name SSW from the town of Púchov, about 500 m SE from the Štepnice settlement (part of the Streženice village). Towards the Váh valley there is an abandoned quarry in the klippe in which substantial part of the klippe lithology is exposed. The klippe (in reversed tectonic position) belongs to the Czorsztyn Unit of the Pieniny Klippen Belt. This development, however, has no analogy in other klippen.

RA-42 Zázrivka Valley – the most complete profile through Triassic to Neocomian of Krížna Nappe. Situated within the buffer zone of Malá Fatra NP. Its basement is represented by Albian sandstones of the Tatric Poruba Formation. They belong to an exotic flysch, containing chrome-spinels of oceanic crust provenance. Continuation of the profile goes by a forest road that starts in the neighbouring Veľká Lučivná Valley and starts at its mouth. At the beginning, the road goes westward into the mountains and later it turns right, and meanders generally to the north. It runs through the Ramsau Dolomites (Ladinian) and after some kilometres the first outcrops start to appear (GPS coordinates: N 49°13'8.17", E 19°09'23.43"). The dolomites are pale-grey, platy to bedded (dipping approximately to the north), with typical features of the super-shallow supratidal sabkha sedimentation. Along the forest road, which still runs in the dolomites we will come to an outcrop, where two about 1 m thick layers are interbedded among the dolomites. (GPS coordinates: N 49°13'15.95", E 19°09'24.31"). These represent a distal onset of the Upper Carnian Lunz Beds. The Lunz Beds reflect the so-called Carnian Pluvial Event, when there was a temporary (for about 3 Ma) climate change from aridic to humid environment. The forest road then also continues in Main Dolomite (Ger.: Hauptdolomit, Ital.: Dolomia Principale). After several hundreds of metres, a change appears at the sides of the forest road. The outcrops disappear, soil turns to red and the slopes show features of instability, expressed by landslides (wavy terrain, bent trees, etc.). All this is caused by the presence of the next formation – Carpathian Keuper (Norian). This formation consists of three various rocks. It is dominated by red, violetish, locally greenish to black shales, often with rod- to needle-like disintegration. There are also isolated dolomite layers up to 1 m thick. Unlike the previous dolomites, these are not pale-grey, but they have yellowish patina crust, disintegrating into sharp debris. Also the oxygen isotope record of these dolomites is closer to the fresh-water carbonate record than the marine one which is typical for the Ramsau Dolomites and the Main Dolomite. It is caused by change from the supratidal sabkha sedimentary environment to the environment of salinary lagoons. Frequent hypersalinity was quite hostile; therefore, the formation contains almost no fossils. The third member of the formation are quartz sandstones to quartzites which also form isolated layers up to several decimetres thick. They locally contain layers of breccias and conglomerates (e.g. in fresh outcrops in the Sokol Valley). In the claystone shales, red silicite concretions (cherts) occur locally. The Carpathian Keuper continues along the forest road almost as far as the intersection with the Tržinovo Valley (GPS coordinates: N 49°13'20.23" E 19°08'36.96"). There appears a not very thick formation of dark limestones, locally with rich fauna forming even coquinas – Fatra Formation (Rhaetian). The fauna, however, is not very diversified and the coquinas are strongly dominated by brachiopods *Rhaetina gregaria*, less represented are other brachiopods and bivalves, among others also *Rhaetavicula contorta*. The limestones contain biostromes of corals *Rhatiophyllia clathrata*, which are, however not seen at the forest road (they can be found for instance on the slopes of the Tržinovo Valley). Still before the intersection with the Tržinovo Valley, the Fatra Formation ends (its true thickness is just several tens of metres) and is replaced by a formation of dark sandy shales and clayey-sandy, platy to bedded limestones with rusty patina on the surface. The limestones contain crinoidal allodapic intercalations, common belemnites and rare ammonites and nautiloids. They also locally contain phosphatic concretions and phosphatized clasts. It is Kopienec Formation of the Hettangian to Sinemurian age (GPS coordinates of an outcrop at the forest road: N 49°13'23.30", E 19°08'25.61"). After several hundreds of metres, the Kopienec Formation is replaced by spotty limestones to marlstones of the Pliensbachian to Aalenian age (the so called fleckenmergel – Allgäu Formation). At several outcrops (GPS coordinates: N 49°13'35.95", E 19°08'37.33") it is obvious that the bedded limestones are dominant, whereas the marlstones form just thinner interlayers. In this formation, ammonites and belemnites may be found locally. The spotty limestones and marlstones represent a deep marine hemipelagic sediment, analogical to the recent "blue muds" on the ocean floors. The spotty appearance is caused by extensive bioturbation mainly by worms. On the bank of the Zázrivka River down in the valley, an isolated lens of manganese shales with some pyritized ammonites occurs within the spotty limestones. The shales were also a subject of raw-material prospection. However, its small dimensions and localization in the national park prevent it from mining and it represents just a small mineralogical occurrence. During the Toarcian, a large anoxic event took place which resulted in deposition of similar black shales all around the Tethys. In that time, the well-known manganese deposits originated (e.g. Úrkút, Marianka, etc.). Upper parts of the Allgäu Formation are silicified and form the so-called "siliceous fleckenmergel" of Aalenian age (GPS coordinates: N 49°13'43.58", E 19°08'34.30"). Right after it, after a tectonic fault contact, the first outcrops of greenish-grey, platy to bedded radiolarian limestones of the Ždiar Formation can be seen (GPS coordinates: N 49°13'45.19", E 19°08'34.53"). In the left part of the outcrop they form a flexure, generally dipping southward. Further along the forest road, the dip of the formation often changes (the beds commonly form folds – GPS coordinates: N 49°13'51.86", E 19°08'31.44") as well as its lithology. The rocks are more siliceous and locally they form true radiolarites, turning to sharp-edged detritus when weathered. Their colour changes from the greenish-grey to red. Only poorly preserved Callovian to Oxfordian radiolarian fauna was extracted from the Ždiar Formation. From macrofauna, rhyncholites and aptychi can be rarely found; finer calcareous shells were mostly dissolved by $CO_2$-saturated water (below CCD). Above the Ždiar Formation, red nodular Saccocoma limestones of the Jasenina Formation occur (Kimmeridgian). This, only several metres thick formation is frequently tectonically reduced and missing. Also at the forest road there are no outcrops visible, only several fallen blocks. Immediately behind them, however, next formation crops out. After a tectonic contact, outcrops of the Osnica Formation appear (GPS coordinates: N 49°13'55.33", E 19°08'35.17"). They represent grey, fine-grained micritic limestones of the Tithonian to Berriasian age. They often contain pressure sutures – styloliths. Unlike similar Tatric Lučivná Formation they do not contain cherts. The limestones are almost free of any macrofauna. Immediately after some tens of metres, at the next curve of the forest road, there is and outcrop of Mráznica Formation (GPS coordinates: N 49°13'58.32", E 19°08'36.05"). It represents shaly, locally spotty marlstones of the Valanginian to Barremian age. This formation is the thickest one of the whole nappe and cause relatively smooth relief forms on the Krížna Nappe rocks. At a curve (GPS coordinates: N 49°14'04.56", E 19°08'24.04") between the hills Ostré (1,167m a.s.l.) and Na Ostrom (931 m a.s.l.), where the forest road turns westwards to the Medziholie Pass, thin turbiditic sandstone layers are visible. They are Strážovce Turbidites (Hauterivian) which are the first expression of sedimentary unrest and onset of the exotic material. Some Lower Cretaceous ammonites and belemnites can be found at the locality.

RA-43 Butkov – complete profile through Lias to Neocomian of the Manín unit. One of the largest quarries for limestone in Slovakia. The main raw mineral are Jurassic to Cretaceous limestones of the Klippen zone (Butkov development). There are also Albian-Cenomanian marlstones present in the quarry, which serve as correction component for the Portland cement production.

RA-44 NNR Ždiarska vidla Ridge – Krížna Nappe facies, Triassic to Cretaceous. Situated within TANAP NP. The Muráň limestones give picturesque and geologically remarkable morphology of the rocky massives, mainly on the main ridge of the Belianske Tatry Mts. and on their northern flanks. The thisckest and most consistent mass is developed within the central part of the mountain range, from Muráň, through Ždiarska vidla, Hlúpy till Plačlivá skala peak.

RA-45 Brodno – type profile of the Kysuca unit of the Klippen Belt, Jurassic to Cretaceous in natural outcrops. Posidonia Layers – grey and black shales with horizons of sandstones and limestones, and Czorsztyn Limestone – are exposed in the roadcut Žilina – Čadca and abandoned quarry near the railway station Brodno. The upperlying members Supra-Posidonia layers and radiolarites have been preserved in the slope debris.

RA-46 Marianka – Mariatal shales – Toarcian – Jurassic Mariatal shales of the Borinka unit, relics of abandoned quarry, stope and gallery. Dark anoxic shales with calciturbidite intercalations represent sedimentary filling of axial parts of the Borinka Basin, an inferred halfgraben formed by Lower Jurassic rifting at the Penninic (Vahic)-Austroalpine (Tatric) interface. The Lias/Dogger boundary is marked by a considerable change in the basin evolution, probably as a reflection of the break-away event of the Penninic ocean. In the last century, the Marianka shales (Mariathaler Schichten) were mined as roofing slates and writing tablets.

RA-47 NR Borinka – Medené Hámre – Borinka Limestone and Somár Breccia of the Borinka unit in the abandoned quarry, Lias, situated within Malé Karpaty PLA. The base of the Bratislava Nappe comprises an association of rocks and structural elements characteristic for ductile-brittle shear zones. The zone is a few tens of meters thick, accompanied by mylonitized granites, indistinct S-C mylonites, phyllonitized metapelites, en-enchelon systems, ultramylonites and tectonic breccias. Asymmetric structures of S-C mylonites, indistinct stretching lineation and quartz c-axes fabrics prove for non-coaxial deformation with simple shear component from the SE to the NW. Being more ductile, the Borinka Lias limestones display distinct stretching lineation in the footwall of the overthrust plane of the Bratislava Nappe, slightly dipping to the SE.

RA-48 Vysoká + Prístodolok – profile through the Vysoká unit, Jurassic, situated within Malé Karpaty PLA. In the profiles through the stratified cliffy ridge of the Vysoká Hill and its eastern branch towards Oberheg there are several points with very good exposed lithology and sedimentology of a remarkable development of Middle Triassic Gutenstein Formation of the Fatricum Vysoká Nappe (Michalík et al, 1992). Bioclastic, synsedimentary deformed and other types of limestones were allocated to the sediments of extremely shallow carbonate ramp – platform – affected by storm inrushes and seismic activity (tempestites, tsunamites – Michalík, 1997).

*Fig. 1.10 Beňatina, abandoned limestone quarry, detail of "whale" (Photo P. Liščák)*

RA-49 Beňatina – Lias + Dogger of the Czorsztyn unit of the Klippen Belt in the abandoned quarry (Fig. .10). Beňatina Klippe in the Pieniny Klippen Belt in eastern Slovakia shows the complete succession, which may be interpreted as a variety of the Czorsztyn Succession. It is formed by Lower Jurassic to Upper Jurassic (Oxfordian) deposits well dated by ammonite fauna. The Lower Jurassic includes: sandstones and sandy marls (Dolný Mlyn Fm., ?Hettangian – Early Sinemurian), spotty limestones and marls (Allgäu Fm., Late Sinemurian – Late Domerian), glauconitic sandstones overlying marlstones (Hôrka Fm. – Late Domerian), red marls (Hŕbok Marl Fm. – new formation, Toarcian). For the latter two formations, Beňatina represents locus typicus. The Middle Jurassic part of the succession comprises thick crinoidal limestone formation (Aalenian – Bajocian), which is abruptly overlain along a marked omission surface by pelagic ammonitico-rosso type limestones of the Czorsztyn Limestone Fm. (Late Bajocian – Oxfordian). The Lower Cretaceous occurs also in the quarry. It corresponds to the Nižná Fm. and consists of various deposits such as crinoidal limestones, synsedimentary limestone breccia and marls containing abundant organodetrital material of the Urgonian shallow-water carbonate platform origin.

RA-50 Prístodolok – profile through the Vysoká unit. The Vysoká nappe stratigraphic profile covers Middle Triassic to Middle Cretaceous rocks, situated within Malé Karpaty PLA. The Vysoká nappe stratigraphic profile covers Middle Triassic to Middle Cretaceous rocks. From the Cottage Vývrat we are passing by red shales of Carpathian Keuper, which is exposed in the railway cut. Further on, there are Late to Middle Jurassic limestones – the rock walls are made of thick-bedded red crinoidal limestones (Middle Dogger). Lias limestone complex sets on in a small abandoned quarry with grey, sandy, crinoidal thin-bedded limestones (Vývrat Fm.). They overlie dark-grey to black markedly crinoidal liemstones with abundant cherts rich in brachiopod, belemnites, ammonites and crinoids of the Sinemurian age.

RA-52 Hatné – Hrádok – profile through the Czorsztyn unit of the Klippen Belt. The klippe of red crinoidal limestones of Bajocian age (Krupianka Lst Fm.) passing upwards in the uppermost preserved part, to red nodular limestone (Czorsztyn Lst Fm.). The locality has been mentioned by Pevný (1969), who described its brachiopod fauna in detail. He reported the following Bathonian brachiopods from this locality: *Loboidothyris perovalis* (Sow.), *Gnathorhynchia trigona* (Quenst.), *"Rhynchonella" balinensis* (Suess) and *Aulacothyris concava* (Parona). Crinoidal limestones forming the main portion of the klippe display sedimentary features which are not typical for these sediments known from the Czorsztyn Unit. Their sedimentary environment appears to be shallower and more dynamic than of the other localities of the Krupianka Lst Fm.

RA-54 Horné Sŕnie – Ostrá hora – profile through the Czorsztyn unit of the Klippen Belt in the uppermost levels of the active quarries, Jurassic–Cretaceous. Contact of the Albian sediments of the Czorsztyn Succession (Pieniny Klippen Belt) with their basement was observed at SW margin of the highest level of the quarry and its continuation was found below, in the lower part of the quarry. The locality is unique by depth of pre-Albian erosion and by preserved paleokarst phenomena (Aubrecht et al., 2006). In an overturned position, contact of Upper Bajocian crinoidal limestone (Smolegowa Lst Fm.) and Albian sediments is visible. Along with crinoids and brachiopods, the limestones also contain numerous bivalves. Except the crinoidal limestones, some relics of younger organodetritic limestones with "filamentous" microfacies (Bathonian – Callovian) were found in the basement rocks, mainly as filling of fissures in the crinoidal limestones.

RA-55 Horné Sŕnie – Samášky – profile through the Pruské unit of the Klippen Belt in active quarry, Middle–Late Jurassic. Regular alternation of crinoidal turbiditic layers and marlstones to claystones is the most characteristic feature of the formation. The thickness of the formation is 35 – 40 m. This crinoidal flysch begins with relatively thick turbiditic layers with thick sandy shale intercalations, but it becomes more regular higher in the section. Slump structures are rare. Several thickening-upward cycles can be distinguished, indicating prograding of the turbiditic fan. Many of the turbiditic layers contain A and B Bouma intervals; the C interval is absent, which suggests a relatively high proximality indice. The crinoidal beds are white to light-grey in colour.

RA-56 Jablonica – profile through the Veterník Nappe, Hronicum, Middle Triassic, in the quarry. Situated within Malé Karpaty PLA. The quarry, situated in a small valley east of the village, was excavated in limestone complexes forming the bottom of the Vienna Basin more to the SW. The tectonic situation is rather complicated here: a normal fault system limiting W slopes of the mountains crosses this area. These faults co-acted in the subsidence of the Vienna Basin. They cross the wrench faults controlling the E slopes of the mountains, cut by a NW-SE young transversal fault system. The basement unit resembles the Choč (Biely Váh), or the Goller Nappe Unit. The oldest member is formed by dark gray well-bedded microsparite limestones, affected by tectonization, cropping out in an abandoned quarry east of the active one. More upwards, they pass into Gutenstein dolomites and limestones and then into gray cellular Ramsau Dolomite, Well-bedded nodular cherty Reifling limestones appear in the uppermost part of the active quarry wall in its right side. Lunz (=Reingraben) shales of the next member of this sequence contaminate the limestone raw material, complicating the exploitation. The sequence is separated by a 2 – 10 m wide thrust fault zone from the neighbouring Veterlín (Schneeberg ?) Unit, forming the central and western part of the quarry wall.

RA-57 Jasenová – profile through Krížna Nappe, Fatricum, Barremian, Aptian, natural exposure. The locality occurs at the roadcut at a bus stop near Jasenová Village. The outcrop consists of greyish black marly shales with local thin to thick (150 cm) intercalations of fine grained marly limestones. The bedding is poorly visible and chaotically arranged. The limestones disintegrate irregularly;

ellipsoidal shapes of some pieces are noteworthy. They probably represent cores of slump folds. Inside of some limestone beds, 16 cm big round bodies are weathered out, resembling some drowned pebbles. However, they do not macroscopically differ from the surrounding rock. They likely represent concretionally lithified portions of the wall rock. They can be identified as limestone nodules.

RA-58 Jelšava at Dolný Kubín – Klippen Belt, Jarmuta Fm., Santonian, Maastrichtian, in natural outcrops on the bank of the Orava River. The 430 m long escarpment of the Orava River near Jelšava Village, where small quarry was previously situated, exposes the Jarmuta Formation of the Pieniny Klippen Belt. Conspicuous alternation of the red and grey coloured parts of the section is the result of the tectonics. The lower (I) slice of the grey flysch with reversed order is overlapped by the second slice (II) in which the red marlstones are dominant. Further, (III) slice of the grey flysch has reversed order again. It is overlapped by the IV$^{th}$ slice which consists of the red as well as partly grey marlstones. According to the nannoflora succession, the last one slice is in a normal position.

RA-59 Kňažia – in the outcrop, an unconformable overlying of Pieniny Klippen Belt Palaeogene on the Záskalie Breccias (Senonian) is visible. A slightly dipping complex of the carbonate breccia layers and the coarse grained Priabonian sandstone beds rests unconformably on the steep dipping Záskalie Beds of Maastrichtian age (Marschalko et al., 1979). The Palaeogene breccias and conglomerates in similar discordant position, also in other parts of this stripe within the Orava territory, are formed by the clasts coming from the direct basement. The clasts of quartzites, vein quartz and metamorphics can be found, probably redeposited from the Cretaceous conglomerates.

RA-60 Košariská – Brezová Group of the Klippen Belt. The road cut N above the Košariská village exposes a sequence of red marlstones with occasional thin intercalations of fine-grained sandstones, Early Campanian. In the marlstones, micritic matrix and numerous cross-section of organisms are observable in thin-sections. The organic remnants are represented by globotruncanas, fragmented hedbergelids and fine organic detritus. Fine clastic admixture is represented by quartz grains. Their size is about 0.01 mm. The variegated marlstones are very rich in globotruncanas and can be named as Globotruncana-biomicrite.

RA-61 Košeca – profile through Jurassic of the Choč Nappe, in abandoned quarry. Almost complete Jurassic succession, from Lower to Upper Jurassic is exposed in the quarry (Maheľ, 1985). The beds are in normal stratigraphic position. Lithostratigraphic succession. 1. Hierlatz Formation. Grey to pinkish crinoidal limestones with microdykes of pink crinoidal limestone in the uppermost part. They contain numerous brachiopod fauna (Maheľ, 1962): *Zeilleria alpina* (Geyer), *Z. waterhousi* (Davidson), *Z. subnumismalis* (Davidson), *Z. choffati* (Haas), *Z. mutabilis* (Oppel), *Lobothyris punctata* (Sowerby), *L. basilica* (Oppel), *L. andleri* (Oppel), *Furcirhynchia* sp., *Cincta numismalis* (Lam.), *Cuneirhynchia retusiformis* (Oppel), *Rhynchonella aff. palmata* (Oppel), *"Rhynchonella" belemnitica* (Quenstedt), "Rh." *fraasi* Oppel, *"Rh." sublatifrons* Böse, *"Rh." greppini* Oppel, *"Rh." plicatissima* (Quenstedt), *Spiriferina ex. gr. tumida* (Buch). These association indicates Middle Lias age of the limestones. Moreover *Amaltheus* sp. was collected from the upper part of the section, also proving the Domerian age.

RA-62 Dolná Súča – Krasín – profile through the Czorsztyn unit of the Klippen Belt, Bajocian, in the abandoned quarry, situated within Biele Karpaty PLA. Following members may be discerned there (Mišík et al., 1994): Smolegowa Lst Fm. White bedded to massive crinoidal limestones with ammonite *Teloceras blagdeni*, with small fragments of dolomites, rare red neptunian dykes and void fillings. Clastic admixture is more or less abundant, mainly represented by quartz grains and dolomites. The limestones form also the whole crest of the Krasín klippe. Stratigraphic age is Bajocian. Krupianka Lst Fm. Greyish fine-grained crinoidal limestones with brown chert nodules and red crinoidal limestones with loafy weathering forms. They are limited only to the northern confines of the klippe; the best outcrops could be found in the old quarry, now entirely covered by vegetation. Supposed age is Bajocian. Krasín Breccia. Grey, pinkish and red brecciated crinoidal limestones (submarine scarp-breccia), massive with small dolomite fragments and frequent void fillings, penetrated by neptunian dykes of red micritic limestone, roughly of the same age. Supposed stratigraphic age is Bajocian – Bathonian. This rubble breccia usually has very complex filling. The clasts are coated by at least one generation of stromatolite (mostly cryptic stromatolites) and subsequently cemented by radiaxial fibrous calcite.

RA-63 Krivá – this locality is an example of the conglomerates containing exotic material which is rare or unknown from the other Western Carpathian units. These are so-called Upohlav conglomerates. Formerly, they were considered as Senonian ones; later the Albian age has been proved in the majority of them in the Váh River valley.

RA-64 NNR Manínska tiesňava Gorge – profile through Manín unit of Klippen Belt, Jurassic–Cretaceous, situated within Strážovské vrchy PLA. In the epigenetic valley defile, we can see the Mesozoic sequences of the Manín Unit. The oldest member of the stratal succession is formed by grey bedded cherty limestones of sponge wackestone microfacies, Lower Lias in age. They are exposed on the right side of the NV end of the valley. The Upper Lias to Lower Dogger sediments are represented by white sandy crinoidal limestones on the left side of the valley ca. 50 m from the previous point. The Upper Dogger to Lower Malm red nodular limestones are exposed at the first sharp curve of the road. They often contain glauconite and belemnites. The nodular limestones gradually pass into brown-grey calpionellid-bearing limestones of Upper Malm age. Next higher member of the succession is formed by bedded marly limestones with black cherts of Neocomian age. The highest walls in the central part of the valley are built by white massive organogenic limestones of Urgonian facies, Aptian in age.

RA-65 Mojtín – bauxite occurrence in paleokarst cavities in the active quarry for Late Cretaceous limestone, situated within Strážovské vrchy PLA. The Mojtín bauxites had to originate after thrust of the Subtatric nappes and before Eocene (Lutetian), as the bauxite layers are covered by nummulitic limestones and breccias with bauxitic cement. Presumed age of the bauxites is Upper Cretaceous (Senonian). Part of the bauxites was likely eroded still before Eocene. Presence of the spores of lycopodian plants (*Retienlatiporites caelatus*), spores and pollen grains of *Stereisporites stereoides*, *Taxodium* sp., pollen grains of the genera *Ginkgo*, *Tilia* (lime-tree), *Nymphea*, etc. indicate that the bauxite originated in very humid and warm environment of lakes or swamps. The bauxite occurrences are small and without industrial importance.

RA-66 Považská Bystrica – Orlové – Orlové Sandstone, Klapy unit, Cenomanian, in the roadcuts below the castle. Sedimentological, lithological and biostratigraphical research (Marschalko & Samuel, 1980) showed that the Orlové Sandstone represents various genetic types with different stratigraphic position. Great part of the sandstones displays a flysch character and is of Middle and Upper Albian age, whereas the other part of the sandstones are turbidites formed in submarine fans of deep sea plains. On the other hand, the beds with accumulations of oysters possess typical shallow water sedimentary structures.

RA-68 Podbiel – Červená skala – profile through Orava unit of Klippen Belt, Jurassic–Cretaceous, in the railway cut and natural outcrops. The klippe consists of Lower Lias to Lower Cretaceous deposits (Borza et al., 1994), belonging to one of the transitional units of the Pieniny Klippen Basin deposited between the former Czorsztyn Ridge and the Kysuca-Pieniny Basin. The whole succession is in overturned position.

RA-69 NR Skalica – profile through Manín and Krížna units, Aptian, Albian. It forms a part of megabreccia structure of the Manín belt, containing various bodies of Central Carpathian affinity which have been derived from the Belá Unit of the Krížna Nappe front.

RA-70 Slavnické Podhorie – Smolegowa sandstones of the Czorsztyn unit of the Klippen Belt, Bajocian/Bathonian, in abandoned quarry. It represents a tectonically overturned klippe revealing a stromatactis mud-mound core. A 32 m long profile was sampled in the southern part of the quarry (Aubrecht et al., 2002). The major part of the quarry cuts the Middle Jurassic crinoidal limestones (Smolegowa Fm.) that is stratigraphically older than the mud-mound. In the crinoidal limestone at the base of the profile, a fragment of the Parkinsonia was found indicating the Bajocian/Bathonian boundary.

RA-71 Sološnica – contact between Hronicum and Inner Carpathian Palaeogene, in abandoned quarry. Situated within Malé Karpaty PLA. Palaeogene breccia, fine-grained conglomerates, sandstones, sandy limestones organogenic and organodetritic limestones. They overlie carbonate rocks of the pre-Tertiary fundament of Hronicum.

RA-72 Stupné – profile through Klapy unit of Klippen Belt, Santonian polymictic conglomerates in abandoned quarry. Flysch sequences with conglomerates in the territory of Stupné and Prosné villages were regarded as constituents of Kysuca Unit of Santonian age. According to recent data (Mello ed., 2005), these conglomerates belong to the Klape Unit and are of Albian to Early Cenomanian age.

RA-73 Turá Lúka – an abandoned quarry with isoclinal anticline in the deep water facies of the Pieniny Klippen Belt, the core of the anticline is formed by the Callovian-Oxfordian radiolarites and siliceous limestones. From macrofossils, aptychi, rhyncholites and rare belemnite rostra can be found. On both sides of the radiolarite body, the core is rimmed by the Kimmeridgian pinky nodular limestones and by the Tithonian-Neocomian cherty limestones. Polyphase character of the deformation is visible from complex deformation in the core of large anticline, where chevron folds are well developed.

RA-74 Uhry – exotic flysch of the Klape Unit of the Klippen Belt in abandoned quarry. The flysch consists of monotonous alternation of sandstones and marls formed by turbiditic currents, Albian. The medium- to coarse-grained sandstones are calcareous, with high content of carbonate rock detritus, quartz, less volcanic rocks, metamorphic rocks and granites.

RA-75 Vajarská – Veterník limestone breccia in active quarry, Jurassic, Bajocian. The Rohožník cement factory exploits white limestones of the Vajarská Hill, mounting over the Záhorie Lowland. This gigantic limestone block was elevated by Miocene (Styrian ?) fault tectonics. Its complex tectonic history can be deciphered according to its geomorphology. However, its geological structure is very complicated, too. The hill consists of Veterlín fore-reef limestone breccias with partially dolomitized fine-grained matrix. Limestone clasts yielded Anisian and Ladinian teutloporacean algae, corals and gastropods.

RA-76 Valchovský mlyn – Valchovský mlyn Conglomerate of the Brezová Group, Cretaceous, Coniacian, in the roadcut, overlying Late Triassic Hauptdolomit of the Jablonica Nappe. The escarpment of the road between Jablonica and Brezová pod Bradlom exposes contact of the Coniacian Valchov Conglomerate with the underlying Upper Triassic Hauptdolomit of the Jablonica Nappe. Dolomite layers are of cyclic character with fine clastic base, indistinct bands of detritus with occasional pseudomorphs after evaporites in the middle part, being terminated by loferitic algal mats lamination. The Valchov Conglomerate starts with unsorted dolomite breccia alternating with yellow clayey intercalations. The main part of the conglomerate body consists of well rounded clasts of local material with red matrix. The conglomerate represents the basal unit of the Brezová Group which is an equivalent to the Gosau Group of the Eastern Alps and represents the first relatively post-tectonic cover of the Central Western Carpathians, after the nappe thrusting in the Turonian.

RA-77 Považský Chlmec – Vranie – on the right side of the Kysuca River bed, the road escarpment near Považský Chlmec – Vranie exposes the flysch sequence of the Pieniny Unit of the Klippen Belt, Coniacian-Santonian. The sequence is divided into two parts: Snežnica Formation and Sromowce Formation. The Snežnica Formation, forming the lower, 100 – 400 m thick part consists of sandstones (their thickness is 560 cm), pelites and aleurites (with the beds up 1 to 40 cm thick), in which Ta intervals of the Bouma's cycle are frequent, as well as of the coarser non structured layers. Tb and Tc intervals are frequently visible within the marl sequence of the section. Marschalko (1980) supposed that the turbidites of the Snežnica Formation belong to the C and D facies of the middle and outer part of the fan. The Turonian age is proved by foraminifers. The upper part represented by Sromowce Formation contains the Coniacian to Santonian polymict conglomerate layers and intercalations in which the inverse gradation can be seen frequently. Their thickness is 212 m. Conglomerates belong to simmictites, slides and olistostromes, proving unsteady slope conditions during the source zone extinction.

RA-78 Kyjov – Zadné Skálie – Smolegowa and Krupianka limestones of Czorsztyn unit of Klippen Belt, Jurassic-Cretaceous, in abandoned quarry. It represents one of the largest outcrops in this section of the Pieniny Klippen Belt. Klippe consists of at least two tectonically connected Pienidic units with relatively independent Palaeogene cover above. In the left and lower right parts of the quarry, a section of the Czorsztyn Unit is observable. It is represented by grey and red crinoidal limestones of Bajocian-Bathonian age (Smolegowa and Krupianka Limestones), covered locally by red nodular limestone (Czorsztyn Limestone) of Callovian to Kimmeridgian age.

V-31 Slavoška – metabasalts and marbles of Dúbrava Fm., in active quarry, Middle-Late Triassic, Meliaticum, Bôrka nappe. The Bôrka Nappe structurally represents the lowermost tectonic unit in a pile of several autochthonous units overlying the Southern Gemericum. The Bôrka Nappe does not form a continual nappe body and consists of numerous larger and smaller erosionally and tectonically separated nappe fragments. The numerous occurrences are widespread in the Nižná Slaná Depression. The most characteristic part of the Bôrka Nappe is the Dúbrava Formation sequence, which consists of metabasic rocks associated with white, slaty marbles. Petrological characteristics of the metabasic rocks indicate polymetamorphic evolution with the first HP/LT stage (P >1.3 GPa, T ~ 500°C) and with the second LP stage (P ~ 0.5 GPa, T ~ 400°C).

V-32 Malá hôrka – marbles of Dúbrava Mb., in abandoned quarry, Middle-Late Triassic, Meliaticum, Bôrka nappe. Light-coloured marbles of the Dúbrava Formation, occasionally with fine laminae of grey or lightgrey-brown colour. They are a characteristic lithological member of the Bôrka Nappe (Meliaticum Unit). Nearly monomineral medium- to coarse-grained calcite aggregate is dominant, associated with muscovite + paragonite ± albite, quartz and with very scarce chlorite ± actinolite, winchite, glaucophane in laminae. Marbles are platy, with distinct preferred orientation of calcite aggregates.

V-43 Ladmovce – quarry, thin-bedded carbonates of Middle and Late Triassic, Zemplinicum. The Ladmovce Formation comprises a complex of well bedded dark-grey and black muddy limestones, interveined with white calcite. The limestones originate from a facies of Gutenstein limestones passing upward in a sequence of light-coloured dolomite with limestone layers. The Middle Triassic age was proved by conodont fauna (Straka in Baňacký et al. 1989).

V-56 Abandoned quarry near Podbrezová – syncline structure in Early Triassic sediments of envelope sequence, Northern Veporicum. The Lower Triassic quartzose sandstones are slightly metamorphosed and folded (Vozár, 1965). These well stratified sediments form the overturned fold. The synclinal part of the fold is preserved in this abandoned quarry. Steeply dipping limb of this synform is cut by the younger vertical fault of the NW-SE orientation. These sediments are a part of envelope sequence of the Northern Veporicum, occurring in a gently folded monoclinal southern limb of the Ľubietová Zone synclinorial structure.

V-60 Tuhár – metamorphosed Mesozoic of Foederata Group, system of abandoned and active quarries for "Tuhár" marble, Middle Triassic, Southern Veporicum. The varicoloured Middle Triassic Tuhár Marbles (lithostratigraphic member of the Föderata Group) are present in the middle part of the metacarbonate Tuhár succession. These marbles locally pass to siliceous and cherty metacarbonates, considered to be the deepest-water part of the Föderata Group. According to their position in the succession and analogy with other areas of the Föderata Group, they correspond probably to Upper Anisian/ Ladinian age. Lithologically they are similar with the Steinalm, Wetterstein and Raming limestone facies. These metacarbonates represent originally sedimentary rocks of the Middle to Upper Triassic carbonate platform; they lost their primary microfacial features due to metamorphic recrystallization.

V-62 Dobšinský potok – metaquarzites of Foederata Group, abandoned quarry, Early Triassic, Southern Gemericum. They are characteristic of platy structure, with distinct linear orientation of metamorphic minerals within foliation schistosity. The metamorphic mineral assemblage is represented by muscovite + quartz ± albite, chlorite, turmaline. Detritic relics of quartz (88 – 92%), K- feldspars (8 – 12%) and heavy minerals (zircon, turmaline, rutile) indicate the sub-arkosic pre-metamorphic composition of these metaquartzites. Metamorphic temperatures ca. 335 – 380°C at pressures ca. 4 – 4.5 kbar were calculated from Permian-Triassic metasediments based on phengite geobarometer and chlorite geothermometer (Lupták et al., 2003).

### 1.4.4 Palaeogene localities

The theme involves sediments of the Flysch Zone, as well as the sediments of the Inner Carpathian Palaeogene and the sediments of the Buda Basin (Palaeogene – Egerian, Fig. 1.11)).

The Flysch Zone of the Western Carpathians forms a characteristic arc around the outer perimeter of the Carpathians. It reaches the territory of Moravia, Slovakia, Poland and Ukraine, where it connects with the Flysch zone of the Eastern Carpathians. The Flysch zone is built up by partial nappes and overthrusted slices. These structures are divided according to the lithofacial filling of their bed successions on outer (Krosno) Group of nappes, and inner (Magura) Group of nappes. In the territory of Slovakia the substantial part of the Flysch Belt is formed by the Magura Group of nappes. From the outer (Krosno) Group of nappes in the western part of the country only Silesian nappe outcrops in small territorial extent, and in the eastern part – in northeastern borderland the Dukla nappe occurs.

Inner Carpathian Palaeogene sediments, which discordantly overlap the pre-Tertiary Inner Western Carpathian units, are retained within Inner Carpathian basins, as well as north of the zone of Core Mountains, locally they are exposed in the erosional outliers from below Central Neovolcanites (Štiavnické vrchy Mts.).

The Upper Cretaceous (Senonian) sediments belong to Gosau Group. They were deposited after the main phase of displacement of Inner Carpathian nappes and covered them transgressively. Superficially they outcrop mainly in the Brezovské Karpaty Mts. and in the Myjavská pahorkatina upland. In the innermost zones of Western Carpathians the Senonian sediments are known only in rudimentary occurrences.

The sediments of the Buda Basin (Palaeogene – Egerian) encroach on the territory of Slovakia from the south to the area of Štúrovo; they fill up the Ipeľská, Lučenská and Rimavská kotlina basins, Cerová vrchovina Highlands and Turnianska kotlina Basin.

Np-01 NNL Markušovské steny – basal conglomerates, Palaeocene-Eocene. The Hornád Mb. is cropping out in the erosive scissions of the Hornád River in the Markušovce Village and eastwards, all-in-all with a length of several hundreds of metres. They are protected as NNLs "Transgression of Palaeogene in Markušovce" and "Markušovce Cliffs" and NL "Markušovce Stone Mushroom".

Np-02 Kežmarok – type profile of Kežmarok Fm., Oligocene. In the abandoned quarry the Kežmarok Mb. is exposed. The layers represent the transition from flysch facies of Zuberec Fm. into the overlying sandstones of Biely Potok Fm. of the Subtatric Group, Inner Carpathian Palaeogene.

Np-03 Spišské Tomášovce – Tomášovské vrstvy Mb., type profile. In the quarry 1 km south of Spišské Tomášovce, Tomášovce Mb. is exposed. The layers represent the highest complex (Eocene/Oligocene) of the basal member of the Borové Fm. of the Subtatric Group.

Np-04 Hričovské Podhradie – NL Hričovské rífy (Hričov Reefs) – olistoliths, Palaeocene. In the abandoned quarry organogeneous limestones of the Hričovské Podhradie Fm. are exposed.

Np-05 Lisková–Mohylky – NR Mohylky – Nummulite sandy limestones, Late Cretaceous to Early Oligocene. In the abandoned quarry NNW of the Lisková Village limestone of the Borové is exposed. The deposits are of marine origin; they represent transgressive facies of the Subtatric Group.

Np-07 Oravský Biely Potok – Biely Potok Fm., type profile, Oligocene. In the abandoned quarry ca 2 km NE of the village Oravský Biely Potok, in the right bank of the Blatná Creek, the Biely Potok Fm. is exposed. It is made of massive sandstones and it represents the last period of sedimentation of the Subtatric Group.

Np-08 Sološnica – quarry – Palaeogene transgression. In the abandoned quarry at the SE edge of the Sološnica Village Jelenia Góra Fm. is exposed. It represents transgressive basal facies of the Palaeogene transition between Subtatric Group facies and Myjava-Hričov Group.

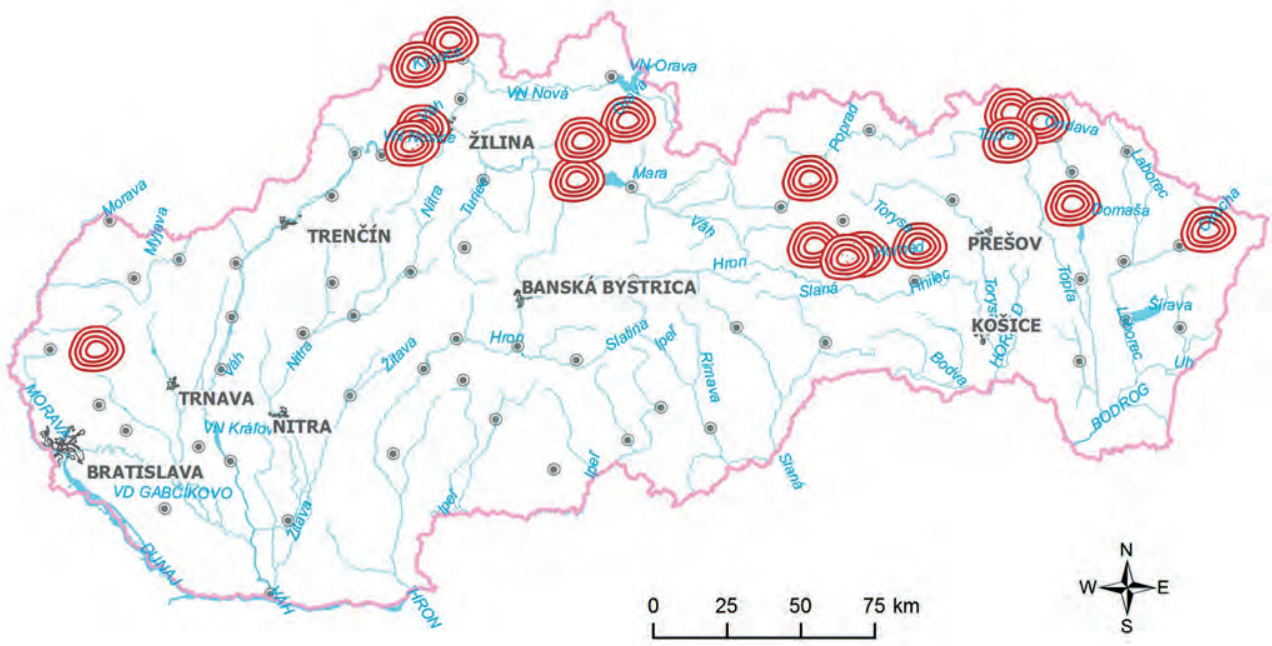


*Fig. 1.11 Distribution of the Palaeogene sites in the Slovak territory*

*Fig. 1.12 Conglomerates of Palaeocene-Eocene age made of carbonatic rocks, Súľov Cliffs (Photo L. Martinský)*

*Fig. 1.13 Korniansky ropný prameň – Korňa Oil Spring situated in flysch rocks of the Rača unit (Photo L. Martinský)*

Np-09 NNR Súľovské skaly (Súľov Cliffs) – Palaeocene-Eocene conglomerates (Fig. 1.12). Súľov conglomerates are coarse clastic lateral sediment supplies into the marine pool. The Súľov conglomerates are wide-spread in the middle part of the Váh River catchment area. Situated within PLA Strážovské vrchy.

Np-10 NL Pucovské zlepence (Pucov Conglomerate) – type profile, Eocene/Oligocene. At the western edge of the village, in the roadcuts as well as in the bed of the local creek, Pucov Conglomerates are exposed. They demonstrate an episode in the sedimentation of the Subtatric Group units.

Np-11 NL Milošová-Megonky – In the abandoned quarry at the settlement Padyšákovci Ciężkowice Sandstone is exposed. The sandstone-conglomerate facies of the Ciężkowice Sandstone is characterized by spherical separation. The sandstone belongs to the bottom horizon of the Submenilite Formation, Palaeocene/Eocene in age.

Np-12 Chrasť nad Hornádom – NL Farská skala – cross-bedded Eocene sediments. In the erosion bank of the Hornád River in the northern edge of the Chrasť nad Hornádom Village, Chrasť Mb. is exposed, coarse- to fine-grained sandstones, which are member of the Borové Fm.

Np-13 Beloveža – type profile through Beloveža Mb., Palaeocene–Eocene. Beloveža Mb. are deposits made of a complex of variegated (red and green) shales with intercalations of green, mica-rich sandstones with frequent hieroglyph textures.

Np-14 Víťaz – NL Podmorský zosun (Submarine Slump), olistoliths in limestone, Eocene. According to their lithology and mode of deposition (poor roundness, fragments of claystones, and mixture of various lithologies) these sediments represent a slump body, which developed in the marine environment out of flood-tide effect.

Np-15 Starina – Menilite Mb. The rocks of the Dukla unit of the Outer Flysch Zone. They are represented by subvertical grey to ochreous calcareous claystones, calcareous laminated fine-grained sandstones of Čergov layers (Early Oligocene) and black claystones of the Menilite Mb. (Late Eocene–Early Oligocene). Situated within Poloniny NP.

Np-16 NL Korniansky ropný prameň (Korňa Oil Well), Palaeocene–Eocene. The Korňa oil spring (Fig. 1.13) is currently the only surge of crude oil in Slovakia. It is associated with the production of oil and implementation of wells in this area at the turn of the 19$^{th}$ and 20$^{th}$ centuries. Situated within Kysuce PLA.

Np-17 Mrázovce – type profile through Mrázovce Mb., Palaeocene–Middle Eocene. In the incision of the creek southwest of Mrázovce, Mrázovce Mb. of the Beloveža Fm. of the inner Rača unit of Magura nappe is exposed.

Np-18 Smilno – type profile through Upper Smilno Mb., Late Eocene–Early Oligocene. In an abandoned quarry thin, slightly deformed layers of the menilite cherts and dark siliceous claystones are exposed.

Np-19 Vyšný Orlík – type profile through Makovica Sandstone, Middle Eocene–Late Oligocene. In an abandoned quarry Makovica sandstones of the Zlín Formation of the internal Rača unit are exposed.

### 1.4.5 Neogene localities

The Neogene sedimentary complexes and their sites (Fig. 1.14) are distributed in the Foredeep, in the Vienna, Danube, South Slovakia and East Slovakia basins and in majority of the intramountain depressions (Vass et al.1998). Typical feature of the intramountain depressions is their distinct fault limitation against the Core Mountains. In the area of Foredeep its deposition started in the Egerian, in the area of the South Slovakia (excluding the Cerová vrchovina Upland) in the Kiscelian, in other parts of the Western Carpathians in the Eggenburgian. The Neogene deposition in the Carpathian Foredeep territory lasted till the Early Badenian, in the South Slovakia and along the margins of the Danube Basin till the Pannonian, in other territories as a rule till the Rumanian, at places only till the Sarmatian. During the Pliocene the deposition in some sections of the Carpathian Foredeep was renewed (Seneš in Andrusov and Samuel et al., 1983). Due to tectonic differentiated activity individual Neogene stages have different lithological facies. At places they started with sea-transgression, at other places they continue without any interruption from the below stage. Based upon the recent knowledge on the facies evolution of the Neogene sediments it would be convenient to abandon the names of the divisions (Miocene, Pliocene), because the lacustrine-fluvial subformation was deposited in the Badenian, Sarmatian and Pannonian (except of the Vienna Basin and the central parts of the Podunajská nížina Lowland) and the transitional (brackish) sediments occur in variable stratigraphic position (ib.). Regarding the above facts it would be suitable to rename the lowest subformation to the subformation of marine and brackish sediments and to single out the brackish sediments subformation only for the territory of the Vienna Basin and the central part of the Podunajská nížina Lowland. The lithological content of the marine and brackish involves gravelly-sandy, conglomerate-sandstone and clayey-silty (frequently marly) sediments; the subformation of the brackish sediments is made of gravelly-sandy, clayey-silty and tuffaceous clayey-silty sediments; the lacustrine-fluvial subformation is composed of gravelly-sandy and clayey-sandy sediments with sandy layers. In several depressions the Badenian sediments of the latter subformation are of volcanic-limnic facies, containing carbonate conglomerates at the base (e.g. the Budiš Formation). The younger lacustrine-fluvial sediments are characterised by a lower relative density degree, or consistency when comparing with marine and brackish sediments.

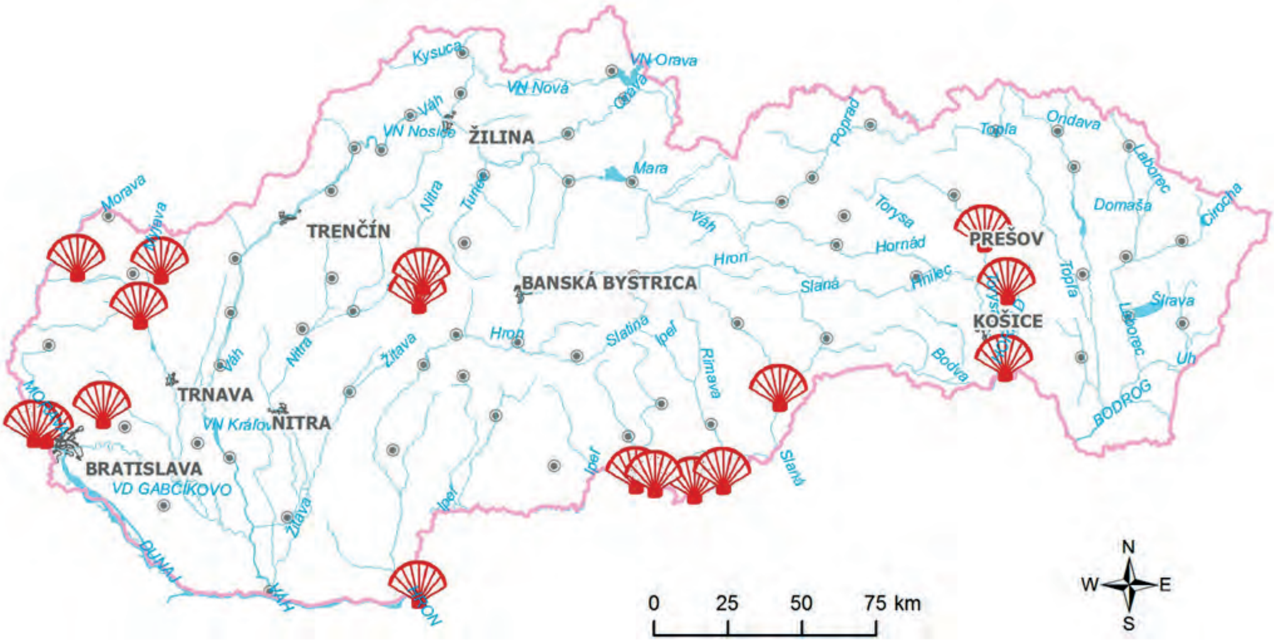


*Fig. 1.14 Distribution of the Neogene sites in the Slovak territory*

Nn-01 NL Jalovské vrstvy (Jalové Mb.) – type profile of cross-bedded limestones, transgressive stage sediments of sedimentary space, Eggenburgian. South Slovakia Tertiary sediments form a fill of three basins: Buda (Hungary Palaeogene basin) Fiľakovo (Fiľakovo-Pétervásar) and Novohrad (Nógrád). Between the sediments of the latter two basins continental sediments of Bukovinka strata are developed; they can be considered pre-transgressive Nógrád Basin sediments. The sediments of these basins fill three sub-basins – Ipeľ, Lučenec, Rimava and participate in the setting of the Cerová vrchovina Highlands. Within the Fiľakovo strata we distinguish a number of members, which in some cases overlap each other laterally and horizontally. Jalové Mb. represent the basal members – transgressive stage sediments of sedimentary space.

Nn-02 Bretka, abandoned quarry, Egerian. The Bretka Mb. is stratotype of shallow-water littoral facies of the Lučenec Fm. South Slovakia Tertiary sediments form The Bretka Mb. are stratotype of shallow-water littoral facies of the Lučenec Formation of Egerian age, developed on the northern outskirts of the former sea flooding in Rimava Basin area.

Nn-03 Devínska Nová Ves – NR Štokeravská vápenka (Stockerau Limeworks) – Early Badenian vertebrates. On pre-Tertiary, by weathering and erosion dissected basement, deposited continental breccias, and terrestrial sediments filled also neptunic dikes. Along with them a considerable number of bones of vertebrates were washed in (particularly mammalian), and also the bones of ancestors of man.

Nn-04 Pezinok, brickwork, abandoned claypit, unfortunately almost fully destroyed by landfill – Pannonian index fauna. By Early Pannonian sudden drop of water table level in the brackish lake resulted in its retreat to the south. After subsequent increase in water table level in zone Pannonian-B flooding of the Blatné depression took place with the accompanying deposition of mostly pelitic Ivánka Fm., which is exposed in the former brickyard in Pezinok. During the whole Pannonian the whole area passed gradually into more-and-more brackish water.

Nn-05 Cerová-Lieskové – Karpatian index fauna. At the Cerová-Lieskové locality, the deposition of Lakšár Formation shows a rapid subsidence of the Vienna Basin in an initial pull-apart system. These marine basinal deposits with turbiditic influx contain rich associations of fossil fauna. The fauna is highly diversified, containing both benthic and planctonic forms, as well as several redeposits of shallow water associations.

Nn-06 NNR Kostná dolina Valley, Hajnáčka (Valley of Bones, Fig. 1.15) – Pliocene vertebrates. In the Kostná dolina Valley the fossils of vertebrates are especially found in the lenses and intercalations of gravely rusty-brown tuffaceous sand. The bones of tapirs, rhinos, proboscideans and micromammals (especially rodents) have been found the most frequently of all terrestrial vertebrates in these fossiliferous layers. Besides of the Pliocene faunal remains, the fossils of redeposited Miocene (foraminifers, shark teeth) and Pleistocene (gastropod, mammoth and horse remains) elements have been found, too. Situated within the Cerová vrchovina PLA.

Nn-08 Devínska Nová Ves – NNR Sandberg – type profile of Sandberg Mb., Tortonian fauna in abandoned sandpits. Situated within the Malé Karpaty PLA. Studienka Formation is made of grey, calcareous pelitic sediments, mainly clay/claystone, calcareous clay passing through the sand. The marine environment corresponds to basinal, neritic one. Towards the margins of the basin the environment passed into the lagoon to freshwater one. The stratotype has not been defined, but it can be found in the vicinity of the village Studienka where the strata were encountered by prospecting drilling for oil exploration. The layers overlie the Jakubov Formation with gradual transition contact, or they rest upon pre-Badenian sediments, for example Závod Formation (Karpatian age). The Studienka Fm. is overlain by Holíč Formation, Sarmatian in age. The component of the Studienka Formation, which evolved in the littoral zone, are Sandberg Mb. The deposits are exposed in abandoned quarries on the SW flanks of Devínska Kobyla, near Devínska Nová Ves.

*Fig. 1.15 Hajnáčka, clayey, fine-stratified rock with volcanic sandy admixture of Pliocene age (Photo L. Martinský)*

Nn-09 Podbranč – the transgression of the Neogene sea is well documented by littoral conglomerates and sandstones with fossil molluscan fauna at the Podbranč locality. The unique exposure with a contact of the underlying Mesozoic carbonates of the Pieniny Klippen Belt, and the overlapping basal conglomerates of Neogene (Eggenburgian) age, makes possible to observe the dynamics and forestepping of the marine transgressive process.

Nn-10 Kobylince – coal outcrop, Late Badenian. In the Handlovská deposit a coal seam 7 – 9 m thick is present; in the northeastern part two 5 – 7 m thick (upper) or 2 – 6 m (lower) seams are present, respectively. In the Nižná Lehôtka area there is additional third bottommost seam 1 – 4 meters thick. Locally the seams conjoin and thus the seam can reach a thickness of 17 m. Between the seams the fissile clay is present, along with sandy-clayey tuffite and tuffaceous sandstone. At the Nováky deposit a major coal seam is 8 – 10 m thick, at places up to 25 m with interlayers of pale clays and tuffs, which divide into two or three benches (Čechovič, 1959; Gašparík, 1959; Brodňan, 1970).

Nn-11 NNR Kováčovské kopce (Kováčov Hills) – Egerian fauna. Uncommonly rich macrofauna of the Egerian age at the locality Kováčovské kopce is unique in Slovakia. It reflects the palaeogeographic and palaeoceanographic conditions in the area of ceasing Buda Basin, shortly before the origination of a new basin system of the Central Paratethys.

Nn-13 Čakanovce – NL Čakanovský profil (Čakanovce Profile) – Čakanovce Mb. forms a facies with deeper water (Čakanovce Mb., Vass, et al. 1992). Outcrops can be found near Čakanovce, in the Pleš Mountains, W from Radzovce and between Ratka and Trebeľovce. Remarkable outcrops form Čakanovce section, in the SE edge of the village, which, at the same time, is the type-site of the stage. It deposited in the lowermost stages of the Fiľakovo Formation, in the bottom of the deeper sea. The Fiľakovo Formation attains a thickness of 250 – 300 m. In Cserhát (northern Hungary) its thickness increases up to 500 m. The age is Eggenburgian. Containing marine fauna. Originated in the marine environment.

Nn-14 Varhaňovce – Klčov Fm., type profile, Badenian. Varhaňovce Gravel, a member of the Klčov Fm., is exposed in the abandoned gravel pit at the southern edge of Varhaňovce village. The Klčov Formation represents delta sediments advancing from the northwest towards the basin.

Nn-15 Cigeľ – brown coal exploitation, Late Badenian. The Upper Nitra brown coal basin is the richest and the most extensive in the Slovak Republic. The first attempts to extract coal stretch back to the 18$^{th}$ centuries. Purposeful industrial mining dates from the period when Západouhorská kamenouhoľná spoločnosť (West Hungary Coal Mine Company) was incorporated into the Business Register on 1 July 1909 with the opening of the Handlová Mine. At the time of the Second World War, Handlovské uhoľné bane (Handlová Coal Mines) was the sole mining company in Slovakia. During the war it had started prospecting for coal in Nováky, where the first car full of extracted coal ran in 1940. The youngest Cigeľ Mine joined the Upper Nitra region's two existing mines in 1962.

Nn-17 Gbely – oil exploitation, Late Badenian. In Slovakia the hydrocarbon exploration and study started in 1913, when an oil reservoir was discovered near Gbely (Vienna Basin). It is a structural type of reservoir, bound by fault. The area of this reservoir was the first systematically studied hydrocarbon area in the whole Hungarian Kingdom.

Nn-18 Lipovany – NL Lipovianske pieskovce (Lipovany Sandstone). The Lipovany Sandstone, which is exposed in the sandpit at the southern edge of the Lipovany Village, is represented by disintegrating sandstones with loaf-like nodular bodies. It is rich in fossil remains of organisms of Eggenburgian age.

Nn-19 Nižná Myšľa – type profile through Myšľa Mb. The sediments contain strata of light-grey rhyolite tuff with biotite and pale pumice fragments (this tuff is described as a single member – Rankovce tuff). The Myšľa Mb. rests upon the Olšava Mb. and forms the upper part of the Early Sarmatian profile of the Stretava Fm.

Nn-20 Prešov-tehelňa (Prešov-Brickworks – abandoned) – type profile through Prešov Fm., Eggenburgian. Partial stratotype profile is exposed on the eastern edge of Prešov in an abandoned brickyard.

### 1.4.6 Neovolcanites localities

In the Neogene period the Carpathians represented an island arc with microcontinent of the Central Western Carpathians, which migrated to the N-NE to E; as a result of oceanic or suboceanic crust subduction of the flysch basins it gradually collided with a passive edge of the European platform. The arc retreat in the above direction was compensated by a back-arc extension, which included diapiric upwelling of the asthenosphere and a lateral escape of the lithosphere from the collision zone of Alps (Csontos et al., 1992).

The magmatic material originating from partial melting of metasomatically affected mantle (after the previous subduction of the crust of the Magura-Pieniny flysch basin) with the following diapiric upwelling in the conditions of the back-arc extension provided the

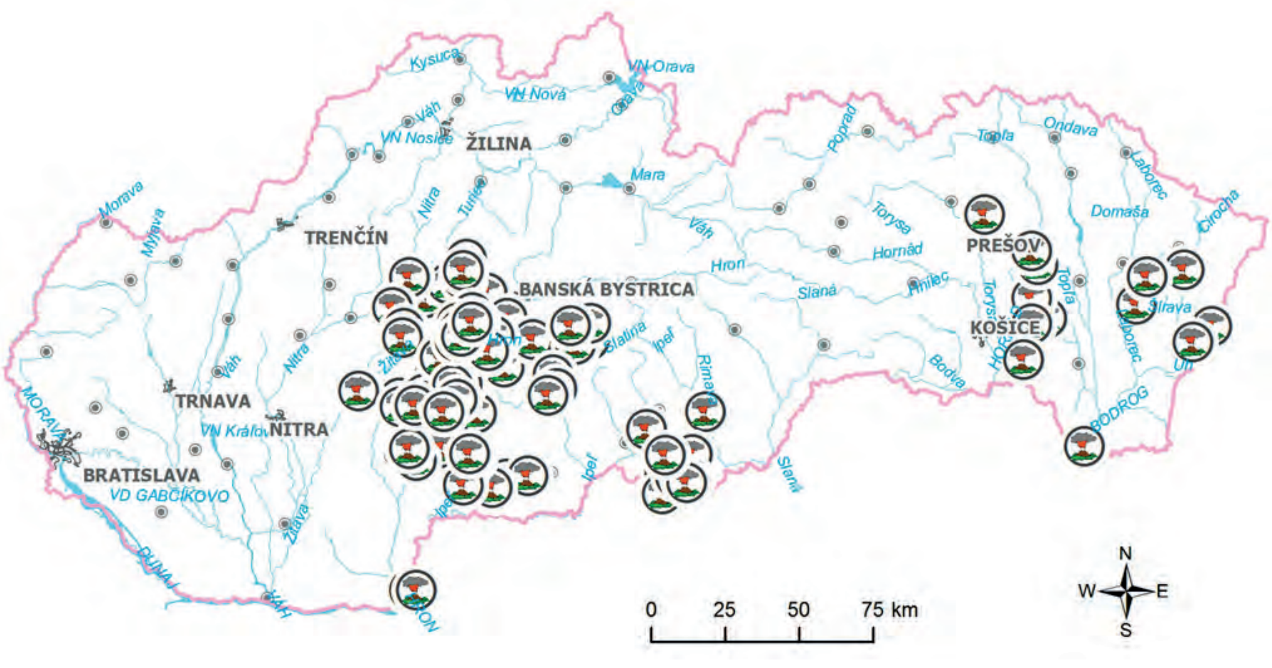


*Fig. 1.16 Distribution of the neovolcanites sites in the Slovak territory*

sources for andesite volcanic activity of the areal type in the territory of Central Slovakia (Lexa and Konecny l.c.). The andesite volcanism was preceded by acid rhyodacite – rhyolite volcanism of the areal type. Its sources were magma masses generated by crustal material melting due to diapiric upwelling of the asthenosphere. The centres of this volcanic activity situated within the Pannonian basin in the northern Hungary produced large volumes of pyroclastic ash-pumice material which was deposited in the southern and eastern Slovakia in marine sediments of Eggenburgian, Karpatian and Lower Badenian ages.

The andesite volcanism activity in the Central Slovakia territory lasted from the Lower Badenian (15.5 Ma) till Pannonian (8.5 Ma) and it resulted in the emergence of the Central Slovakia Neovolcanic Field covering an area of approximately 5,000 km$^2$. The distribution of the important sites of the neovolcanites corresponds to this pattern (Fig. 1.16). The andesite volcanism was preceded by acid rhyodacite-rhyolite volcanism of the areal type. The centres of this volcanic activity situated within the Pannonian basin in the northern Hungary produced large volumes of pyroclastic ash-pumice material which was deposited in the southern and eastern Slovakia in marine sediments of Eggenburgian, Karpatian and Lower Badenian ages.

The basalt-andesite to andesite volcanism of the island arc type was active in Upper Badenian-Middle Sarmatian period in the area of East Slovakian Basin and is characteristic of intensive volcanic activity tied to the fault systems at the margins of the basin. This volcanic activity resulted in the origin of volcanic mountains of Slanské vrchy and Vihorlat having distinct linear arrangement of andesite stratovolcanoes.

The alkaline basalt volcanism active during the Pannonian, Pliocene and Pleistocene periods represents the final stage of the volcanic activity on the territory of Slovakia.

JL-04 Šurice – NL Soví hrad (Owl`s Castle) – basalt feeder – exposed diatreme, Cerová basalt Fm., Pliocene, Dacian, situated within the buffer zone of Cerová vrchovina PLA. The maar fill represents a stratified succession of tuffs, lapilli tuffs, agglomerates and agglutinates corresponding to a transition from the phreatomagmatic eruptions of the Hawaiian type. The youngest volcanic products are thin basalt dikes.

JL-05 NR Hermanovské skaly (Hermanovce Cliffs) – castellated rocks in andesites, Fm. Lysá stráž – Oblík, Late Sarmatian. The massive rock cliffs expose massive to finely fissured rock of the internal part of the intrusion (laccolith), passing locally into zones of intense brecciation.

JL-06 Jastrabia skala – rhyolite extrusive body (dome-flow), Jastrabie Fm., Late Sarmatian, situated within the buffer zone of PLA Štiavnické vrchy Mts. The rock is scarcely-porphyric sanidine-plagioclase rhyolite, with variably spherolitic, spherolitic-glassy or glassy matrix.

JL-08 Šiatorská Bukovinka – NL Mačacia – basalt lava sheet, lava flow, pyroclastics, Cerová basalt Fm., Pliocene, Dacian, situated within Cerová vrchovina PLA. In the past the basalt was used for the production of paving blocks and curbs.

JL-09 NL Sninský kameň – relic of lava flow with platy jointing, Sninský kameň Fm., Early Pannonian, situated within PLA Vihorlat. Rocky cliffs of about 20 m height represent the bottom of the lava flow of a coarse porphyric pyroxenic andesite with well-developed lamination and platy jointing.

JL-100 Dolná Klapa – rhyolite lava flow, type profile of Jastrabie Fm., Late Sarmatian. The lava flow with a thickness to 50 m consists of massive to slightly porous, pink to brownish-red plagioclase-sanidine rhyolite with spherolitic matrix, with blocky-columnal, thin-bedded or brecciated jointing.

JL-101 Stará Kremnička – type profile of Jastrabie Fm., Late Sarmatian (Fig. 1.17). The pyroclastic succession corresponds to the development of explosive activity that preceded and accompanied the formation of extrusion dome and flow “Klinčok” with its centre situated north of the site.

*Fig. 1.17 Stará Kremnička, detail of layers. Impact structure of andesite cobble in fallen tuffs horizon. The overlying layer of pyroclastic flow covers the unevenesses and is flat at the surface. Upwards laminated deposits of pyroclastic surges are present (Photo J. Lexa)*

JL-103 Lopúchový vrch – epiclastics of Zlatá studňa Fm., Late? Badenian. The site represents the internal part of the dome extrusion scarcely-porphyric sanidine-plagioclase rhyolite.

JL-108 Brehy – Grunty – dykes of quartz-diorite porphyries, rhyolite, Tatiar intrusive complex, Jastrabie Fm., Late Sarmatian, situated PLA Štiavnické vrchy.

JL-11 Nová Lehota – NR Biely kameň – lava flow and slide, Biely kameň Fm., Sarmatian, situated within PLA

Ponitrie. The rock wall height of 50 m represents the base of the lava flow of coarse porphyric pyroxenic andesite with accessory amphibole.

JL-113 Prievidza – lahar, Vtáčnik Fm., Late? Sarmatian. The site represents an outcrop of up to 25 m thick volcanic blocky epiclastic breccias of the Vtáčnik Formation of Sarmatian age. The breccias were deposited by debris avalanche (slump).

JL-149 Zolná – NL Zolniansky lahar (Zolná Lahar), Abčiná Fm., Late Sarmatian, situated within the buffer zone of PLA Poľana. At the site, layers of volcanic epiclastic sandstones, conglomerates and fine breccias of pyroxenic andesites are exposed, overlain with a thick chaotic breccia of a lahar with openings after tree trunks and with the impressions of wood.

JL-151 Sikenica – hyaloclastites, Baďan Fm., Late Sarmatian, situated within the buffer zone of PLA Ponitrie and NNR Horšianska dolina Valley. The hyaloclastite breccias associate with a lava flows of pyroxenic andesite which had entered the sea coastal zone.

JL-152 NL Ostrovica – neck. Šibeničný vrch complex, Pannonian, situated within the buffer zone of PLA Ponitrie. At the site situated in the southern part of the Kremnické vrchy Mts., two necks of fine-grained basalt to basaltic andesite are exposed.

JL-155 NR Slanský hradný vrch – (Slanec Castle Hill) – extrusive dome, Hradisko Fm., Sarmatian. It consists of a massive andesite with blocky separation. On the top are the ruins of a medieval castle.

JL-156 Zamutovské skaly – lava flow, Zlatá baňa Fm., Sarmatian. The lava flow of augit-hypersthene andesite is a component of a dominantly effusive complex of the Stratovolcano`s medial zone. The lava flow thickness reaches 25 m.

JL-157 Košický Klečenov – phreatic cone, Klečenov Fm., Late Sarmatian. The parasitic volcano was the product of phreatomagmatic eruptions of Surtsey type.

JL-158 NNR Bačkovská dolina Valley – stratovolcanic complex, Strechový vrch Hill Fm., Late Sarmatian. In the profile, which is disturbed in the central part by sliding, extrusive dome is exposed, along with lava flow, pyroclastic breccia sequence, agglomerates and tuffs and upper lava flow of a relatively large thickness.

JL-160 Veľký Grič – basalt body, Kľakovská dolina Valley Fm., Late Badenian. The dome-shaped body reaches a thickness of more than 200 m and is formed by massive basaltic andesite. Its separation is blocky, mostly, but at places it passes into indistinct columnar or platy jointing.

JL-161 Kamenec pod Vtáčnikom – type profile through Kamenec Fm., Early Badenian, situated within PLA Ponitrie. With the total thickness of about 10 m redeposited pumice tuffs and tuffs, mostly coarse volcanic epiclastic sandstones with intercalations of small conglomerates to lenticular irregularly stratified coarse conglomerates with volcanic epiclastic positions of small conglomerates and coarse sandstones, fine epiclastic volcanic sandstones are exposed here.

JL-164 Kamienka – type profile through Kamienka Fm., Late Sarmatian. Explosive necks and dikes of andesite penetrate across the chaotic coarse to blocky pyroclastic breccia and agglomerates of Vulcanian type.

JL-166 Priekopa – Temlov – pyroclastics of Popriečny Hill, Late Sarmatian. The site displays a succession of lava flow and pyroclastic rocks of the proximal zone of the Stratovolcano with a primary deposition slope from 15 to 20° to the west.

JL-167 Orechová – lava flows of Popriečny Hill, Late Sarmatian. The lava flows formed effusive plateau at the foothills of the Stratovolcano. In the quarry two separate lava flows separated from each other by blocky breccia zone are exposed.

JL-168 NR Rankovské skaly – volcanic cone, Rankovské skaly Fm., Late Sarmatian. The pyroclastic rocks are the product of Vulcanian type of eruptions, the lava flows of the Strombolian type of eruptions. The material is pyroxenic andesite.

JL-21 Stará Kremnička – rhyolite extrusion, Jastrabie Fm., Late Sarmatian. The site represents the internal part of the dome extrusion scarcely-porphyric sanidine-plagioclase rhyolite.

JL-24 Nevoľné – lava flows, type profile of Kremnický štít Fm., Late Badenian. The formation has a character of an effusive complex, with individual flows reaching 30 – 150 m in thickness and a considerable areal extent.

JL-25 Kamenica nad Hronom – type profile of Burda volcanites, Late Badenian, situated within PLA Dunajské Luhy and NNR Burdov. The Burda Fm. represents a set of products of extrusive and explosive activity of hypersthene, amphibole-biotite-hypersthene- andesites to dacites.

JL-27 Dolná Štubňa – type profile of Flochová Fm., Sarmatian. At the base of the profile there is a lava flow with cinder-block lava breccia, followed by the above sequence of fine to coarse epiclastic volcanic breccia deposited by debris flows and hyperconcentrated flows.

JL-28 Remata – Bralová skala (Cliff Rock) – type profile of Remata Fm., Late? Sarmatian. At the bottom of the profile two lava flows are present, with substantial representation of cinder-blocky lava breccia, followed atop by pyroclastic flows deposits separated by the layers of fallen pyroclastics and redeposited pyroclastic breccia.

JL-29 Nižná Pokoradz – lahars, conglomerates, sandstones, type profile of Pokoradz Fm., Sarmatian, situated within NR Pokoradzké jazierka (Pokoradz Lakes). Above the basal layers of epiclastic volcanic sandstones chaotic lahar breccias crop out, passing upwards into succession of epiclastic volcanic conglomerates and sandstones and in the upper of the formation 25 m thick deposits of the block-ash pyroclastic flows.

JL-30 Suchá hora – stratovolcanic cone, Vlčí vrch Hill Fm., Early Pannonian. At the site the outer section of the stratovolcanic cone is cropping out along with a thick lava flow at its flank.

JL-32 Stará Kremnička – limnosilicites, Jastrabie Fm., Late Sarmatian. The site is one of the two type profiles of a succession of redeposited tuffs and sediments with tuffaceous limnosilicites.

JL-36 Hrochoť – NL Jánošíkova skala (Jánošík`s Rock) – type profile through Abčiná Fm., Late Sarmatian, situated within PLA Poľana. The profile is made of the sequence of epiclastic volcanic breccias which were deposited by pyroclastic flows.

JL-40 Streda nad Bodrogom – rhyolite tuffs, submarine slump, Middle-Late Sarmatian, situated within PLA Latorica. In the abandoned quarry at Streda nad Bodrogom, with exceptional wine cellars, a massive body of submarine slump of 20 – 30 m thickness, is exposed, in particular in the west wall of the quarry.

JL-41 Burda – Kováčov – extrusive bodies and lava breccia flows, Early Badenian, situated within PLA Dunajské Luhy and NNR Burdov. The Burda Fm. represents a set of products of extrusive and explosive activity of hypersthene, amphibole-hypersthene and biotite-amphibole-hypersthene andesites to dacites, with accessory garnet especially at the base.

JL-42 Horná Štubňa – stratotype of Turček Fm., Late Badenian. The outcrop is an example of a smaller stratovolcano structure, at its flank (in the proximal zone). In this volcanic framework it is possible to identify mud and debris flow deposits, surface erosion stages, pyroclastic breccias and fallout tuffs of the Vulcanian eruptions type and lava flows of pyroxenic andesite.

JL-50 Vinné – Šútová – extrusive dome of Vinné Complex, situated within PLA Vihorlat, Middle Sarmatian. The extrusive body is formed by the massive andesite of blocky to blocky-columnar jointing, which in the distal part passes into the blocky extrusive breccia.

JL-51 Ihráč – lava flow of biotite-amphibole andesite of Krahule Fm., Late Badenian. The lava flow rests upon lacustrine sediments of the Early-Badenian; at the contact the hyaloclastite breccias up to 20 m thick are present.

JL-52 Bartošova Lehôtka – rhyolite volcanoclastics, Late Sarmatian. The succession of epiclastic volcanic breccias of debris flows and layers of fallout tuffs and lapilli tuffs represent deposits of outwash cone of medial zone that correspond with the growth of dome extrusion in the central zone, accompanied by explosive eruptions.

JL-55 Turová – NL Turovský sopúch (Turová Feeder), stratotype of Turová Fm., Middle-Late Sarmatian, situated within protected zone of PLA Poľana. The cylindrical body of a diameter of 60 – 80 m is formed by explosive breccia. Within the chaotic breccia, sometimes with traces of fragmentation, there can be observed vertical zones with varying degree of disintegration.

JL-61 Záhradné – intrusion of andesite with garnet, Fm. Lysá stráž – Oblík, Middle Sarmatian. The andesite porphyry with microhypidiomorphic to allotriomorphic grained matrix contains rare inclusions of cherts and porcelainites.

JL-68 Stará Kremnička – Jelšový potok – limnosilicite, bentonite, Jastrabie Fm., Late Sarmatian. At the site we can observe light laminated limnosilicites deposited in the distal zone by hot springs. At the same time it is a classic site of bentonite limnosilicite – a non-ore mineral raw material.

JL-69 Klokoč – Pod Polomom – quarzites, intrusive complex Kalinka, Late Badenian. This locality is the area of advanced argillitization of high-sulphidic epithermal system associated with to diorite stockworks in the central zone of the Javorie Stratovolcano.

JL-86 Bulhary – maar and intrusion, Cerová basalt Fm., Early Pleistocene. The maar lithology comprises: deformed phreatomagmatic palagonitized tuffs, intrusion of laccolith type emplaced in the tuffs, phreatomagmatic cinder accumulation as a result of contact of the intrusion with the lake water, lava flows interfingering with phreatomagmatic pyroclastics of Surtsey type and terminal cinder cones and lava flows associated with the activity of the Hawaiian type.

JL-97 Tŕnie – Kašova Lehôtka – pyroclastic flow, Turová Fm., Middle Sarmatian. The coarse-debris block-ash pyroclastic flow around Turová represents a relic of a larger sheet with a thickness of 20 – 70 m.

JL-98 Badín – pyroclastic flow, Turová Fm., Middle Sarmatian. At the site, deposits of pyroclastic flow are exposed covered with thick layers of epiclastic volcanic conglomerates with layers of coarse epiclastic volcanic sandstones with thin horizons of redeposited tuffs.

JL-99 Jastrabá – Lazy – rhyodacite epiclastics, Jastrabie Fm., Late Sarmatian. In the railroad cut there is exposed a sequence of epiclastic volcanic breccias with the predominant material of rhyodacites.

LS-37 Detva – NL Kalamárka – lava flow, Veľká Detva Fm., Early? Sarmatian, situated within the buffer zone of PLA Poľana. The base part of the lava flow has been preserved with the characteristic lamination and platy jointing. From the petrographical point of view it is an augite-hypersthene andesite with olivine (or basaltic andesite).

LS-89 Čierny Balog – Brusniansky grúň – lava flow, Fm. Poľana, Early? Sarmatian, situated within PLA Poľana. At the bottom the lava flow has blocky to platy jointing, which passes upwards into the irregularly blocky to brecciated ones. The upper part of the flow is a porous blocky lava breccia.

LS-90 Hriňová – NNL Bystré – lava flow, Fm. Poľana, waterfall, Early? Sarmatian, situated within the buffer zone of PLA Poľana. At the bottom the lava flow of pyroxenic andesite has blocky to platy jointing, which passes upwards into the irregularly blocky to brecciated ones. The upper part of the flow is a porous blocky lava breccia.

LS-92 Kľak – Kláštorná skala – lava flow, Vtáčnik Fm., Late Sarmatian. Originally, lower part of the flow is made of the dark grey andesite with platy, thick-platy and columnar jointing. The rock is resistant to weathering and this is the cause of the formation of the rocky cliffs.

LS-93 Brehy – abandoned quarry, basalt lava plateau, Pleistocene (Fig. 1.18). The site is a nepheline basanite lava flow of the volcano Putikov vŕšok Hill, which is of Mid- to Late Pleistocene age, and thus the youngest

*Fig. 1.18 Brehy, transition from columnar jointing in the bottom part of the flow into thin-bedded one in its central part and again the columnar one in its upper part (Photo L. Šimon)*

volcano in Slovakia. The volcano is a cinder cone and a set of lava flows forming lava plateau which lies near the Hron River atop the Riss terrace.

LS-94 Tekovská Breznica – NL Putikov vŕšok, basalt volcano, cinder cone, Late Sarmatian, situated within PLA Štiavnické vrchy. The rocky cliffs expose tuffs, lapilli tuffs, agglomerates and prevailing agglutinates deposited with the primary slope of about 20 to 30 °. The cinder cone is the product of the Vulcanian, Strombolian and Hawaiian eruption types.

VK-01 Vyhne – NR Kamenné more (Stone Field) – rhyolites, Jastrabie Fm., Late Sarmatian, situated within PLA Štiavnické vrchy. The block sea represents a colluvial accumulation of rhyolite blocks which originated during the last glaciation period.

VK-02 NNR Sitno – castellated rocks in amphibolic andesites – lava flow, Sitno effusive complex, Late? Sarmatian, situated within PLA Štiavnické vrchy. The lava flow rests on tuffs of the Biely kameň Fm. Thanks to its resistance against weathering it creates massive cliffs.

VK-03 Krupinské bralce – NL Štangarígel – relic of lava flow with columnar jointing – lava flow, effusive complex of Jabloňový vrch Hill, Sarmatian, situated within PLA Štiavnické vrchy.

VK-10 Banská Štiavnica – Kalvária (Calvary), basalt feeder, situated within PLA Štiavnické vrchy. The site represents a lava neck of nepheline basanite exposed due to erosion; its age is estimated to 7.2 Ma.

VK-139 Hronská Breznica – pyroclastic flow, Breznica complex, Early Sarmatian, situated within PLA Štiavnické vrchy. The site displays chaotic block breccia of amphibole-pyroxenic andesite, which can be described as moderately welded deposits of block-ash pyroclastic flow deposited at the northern foot of the Štiavnica Stratovolcano.

VK-145 Hajnáčka – Kostná dolina Valley (Valley of Bones) – maar, Cerová basalt Fm., Pliocene, situated within PLA Cerová vrchovina. The maar is world-famous paleontological site thanks to the findings of the bones of mammals. Is the type site of the zone MN 16a of biostratigraphic scale of European continental Neogene. The bones are not in the primary sediments of the maar lake, but in the sediments of a bit younger lake, which evolved in the space of maar after its denudation.

VK-16 Plášťovce – type profile of Sebechleby Fm./Plášťovce Mb., Early Badenian. The Plášťovce Mb. involves tuffaceous siltstones, epiclastic volcanic sandstones and sliding bodies of conglomerates. From the petrographical point of view the rock material consists of amphibole-hypersthene andesites and augite-hypersthene andesites with accessory amphibole.

VK-17 Medovarce – lahar breccia, type profile of Sebechleby Fm., Early Badenian. The age of the deposits is medium to upper part of Early Badenian. The profile involves alternating layers of blocky well-sorted conglomerates, fine conglomerates and sandstones with massive layers of chaotic breccias of lahars (mudflows), which crossed the coastline and moved on the shallow sea floor.

VK-18 Ladzany – Husárka – lava flow, type profile through Ladzany Fm., Sarmatian, situated within PLA Štiavnické vrchy. The lava flows of pyroxenic andesite shows at its base and its margin distinct lamination and platy jointing, which is parallel to the slope of the flow, or to a direction of its course.

VK-19 Drastavica – ignimbrite, type profile of Drastavica Fm., Early? Sarmatian, situated within PLA Štiavnické vrchy. Intensive welded ignimbrite of amphibole-pyroxenic andesite with biotite shows coarse-columnar to blocky jointing. At the base of the ignimbrite a horizon of non-welded unsorted pumice tuff is placed. The ignimbrite is the product of explosive eruptions of the Plinian type.

VK-20 Boky – Čertova skala (Devil`s Rock) – lahars, type profile of Breznica complex, Early? Sarmatian, situated within NR Boky. The Čertova hlava natural formation is a perched block, which evolved due to weathering out of isolated blocks of andesite from the thick breccia.

VK-22 Ilija – pumice flow, profile through Štiavnica caldera fill, Studenec Fm., Late Badenian, situated within PLA Štiavnické vrchy. The profile is dominated by pyroclastic and epiclastic volcanic rocks – deposits of pumice-ash flows, redeposited tuffs and epiclastic volcanic breccias and sandstones.

VK-23 Stará Huta – Blýskavica – hyaloclastites, type profile of Blýskavica Fm., Early Badenian.

VK-26 Žiar nad Hronom – Šibeničný vrch – tuff cone, type locality of Šibeničný vrch Complex, Pannonian. The site is a monogenetic volcano of calcium-alkali basalt to basaltic andesite. The cone is made of fallout tuffs, deposits of pyroclastic fluxes and bombs, which travelled along ballistic curves and created impact structures at that time surface.

VK-35 Hliník nad Hronom NR– Szabóova skala, rhyolite, Jastrabie Fm., Late Sarmatian. The rock wall on the west side of the body preserved spherolitic rhyolites with a well developed fluidal texture emphasized by oriented bubbles (lithophyses). On the east side there is preserved the original vitreous edge of the body, and associating glassy breccias, which are a perlite deposit.

VK-38 Šomoška – lava neck, Cerová basalt Fm., Pliocene, Dacian, situated within PLA Cerová vrchovina. The site Šomoška represents a lava neck of alkali basalt of Early Pliocene age exposed by erosion of surrounding sediments.

VK-44 Hodejov – maar, Cerová basalt Fm., Pleistocene. Abandoned quarry exposes a maar filling of Early Pleistocene age. The older part of the filling consists of typically stratified phreatomagmatic lapilli tuffs with prevailing dry pyroclastic deposits of inrushes. This filling was cut in by a new crater, which created within extremely energy phreatoplinian eruption; this is indicated by the deposits of tuffs and pumice tuffs on the crater wall. The horizon of agglutinates atop tuffs indicates the subsequent stage of the Hawaiian type eruptions, which were soon replaced by eruptions of the Surtsey type as a result of maar lake formation.

VK-46 Hajnáčka – diatreme (volcanic pipe), Cerová basalt Fm., Pliocene, Romanian, situated within PLA Cerová vrchovina. The site is a neck (feeder) exposed by erosion – diatreme of alkaline-basaltic monogenetic volcano, which was active during the Late Pliocene.

VK-47 NNR Ragáč – cinder cone, Cerová basalt Fm., Pleistocene, situated within PLA Cerová vrchovina. The site is the relic of a cinder cone and lava flow associating older Pleistocene, volcanic forms of a basalt monogenetic volcanic field of southern Slovakia and northern Hungary.

VK-48 Fiľakovo, hradný vrch (Castle Hill) – Cerová basalt Fm., Pleistocene. The Fiľakovo Castle Hill is an example of less eroded maar of the Cerová basalt Fm. of Early Pleistocene age with preserved fill of phreatomagmatic pyroclastics.

VK-54 Počúvadlo – ignimbrite, Drastavica Fm., Early? Sarmatian, situated within PLA Štiavnické vrchy. Ignimbrite at Počúvadlo is a member of the Biely Kameň Fm. of the Early Sarmatian age.

VK-56 Čelovce – necks, Čelovce Fm., Early Badenian. Explosive neck at the Čelovce village is one of the feeders of pyroclastic volcano of the Čelovce Fm. Its age is younger than the Early Badenian. The volcano evolved in the coastal zone of a shallow sea.

VK-57 Tanád – andesite porphyry, Tanád intrusive complex, Early? Badenian. The Tanád intrusive complex ranging in the age from Early to Late Badenian represents a set of sills and laccoliths of andesite porphyries, which intruded the stratovolcanic structure. Situated within PLA Štiavnické vrchy.

VK-58 Juraj štôlňa – quartz-diorite porphyry, dyke, intrusive complex Banisko, Late Badenian, situated within PLA Štiavnické vrchy.

VK-60 Breziny – extrusion of pyroxene-amphibole andesite with garnet, Neresnica Fm., Early Badenian. The extrusive dome is exposed in a quarry Brezina; it is formed by massive andesites with fluidal texture with vertical orientation.

VK-62 Čamovce – NL Belinské skaly (Belina Rocks) – basalt flow, Belinská skala Mb., Cerová basalt Fm., Pliocene, Dacian, situated within PLA Cerová vrchovina. The source of alkali basalt lava flow was a cinder cone Monosa. The lava flow with platy jointing at its base and columnar jointing upwards, rests upon Pliocene river sediments.

VK-63 Pinciná – maar, Podrečany basalt Fm., Pliocene, Pontian/Dacian. The maar is characteristic for the presence of maar lake sediments – diatomitic clays and alginites. The abandoned quarry exposes a profile through tuff ring and the edge of the maar lake deposits.

VK-65 Machulince – lava flow, Inovec Fm., Middle–Late Sarmatian. After reaching the sea coastal zone the lava flows of pyroxenic and leucocratic andesites were transformed into accumulation of hyaloclastite breccias.

VK-70 Banská Štiavnica – Šobov – secondary quartzites, situated within PLA Štiavnické vrchy, Late Badenian. The site Šobov is a typical example of a high-sulphidic hydrothermal system with alteration of the advanced argillitization type, which is characterized by extreme leaching-out of rocks by acidic solutions.

VK-73 Hliník nad Hronom – Panská hora, NR Bralce – rhyolite cryptodome, Jastrabie Fm., situated within PLA Štiavnické vrchy, Late Sarmatian. The body consists of massive to porous and vesicular plagioclase rhyolites, especially in the peripheral parts with banded structure of fan-shaped course. In the apical part of the body manifestations of adularization and silicification are visible.

VK-75 Brhlovce – tuffs and epiclastics, Baďan Fm., Early Sarmatian (Fig. 1.19). The site represents epiclastic volcanic sandstones facies and redeposited tuffs of the Baďan Formation, Early-Sarmatian in age. The tuffs and tuffaceous sandstones were used in the past as construction material and served also as unique rock dwellings.

VK-79 Hrušov – epiclastic volcanic sandstones, Čelovce Fm. Epiclastic volcanic sandstones near Hrušov represent deposits of distal zone of the pyroclastic volcano of the Čelovce Formation, Early-Badenian in age.

VK-80 Vinica – Sokolia skala (Falcon`s Rock) – extrusion, Vinica Fm., Early Badenian. The site is one of the type profiles of the Vinica Formation, Early-Badenian in age; it corresponds to submarine extrusive domes, and to the processes of their brecciation. Sokolia skala cliff

*Fig. 1.19 Cellars worked-out in tuffaceous sandstones in Brhlovce (Painting by V. Konečný)*

represents the submarine extrusion of pyroxenic andesite with amphibole; the brecciation took place at the level of sea bottom.

VK-82 Stará Huta – lava flow, Javorie Fm., Early Sarmatian. The lava flow near Stará Huta is the type profile of the Javorie Formation of Javorie Stratovolcano. The age of the formation is the Late Badenian to Early Sarmatian.

VK-87 Príbelce – tuffaceous sands, Vinica Fm., Early Badenian. The site is the stratotype of Príbelce Member (beds); the beds constitute the basal transgressive Early Badenian layers atop the sediments of early Miocene.

VK-88 Domaníky – conglomerates and sandstones, Sebechleby Fm., Early Badenian. The type profile of the Sebechleby Formation near Domaníky represents the littoral sea facies in the distal zone of Štiavnica Stratovolcano. The age of the deposits corresponds to the Mid- to the Upper zone of Early Badenian.

### 1.4.7 Quaternary localities

The Quaternary of the Western Carpathians represents a particular evolutionary stage, which is typical for continental facies of irregular spatial distribution. The largest extent and thickness have developed in the lowlands and depressions, in opposite to high mountains (Fig. 1.20). The largest thicknesses (reaching several tens of metres, even above 100 m) have been documented in the Quaternary tectonic depressions of the Záhorská, Podunajská and Východoslovenská nížina lowlands and the Liptovská kotlina Basin. The fill of these depressions consists of deluvial, proluvial, eolian, fluvial and glaciofluvial deposits. In ordinary development the largest thicknesses have been observed in glacial, deluvial, eolian, fluvial and glaciofluvial sediments (usually up to 20 to 30 m).

Y-01 NL Axamitka Cave – 38 – 30 ka, 18 – 10 ka, Aurignacian; Late Epigravettian, palaeontolology. The Axamitka Cave was named after the Commander of “Bratríci” or “Brothers” (combative groups of Czech Hussites in Slovakia) Peter Aksamit of Liděřovice and Košov, which dwelled here in the year 1458. Of particular interest are the findings of the settlements of people from the Early Stone Age. A finding of a split tip of the Reindeer antler is the oldest evidence of the settlements of Zamagurie (Magdalénian). Situated within PIENAP NP.

Y-03 Bojnice – 120 – 90 ka (travertine mound), 60 ka (Prepoštská jaskyňa, Prior`s Cave) Mousterian, palaeontology, archaeology (*Homo neanderthalensis*). The travertines are exposed in terraces in Bojnice over the alluvium of the Nitra River.

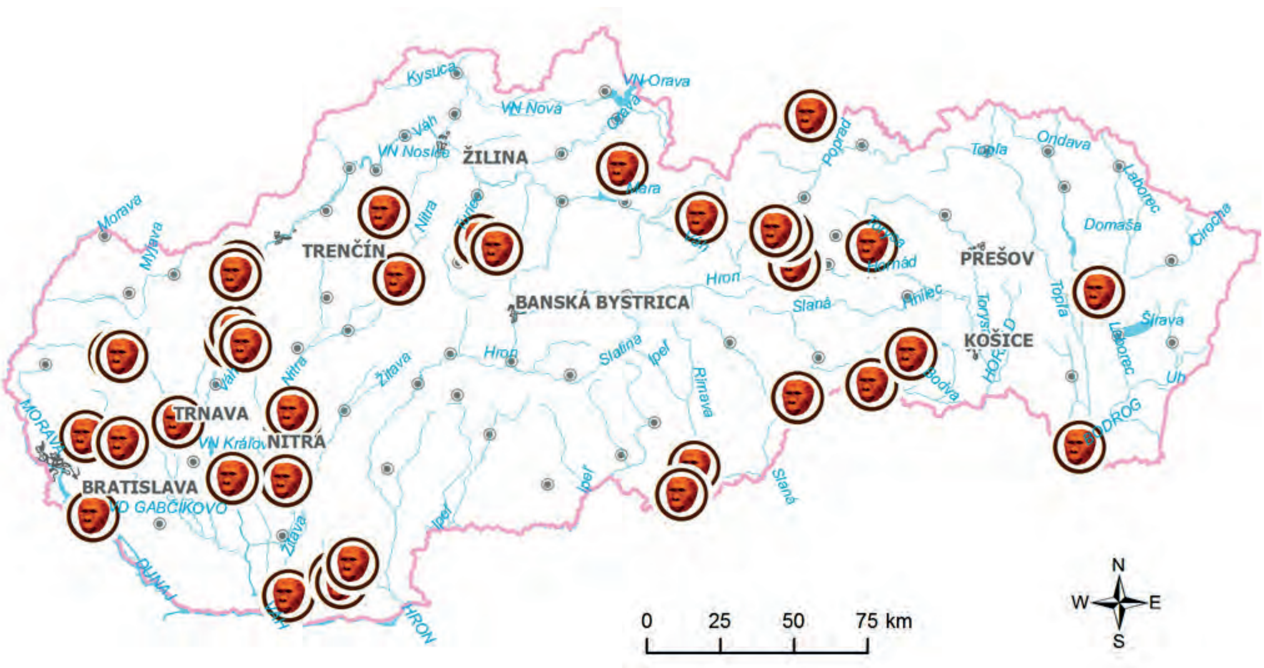


*Fig. 1.20 Distribution of the Quaternary sites in the Slovak territory*

Y-04 NL Čertova Pec Cave – 200 – 40 ka, 40 – 32 ka, 30 – 20 ka, Mousterian, Szeletian, Gravettian, palaeontology, archaeology. It is the first Slovak cave with the findings of the three Palaeolithic cultural layers in superposition to each other (Gravettian, Szeletian and Mousterian). The findings of a Middle-Palaeolithic Mousterian industry of Riss-Würm interglacial rank it to the oldest cave with Palaeolithic population (Bárta, 1972).

Y-05 NNR Dreveník – Pleistocene travertine mounds (Fig. 1.21). Dreveník represents the largest travertine territory in Slovakia, with lots of caves and cavities, the rocky city, and travertine mounds and tectonic faults; it manifests a wuthering geological evolution of the Earth.

*Fig. 1.21 Rock city of Dreveník, gravitational disintegration of travertine mound at its edge (Photo P. Liščák)*

Y-06 NL Dzeravá skala – okolo 57 – 24 ka, Micoquien, Aurignacian, Gravettian, palaeontology, archaeology. Thanks to its palaeontologic and archaeologic findings Dzeravá skala has become a significant object of both professional and amateur investigation since the year 1913 (Hillebrand, 1913). Situated within PLA Malé Karpaty.

Y-07 Gánovské travertíny (Gánovce Travertines) – 105 ka, Mousterian, palaeontology, archaeology (*Homo neanderthalensis*). In 1926, in the travertine quarry in Gánovce stonemason foreman K. Koky discovered and subsequently saved a cast of cranial cavity of an early Neanderthal. The absolute age of the Neanderthal findings based on uranium-thorium method dating of the travertines is 105 000 years (Vlček, 1955).

Y-10 NR Chotínske piesky (Chotín Sand Dunes) – sand dunes. The surface area of 7 ha provides a habitat for sand-based and xerophyllic plant and animal communities on stabilized sand dunes. The layer of aeolian (wind-blown) calcareous sands attains a height of 2 to 3 m.

Y-12 Jasovská jaskyňa (Jasov Cave) – Palaeolithic, Neolithic, Hallstatt, Roman times, palaeontology, archaeology. Jasov Cave is the oldest show cave in Slovakia; since 1846 it was made accessible thanks to the monks of the Jasov Monastery. Among the remains of former fauna the Cave Bear bones (*Ursus spelaeus*) were found, as well as the Cave Hyena (*Crocuta spelaea*). Situated within NP Slovenský kras.

Y-13 Kolíňany – Early and Middle Pleistocene (Villanyian MN 17, Biharian MQ1), palaeontology. In the operating limestone quarry Málok southwest of the village Kolíňany, in the system of parallel narrow vertical karst crevices filled with terra rossa (partial sites Kolíňany 1 – 3) there were found the fossil remains of mainly small mammals from the upper Villafrank (biozone MN 17).

Y-14 Ladmovce – Middle Pleistocene (Biharian), palaeontology. In an abandoned quarry with dolomitic limestone at the village of Ladmovce, there were found at a depth to about 5 m from the surface, the residues of the fossil vertebrates of the and malacofauna in the fill of the former cave space. Situated within PLA Latorica.

Y-15 Pružinská Dúpna jaskyňa (Dúpna Cave) – skeleton of Cave Lion. The lion (*Panthera spelaea*) finding in the Pružinská Dúpna Cave is extraordinary and unique evidence of the presence of this species on the territory of Slovakia.

Y-16 NR Blatnica – Ružový previs (Pink Overhang) – creation of foamstone, Holocene profile, situated within NP Veľká Fatra. This overhang became the classic site of the foam sinter overhangs in the Carpathian Mountains (Ložek, 1976). This is a typical foam sinter overhang in a humid location at the bottom of the valley. Therefore, almost the entire Holocene profile has been preserved in the foam sinter, with numerous speleo-pearls and abundant shells of aquatic mollusc *Bythinella austriaca* (Frfld). Situated within Veľká Fatra NP.

Y-17 NL Mažarná Cave – relics of Cave Bear. The cave is located in the Middle Triassic Gader limestones of the Choč nappe. Situated within Veľká Fatra NP.

Y-18 NNL Medvedia jaskyňa (Bear Cave; Glac Plateau) with a length of 497 m and depth of 30 m represents two extensive major corridors, which unite morphologically into single passage. Entrance of the cave is a spacious abri with a length of 9.6 m, a width of 8 m, and the height of 6 m. Significant is the large number of well-maintained fossil osteologic materials of the Cave Bear (*Ursus ingressus*). Situated within Slovenský raj NP.

Y-19 NNL Medvedia jaskyňa v Západných Tatrách – (Bear Cave) in the Western Tatras, in NNR Suchá dolina, situated within TANAP NP, was discovered in 1953, and already the first mention on it in the literature testified for a large amount of palaeontologic findings collected – the whole skeletons of Cave Bears (*Ursus spelaeus*) and other Pleistocene carnivores (Benický, 1953). In addition to the complete skull and skeleton of the Cave Lion (*Panthera spelaea*) in 2007 there were found in the cave the bones of the Wolf (*Canis lupus*).

Y-20 Mnešice – 270 BP – 10 ka, Clactonian, Mousterian, Szeletian, Gravettian, palaeontology, archaeology (*Homo stenheimensis*). The loess are separated by several fossil soil horizons with archaeological cultures of Early Palaeolithic. The thickness of the profile is 30 m. The loess were formed during Mindel up to Würm glacials (ca 445,000 up to 10,000 years BP).

Y-21 Moravany nad Váhom – Banka – from 40 till recent, Szeletian, Gravettian, Epigravettian, Neolite, Eneolite, Recent, palaeontology, archaeology. Here, in 1938 the "Venus of Moravany" was accidentally found, a statuette of Palaeolithic women from mammoth tusk (originating from the period 22,500 years B.C.).

Y-23 Ondrej-Hôrka – LP Eemian, IS 5e Middle Palaeolithic, Mousterian, palaeontology. The travertine mound Skalka and a surge of still active mineral water located close to the site. The age of travertines was determined by the U-Th and Th-Th dating to 228,000, 186,000, 160,000 to 116 years BP (Kovanda et al., 1995). Similarly, the oldest archaeological findings are from the Mindel-Riss (Holstein) interglacial and belong to an earlier phase of the Middle Palaeolithic. Other findings come from the Riss-Würm (Eemian) interglacial.

Y-24 Senec – The Senec brickyard site is a significant finding of the Woolly Mammoth (*Mammuthus primigenius*) with the most complete skeleton on the territory of Slovakia, which was found in 1961 (Činčurová, 1963).

Y-26 Ratnovce – Late Pleistocene, palaeontology, archaeology (Fig. 1.22). The site consists of about 700 m long path in a rill. The loess walls in the rill are up to 8 metres high, and in several places the remains of Pleistocene mammals (Mammoth, Reindeer, Arctic Wolf) and also malacofauna are found.

*Fig. 1.22 Ratnovce, mammoth tusk in loess (Photo M. Vlačiky)*

Y-27 NNL Spišský hradný vrch (Spiš Castle Hill) – travertines. Spiš Castle is a castle ruin atop travertine mound, forming the Spiš Castle Hill, which thrones over a wider surrounding of the main road that connects the neighbouring Spiš and Šariš regions. It is not only a testament to the evolution of architecture from $12^{th}$ to $18^{th}$ centuries, but with its more than 4 hectares (exactly 41,426 $m^2$) it is the largest castle complex in Slovakia and one of the largest in Europe. Biochemical sediments, which are the main subject of our interest, are the travertines and foam sinters, Late-Miocene to Holocene in age. The castle is a National Cultural Monument and since 1993 it is a component of the Levoča, Spiš Castle monuments registered on the list of UNESCO World Heritage.

Y-28 Strekov – 2.6 Ma, Villanyian, Late Pliocene/Pleistocene MN 14, MN 16b, MN 17, palaeontology. Sandpits, which contain important vertebrate fauna of large fossils from the period at the turn of Tertiary – Quaternary. The fauna is typical of the so called "Mammuthus-Equus event" (Vlačiky et al., 2008).

Y-29 Šaľa – 80 – 40 ka, Mousterian, palaeontology, archaeology (*Homo neanderthalensis*). The site consists of two locations Šaľa 1 and 2. The Šaľa 1 was discovered in 1961. It represents very well preserved fossilized frontal bone of brown-black colour apparently belonging to an adult from around the late Pleistocene Central European Neanderthal – probably woman who has died aged around 20 to 39 years. With regard to the current prevalence of animal species *Dicerorhinus hemitoechus* and *Megaceros giganteus hibernicus* initially estimated at young Pleistocene, Early Würm last glacial period (some 70,000 – 50,000 years BP). The Šaľa 2 finding was found in July 1993 and in early December 1995 in the local part Šaľa-Veča. The finding consists of two parts, which belonged to one individual. The fossil Šaľa 2 is older and more robust than Šaľa 1 and belonged very likely to an adult male, who died aged around 40 – 59 years.

Y-30 NNR Šúr – the last and largest relic of a high-stem swamp-bog alder-tree forest, with remains of the wet and peaty meadows on its periphery. The site contains a detailed limnologic record of the changes in the environment by the end of the last glacial and onset of Holocene in buried organic lacustrine sediments.

Y-31 NL Tmavá skala Cave – 127 – 10 ka, palaeontology. The cave was formed in Middle Triassic limestones of the Choč nappe along the joint N-S direction. The site represents the typical bear cave, which thanks to its relatively stable temperature and voluminous subhorizontal spaces with sufficient water in the past, was used by tens to hundreds of specimens of Cave Bear for hibernation and the giving a birth to cubs during a relatively long period of Late Pleistocene (Sabol, 1997). Situated within PLA Malé Karpaty.

Y-32 Trenčianske Bohuslavice – around 20.3 ka – 29.13 ka, Gravettian, palaeontology, archaeology. Gravettian site is the most comprehensive and the most modern studied Palaeolithic site in the territory of Slovakia. Qualitatively, a significant component of industry create both-sides processed leaf-shaped spikes, otherwise the findings correspond to standard Gravettian industries. Another of the specificities of the site is the presence of a large quantity of paleontological material; mainly Reindeer and Horse, Mammoth, Polar Fox, a representative of the Bovidae family (Bos/Bison), Woolly Rhinoceros, Wolf, Brown Bear and Beaver, Hare (Vlačiky, 2009).

Y-33 NNL Važecká jaskyňa Cave – more than 40 ka, palaeontology. In the cave deposits (extraordinary lot of the Cave Bear bones (*Ursus spelaeus*) have been preserved. The findings of the bones of the Cave Bears were dated by radiocarbon method to over 40 000 years (Sabol & Višňovská, 2007).

Y-34 Včeláre – MN 17 Villanyian, MNMQ1 Biharian, palaeontology. Significant palaeontological site Včeláre consists of separate sites, dating back to the period of Late Cenozoic.

Y-35 Malá ľadnica Ice Cave – 56 metres deep abyss Malá ľadnica is located in the cadastre of Silická Brezová at the altitude 441 m a.s.l. Human tooth from the Malá ľadnica sedimentary fill is the first finding of the remains of a man on the territory of Slovakia of Young Pleistocene age. Situated within NP Slovenský kras.

Y-36 Komjatice – Komjatice brick-yard is an important location of the first finding of a layer of volcanic ash in Pleistocene loess on the territory of Slovakia.

Y-37 Žirany – Early and Middle Pleistocene (Biharian, MQ1), palaeontology. Palaeontologic site in the quarry on the East slope of the Hill of Žibrica, very rich and unique fauna was obtained here with two leading taxa: *Lagurus (Prolagurus) pannonicus* and *Allocricetus bursae*. There were discovered additional 17 taxa of small mammals, and 5 species of large mammals (Fejfar, 1964).

Y-38 Hajnáčka – Pleistocene fauna. In the vicinity of Hajnáčka two world-famous sites are located with Late Pliocene fauna. Hajnáčka is the type site of the European Neogene Scale defined on the basis of mammalian fauna. It belongs among the type sites of the MN 16 – subzone MN 16a – Villafrank. Its age is 3.3 – 2.8 Ma. Situated within PLA Cerová vrchovina.

Y-40 Vlčkovce – loess profile, Palaeolithic settlement. The Palaeolithic station Vlčkovce is located in the area of the former Slezák brickyard. The loess profile in Vlčkovce is a comparative site for the Danube and Váh Palaeolithic populations. Žebera (1958) ranked it among the most important Palaeolithic stations in Slovakia.

Y-43 Gortva – succession of fossiliferous sediments is located on the upper part of an earlier stage of Middle Pleistocene terrace, which is located above the younger Middle-Pleistocene (principal – Riss) terrace.

Y-45 Danube River – The Danube is the second longest river and the longest river in the European Union. Already the ancient Romans knew this river, which created a major natural northern border of their empire, fortified Limes Romanus. The river and its basin are a valuable and unique eco-system that provides the habitat for very diverse fauna and flora.

Y-46 Svodín – Shallow mapping structural borehole DŽ-2 (reached the depth of 36 m), drilled North of the village Svodín. Massive loess was drilled here through (36 m) with well-preserved fossil soils, ranging up to the Earliest Pleistocene. For this reason, this area is of great importance for the Quaternary study.

Y-47 Brekov – Neogene/Pleistocene fill of karst cavities. Active limestone quarry south of the village of Brekov. In the quarry there was exposed an extensive profile through the Gutenstein limestone, disrupted by fault. The fossil findings come from a sandy subsoil of coarse dark-red terra-type deposits.

### 1.4.8 Localities of historic mining

The mining (Fig. 1.23) is an important aspect of the Slovak history, which in the past had employed directly tens of thousands of people, and scores of others on

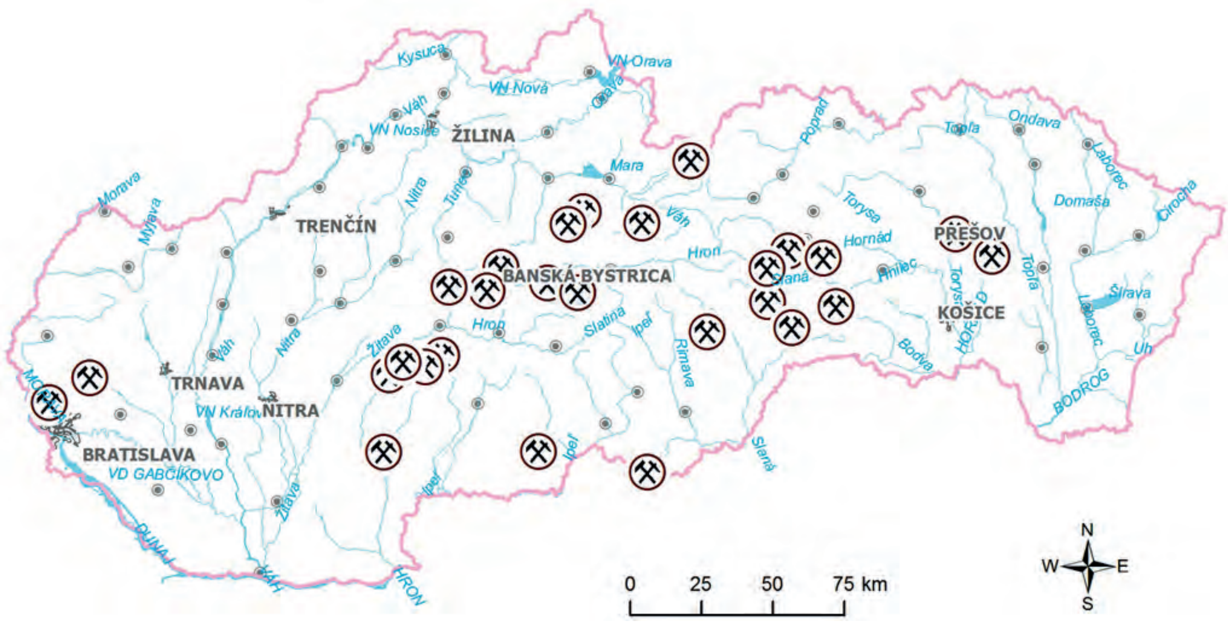


Fig. 1.23 Distribution of the sites of historic mining in the Slovak territory

supplementary activities (Zámora et al., 2008). Geological processes have also created accumulations of a whole range of mineral resources, some of which have a world reputation. The places of concentration of such sites are the historical mining towns (Banská Štiavnica, Kremnica, Ľubietová, Dubník opal mines). Some of them are the sites of the first description of minerals (Ľubietová – euchroite, libethenite, mrázekite; Sirk – evansite, vashegyite, Smolník – kornelite, rhomboclase, szomolnokite; Hodruša – hodrušite).

Of the ore deposits, deposits of gold, silver, copper, lead, zinc antimony and mercury were the most important. In the environment of the Crystalline and the younger Palaeozoic of Tatricum and Veporicum there are syngenetic high-sulphidic mineralisation (HSM) deposits of pyrite and pyrrhotite, veins/stockworks and occurrences of gold-arsenopyrite, gold-scheelite and polymetallic veins/stockworks and residual placers of gold. In the Spiš-Gemer Ore Mts. of Palaeozoic environment, the HMS copper and polymetallic deposits, the siderite metasomatic deposits, siderite-sulphide deposits of copper and siderite, barite, gold-stibnite vein deposits, and syngenetic deposits of manganese and iron. In neovolcanites we can find porphyro-skarn deposits of copper and gold, magnetite skarn deposits, polymetallic pre-impregnation deposits, polymetallic and precious ore veins and stockwork-impregnated mercury deposits.

Slovakia is rich in non-metallic deposits. Magnesite, talc, gypsum, limestone, dolomite, quartzite, pearlite, zeolite, bentonite, ceramic clay, quartz sand, petrurgic basalt and natural pigments are of the greatest importance. From the point of view of the economy, large sources of building materials – building stone, gravel, sand and brick raw materials are important.

Slovakia is not rich in energy raw materials. Only the deposits of brown coal and lignite have a larger extent in Tertiary depressions. There are several small petroleum deposits in the Slovak part of the Vienna Basin.

B-01 Banská Štiavnica – mining of polymetallic ores, Mining Academy (1762), established by Maria Theresia. Situated within PLA Štiavnické vrchy. The mining education in the former Austrian-Hungarian Monarchy, as well as in Europe, was significantly influenced by the foundation of the Mining Academy in Banská Štiavnica. It was the first school of its kind and at the same time the first academy of technical education all over the world. The elimination of the Ottomans' danger in the Middle Europe gave significant economic impulses. At the meeting of excellent persons of the Royal Court in Vienna on October 22$^{th}$, 1762, the decision was made to establish in Banská Štiavnica the academy, which ought to produce mining and metallurgy specialists. The crucial moment in decision about the seat of such a academy was the fact, that within the Habsburgs' Monarchy the Banská Štiavnica region was front ranking in adopting of most advanced technologies in mining, ores processing and metallurgy. The final decision on the seat of the Mining Academy made Maria Theresia on December 13$^{th}$ 1762. The first professor of the Mining Academy in Banská Štiavnica was appointed Michael Joseph Jacquin, one of the most excellent scientist in Europe of that time, known for his knowledge of chemistry and botany. Professor Jacquin gave his first lecture on September 18$^{th}$ 1764. Until 1765 The Academy had only one department — the Department of Chemistry and Metallurgy, headed by Professor Jacquin. In 1765 the second department was established – the Department of Mathematics, Mechanics and Hydraulics with its first professor Michael Poda. In 1770 the third department was founded — the Department of Mining with the first professor Cristoph Traugott Delius. On the same date a precise study plan at the Mining Academy was elaborated in accord with Decree. From the founding of the school, the teaching was on high level, thanks to excellent professors. Already Professor Jacquin made a distinct advance in the education process by complementation of the theoretical education by laboratory tests. Another important fact is, that the Mining Academy opened free study for any student either from the Habsburgh' Monarchy or from abroad. The lecture attendance as well as utilisation of mnemonics were free of charge. The first mining evaluation of the Banská Štiavnica area comes from Agricola (1558), describing mining activity and methods of ores processing. G. A. Scopoli, professor of the Mining Academy, issued significant mineralogical works. Exceptionally valuable is the textbook by K. T. Delius "Anleitung zu der Bergbaukunst" (Introduction to Mining), which due to its complexity and interpretation of the subject reached the highest level in the 18$^{th}$ Century. The advance in mining was closely connected with international meeting of mining and metallurgy specialists in Sklené Teplice (12 km from Banská Štiavnica) in 1786, when Ignác Born introduced and demonstrated so-called indirect amalgamation. At the same occasion the participants decided to create a society, which has been supposed to be the first scientific society world-wide. The society included 147 members from 15 European countries (among them J.Watt, J.W.Goethe, L.Lavoisier and other significant scientists). The progress in cartography was largely influenced by M. Zipser and mainly by S. Mikovíni, the first professor at the Mining School (founded in Štiavnické Bane, 1735). The pioneer wok in the ores processing within the Banská Štiavnica area made P. Rittinger, who, besides other inventions, applied for the first time in the world hydraulic sorting of fine-grained ore products. The Banská Štiavnica area experienced also great progress in water-power engineering. Within 16$^{th}$ to 19$^{th}$ centuries the most developed water management system was introduced here, providing the energy for mining machinery operation. In the second half of the 19$^{th}$ Century S. Schenek and Š. Farbaky, the professors at the Academy, constructed the first applicable licensed accumulator in the world. Significant impulse to the progress of geological science gave the establishment of the Department of Mineralogy, Geology and Petrology at the Mining Academy in 1840. Throughout its duration (from 1840 to 1918) professors J. Pettko, B. Winkler, H. Bockh, Š. Vitalis and others gave their lectures here. Each of them significantly contributed to progress in geological knowledge. In 1853 J. Pettko compiled the first geological map of Banská Štiavnica and its surrounds, in which the rock types are distinguished by colours. H. Bockh issued within 1903–1909 1,400 pages textbook of geology, which due to its extent and quality ranked among the most acknowledged geological monographs of the then world.

B-02 Banská Bystrica, Malachov – historic mining of Hg in Europe. Malachov mercury area belongs to the oldest sites in Central Europe with mercury exploitation. The biggest boom here had seen mining around 1565. In 1535, for example, approximately 20 kg of mercury was extracted from cinnabarite. In 1796 last mining work in the ore field terminated.

B-03 Dobšiná – mining of Ni-, Co-ores. The largest expansion of mines experienced Dobšiná in 1780, with the beginning of Ni-Co ores mining. This "golden age" lasted about 100 years. The richest mines were the Zembergu (Mária adit) and Gugli (adit Hilfgottes).

B-04 PF Dubník – historic mining of precious opal in Europe. Dubník Opal mines are the oldest opal mines in the world today with the historically most important opal mining in Europe. The first opals probably originated from Roman times, but the first systematic search begun probably in 11th/12th Century. To date there are known over 30 adits and more than 22 km of corridors at the deposit.

B-05 Dúbrava – historic mining of Sb-ores. The deposit Dúbrava is one of the greatest Sb deposits in Central Europe and the most significant Sb deposit in Slovakia. The ores were exploited here from 13th up to 20th Century.

B-06 Kremnica – mining of gold, historic mint (Fig. 1.24). The history of the gold mining is immediately associated with acunation and Kremnica Mint, which was founded in 1329, and till today the coins have been minted here. The first coins that were produced here were silver groats. From the year 1335 there were produced the most famous golden Kremnica ducats. The greatest flowering experienced Kremnica in the 14th Century, when it became the most important mining city in the Kingdom of Hungary, with an annual production of around 250 kg of gold.

B-07 Levice – mining of "Levice Golden Onyx". It represents the mining of historically the most relevant and the most exclusive Slovak decoration stone, whose products were sold under the brand "Levice Golden Onyx" or "the Golden Onyx". Its mining began in 1926 and was exploited in particular in the quarry Šiklóš.

B-08 Hodruša – Hámre – Ag-, Au-ore deposit. Since the Middle Ages (at least from the 16th Century) until the 1950s, rich silver and gold ores were mined here. Situated within PLA Štiavnické vrchy.

B-09 Nižná Slaná – mining of Cu-, Hg-, Fe-, Ag-ores. The beginnings of mining date back to 13th Century. First, Hg, Cu and Ag ores were mined, later moved the exploitation to iron ore.

B-11 Ľubietová – Podlipa – mining of Cu-ores. Ľubietová ranks among the most important copper deposits in Europe. In addition, Ag, Ni, Co and Fe ores were mined here.

B-12 Ľubietová – Tri Vody – Near the gamekeeper`s lodge Tri Vody (Three Waters) a blast furnace for iron ores is located. The first written report on the iron ore exploitation is from the year 1580.

B-13 Magurka – mining of gold. The gold mining here was already known from the 13th Century. At the turn of the Century (13th and 14th) the gold was mined already by underground technology. The great boom of mining occurred in the 80s of the 18th Century, when, together with gold started antimony ore mining. Situated within NAPANT NP.

B-14 Marianka NL – mining of Mariatal Shale, stope with museum. It became famous for its Mariatal shale mining, which was exported to many European countries (e.g. to England and Serbia), and also to the Orient and South America. The shale was exploited first in the quarry, later also by underground mining. In the 60s of the 19th Century a large factory for extraction and processing of shale was built here, in which worked up to 200 people.

B-15 Nižná Boca and Vyšná Boca – mining of Au-ores, historic placers, education trail. In both of the old mining villages in particular gold was mined in the past, but also silver, copper, antimony and, later, iron ore and tentatively Ni-Co ores. Situated within NAPANT NP.

B-16 Nová Baňa – Althandel Mine, Newcomen`s steam engine. In Nová Baňa there was the oldest hereditary adit (y. 1383) in Slovakia according to the available sources. Nová Baňa is a major site of mining-technical interest; here, at the Althandel Shaft, the first Newcomen's atmospheric fire machine

*Fig. 1.24 Kremnica, Shaft František, visit of President Masaryk, by 25/08/1923 (private collection D. Kúšik)*

(steam engine) for pumping water from mines was used in Europe.

B-17 Novoveská Huta – mining of U-, Cu-ores. Throughout its history Novoveská Huta was called (except for the most part of 20th Century) in the literature as "Igló", Spišská Nová Ves. The mining privilege obtained Spišská Nová Ves in 1271, in the year 1380 it became a free Royal town and since 1487 it was a member of the Association of the seven Upper Hungary mining towns. In 1771 the copper smelting works were built here. In particular, copper and iron ore, but also the Sb, Ag and Co ores were mined.

B-18 Pezinok – mining of Fe- and Sb-ores. Pezinok is the largest and most famous ore deposit in West Slovakia. First, gold was mined here, then antimony ores and finally the pyrite for the production of sulphuric acid. The gold deposit (Old City) was discovered in 13th Century and the first gold was mined from placers, later in the mid of the second Millennium the gold was gained by underground mining. Situated within PLA Malé Karpaty.

B-19 Rožňava – Čučma – mining of Au-, Ag-, Cu-, Sb- and Fe-ores. Rožňava was the centre of the mining of gold, silver, copper, antimony and iron ores since the 13th Century.

B-20 Rudňany – mining Fe-, Hg-ores. Rudňany belongs to their largest siderite deposits in Europe. Probably the largest siderite vein in the world – Droždiak is located here, which has length 7 km and maximum thickness of 40 m. The exploitation of minerals began at the end of the 13th Century, however, the big boom occurred in the 18th Century.

B-21 Sirk – Železník – mining of limonite, anhydrite, pyrolusite. The Železník Hill near Sirk is the largest deposit of metasomatic siderite in Slovakia. It consists of three lenses in the length of 4.6 km, which join together into single body in depth. The maximum thickness of the lens was 80 m and the workings are extended to a depth of 500 m below the surface.

B-22 Smolník – mining of Cu-ores. Smolník belongs to the most significant ant the longest known copper deposits in the Spišsko-gemerské rudohorie Mts. For almost 600 years it ranked among the largest producers of copper in Slovakia.

B-23 Solivar – Prešov – mining of salts, National Cultural Monument. Solivar belongs among the most significant technical monuments in Prešov. It is the most important and historically the oldest, largest salt deposit in Slovakia. The deposit is extended over several municipalities covering an area of about 25 km$^2$. The salt springs here were known already in 898, but the underground salt extraction began in Solivar by the mid of the 16th Century, when Jama (Shaft) Leopold was built.

B-24 Šiatorská Bukovinka – quarry Mačacia – mining of basalt. The site is a succession of lava flows of alkali basalt (tephrite), forming a lava plateau. The age of lava flows is around 2.6 to 2.25 Ma. In the past the basalt was used for the production of paving blocks and curbs. Situated within PLA Cerová vrchovina.

B-25 Špania Dolina – mining of Cu-ores, important mining already in Eneolithic (a, b). pania Dolina is historically one the most important copper mines in the world. The copper mining in the younger Stone Age was proven here, which is evidenced also by stony sledgehammers; their accumulation belongs to the largest in Europe. Situated within buffer zone of the NAPANT NP.

B-26 Veľký Krtíš – Dolina Mine – mining of brown coal. Brown coal in Veľký Krtíš was discovered by J. Messa in 40s of the 19th Century. The deposit was extracted in the mine Baňa Dolina, which had 4 excavation sections: Dolina, Háj Slatinka and Bukovec.

B-27 Voznica – mouth of Heritage Gallery. Voznica Hereditary Gallery is probably the most significant mining work in Slovakia. This deepest hereditary gallery in the vicinity of Banská Štiavnica was developed in the years 1782 – 1878 (96 years!). Its function has been to drain the Štiavnica-Hodruša ore field; it mouths in the Hron River at the village Voznica. Situated within PLA Štiavnické vrchy.

B-28 NNR Vysoké Tatry Mts. – Kriváň – mining educational trail, situated within TANAP NP. Below Kriváň Hill in High Tatras the remains of the historic gold mining have been preserved. There are probably the highest laid mines in the Carpathians. The highest adit is located at 2,115 m a.s.l. The first gold on the slopes of Kriváň was found in the 15th Century. Situated within TANAP NP.

P-49 Old All the Saints Mine – Banská Hodruša – the first written mention of the Mine is dated back to 1378, it is likely more than 700 years old. The gallery and some passages, along with a mineralogic exposition, are open to visitors. Situated within PLA Štiavnické vrchy.

### 1.4.9 Mineralogic localities

There are more than 1,100 minerals identified within the territory of the Slovak Republic (Ďuďa & Ozdín, 2012). Of them, 21 were for the first time described from the nowadays Slovakia, from 14 sites, mainly of historical mining (Ozdín, Kúšik, 2018, article no. 2 of this issue). The specimens of the Slovak minerals are scattered throughout mineralogic exhibitions worldwide. The distribution and the list of mineralogical sites (Fig. 1.25) includes also the 5 Slovak localities of meteorites (all-in-all there are known six confirmed meteorite finds from Slovakia, further two sites are assumed; Gargulák & Tóth, 2014).

DO-01 Banská Belá – occurrence of historically important minerals zunyite ("dillnite"), diaspore and "coryllite".The diaspore was discovered in 1823 during the Ferdinand Gallery development. At that time it was probably the second known occurrence of this mineral in the world, and soon its samples expanded throughout the world. Despite the fact that the type locality is located in Russia (discovered and described in 1801 near Sverdlovsk, Ural Mts.), up to about mid of the 20th Century the diaspore was world-wide known just from Banská Štiavnica, later from Turkey, where the much larger, even gem-stone diaspores occur". The diaspore forms aesthetic pink crystals, often dichroic, mostly up to 1 cm large, in alumosilicate rocks. Situated within PLA Štiavnické vrchy.

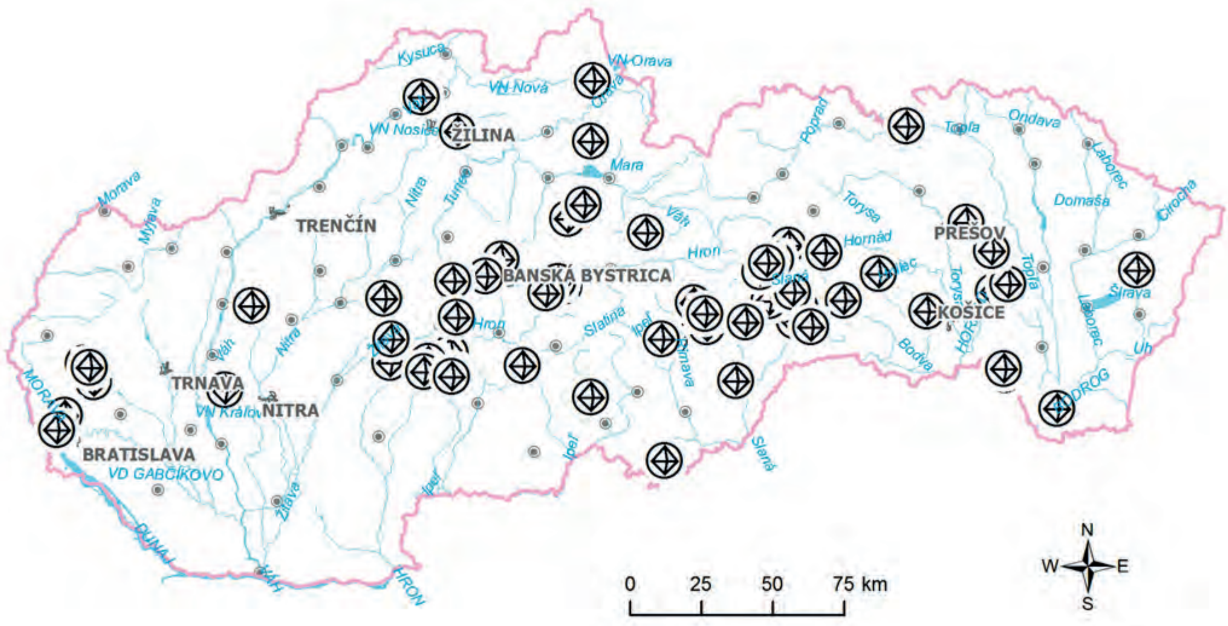


*Fig. 1.25 Distribution of the mineralogical sites in the Slovak territory*

DO-02 Banská Štiavnica – World Cultural Heritage Site UNESCO, occurrence of barite, sphalerite, calcite, quartz (var. sceptre; amethyst, smoky quartz), stephanite, pyrargyrite and Fe, Ma, Al sulphates. Banská Štiavnica is from the mineralogical point of view the site with the most colourful mineral composition in the Carpathians. Thanks to a large number of metalliferous veins here there were described the most minerals on Slovak deposits – over 150. Crystals of individual minerals are characterised not only by their size, but in particular by colour and morphological diversity. The most colourful and morphologically diverse are carbonates (calcite and dolomite), quartz, and barite. Among carbonates manganocalcite from here was described already in the mid of the 19th Century. Later it was found that this is only enriched calcite and according to the latest data, the most of calcites described as manganocalcites do not contain significant proportion of manganese. Calcite and dolomite form a very large number of colour and morphological types, shrubby, spherical, sheaf-like and other aggregates. Practically in each cavity we can find a little bit different carbonate. There occur also the most beautiful and the largest Slovak rhodochrosites of rich-pink colours. A relatively uncommon kutnohorite creates aesthetic macroscopic aggregates, but also of siderite, dolomite and ankerite. A great deal of variety have barites. Typical for the site are so called leaf-shaped barites, whose crystals resemble leaves. Their size reaches up to 15 cm, white colour, sometimes with brown pigment on one side of the "leaves" and frequently with quartz pseudomorphoses. The most beautiful barite druses in the Carpathian Mountains attain several dozen kg and some samples from several metres large cavities attained the size of ~ 60 x 60 cm; and they have become a boasts of many museums and collections. Very aesthetic aggregates, particularly polymetallic minerals like galenite, sphalerite, pyrite and chalcopyrite, with several centimetres large crystals associated into aesthetic druses. Historically, very well known were particularly transparent, green sphalerites with intensive lustre, mainly in the vicinity of Štiavnic Bane. In particular, the extraction of silver ore is famous. There are samples of rich silver ores of particular historical value, even if their quality is below the level of Saxonian, Czech, Mexican and other Latin-American ones. The typical paragenesis of silver ore is represented by stephanite, polybasite, pyrargyrite, acanthite and silver. Of the varieties of quartz, the most represented in world museums and private collections is the violet amethyst. In Banská Štiavnica it must had been fairly common in certain parts of the deposits during exploitation, as in larger collections are dozens of amethysts from this site. The last historic mineralogical specialty is quartz with very minor haematite scales dispersed – cinopel. Situated within PLA Štiavnické vrchy.

DO-03 Banská Štiavnica – Šobov – occurrence of unique anatase and sceptre quartz. The site is known for incidence of up to 20 cm large crystals of quartz, crystallising in the caverns within the Šobov quartzite. The quartz crystals were abundant, particularly at the top of the quarry. The quartzes of Banská Štiavnica were already described by Scopoli (1774), who reported about 90 varieties of quartz differing in colour and shape. Very often sceptre quartz occurred; however, the opposite form with thicker crystal on the bottom, and the thinner one atop was also quite abundant. Situated within PLA Štiavnické vrchy.

DO-04 Banské – occurrence of limnoquartzite. From the mineralogical viewpoint, the limnosilicites are made of opal, in particular. The microcrystalline silica forms are rare. Brown colour comes from iron oxides is silicites, which originate by degradation of the pyrite. The pyrite occurs mostly in the framboidal form. The most likely it originated as a product of the hydrothermal alteration associated with the supply of $SiO_2$ gels, which is confirmed by microtexture character of the silicite. The limnosilicites are characterized by relatively high hardness and compactness. They were formed under the conditions of proportion of silicic acid in sweet-water, probably at relatively higher temperatures because they do not contain any fossil. Thanks to the intense silicification, fair jointing and appropriate and aesthetic colour balance they are very suitable for ornamental purposes, in particular for the production of smaller commemorative items, letter-weights, ashtrays, etc.

DO-05 Brezina – occurrence of quartz (var. agate). Brezina is a site with the most colourful agates in Slovakia. The agates can be found on the fields. They are the products of Miocene postvolcanic activity with the supply of silicic acid into rhyolites. The size of the agates is about 15 cm. The agates are less or not at all fissured and attain the yellow, white, grey, blue-black, pink-violet, orange and greenish colours. Light grey varieties predominate with a very conspicuous banding. A very small part of the agates has a central part of the cavity filled with white-grey banded agate. Some of the zones in the agates and chalcedonies have a strong greenish luminescence.

DO-06 Byšta – occurrence of quartz (var. chalcedony and agate). The Byšta chalcedonies are the most beautiful in our territory. In addition to the chalcedony at the site have been described: barite, cristobalite forming tiny crystals; dolomite, calcite forming locally the fill of the central part of $SiO_2$ veins; quartz (sometimes forms a amethyst variety), pyrite sometimes forming separate small veins and opal, which precipitated in peripheral and internal zones of $SiO_2$ veins. It is of a light colour with grey-brown shades. Less frequently it occurs in the form of hyalite (water-transparent) and milk opal (white). Zeolites forming up to 2 mm large crystals are represented by stilbite, epistilbite, clinoptilolite, mordenite and heulandite. According to chemical analyses, the $SiO_2$ crusts contain up to ~ 3% Fe oxides ($Fe^{2+}$ and $Fe^{3+}$). Currently there are known some 64 minerals from the Byšta site.

DO-07 Čučma – occurrence of rhodonite. Manganese mineralisation is linked with pelitic black lydites and phyllites of Holec strata in the Gemer zone. The manganese mineralisation is made up of two lenses of silicate-carbonatic nature, with a length of 50 – 100 m, and the thickness of max. 4 m. The primary ore contained 30 – 38% of MnO and 6% of FeO. The ores over 15% Mn were exploited; they had been processed in blast furnaces in Ózd in Hungary. The manganese ore had been extracted here for the last time during the World War II (1939 – 1944). On the basis of mineralogical research 3 mineral associations were identified: 1. metamorphic, 2. hydrothermal, 3. supergenic. The views on the genesis vary, but the prevailing opinion is the polystage nature of ore mineralization.

DO-08 Divina – historic occurrence of meteorite. Meteorite fell on July 24, 1837 in the village of Divina, approximately 73 m of the Church in the village, on the south-west slope of Javorník. The Divina Pastor, Štefan Závodník recorded this event as follows: "Divina was excited by special event of July 24, 1837. On this day about a half hour before lunch, the Sun eclipsed and in the 50-degree angle in a distance of 40 fathoms from the Church in the direction of the upper end of the village roaring meteor fell, weighing some 19 Viennese pounds... ". Countess Csákyová Ľudmila, neé Lašanská, took the meteorite to her Castle in Budatín. From here it was donated to the National Museum in Budapest in 1838, where the dominant part has been deposited till today. The original size of the meteorite was 24 x 23 x 13 cm and it had a mass of 10.75 kg. According to historical data, the impact penetrated some 70 cm deep into the soil, and approximately for half an hour after the impact it was still warm. Its advanced research has not been done so far. According to the classification of meteorites it is an olivine-bronzite chondrite (H5). Its mineral content is as follows: group of olivine and pyroxene minerals, nickel iron, and pyrrhotite. Its smaller pieces are stored in museums in Vienna, Paris, Tübingen, Vatican City and Chicago.

DO-09 Dobšiná I – occurrence of extraordinary minerals in serpentinite – quartz (agate), andradite (demantoid), ortochryzotile (asbestos). At its time the largest deposit Ni-Co ores in Europe; the main object of exploitation was gersdorffite. The gersdorffite is a sulphoarsenide of nickel, especially (less Co and Fe) and Dobšiná is its classic site. From Dobšiná it has been described under different names such as amoibite, plessite, wodankies and especially dobschauite. The majority occurrences are of massive or fine-grained structure. It weathers often into green secondary nickel mineral annabergite. Erythrite is the second typical Ni-Co mineral in Dobšiná. Often, it forms powdered pink coatings on ore samples. Rarer forms are pink-red, sheaf-like and radial spherical aggregates of a few mm size. The samples of erythrite from Dobšiná we can find in any major museum collection, in particular in Europe and the USA.

DO-10 Dobšiná II – occurrence of Ni-Co minerals (skutterudite, gersdorffite, arsenopyrite). All minerals are on the most famous and historically the most fundamental deposit in Austrian-Hungarian Kingdom, in the Dobšiná site, where the asbestos (mineral chrysotile) started to be exploited by the early $18^{th}$ Century for the manufacture of fireproof paper. The chrysotile creates smaller veins in the serpentinized peridotite (serpentinite). The size of individual fibres in the fibrous green-yellow up to grey-brown shades with a characteristic silky covering reaches 3 cm. From a historical point of view, the most represented in the old mineral and mineralogical collections and museums besides erythrite was andradite. In the long term view the andradite was the most attractive mineral from the serpentinite quarry in Dobšiná. It occurs in the form of diamantoid and topasolith mixtures. It forms up to 3 mm large crystals, mostly of grass-green colour with glass sheen. It occurs together with magnetite, forsterite, magnesiochromite, and other minerals. Among the major findings from recent years we shall point out the finding of agates in serpentinites.

DO-11 Dubník – opal (var. precious), occurrence of Fe, Mg and Al sulphates (copiapite, pickeringite, halotrichite, fibroferrite, alunogen). Opal is the most important Carpathian gemstone. It is believed that the first opals found in this area originated from Roman times. Up to 19th Century when much larger Australian deposits were discovered the Dubník opals had no other occurrence to compare and they had been the nicest European gemstone. The Dubník precious opal is characterised by a very nice colouration with the preponderant majority of blue and green colours. The most valuable was the red colouration. Precious opal occurs mostly in milk or a glass opal varieties, sometimes in hydrophane. The hydrophane is the opal with a unstable amount of water. These variable contents cause the opals cracking and their depreciation. Unfortunately, most of the Dubník opals have at least from the part the hydrophane properties. The precious opal occurs together with other varieties of opal, with pyrite and antimonite. Its intergrowths with the antimonite needles are unique across the world. The most precious opal, which was found in Dubník, has dimensions of 13 x 7 x 7 cm and a weight of 594 g (2,970 ct). It was found probably around the year 1775 in the creek bed. It belongs among the most valuable historical gems in the world. It is exposed is the Nature Museum in Vienna. The largest Opal's nest was found in 1889 in Viliam Gallery and was weighing around 200 kg. In particular, it was formed by milk opal and precious opal was in 3 layers up to 1.2 cm thick. The Hungarian National Museum possess the largest collection of precious opals from Dubník – around 240,000 pieces of total weight approximately 7.6 kg.

DO-12 Dúbrava – type locality of scainiite and dadsonite. Dúbrava deposit is the most important mineralogical deposit site of Sb. Two stages occur at the deposit Dúbrava: quartz-pyrite vein mineralization with scheelite ± molybdenite and gold and the genetically younger quartz-sulphides veins. Rarely in the veins of the first stage Fe-dolomite, tetrahedrite, chalcostibite, bismuthinite, tetradymite, bismuth and joséite-A, and other tellurides were found. The main mineral at the deposit is stibnite, forming the main fill of hydrothermal veins. Yet there have been described 70 minerals on the deposit, including Nb-Ta, Te, U, Cu and Sr minerals. The deposit is the world-famous thanks to sulphosalts, in particular of lead and antimony, with the most widely spread zinkenite. Dúbrava is a world scaiinite site, Pb-Sb oxosulphosalt, which forms here macroscopic, grey felt-like or grained aggregates. Rarely it makes up the dominant fill of smaller veins. Yet nowhere in the world has been known such a massive presence of this sulphosalt, forming in general only isolated, mostly microscopic needles. Of the other sulphosalts present here are for example tetrahedrite, dadsonite, chalcostibite, andorite IV, bournonite, andorite VI, tetradymite, joséite-A, heteromorphite, boulangerite, jamesonite, fülöppite, krupkaite, plagionite, robinsonite, semseyite and tintinaite. Detailed and intensive mineralogical study of Dúbrava sulphosalts in the first decade of this Century culminated in the description of the mineral chovanite, named in honour of Martin Chovan, Professor at the Faculty Natural Sciences of the Comenius University in Bratislava.

DO-13 Gelnica – (cotype) marrucciite. Marrucciite became probably the mineral with the most laborious description in the world (more than 40 years). Marrucciite forms the majority of grainy aggregates, exceptionally up to 0.5 mm long grey needles. It occurs in 2 mineral parageneses: 1. zinkenite-scainiite-chalcostibite-cinnabar and 2. bournonite-boulangerite. In the surroundings of Gelnica at the spoil heaps of the vein Krížová, in local part of Cechy, a significant site of secondary copper minerals is located. Detailed data have been published up to the beginning of the 21st Century. The most significant is cornwallite, which has the most beautiful and richest aggregates in the Carpathian Mountains here. It is well developed with shiny, intense dark-green crystal shapes. Table-shaped up to 1 mm large crystals are grouped together into spherical aggregates. Atacamite forms here up to 1 mm long, dark-green, needle-shaped crystals, with a sole macroscopic presence in the whole Carpathians. The other secondary copper minerals are malachite, azurite, brochantite, antlerite, cornubite, clinoclase, posnjakite and cuprite.

DO-14 Gemerská Poloma I – occurrence of axinite and actinolite in Carpathians. Historically, the most famous and classic site of axinite minerals in the Carpathian Mountains is Gemerská Poloma. The axinite here forms brown, up to 3 cm large crystals intergrowing with amphiboles. According to the latest data, the crystals are formed of the axinite-(Mn), mostly, but part of the analysis corresponds to the axinite-(Fe). Together with the axinite-(Mn),/axinite-(Fe) there is also an actinolite, forming the long-prismatic of up to several cm long, dark-green crystals. The axinites and actinolites occur in association with apatite, garnets, magnetite, calcite, and other minerals, and are part of the Alpine paragenesis related to igneous rocks.

DO-15 Gemerská Poloma II – historic locality of Cu-minerals in Carpathians, occurrence of chrysocolla. Gemerská Poloma is a classic site of a chrysocolla, although in the collections the samples from Gemerská Poloma are very rare. It occurs in the local part Šramky, where the Cu-ore was exploited. It is dark-green and it forms up to a few centimetres fills of metalliferous veins with the characteristic collomorphic texture. It occurs along with azurite, malachite, cuprite and other copper minerals.

DO-16 Gemerská Ves – occurrence of world-famous fantom calcites. The site (quarry) is an exceptional occurrence of phantom variety calcite, which belongs among the most beautiful, at least on the European continent. The calcite forms mostly small veins in limestones, of white-pink to the reddish colour, rarely forming in the karst cavities single crystals whose size does not exceed 7 cm. In the superficial parts of the quarry are these caverns brick-red to grey-white clayey sludge aluminium filled in. The calcite crystals are mostly well developed, idiomorphous, in particular the smaller colourless crystals (up to 1 cm) use to associate into to spherical aggregates. The calcites from Gemerská Nová Ves are transparent, translucent and opaque. The opacity causes an enormous concentration of oxides of iron (± Mn) in the calcite.

DO-18 Hajnáčka – Hajnáčka is a classic site of corundum var. sapphire in the Carpathians and the occurrence was published already in 1899 by Szádeczký. The sapphire is the only true gemstone, along with the precious opal, in Slovakia. The sapphires are found primarily in sandy sediments, forming the maar fill. The sapphires are predominantly dark blue, but also pink-violet, grey, etc. They are translucent, transparent, with glass sheen. Their size is max 7 mm. The corundums contain inclusions of zircon, monazite-(Ce), spinel, pyrrhotite, and rare and euxenite-(Y) (?). A similar occurrence of the sapphires is located in the neighbourhood of the near village Gortva. Situated within PLA Cerová vrchovina.

DO-19 Herľany – occurrence of brown opals. From the site Herl'any very rare violet opals occurrence is known. The opals are predominantly violet, yellow to brown in colour. A specific feature is the banded texture. Along the joints in opals the Fe-oxides use to precipitate and sometimes form dendritic textures. For their violet-brown colour and fine texture this variety was termed a fleshy opal. Similar opals are unprecedented at least in Europe.

DO-20 Hnúšťa-Mútnik – Hnúšťa-Mútnik is the oldest and largest exploited deposit of talc in Slovakia. The talc from here has been utilised since the year 1870. Magnesite started to e exploited later, after the establishment of rotary kilns in 1909. With a few breaks its mining here along with the talc is running till today. The site is an exceptional due to occurrence of large pyrite crystals which reach up to 20 cm. They form pentagonal dodecahedral shapes in talc and are often distorted by the action of pressure or typically rounded. They are found mainly in association with chalcopyrite, pyrrhotite, arsenopyrite, sphalerite, galenite, tetrahedrite and other sulphides. There are also a number of sulphosalts (gustavite, cosalite, bismuthinite, boulangerite, cobellite) and the minerals of Se and Te (laitakarite, tsumoite, hessite, pilsenite, and tetradymite). The site is notable by the fact that there was in 1973 described the mineral from the tourmaline group, uvite. At that time it was the first occurrence of this mineral in ČSSR and one of the most notable occurrences of this mineral in the world since 1989, with up to 3 cm large radial aggregates in marble, composed of prismatic crystals. Later, the modern mineralogical analytical methods found out that this had been only calcium-rich dravite, containing a large number of inclusions of different Ca-minerals frequently (e.g., amphibole, pyroxene, titanite, apatite). Besides the omnipresent white magnesite, we can find at the deposit nice crystals of dolomite, clinochlore and Mg-silicates (sepiolite, palygorskite, etc.). At the deposit there have been described 65 minerals so far.

DO-21 Hodruša-Hámre – occurrence of minerals Ag – hodrušite, polybasite, and inesite. On this site for the first time in the world a hodrušite was described – a sulphosalt of copper and bismuth bearing the name of its finding. So far, at the Hodruša-Hámre site are the biggest and the most beautiful aggregates needles of this mineral. The hodrušite occurs here in several types. It forms a separate up to 1.4 cm long, very thin needles in quartz cavities of quartz, bronze-brown needles in hematite and often creates bronze-brown fine grain aggregates composed mainly of hodrušite and emplectite. It was found in the mine Rozália, which is also currently mined for gold. Another important mineral, which was found here, is inesite. The inesite is a pink silicate of manganese and calcium forming radial aggregates composed of up to 1.7 cm long needles. It was originally described in 1899 as a Mineral agnolite. Some quarter of a Century later it was found that a Mineral is identical to the previously described inesite. The inesite in Hodruša-Hámre was very rare and has belonged to the biggest jewels among the significant historical samples of minerals. Hodruša-Hámre, similarly to Banská Štiavnica and Vyhne, is famous for Au-Ag ores mining with dominance of Ag over Au. The most of the samples of silver ore from the Banská Štiavnica region comes from Hodruša-Hámre. Situated within PLA Štiavnické vrchy.

DO-22 Kamenec pod Vtáčnikom – occurrence of opal – hyalite, situated within PLA Ponitrie. The quarry at Kamenec pod Vtáčnikom is currently hosting the most beautiful hyalites in Slovakia. It creates here wonderful water-transparent sinter-like aggregates on the areas of several tens of cm2. Unlike the other sites in Slovakia, hyalite is typical of glass shine and sinter-like aggregates are often around 8 mm thick.

DO-23 Klenovec – Klenovec is the most classic site of the Alpine type veins in Slovakia. There occurs a paragenesis of quartz, calcite, albite, orthoclase, clinochlore, rutile, brookite, titanite, and other minerals. Klenovec is also a classic site of orthoclase – adular, which forms transparent up to 1.5 cm large opaque white crystals here, which are locally dyed by clinochlore into the green. The clinochlore here is creating the typical spherical, up to 0.5 cm large grey-green to dark-green aggregates composed of fine flakes. Such a chlorite in the past was known as a variety ripidolite. Another representative of the Alpine veins type is dark blue anatas, forming the 2 mm large crystals grown along joints of metamorphosed rocks. The characteristic minerals of the whole area are large crystals of morion (brown variety of quartz).

DO-24 Kociha – world occurrence of volborthite and phosphates (vashegyite, evansite, koninckite). The site is a location of aluminium phosphate, vashegyite in particular. The vashegyite of white colour creates here the massive fills of crevices several dozen cubic centimetres in the volume. In addition evansite and allophane are present, which form the sinter-like, translucent to opaque aggregates of white, green, and blue colours. Sometimes they are even colourless. According to the latest research the allophane greatly predominates over the evansite. Scarce copper polyvanadate – volborthite is here with the only occurrence in Slovakia. It forms up to 1 mm large sulphur-yellow sinters or leaf-like crystals, rarely up to 8 mm large spherolitic aggregates on phosphates or limonite. Similarly, an exceptional occurrence, so far the only one on our territory, has a rare iron phosphate – koninckite, with the white to slightly-pink, max. 5 mm large aggregates grown predominantly on quartz.

DO-25 Kopanice, Úškrtová dolina Valley – Ca-Mg skarn – occurrence of augite-diopside (var. fassaite) and spinel (var. pleonaste). From the historical-mineralogical point of view the fassaite skarn in Hodruša-Hámre (in the cadastre of Kopanice) is the most significant skarn in Slovakia. In the mid of the 19th Century there were discovered the large crystals (up to 5 cm) of light- to grey-green augite, var. fassaite, which constitutes the main component in skarn. The second most abundant mineral is a black spinel – the pleonaste – with octahedral up to 1.3 cm large crystals in the augite cavities. Situated within PLA Štiavnické vrchy.

DO-26 Košice – meteorite. On February 28, 2010 there was observed the meteorite impact near Košice. So far, more than 80 pieces have been found. According to provisional results, this is the H5 chondrite and contains the main minerals olivine, pyroxene, iron and troilite.

DO-27 Kremnica – Šturec – gold, antimonite, epsomite and voltaite. Kremnica is the most important ore deposit of gold in Slovakia. Strips, leaves and wires of gold form the moss-like and shrubby aggregates in quartz. Rarer forms are very tiny crystals. The gold occurs in a variety of electrum, i.e. there is a strong isomorphism between Au ↔ Ag. The samples of Kremnica gold are among the most classic samples of this mineral from Europe. Along with gold very often is stibnite. Stibnite has dozens of sites in Slovakia, but the richest druses crystallizing within the cavities occurred in Kremnica. The Kremnica stibnite is typical of frequent pseudomorphoses with chalcedony. The interesting thing is that from the Kremnica deposit very many minerals have been described (~ 111 minerals), but except the quartz, pyrite, gypsum, gold, stibnite, barite, dolomite, calcite, and on certain sections in the mine also epsomite, the other minerals are very rare and similarly, very rarely are also represented in the collections. These minerals are minerals of silver (proustite, pyrargyrite, polybasite, acantite), but also polymetallic minerals (galenite, sphalerite, chalcopyrite), also arsenopyrite, tetrahedrite, cinnabar. Secondary minerals are very scarce (e.g., vivianite). In 1867 a mineral was described here as "pettkoite", but still in the same year Tschermak concurred it with existing voltaite. The voltaite built here black, up to 6 mm large tetragonal crystals. In Kremnica thanks to a weathering of voluminous pyrite contained in quartz a large quantity of sulphates evolved. One of the largest crystals epsomite reaching up to 50 cm occur in the mines. The epsomite forms white hairy, very aesthetic, but also very fragile aggregates expanding on the walls of underground corridors. Sometimes it occurs together with a green melanterite and white hexahydrite. In recent times there have been found in old mines rich aggregates of rare secondary sulphate, klebelsbergite, which forms white to yellow, up to 3 mm large radial, rose-shaped aggregates.

DO-28 Lenartov – occurrence of historically important meteorite, found in 1814 by shepherd. The total weight of the original meteorite was 108 kg. According to the classification of meteorites it falls between the differentiated iron meteors.

DO-29 Ľubietová-Podlipa, Svätodušná – Ľubietová ranks among the most important copper deposits in Europe (Fig. 1.26). In addition, Ag, Ni, Co and Fe ores were mined here. Archaeological research shows that copper in Ľubietová was exploited already in Bronze Age, although the first written mention is from the year 1340. Ľubietová belonged among the 7 Upper Hungary mining towns. The biggest boom of mining here was in 15th and 16th centuries and lasted for almost 200 years. Later, the mining declined, and in 1863 the exploitation terminated and only prospecting continued. According to published data within 500 years of exploitation at the deposit Podlipa the output amounted to about 25,000 t of copper. On the other 2 deposits Svätodušná and Kolba, the exploitation stopped by the mid of the19th Century. However, at these two deposits the Ni-Co and silver ores were mined.

*Fig. 1.26 Malachite from Ľubietová, figure width ~ 3 cm (Photo D. Ozdín)*

DO-30 Ľubietová – Tri Vody – At the site iron ore is historically very well known. In the cavities of iron hydroxides are very distinctive and particular aesthetic of dripstone-like aggregates of white-grey to shark chalcedony. The fill of these max. 15 cm large cavities forms besides the chalcedony to brown, orange, grey, or white opal, sometimes hyalite and fine-crystalline quartz. The site was well known in the former Austria-Hungary, with written references at least since 1817, when the "small caverns forming chalcedony" in limonite noticed already A. Zipser. Similar occurrences are also on the other side of the Hill of Hrbno, Jamešná, and in nearby Poniky.

DO-31 Vyšná Šebastová – the quarry Maglovec in Vyšná Šebastová belongs to the most attractive from the mineralogical point of view in Slovakia. There occur here both aesthetically and scientifically exceptional samples of very interesting minerals. One of these minerals is chabazite-Ca, which form up to 5 cm big, grey and grey-green crystals in association with calcite, palygorskite and dolomite. The second significant mineral is relatively rare danburite, quite rare boronsilicale with up to 5 cm long prismatic crystals with glassy sheen. This predominantly white mineral creates radial and rose-shaped aggregates on xenoliths in andesites. It occurs here along with the dadolite, which was known only from Maglovec and Fintice. The danburite has so far the only site in Slovakia and one of two known in the Carpathians. Its crystals are remarkable from a pan-European perspective.

DO-32 Magurka – Magurka is historic classic gold site in Central Europe. Unlike gold ore veins originating from Tertiary volcanic activity, the Magurka gold lodes are bound to Palaeozoic granitoid rocks. The gold appears in the form of up to 1 cm large leaves, wires, lumps, and foils grown on quartz or antimonite. The gold occurs in the paragenesis with antimonite, tetrahedrite, galenite, pyrite and chalcopyrite. The most recent finding from Magura ore veins is the discovery of a mineral chovanite. It is the sulphosalt of antimony and lead, and was described in the form of needles of microscopic sizes at Malé Železné and Kľačianka. Situated within buffer zone of the NAPANT NP.

DO-33 Mlynky – despite the fact that Slovakia has a large number of sites with an abundance of ankerite, Mlynky Village is its classic site. The ankerite here forms the main fill of hydrothermal ore veins. There are known 4 generations. Usually it is white, light yellow to pale-brown and characteristic are its rhombohedral crystals crystallising into cavities, in particular, together with quartz. It occurs in association with rutile, tourmaline, barite, siderite, hematite group of minerals (var. specularite) and sulphides. Among the sulphides present are bornite, enargite, tennantite, pyrite, chalcopyrite and galenite, tetrahedrite. In addition to the ankerite the classic site has the sulphide of arsenic – enargite ($Cu_3AsS_4$), which forms up to 0.5 cm long crystals grouped into lens-like and stem-like aggregates in cellular ankerite aggregates. It is of steel-grey colour with blue-violet shading.

DO-34 Moravany nad Váhom – Striebornica – occurrence of beryl, gahnite, albite var. clevelandite, muscovite and columbite-tantalite. The Striebornica site is the largest, scientifically best explored and most differentiated Slovak pegmatite. There was found here so far, the biggest Slovak beryl, whose base measured 15 cm. Similarly, there are also present dark-green to 4 mm large crystals of gahnite. The pegmatite is approximately 8 m thick and is situated in the biotitic to two-mica granodiorites, Carboniferous in age. The main pegmatite minerals are, however, quartz, feldspars (microcline, albite + var. cleavelandite), and muscovite, creating very aesthetic crystals and aggregates in quartz. In addition to the beryl and gahnite among the accessory minerals here were described garnets (almandine to spessartine), ferrocolumbite, ferrotantalite, manganocolumbite, zircon, manganotantalite, ferrotapiolite, pyrochlore, bertrandite, fersmite, minerals of uraninite monazite-(Ce), xenotime-(s), apatite, tourmaline, pyrite and sphalerite.

DO-35 Muránska Dlhá Lúka – the site is notable for the occurrence of very aesthetic green talc and long-prismatic crystal amphiboles. These minerals occur in metamorphosed ultrabasic bodies of garnet-bearing mica-schists complex (mica-schists of the type Breziny) and biotitic mica-schists gneisses and migmatites of the Kohút zone of Veporicum. The base rock of the ultrabasic body is antigoritic serpentinite. Towards the tectonitized zones in serpentinite the presence of tremolite, talc, clinochlore, and other minerals is increasing at the expense of antigorite. The body of the serpentinite has a length of 150 – 250 m and maximum thickness of 50 m. The emergence of the talc and other minerals is related to the hydrothermal processes enriched in $CO_2$ during the regional metamorphosis of the complex. The most abundant mineral is actinolite which creates up to 10 cm long, dark-green prismatic crystals. Very frequent is also light-brown-green tremolite, forming several centimetre columnar crystals. The characteristic large petal-like talc consists of up to 20 cm thick veins in particular on the outskirts of the serpentinite of the body. Among the chlorites clinochlore forms dark-green leaf-like crystals associated with actinolite, tremolite, talc and antophyllite. In addition to the above mentioned minerals here were described antigorite, antophyllite, biotite, muscovite, serpentine, magnetite, goethite var. fuchsite, ilmenite, chromite, magnesite, and among the sulphidic minerals have been identified heazlewoodite, chalcopyrite, pyrrhotite, pentlandite, pyrite and violarite. Situated within buffer zone of the Muránska planina NP.

DO-35a Nižná Slaná – Nižná Slaná is a locality of Pb-Sb sulphosalts, in particular, at least of European importance. There occur here a paragenesis of sulphides and sulphosalts, which, unlike at the most other sites exist in the macroscopic crystal form. Boulangerite is in the form hairy-like aggregates consisting of needles up to 5 cm large, crystallizing into the cavities. They are the largest spatial aggregates of this mineral in the Carpathians. Similarly, a jamesonite constitutes here up to 5 cm long needles. The most beautiful and often times the biggest crystals had also bournonite (crystals of up to 3 cm) and millerite. For example, geokronite found here its second presence in the former ČSSR (described by Varček, 1965). There occurs here also varied paragenesis of nickel minerals such as gersdorffite, violarite, siegenite, ullmannite, etc. Nižná Slaná is historically very well known by Hg ores extraction. From this paragenesis here were described cinnabar, up to 4 mm large droplets of mercury, amalgams of Hg (schachnerite?), and metacinnabar. In the Nižná Slaná oxidation zone there were found very rich aggregates of evansite, belonging to the most beautiful in Europe.

DO-36 Nová Baňa – in 1874, at the time of its discovery the pharmacosiderite from Nová Baňa was only the third occurrence of this mineral in Europe (fourth in the world). Great importance was, moreover, that this was also the first appearance in Austria-Hungary, because it built up very nice, up to 4 mm long, dark-green hexahedral and octahedral crystals. Because of its quality (large crystals, often with a light sheen along the joints of decomposed andesite) it quickly spread to the majority of leading

European collections, in which it has to this day, the honourable place and great historical value. The latest study found that it occurs in particular paragenesis with scorodite.

DO-37 Novoveská Huta – the site is notable for the occurrence of secondary copper minerals, in particular of tyrolite, which creates one of the most beautiful aggregates here. The tyrolite occurs in rock joints in the form of fan-shaped or radial green aggregates with pearl sheen. The size of individual flakes of the tyrolite reaches up to 2 cm. It occurs together with olivenite, clinoclase, strašimirite, cornwallite, chalcophyllite and other secondary copper minerals. The most important and probably the best known site of cornwallite in Slovakia is the spoil heap of the Bartolomej Gallery. The pale-green strašimirite finds its world site here, probably the second one in the world. The largest and most beautiful aggregates of the tyrolite remained at the settlement Vojtechová. At the soil heap of the Peter and Pavol Adit there is probably the most significant occurrence of chrysocole in Slovakia. This dark-green to blue-green silicate has a large number of colourful varieties.

DO-39 Bratislava – NL Rösslerov lom (quarry) – pegmatites in the Rössler Quarry are a typical representative of granite pegmatite in the Western Carpathians. In Bratislava and its vicinity there is the largest concentration of pegmatites in Slovakia and the best evolved are the pegmatites in the Rössler Quarry. In the pegmatite mine are very rare grey quartz crystals, also the largest Carpathian annites (dark mica, biotite), reaching a length of up to 40 cm. There occur up to several cm large crystals of muscovite, garnets, and in particular feldspars. Lately there have been discovered macroscopic beryl and microscopic phenacite and bertrandite. From this quarry described professor Kenngott in 1853 a new mineral – eucamptite, at that time the only type of mineral from western part of Slovakia. Later it was found that this was chloritized biotite. Unlike the annite, which is black, the eucamptite is dark-green or green-black. In addition to the above mentioned minerals in pegmatites are also accessory minerals, for example zircon, apatite, monazite-(Ce), allanite-(Ce) and iron tourmaline (?).

DO-40 Oravská Magura – occurrence of meteorite discovered in 1840. A large number of meteorites were found on the surface in the vicinity of Slanická Osada in the years 1830 – 1840. The official date of the discovery was 1840. Originally, the fragments of ”the iron ore” were processed to various commercial items (hoes, shovels, etc.), until Haidinger noticed (1844) their extraterrestrial origin. So far, there have been preserved in the museums about 150 kg of Magura meteorite. According to the classification of meteorites it is the iron meteorite (octahedrite) of the IAB-MG group. For the first time in the world there were described from this meteorite 2 new minerals iron and nickel carbide – cohenite and schreibersite – iron and nickel phosphides. Both are quite abundant minerals of iron meteorites. Later they were described the diamonds in the Magura meteorite. Yet this is the only occurrence of this mineral in Slovakia. The meteorite is made up of mainly iron (= kamacite), tenite, less troilite, enstatite, chromite, graphite and rarely lawrencite and other minerals. Quite exceptional is the occurrence of secondary iron-phosphate vivianite. Sometimes the iron and nickel minerals form characteristic Widmanstätten`s images.

DO-42 Pernek – Krížnica – occurrence of schafarzikite and brandholzite. Sb-deposit Pernek is so far the only mineralogical site in West Slovakia, where it was described the type mineral. In 1921 Krenner discovered here Fe-Sb oxide schafarzikite. The schafarzikite forms mostly very small brownish black or short-prismatic crystals or sun-shaped aggregates in association with kermesite, antimonite, sénarmontite and valentinite. Since the first description, for more than 80 years, no other occurrence was known from the site and only in 2002 and in later years the mineralogists have managed to find a sufficient number of samples for a detailed mineralogical research. During the research there was identified a very rare Mg-Sb oxide brandholzite. After the type site, it was the second appearance in the world. In Pernek there are 2 types of brandholzite. The majority type forms very small grey crystals with hexagonal habit. Very rare are table-shaped isolated transparent crystals up to 2 mm in size. The brandholzite occurs in association with sulphur compounds sénarmontite, anhydrite, aragonite and minerals from the pyrochlore group. Situated within PLA Malé Karpaty.

DO-43 Pezinok – Kolársky vrch Hill – Sb minerals – One of the most important sites of kermesite in the world is Pezinok. For decades, the most beautiful and largest samples of this mineral were found here. The kermesite here creates very aesthetic radial aggregates or sun-shaped aggregates of red wine colour on joints. The needles of kermesite achieve the maximum length of 12 cm. Valentinite aggregates are one of the most beautiful in Europe. They occur in the form of white-grey sun-shaped aggregates, which reach the size up to 4 cm. It occurs together with gudmundite, antimonite, kermesite. Chapmanite occurs in the form of grey-green to yellow-green powdered aggregates in the joints of rocks and ore veins. At the time of the discovery, it was one of the first sites of this mineral in the world and yet is the only site in the Carpathians. From Pezinok, the mineral schwertmannite was also first described in Slovakia, which is a component of ferrous ochres. Situated within PLA Malé Karpaty.

DO-44 Pezinok – Rybníček – occurrence of goldmanite. Pezinok-Rybníček is a world site of goldmanite. The goldmanite is a cubic mineral from the group of garnet, containing vanadium. It forms maximum 3 mm large crystals and aggregates up to 0.5 cm. usually it is dark-green, some smaller aggregates are grass-green. Excellence of the Pezinok goldmanite lies also in its chemical composition, which is unique. It contains a high quantity of Cr and is the only occurrence of this variety in the world (var. goldmanite-Cr). In recent years, there were discovered at the site Rybníček two important occurrences of minerals of the epidote group. They occur only in the microscopic form, in association with other silicates.

Dissakisite-(La) from here has its second and muchinite its third site in the world. Situated within PLA Malé Karpaty.

DO-45 Podrečany – occurrence of aragonite. At the magnesite deposit Podrečany the exploitation was initiated in 1952. The deposit is mineralogically very poor; however, there have been found here one of the most beautiful and most valuable crystal druses of aragonite in the world. Here are the prismatic aragonite white crystals, transparent to translucent, with glass sheen. The crystals, measuring up to 38 cm fill up the cavities in the limonite ochre in magnesite and dolomite. The crystals are often grouped into very aesthetic rose-like aggregates. Despite the fact that the aragonites of Podrečany are known for only a few decades, they have become a jewel of many museums and private collections.

DO-46 Poruba pod Vihorlatom – occurrence of telurides (teluronevskite, vihorlatite). Situated within PLA Vihorlat. Teluronevskite and vihorlatite are type-minerals and were first described from the metasomatic bodies with Bi-Te-Se mineralization in Poruba pod Vihorlatom. Both minerals are dark grey to black and form fine-grained aggregates and petal-shaped crystals. Their size exceeds 0.5 cm. According to the latest scientific results the two minerals cannot be distinguished macroscopically, similarly to additional telurides-Bi occurring widely at this site.

DO-47 Povrazník – occurrence of wood opal. In the broader surroundings of Ľubietová on the northern slopes of Poľana for at least 200 years occurrences of woody opals are already known. The most characteristic site of the last decades is Povrazník. There are quite abundant, especially on fields and meadows. The collectors often dig out them from depths of up to 4 m. The opalized stems of trees reach several ms in length. In addition, there are the typical wood opals of orange, white, greyscale, brown and black colours. Green opals are rare. Some stems of trees tend to be pretty much the only silicified with a little amount of opal. From the more transparent parts of orange woody opals cabochons are produced, which are quite rare nowadays for wooden opals. The wooden opals of orange colour from the wider surroundings of Ľubietová belong to the classical sites of this mineral in Europe.

DO-50 Revúca – occurrence of rutile and quartz (var. smoky quartz). Revúca and its surroundings are the world-known occurrence of rutile. According to literary sources the type site of rutile is Revúca, however with its designation it is very difficult, because at the turn of the 18$^{th}$ and 19$^{th}$ Century numerous mineralogists paid a visit to this site and from this mineral titanium was later isolated as the new element in the periodic table, Since the rutile have never been in greater amounts, its surface occurrences were quickly worked out. The rutile forms prismatic brown-red crystals, with vertical grooves, in quartz or mica-schists. The name of rutile was introduced several tens of years after the discovery of rutile in Revúca, from where it was known as ‘basalt ruby’.

DO-51 Rožňava – occurrence of siderite, albite, bournonite, malachite, azurite, barite var. wolnyne. From a historical point barite – wolnyne variety belongs to mineralogical specialties in Slovakia. Although this is “only” a variety. For approximately 100 years it drew the attention of leading European mineralogists and is represented in all major European museums. The classic site of wolnyne in Slovakia is the gossan ore Mária-Alojzia, at the deposit Mária-baňa. This site was in the past often referred to as “Betlér” (= Betliar), but the veins are in the cadastre of Rožňava, recently. The wolnyne here is transparent to translucent, colourless, glossy and often heavily grooved, of pale-brown, red-wine, and yellow or bluish crystals, which are typically of thin-table-shaped, short-columnar or columnar habit. The wolnyne has a great variability of crystal shapes and 28 of them were described here. The second classical mineral of Rožňava is albite, which has the max. 3 cm large, very aesthetic, colourless to white crystals with glass sheen, grown on siderite. It is part of the Alpine paragenesis at the deposit similar to apatite and rutile.

DO-52 Rudňany – occurrence of cinnabarite, barite, arsenopyrite, siderite, mercury. In the mid-19$^{th}$ century in Rudňany the Hg ores started to be exploited. Rudňany belong to the largest siderite deposit in Europe. The main ore is siderite, which was the subject of mining; Cu-ore and barite were mined, as well. The site is little known in the world. There are several veins of kilometre lengths and minerals of large dimensions. For example, there were described here the largest barite crystals in the Carpathians, which amounted to 1 m. The site is also known for the largest cinnabar crystals in the Carpathians, which attained 6 mm. Similarly the drops of mercury were close to 1 cm within the siderite-cinnabar ores. Large and aesthetically interesting crystals were formed by quartz (rarely in sceptre-like habitus), siderite, ankerite, arsenopyrite, etc.

DO-53 Rumanová – occurrence of meteorite, ordinary chondrite of the type H5, found in 1994. The only piece of the meteorite was found in August in the year 1994 NNW of Rumanová and had a mass of 4.3 kg and size 18.5 x 14-0 x 12.5 cm. It is intense weathered in the iron oxide and its density is 3.53 g/cm$^3$. The meteorite is classified among the ordinary chondrites of the type H5, the degree of weathering and metamorphoses W2 and S3, respectively. The age of the meteorite was determined to approximately 4.3 billion years and it impacted the ground about 12,000 years ago. Among the minerals there have been described, in particular iron (kamacite), pyroxene, magnetite, troilite, olivines, tenite, chlorapatite and whitlockite.

DO-54 Smolník – secondary minerals (szomolnokite, kornelite, rhomboclase). Smolník is an exceptional site in Slovakia, because there have been described up to three new minerals. All three are secondary sulphates of iron. In the spoil heaps there are other iron sulphates as in the mines. Therefore, the samples of these sulphates have been merely preserved. Their rare occurrence in the mines was probably influenced by frequent fires, and maybe by high temperature arising from the decomposition of pyrite (~ 50 °C). Kornelite consisted of pale-red to purple spherical aggregates of radial organised needles and fibres of silk lustre. Rhomboclase occur in the form of white and transparent flakes. Szomolnokite, named after the locality (Hungarian name of Smolník, Szomolnok) forms bright yellow blankets, consisting of small needles. The Hungarian National Museum holds kornelite in its collections.

DO-55 Stará Kremnička – Jelšový potok – occurrence of limnoquartzite. Limnosilicites in the vicinity of Stará Kremnička are historically best known occurrence of such mineraloids in Slovakia. Already in prehistoric times they were used for the production of various cutting and fissile tools, later in the Medieval Ages for the production of mill stones. Their emergence is linked with the Tertiary volcanic activity and its products – $SiO_2$ solutions. The limnosilicites often contain various organogenic residues, such as different algae, freshwater gastropods, and molluscs. The limnosilicites have a variety of colours (red, white, black, grey, bluish, etc) and contain more than 98.5% $SiO_2$. They are made up primarily of quartz, but also of chalcedony and opal-CT.

DO-56 Špania Dolina – occurrence of devilline, aragonite and celestite. Špania Dolina belongs to the historically most important copper deposits at least in Europe. The mining of copper started here already in the younger Stone Age. For many centuries copper sulphides were extracted (minerals of tetrahedrite and chalcopyrite) and cementation copper. The most famous mineral was devilline. The devilline was described as a new mineral by Brezina in 1879, and was named after the German name of Špania Dolina (Herrengrund) herrengrundite. Later it was found that the mineral is identical to the previously described devilline of the English Cornwall. However, the best samples of the mineral were in Špania Dolina, and are true jewels of many leading science museums. A typical devilline from Špania Dolina forms a blue-green table-shaped crystals which are grouped into balls of about 1 cm in size. Such balls are on the surface of deep green colour. Another very important mineral is celestine, which forms up to 1.5 cm large crystals of sky-blue colour on white calcite. Mostly it is transparent with strong glass sheen. Its very aesthetic samples belonged among the most beautiful in Europe in the 19th Century. The third significant mineral is aragonite which was already described by Haidinger in the year 1827. The aragonite forms columnar, pseudo-hexagonal, white to yellow, up to 10 cm large crystals which are grouped in very aesthetic aggregates. The largest druse of aragonite, almost 6 m large, was found in 1840 and part of it is exposed in the Natural Museum in Vienna and belongs to the most beautiful samples of aragonite in Europe. From Špania Dolina, there are so far known about 75 minerals, in particular secondary minerals of Cu. The richest Slovak sample of chalcophyllite (crystals into 0.5 cm) and azurite and also one of the two most important sites of malachite in Slovakia is/were from here. Situated within buffer zone of the NAPANT NP.

DO-57 Tajov – occurrence of realgar and auripigment (Fig. 1.27). Tajov is the most famous and historically most significant occurrence of arsenic in Slovakia. The arsenic was exploited here already in the Middle Ages. Auripigment, the main and most important mineral at the site was described in the year 1802. The auripigment

*Fig. 1.27 Tajov, realgar (Photo M. Števko)*

forms golden yellow crystals (usually up to 3 mm) in the joints of limestones and in Tajov its aggregates are the largest and most beautiful in Slovakia. It is associated with red realgar, which forms very aesthetic, max. 5 mm large prismatic crystals in calcite. Together with the aforementioned minerals the site is known for occurrence of arsenolite, which forms mostly very minor, white-grey, skeletal, octahedral crystals. At the site cerussite was described occurring in the form of up to 1 cm large shrubby aggregates on calcite

DO-58 Varín – occurrence of natural asphalt, abandoned dolomite quarry. Extraction of asphalt here ran in particular in the first half of the 20th Century and for example, in 1929 the exploitation amounted to 1,783 t asphalt. The deposit has the thickness of up to 45 m. Natural asphalt occurs here mainly in Middle-Triassic dolomitic limestones and the dolomites, but extends to the Palaeogene (Lutetian) sandstones. The asphalt is very clean, almost 100%. The content of the asphalt deposit was max. 40%, with an average of 6%. The asphalt probably originated from polymerization of oil at low temperatures.

DO-59 Veľké Borové – occurrence of meteorite, an ordinary chondrite of group L5, with recorded impact on 1895. Meteorite of Veľké Borové is officially enlisted as “Nagy Borové” meteorite. It impacted the Earth on 9/5/1895. The details on this meteorite are quite modest and the meteorite is little scientifically reviewed. According the existing knowledge it is an ordinary chondrite of group L5. It is composed mainly of olivine and pyroxenes, feldspars, and its density is 3.37 g/cm$^3$. It was found only in one piece, which, according to the sum of the masses so far known samples of this meteorite in museums had originally weighed 6.149 kg. Today, the largest part of the meteorite is deposited in the collection of meteorites in Vienna in Austria and has a mass of 5.88 kg and dimensions 20x13x13 cm.

DO-60 Vígľašská Huta-Kalinka – Kalinka – occurrence of hauerite and sulphur. Our most popular historical deposit of sulphur, with the first exploitation work already in the year 1810. In 1823 Zipser started to extract sulphur here.

The site is the world occurrence of the mineral hauerite, which forms here light grey to black, max. 2 cm large crystals in association with sulphur, anhydrite and pyrite. The hauerite forms usually octahedrons, less are smaller planes of hexahedron. It occurs also in the form of radial, spherical and granular aggregates. On the road from the village to the site just behind the village is a small quarry (on the left side). It is the site of the most beautiful and largest crystals and aggregates of wavellite in Slovakia. The wavellite forms here the light-yellow radial aggregates, grouped into 4 mm large beads. Along with the wavellite you can find here blue-violet dumortierite and up to 0.5 cm large crystals of pyrite.

DO-61 Vyšná Boca – Paurovská – occurrence of Cu-Pb-Bi sulphosalts and gold. In the years 1994 – 1996 mineralogical research was carried out on the spoil heaps of siderite mineralisation in the neighbourhood of Vyšná Boca. At the Stará Paurovská Gallery there were discovered relatively rare sulphosalts (gladite and krupkaite), but also bismuthinite, occurring in a very nice up to several cm large needle-shaped aggregates in grey-white quartz. Previously, however, an article on sulphosalts from this area was published, which described also other, more rare Cu-Pb-Bi sulphosalts (e.g. friedrichite, lindströmite). Whereas the heap is located by the main road, it was quickly discovered by collectors and in a short time the samples of sulphosalts have expanded rapidly between private collectors in Slovakia, then in Bohemia and later to the whole world. Situated within buffer zone of the NAPANT NP.

DO-62 Zemplín – occurrence of „coral jasper". Zemplín is one of the most famous sites of jasper in Slovakia. Unlike other Slovak sites, especially in the broader surroundings of Banská Štiavnica, where are located the most monotonous wine-coloured, rarely dark-green jaspers, the Zemplín jaspers are of much more colourful patterns. Most of the jaspers are also red, brick-red or brown-red, but the veins are intersected with tiny veins of chalcedony and agate, which create a characteristic coral-like appearance. Therefore, this variety is called coral jasper. Pieces of jasper found on fields may attain a few kg and sometimes have a banded structure. In the cavities in jasper quartzes crystallized (var. crystal); rarely amethyst is present of mostly brighter shades.

DO-63 Železník – Al phosphates (evansite, vashegyite, variscite) + pyrolusite. The deposit Železník was exploited already in Roman times. Mineralogically the site is world-wide significant due to first descriptions of 2 minerals, aluminium phosphates, evansite and vashegyite. It is historically the most important site of phosphates-Al not only in Slovakia but also in the Carpathian Mountains and one the most important in the world. The evansite forms usually white to bluish white sinter-like aggregates; the vashegyite use to be compact. Both are components of the oxidation zone of the deposit, where they occur together with goethite, anhydrite, aragonite, variscite and manganite. The latter two minerals mentioned find here also their most important occurrence in Slovakia. All-in-all at the deposit Železník nearly 60 minerals were described.

DO-64 Župkov – occurrence of tetradymite. Tetradymite belongs to the oldest Slovak type minerals. Haidinger was the first who described it in 1831. It was present in a small gallery, from which it was exploited already in the 19$^{th}$ Century for commercial purposes. Then it followed to many private collections. The Župkov tetradymite forms max. 5 mm large dark-grey crystals. At places it consists of dark-grey leaf-like crystals with intense metallic sheen. The tetradymite occurs within intensely silicified zone in andesite associated with fluorapatite and bismuthium. The tetradymite crystals use to be overgrown by yellow oxide of tellurium – montanite.

DO-65 Bratislava – Okánikova ulica – amphibols (diorite body). The site is an exceptional occurrence of diorite in Slovakia. The diorite from "the Hill of Calvary" is noticed in literary sources already in the early beginning of the 19$^{th}$ Century and thus belongs to the first described rocks from our territory. Later it is mentioned also in the first topographic-mineralogical guide to Hungarian Kingdom, written as a groundbreaking work by Christian Andreas Zipser in 1817. Even the descriptions of amphiboles from this diorite are probably the oldest records of amphibole from our territory. The porphyric diorite is predominantly of dark green colour and is frequently intersected by thin aplite veins. According to the latest data its Hercynian age is basically consistent with the encompassing granitoid rocks. The diorite matrix is made up of mainly fine-grained pale albite, epidote minerals group and quartz. The phenocrysts are made up of various minerals of amphibole group, with dominance of Mg over Fe. Among the accessory minerals present are allanite-(Ce), titanite, apatite, zircon, and pyrite.

### 1.4.10 Geomorphological sites

The complexity of the geological structure of the Western Carpathians is also reflected in the great variety of geomorphological, hydrogeological and engineering geological conditions. Many sites from the above-mentioned "basic geological topics" (Fig. 1.28) are also interesting from the point of view of "applied geological sciences"; some of them in terms of geomorphology (caves, travertine holes, erosive relief), hydrogeology (springs, geyser, lake) or engineering geology in the first place.

P-01 NNL Demänovské jaskyne caves* – the length is 8,126 m with elevation distance of 120 m (Fig. 1.29). The lower oval, river-modelled passages of the cave represent four horizontal development levels (Marble Riverbed, Loamy Passage, Dry Passage, Ground Floor, Král's Gallery). They are in places widened by collapses (Great and Spouting Dome, Pink Hall, Hell Dome). Situated within NAPANT NP.

P-02 NNL Belianska jaskyňa Cave – the cave length is 3,640 m with elevation range of 160 m. The origin of the cave was conditioned by stratification, less the tectonic faults, along which the waters penetrated and flowed into deeper parts of the underground. The primary caverns were entirely filled with water, which except for corrosion worked by slow pressure flow. Large cupolas and smaller

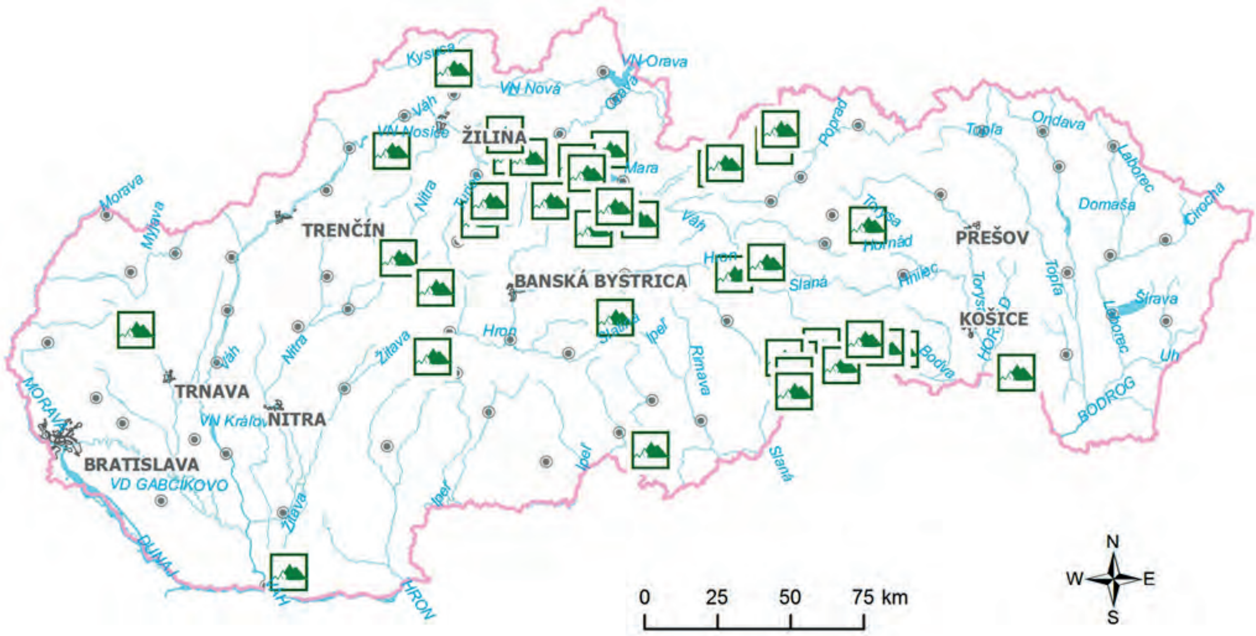


*Fig. 1.28 Distribution of the geomorphological sites in the Slovak territory*

*Fig. 1.29 Jaskyňa Slobody, Cave of Liberty, Čarovné siene – Miraculous Halls (Photo P. Staník)*

kettle hollows were modelled on the ceilings. Situated within TANAP NP.

P-03 NNL Dobšinská ľadová jaskyňa – Ice Cave* – the Dobšinská Ice Cave belongs among the most important ice caves in the world. Since 2000 it is inscribed on the world heritage list. As compared with known high-mountain ice caves Eisriesenwelt and Dachstein-Rieseneishöhle in Austrian Alps or with the Romanian Scărişoara Cave in Bihor Mts., which has the glaciated part at elevations of 1,100 to 1,120 m a.s.l., the monumental glaciation of the Dobšinská Ice Cave persists for thousands of years at elevations only 920 to 950 m. Situated within Slovenský raj NP.

P-04 NNL Zvonivá jama* – karst abyss 100.5 m deep, situated within Slovenský kras (Slovak Karst) NP. It is located in the central part of the Plešivská Plateau, called Mesačná krajina (Moon Country), with a surface divided by a number of dolines. Inside one of them, there is the entrance to the corrosion-collapse abyss 100.5 m deep. It is formed in the Mesozoic Middle Triassic pale Wetterstein limestones of the Silica Nappe. Situated within Slovenský kras NP.

P-05 Brázda – karst abyss with the depth of 181 m, situated within Slovenský kras (Slovak Karst) NP. This corrosion fissure abyss, with several vertical steps or horizons is formed in Mesozoic Middle Triassic pale Wetterstein limestones of the Silica Nappe. Several cave walls are decorated by remarkable peas formed flowstone protrusions. Situated within Slovenský kras NP.

P-07 NNL Jaskyňa Domica Cave* – Domica Cave is connected with the Čertova diera Cave – and together they reach the length of 5,358 m, listed on the World Heritage List since 1995. The cave is formed in the Middle Triassic pale Wetterstein limestones of the Silica Nappe along the tectonic faults by corrosive and erosive activities of Styx and Domický Brook and smaller underground tributaries draining waters mainly from the non-karst part of the basin. Horizontal oval passages with ceiling troughs dominate the cave. The passages are in places widened into domes and halls. The passage of Styx gains a character of underground canyon with meanders. Situated within Slovenský kras NP.

P-08 NNL Jaskyňa Snežná diera (Snow Hole Cave)*. Situated on the Horný vrch Plateau, westerly from the upper part of the Zádielska Gorge. Typical, gravitationally widened crevasse cave reaches the length of 100 m and depth of 25 m. The cave has pea flowstone decoration in some places. There are smaller dripstones and layers of ice fill in the western part of the cave. The ice partially melts in summer months, yet it persists all year round. Situated within Slovenský kras NP.

P-09 NNL Silická ľadnica jaskyňa Cave* – the cave is 1,100 m long and 110 m deep. The entrance of this corrosive-collapse abyss is at elevation of 503 m a.s.l. Breaking down the connection with lower parts formed a close depressive space with cumulation of cold air and formation of ice. It is the lowest lying classical ice cave up to the 50° of the northern latitude temperate climatic zone. Situated within Slovenský kras NP.

P-10 NNL Krásnohorská jaskyňa Cave* – the total length of the cave is 1,355 m. It is known mainly by the mighty dripstone Kvapeľ rožňavských jaskyniarov reaching the height of 32.6 m (among the largest in the world), as well as by mysterious underground riverbed. The cave is opened through an artificial adit with opening near the Buzgó spring lying at 316 m a.s.l. Situated within Slovenský kras NP.

P-11 NNL Hrušovská jaskyňa Cave* – the cave discovered in 1978. The spring cave is formed by underground stream in the Mesozoic Middle Triassic pale Wetterstein Limestones of the Silica Nappe in three developmental levels. The cave consists of mainly river modelled passages, which are in places widened into smaller halls and bigger collapse domes. The cave is 780 m long. Situated within Slovenský kras NP.

P-12 NNL Obrovská priepasť (Immense Abyss)*. This corrosive-fault abyss is 100 m deep. It is formed in the Mesozoic Middle Triassic pale Wetterstein Limestones of the Silica Nappe. The main shaft under the surface depression widens in bottle shape downwards into an underground dome. Situated within Slovenský kras NP.

P-13 NNL Jaskyňa Snežná diera (Snow Cave)* – gravitationally widened crevasse cave with a length of 100 m and depth of 25 m. Typical, gravitationally widened crevasse cave reaches the length of 100 m and depth of 25 m. The roof is closed by collapsed boulders. Situated within Slovenský kras NP.

P-14 NNL Kunia priepasť (Marten Abyss)* – the cave reaches the length of 813 m and depth of 203 m. It is formed in the Mesozoic Middle Triassic pale Wetterstein Limestones of the Silica Nappe. The cave reaches the length of 813 m and depth of 203 m. Situated within Slovenský kras NP.

P-15 NNL Jaskyňa Skalistého potoka (Stony Brook Cave)* – The Skalistý potok Cave is the longest and deepest cave of the Jasovská Plateau and whole Slovak Karst. It is the most important discovery of speleodivers in Slovakia, who have gradually overcome 22 water siphons. Situated within Slovenský kras NP.

P-16 NNL Drienovská jaskyňa Cave* – the length is 1,348 m and vertical span 85 m. As much as 13 bat species were recorded in the winter season here. It is a spring river cave formed in the Mesozoic Midlle Triassic pale Wetterstein Limestones of the Silica Nappe, somewhere also in breccia or limestone conglomerates. The underground stream flows through the lower parts of the cave forming lakes, cascades and smaller waterfalls in some places. Situated within Slovenský kras NP.

P-19 NL Vojtovský prameň (Vojty Spring) – methane emissions – mofette. Prameň Vojty – spring Vojty – is a mofetta with a methane and hydrogen sulphide discharge. This is quite rare phenomenon in the Western Carpathians – generally the term mofette is related to a volcanic activity.

P-20 NL Rojkovská Travertínová kopa (Rojkov Travertine Mound) – travertine mound and mofette. The spring Rojkov – Lake is located on the southern outskirts of the village, on the slope. The spring is also known as "Rojkov Travertine Mound". The water from the spring has created a travertine mound with a crater of circular shape with a diameter of about 10 m.

P-21 NL Bešeňovské travertíny (Bešeňová Travertines) – travertine mounds. Bešeňová travertines represent the abandoned quarry, located a few hundred metres north of the village, but also several travertine cascade covering the area of 3.18 hectares. Down the cascade run constantly streams of mineral water, lending the stone cascades, loafs, and terraces a wonderful living shine.

P-22 NNR Meandre Hrona – Hron River Meanders. The site is a classic example of meandering river. The meanders have low perpetually modelled banks by changing direction of the stream flow. Many of the meanders are today turned to oxbows without water, overgrown with vegetation. Situated within the buffer zone of NAPANT NP.

P-27 Izra – lake dammed by rockslide. Izra is a lake in the Slanské vrchy Mts., in the geomorphologic subunit Milič, on the southeastern foot of Veľký Milič (895.0 m a.s.l.). The lake was formed by the landslide which dammed one of the tributaries of Izra Brook – Malá Izra Creek. Later on, this natural dam was reshaped which resulted in enlargement of the lake area and its depth.

P-28 NNR Dolina Hlboče Valley – karst forms situated within within the PLA Malé Karpaty Mts. The Hlboča Valley is located in the northern part of the Malé Karpaty Mts., near the village Smolenice. The easternmost block of the Vysoká nappe, which is separated by a NS Jahodník fault, has a less tectonically disturbed structure and shows a higher degree of karstification. The Hlboča Valley is a typical half-blind karst valley with the only small waterfall in the mountain range (currently mostly dried up). The steep slopes of the valley up to 100 m high contain exposures of Jurassic crinoid limestones (Lotharingian to Bathian), Bathian-Oxfordian shales and silicates rich in radiolarians. Overlying Oxfordian micritic limestones contain characteristic fiber microfacies. This is followed by Czorsztyn Limestone, which is of the "Rosso Ammonitico marneux" type and represents a shelf facies. It contains the Kimeridgian microfossils of the Moluccana zone, the Lower Tithonian zones of the Malmica, Tithonica and Pulla, the Middle Tithonian zones of Chitinoidella, as well as the Upper Tithonian zones of *Praetintinnopsella* and *Crassicollaria* (Michalík et al., 1990).

P-29 NNR Manínska úžina (Manín Gorge) – karst forms, palaeontology. In the epigenetic valley defile, we can see the Mesozoic (Lower Jurassic to Lower Cretaceous) sequences of the Manín Unit. Specific feature are numerous kettleholes along the incision. Situated within Strážovské vrchy PLA.

P-30 NR Kostelecká tiesňava (Kostelec Gorge) – karst and erosion forms. One of the biggest overhangs of the Western Carpathians can be found in the Kostelec Gorge. The pseudokarstic overhang is called ”The Kostolec Cathedral“ or also ”The Roof of Slovakia“. Underneath dominate majestic scree cones. Situated within Strážovské vrchy PLA.

P-31 Chabenec – slope deformation of sackungen type, NNR Skalka, NP NAPANT. The marked features of the Chabenec Hill are several antislope scarps on the south-eastern slope of the hill, parallel to the Lomnistá Valley (1,300 m a.s.l.). The Chabenec deformation is a compound of the series of similar deformations developed between the Chopok and Prašivá Hills (their distance is 25.2 km) within the granitoid massifs forming the main ridge of the Low Tatras Mts. Situated within NAPANT NP.

P-32 NNR Kvačianska dolina Valley – karst forms. The Kvačany Canyon belongs to the most beautiful and very popular canyons in the Chočské Vrchy Mts., together with Prosiek Canyon nearby. Three little streams (Borovianka, Hutianka a Ráztočianka) are joining, creating Kvačianka Brook with enough water for two watermills – the upper one “Gajdošovský” and the lower one “Brunčiakovský”. Their technology is still functional. Nowadays Oblazy belongs to Slovaks culture and technical monuments.

P-33 NNR Ohnište – natural window in Mesozoic limestone. Ohnište is an important mountain massif made of Gutenstein Limestone and Dolomite of Hronicum. The top part of the hill – a karst plateau – is typical of numerous abysses and sinkholes. Distinct feature are southern and southwestern cliffs on the flank of the hill, reaching several hundreds meters in length, separatefd from each other by narrow benches. The hill is split into two peaks – below the higher on is 125 m deep Veľká ľadová priepasť (Huge Ice Abyss) and not far from the peak an opening in the rock mass – Okno (Stone gate). There are two openings on the surface. The upper one at 1,529 m, and the lower one at elevation of 1,515 m above the sea. Ice coatings from several cm to 15 – 20 cm are on the walls in the entrance 89 m deep abyss. Situated within NAPANT NP.

P-34 NL Šútovská epigenéza (Šútovo epigenesis) – river erosion. It is an unique morphological form, two-fold epigenetic incision of the River Váh and Šútovský potok Creek originating by the end of the Tertiary. The rock environment is made of the Wetterstein Dolomite.

P-35 NNR Mlynická dolina Valley – glacial morphology, NP TANAP. Due to the closeness of the Štrbské pleso Lake, this 6 km long valley belongs among the most-frequently visited, mainly owing to the Skok Waterfall in its middle part. The Mlynický potok stream flows through the valley springing from the Nižné Kozie pleso tarn. It represents a tributary of the Poprad River. The Solisko Ridge, bordering the valley from the west, represents the European divine between the Black Sea and the Baltic Sea.

P-36 NNR Mengusovská dolina Valley – glacial morphology, NP TANAP. This extended glacial valley has a triangular shape, which base “recumbends” on the main Tatry ridge and the triangle peak targets south towards the foothill. The valley terminates by several kettles – in the eastern side there is the Zlomiská Valley with the smaller valleys Dračia and Rumanova, being not accessible for the tourists.

P-37 NL Travertíny na Lúčkach – travertine mounds at the site Lúčky. In the Spa Lúčky, which is located upon the Prosiek Fault dividing Chočské vrchy Mts. and Liptovská kotlina Basin, several sources with temperature of 17 – 33 °C surge out, with a total yield of about 30 l $s^{-1}$. During the water ascent to the surface, the changes occur like reducing the pressure, cooling down, gas escape. Therefore, the precipitation of calcium carbonate deposits takes place at the surface with the additional influence of plants and animals. The plant debris underwent decomposition; however their casts remained, giving the Lúčky travertine its characteristic appearance.

P-44 Handlovský zosun – Handlová landslide – the most famous landslide in Slovakia, dated December 1960/May 1961. The momentum for systematic research in slope deformations in the former Czechoslovakia was reached by activation of catastrophic landslide in the town of Handlová, which in 1960/1961 destroyed 150 housing units, water pipeline, state road, electric line. The sliding volumes equalled to 20 mil. $m^3$.

P-45 Jazierske travertíny (Jazierce travertines) – travertine and foamstone mounds. Right bank of the Trlenská dolina Valley and the left bank of the Revúca Brook are covered by the travertines (strongly recrystallized and karstified), which were dated at the boundary between the Middle and Late Pleistocene (Riss-Würm). The younger Holocene to recent (current) calcareous deposits are the foam sinters and they originated from the cold springs and their flows. Situated within the buffer zone of Veľká Fatra NP.

P-47 PA Meandre Kamenistého potoka – Kamenistý potok Creek Meanders. The Kamenistý potok Creek flows down the picturesque 25 km long Kamenistá dolina Valley. Its upper stream is protected in the form of “Protected Areal” – meandre Kamenistého potoka (meanders of the Kamenistý potok Creek) reaching a length of 2.5 km. Situated within Poľana PLA.

P-48 NNR Vrátna dolina Valley – debris flows, NP Malá Fatra (Fig. 1.30). Huge debris flows on July 21, 2014, triggered in the Vrátna dolina Valley by a rainfall anomaly, exceeding in volume 100,000 $m^3$.

*Fig. 1.30 One of the two main debris flows in the Vrátna dolina Valley (Photo P. Liščák)*

### 1.4.11 Hydrogeological localities

Slovakia is very rich in springs of natural waters (Fig. 1.31). The largest yields are usually bound to karst springs (Malík et al., 2015), but the largest quantities of the groundwater are located in the Danube Lowland, in it part termed as Žitný ostrov ("Rye Island").

In Slovakia, 1,782 natural mineral water sources have been registered, some of them are utilised in balneology (Božíková & Bodiš, 2016). The most important spas in Slovakia are listed among the important hydrogeological sites.

The most important waterfalls, protected as National Nature Monuments, as well as natural lakes of karst, landslide and glacial origin are also included in the database. Sites of specific character are some exploratory boreholes or Turček Water Pipeline.

HG-01 NNL Herľany geyser – artificial geyser. The geyser is one of the few cold-water geysers. The geyser activity has been initialized thanks to borings (1870 – 1875) aimed to capture the water for balneology purposes. The borehole was 404 m deep. The initial eruptions were large (112 m), and later they stabilized at the current level of 15 to 20 m, with inactivity intervals gradually prolonged. Currently, the inactivity period oscillates between 34 to 36 hours.

HG-02 NL Limbašská vyvieračka – (Limbach estavella), situated within PLA Malé Karpaty (Fig. 1.32). The relationship between ponor and exsurgence was proven by two dye tests in the 60's of the last century, when the dye (fluorescein) appeared in the exsurgence after 34 hours. The phenomenon can be described as an "underground river piracy."

HG-03 Vyšné Ružbachy – NL Travertínové jazierko Kráter (Travertine Lake Crater) – crater-shaped lake in travertine. The travertines in Vyšné Ružbachy are complex morphological system of terraced mounds, cascades, craters in the valley of Zalažne and Rieka brooks. Numerous sources of mineral springs surge out along the Subtatric fault.

HG-04 Sivá brada (Spišské Podhradie) – NNR Sivá brada – surge of mineral water, former exploratory borehole. Travertine mound of Sivá brada is about 25 m thick and it evolved by precipitation from mineral water. In the area there are several surges of mineral water, some of them create craters, some are captured as potable water sources. From the borehole 135 m deep the water erupts at irregular intervals due to gaslift – water drilling in the area enriched in gas $CO_2$, resulting in a lower density; it is squeezed out suddenly by hydrostatic pressure of incoming water.

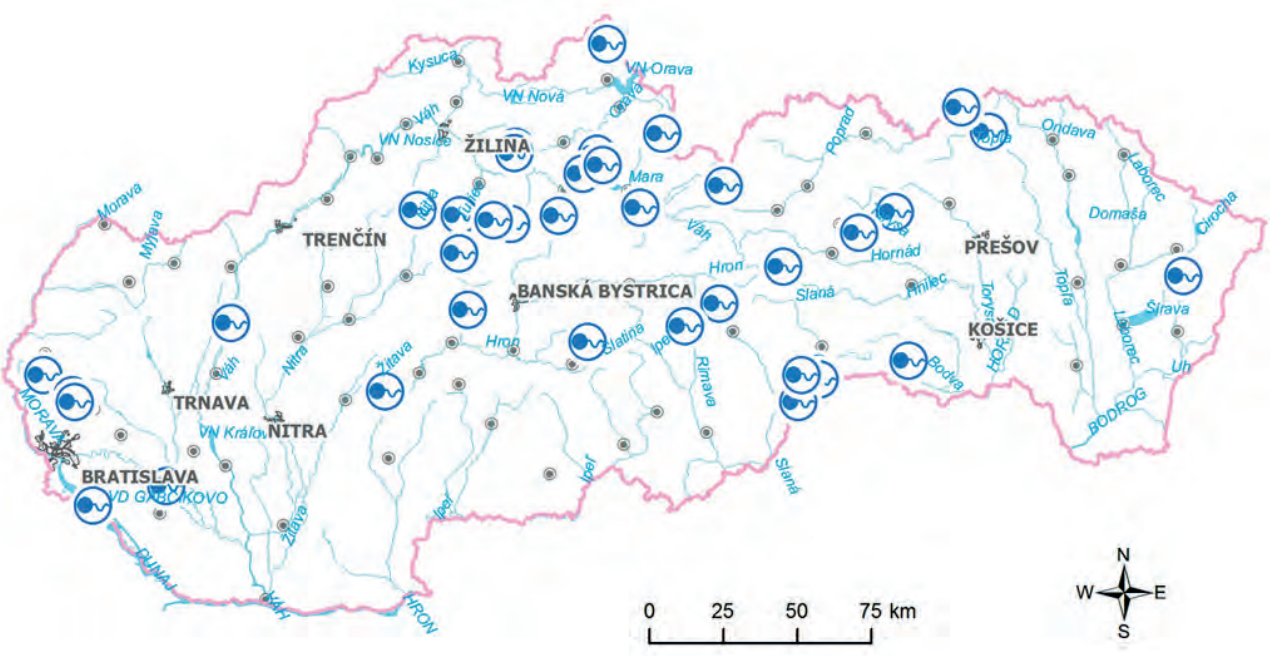


*Fig. 1.31 Distribution of the hydrogeological sites in the Slovak territory*


*Fig. 1.32 Periodic Limbašská vyvieračka – Limbach Estavella 3 (Photo P. Liščák)*

HG-05 Cígeľka – mineral spring, Cígeľka Spa. Cígeľka is high-mineralized natural healing water, carbonated water with a chemical composition of type Na-$HCO_3^{-Cl}$. It is used in the excess amount of stomach acid, gastric and intestinal catarrh, in dermatological diseases, in arteriosclerotic states, diseases of lymphatic system, the upper respiratory tract catarrh.

HG-06 NR Jezerské jazero – lake dammed by landslide, situated within the buffer zone of Pieniny NP. The Jezersko Lake area developed as one of the most extensive slope deformations of the region "Jezersko – Bukovina" with an area of several km2. It is a fossil landslide probably of Pleistocene age with a very rough morphology. Estimated depth of the slip surface is 10 m to 50 m.

HG-07 NNR Morské oko – lake dammed by rockslide, situated within PLA Vihorlat. It is the biggest landslide lake in Slovakia with an area of 13.84 hectares and maximum depth of 25.1 m.

HG-08 NL Brankovský vodopád – waterfall, situated within Nízke Tatry NP. Nameless stream yielding about 3.0 $l.s^{-1}$ overcomes the 55 m rocky step consisting of dark grey limestone with poor-marly limestones with cherts of the Lučivná Formation, Tatricum, Cretaceous in age. In winter, the waterfall turns to impressive icefalls.

HG-09 NNL Lúčanský vodopád – waterfall. The waterfall is located in the village of Lúčky, where the creek Teplianka overcomes a morphological step with a relative height of 12 m (Fig. 1.33). From Lúčky till Liptovská Teplá, to a distance of about 4 km, the stream Teplianka forms foam sinter cascades of Holocene age.

HG-10 NL Starohutský vodopád – waterfall. It is of tectonic origin. A nameless left side tributary of Starohutský potok Brook overcomes about 7 m high morphological step, created by the tectonic shift of pyroxenic andesite blocks.

HG-11 NL Vodopád Bystré (waterfall of Bystrý potok Brook) – waterfall situated within PLA Poľana. The waterfall has a height of 23 m and evolved due to tectonic disintegration and subsidence of the hypersthene andesite lava flow.

HG-12 NNL Kľacký vodopád – waterfall, situated within Veľká Fatra NP. The waterfall with its rapids and kettle holes documents the development of the relief of the Malá Fatra Mts. and fluvial erosion.

HG-13 NL Šútovský vodopád – waterfall, situated within Malá Fatra NP and within NNR Šútovská dolina Valley. The highest waterfall (38 m) in the Malá Fatra Mts. is ranked among the most beautiful waterfalls in Slovakia.

HG-14 NNR Štrbské pleso – dead-ice lake, situated within TANAP NP. It represents a glacier mountain lake (tarn) of so called dead ice lake origin. According to its area 19.76 ha it is the second largest lake in Slovakian part of the Vysoké Tatry Mts.

HG-15 Smradľavé jazero (Stinky Lake) – karst lake, situated within the buffer zone of Slovenský kras NP. It is a natural karst lake developed in deluvial, clayey sediments on Wetterstein Limestones of Silicicum. To-date the lake is extinct, with occasional restoration of its periphery.

HG-16 Jašteričie jazero (Lizard Lake) – karst lake, situated within Slovenský kras NP. Genetically this karst lake developed within a blind valley, at the contact of karstified permeable Gutenstein limestones of Middle Triassic with less permeable layers Szin Mb. of Early Triassic.

HG-17 Farárova jama (Friar Pit) – karst lake, situated within Slovenský kras NP. Karst lake Farárova jama (Pap verem in Hungarian) is located south of the village of Silica, on the Silická Plateau. The lake developed due to

*Fig. 1.33 Lúčanský vodopád Waterfall in winter (Photo P. Staník)*

clogging of the drain of the sink hole, leading to rapid rise in water level by about 2 m within one to two years.

HG-18a NNR Prosiecka dolina Valley – ponor, situated within TANAP NP.

HG-18b NNR Prosiecka dolina Valley – karst surge, situated within TANAP NP. Prosiek exsurgence is located on the left side of the Prosiek valley in the Choč Mountains, close to the gorge Vráta – the valley entrance.

HG-19 Prepadlé – ponor and surge, situated within PLA Malé Karpaty. The water flows beneath the ridge of Malé Karpaty Mts., from the catchment of Morava to the catchment of Danube. The phenomenon can be described as an "underground river piracy."

HG-21 Liptovský Ján – spa spring – travertine lake, situated within the buffer zone of NAPANT NP. At the s. edge of the village Liptovský Ján, at the contact of the Liptovská kotlina Basin with Low Tatras mountain range, there are some 14 surges of low-temperature mineral waters. The water surges out through Quaternary sediments along the fault line of the west-east direction crossing the north-south transversal faults; it originates in Triassic dolomites of the Choč nappe. Two water wells captured groundwater in the dolomites at depths of 95 and 120 m. The waters are of Ca-Mg-$HCO_3$-$SO_4$ type, low mineralized, cold and very low thermal, very poor to strongly carbonated, with a nitrogen and hydrogen sulphide content. A total mineralization ranges from 1.0 $g.l^{-1}$ to 3.8 $g.l^{-1}$, a temperature from 11 °C to 29 °C, the $CO_2$ content from 0.1 $g.l^{-1}$ to 1.7 $g.l^{-1}$, $H_2S$ content from 0, 7 $g.l^{-1}$ to 4.0 $g.l^{-1}$. It is used for drinking, recreation and natural bathing in the travertine pond with bubbling $CO_2$.

HG-22 Oravská Polhora, Slaná voda – spring of J-Br highly-mineralized water. The sources of iodine-bromide waters are situated in the northernmost part of Slovakia near the village Oravská Polhora in Oravské Beskydy Mountains. The water from mineral water wells and from pits was used at local spas for treatment of respiratory, thyroid, asthma diseases, joint diseases and skin diseases and the production of iodinated salt. Situated within Horná Orava PLA.

HG-24 Klátovské rameno – the biggest surge of groundwater in Slovakia. Klátov Oxbow is a 25 km long right tributary of the Malý Dunaj River. The spring surges out behind the village Orechová Potôň – Lúky. The upper section has not a continuous flow; it consists of a series of small lakes.

HG-25 Pod Hradom v Muráni – the biggest karst spring in Slovakia. It is captured and used as the main source of Muráň group water supply of drinking water. It is the spring with the highest documented yield of 8,872 $l.s^{-1}$ in Slovakia. Situated within Muránska planina NP.

HG-26 Čierna vyvieračka (Black Estavella)* – karst spring (adit of Gombasek Cave), situated within Slovenský kras (Slovak Karst) NP, NNL Gombasecká jaskyňa Cave. Through the Čierna vyvieračka exsurgence in the autumn of 1951 Gombasecká Cave was discovered, by reducing the entry level of the exsurgence. The Čierny potok underground stream drains Silica-Gombasek system of the Ardovská partial hydrogeological structure of Silická planina Plateau.

HG-27 NR Bezodné – Mareček – Tančibok – tapped spring, situated within PLA Malé Karpaty. Sources Bezedné, Tančibok (Kozánek) and Mareček are representatives of barrier springs that drain Pernek groundwater reservoir of the Záhorská nížina Lowland.

HG-28 Ležiachov – tapped spring. Ležiachov springs system is one of the largest concentrated groundwater surges in the Turčianska kotlina Basin. The importance of this source of groundwater is highlighted by the fact that Matej Bel (1723 – 1742) mentioned it in his Notitia Hungariae Novae Historico Geographica: "... behind the village surges a spring so rich and warm, that it could turn the millstones both in the summer and in winter".

HG-29 Mojžišove pramene (Moses`s springs) – springs, situated within Malá Fatra NP and within NNR Šútovská dolina Valley. Mojžišove pramene ("Moses Springs") are sources that have an interesting way of surge from the rock wall. The water from these springs supplies Šútovo Waterfall. The name is according to the biblical story, when Moses wandering in the wilderness hit the rock with the stick and it spilled water subsequently.

HG-30 Lučečné – Belianska dolina Valley (Havranovo) – tapped spring, situated within Veľká Fatra NP and within NNR Borišov. The water source is precipitated in form of a foam sinter – tufa, which can be traced along the whole length of the flow to the estuary.

HG-31 Necpaly – Lazce – tapped spring. Spring Lazce is the karst spring with the biggest mean yield (558.02 $l.s^{-1}$) in Slovakia, min. 324.0 $l.s^{-1}$ and max 1,370 $l.s^{-1}$. Situated within Veľká Fatra NP.

HG-32 Vyšný Slavkov – tapped spring. Source Hlavný in Veľký Slavkov drains a hydrogeological structure of the Lačnov syncline in the Branisko Mts. and serves as an important source of drinking water supply for the population.

HG-33 Oravice – Bobrovecká dolina Valley – tapped spring. Source Oravice in the Bobrovecká dolina Valley with an average yield of Q = 194.8 $l.s^{-1}$ (Qmax = 306 $l.s^{-1}$ and Qmin 103.8 $l.s^{-1}$) recorded in the years 1988 to 2010 is the most important source dewatering hydrogeological structure of Osobitá. Situated within TANAP NP.

HG-34 Tisovec – tapped intermittent spring, situated within the buffer zone of Muránska planina NP. It is an intermittent karst spring, one of two springs of this type known in the Western Carpathians. Spring dewaters (with other springs) Steinalm and Wetterstein limestones (Middle Triassic) of Muráň nappe of Silicicum of Tisovec karst – the most western part of the Muránska planina Mts. Spring discharge is in range from cca 2.0 up to 70.0 $l.s^{-1}$, mean yield is 20.5 $l.s^{-1}$ in periodic cycle about 45 minutes. Water is flowing from three holes, from which only one has permanent outflow with discharge 2–6 $l.s^{-1}$. From this basic state the discharge quickly (6 min) rises up to the maximum (cca 70.0 $l.s^{-1}$) via succesive involvement of the first and later the second periodic outflow.

HG-38 Turček water pipeline – an important technical monument, which served as the water supply for mines (mills, stamps, water pumping...). It is located in the Kremnické vrchy Mts., and between Turček and Kremnické Bane municipalities. It served as the water supply for mines (mills, stamps, water pumping...). It was built in the 15th Century (written documents), however it is assumed that it could be operational as early as in the 14th Century. The water was transferred from the catchment of the Turiec River to the Hron River catchment. The water was led around the hill with minimal slope, so as to maintain the highest level of potential energy of water. The channel was dug in the ground, reinforced with logs, bottom lined with clay. Open sections were protected against pollution and freezing by shingles and clay. After decline in mining in the mid-19th Century it was used for supplying drinking water for Kremnica and was an important source of water for a railway Zvolen – Vrútky. Since 1894 there were installed water turbines to generate electricity to power mining machinery. In 1922 the first underground power plant in Europe with three horizontal Pelton turbines with a capacity for 430 kW was put into operation. The entire water and energy system was rebuilt in the 30-ies of the 20th Century. There were built three levels of power stations. The entire length of the system till the estuary in the Hron River measures 34,405 meters and the vertical difference is 587 m. The installed capacity of the whole cascade is 3.46 MW and is used mainly as a source of high energy for the city of Kremnica. The Turčekovský water supply has been declared a Cultural Monument.

HG-39 Havrania skala (Raven`s Rock) – intermittent karst spring, at the foot of the mountain massif of Havrania skala (1,154 m) in the southwestern part of Slovenský raj NP. It is worldwide uniqueness. The water from spring surges out in irregular intervals. The yield oscillates around 35 $l.s^{-1}$, the maximum value measured was up to 45 $l.s^{-1}$. The surge usually takes two to three hours in duration, at monophase surge the maximum yield takes about one hour.

HG-40 Drienovec – tapped spring, situated within Slovenský kras (Slovak Karst) NP and NR Palanta. Source Drienovec with its average yield of 214.8 $l.s^{-1}$ is one of the most important sources of the Košice water supply group. Together with other sources (Teplica, Drienovecké kúpele, Hatiny, Helena, Bezodná studňa, and others) it drains Hačava-Jasov hydrogeological structure of the Slovak Karst, built mainly of Middle and Early Triassic Wetterstein, Waxenegg, Gutenstein and Dachstein Limestones. Their karstification is heavily influenced by tectonics. The water circulation of the spring Drienovec involves two components. The first are the groundwaters infiltrated at the Jasovská planina Plateau. The groundwater flows to the surface through a system of fault lines, which make a limit to the carbonate massif Jasovská planina Plateau. The water rises to the surface in contact with less permeable conglomerates and clayey-marly Tertiary rocks. The second component is the groundwater from the fluvial sediments of the Bodva River that in the space between Jasov and Hatina enters the carbonate massif.

HG-41 Turčianske Teplice Spa – Turčianske Teplice, located in the southern part of the Turiec Basin at the foothills of the Veľká Fatra Mts. is the spa town and the seat of the district. For several centuries, the spa has been known here because of thermal mineral water springs.

HG-42 Bardejovské kúpele Spa – Mineral water in Bardejov Spa is formed by mixing the mineral waters of chemical type Na-$HCO_3$ of the Magura unit and Na-$HCO_3$-Cl waters with a high proportion of heavy isotopes of hydrogen and oxygen from the unit Obidowa – Slopnice – Zboj.

HG-44 Piešťany – kúpele Spa – Piešťany is the most significant and best known spa in Slovakia. The warmest natural surge of groundwater is known from here. The fine sediment in the by-pass channel turns to curative mud as a result of thermo-mineral waters infiltration and consequent ripening of the mud.

## 1.5. Database processing

A considerable part of the sites was documented in the field; we have to point out that some of the objects of the primary database that were originally proposed, no longer exist – they disappear (due to construction, natural stands). An important part of the database was the preparation of the popular educational texts on individual sites. For each site, the resume was processed which was translated into English. The texts were processed at the level corresponding to the students of secondary school education. Along with the field reconnaissance passports to each site were being filled-in, both in written form (Microsoft Word) and by the end of the solution also in the form of an electronic database (Microsoft Access). The passport was created on the basis of the model form of the geological passport drawn up for the needs of SGIDŠ electronic documentation diary in the Microsoft Access. In the passport design and implementation of the database helped with their skills Miroslav Antalík, (Patrik Konečný), Kristína Lacenová and Ivan Dananaj. We have received several suggestions from the professional and amateur public; on the basis of these initiatives, we have added some of the geosites in the database.

The database groundwork was retrieved from geological guides through Slovakia, issued on the occasion of events KBGA and IGC, as well as important monographs, for example, Mišík (1976). Furthermore, the selection of sites was based on own erudition of the authors and relevant literature study. In creation and loading of databases feedback from and broad professional and laic geological community contributed significantly.

In the scope of the project solution geological sites of regional-geological, historical mining, mineralogical, geomorphological and hydrogeological nature were identified, all of them of utmost scientific (educational) and aesthetical value with and potential to become and firm component of the Slovak, even the European geological heritage.

Each site is documented in the inventory sheet, which was subsequently included in the MS Access database. Along with the field reconnaissance the passports to each site were being filled-in, both in written form (Microsoft Word) and by the end of the solution also in the form of an electronic database (Microsoft Access). The passport was created on the basis of the model form of the geological passport drawn up for the needs of SGIDS electronic documentation diary.

High-quality photo-documentation of the vast majority of sites along with the geological sketches and pen drawings by the Slovak volcanologist Vlastimil Konečný and the attached English summaries of each site, along with the explanations to graphic documentation are the values added of the database. Finally, the geosites were divided according to their scientific significance and some of them have been proposed for their further legislative protection. All-in-all, 39 sites are of minor importance, 118 of the moderate one, 193 of the major one and 129 of the extraordinary one have been identified, and 77 of them proposed to launch a process of their enrolment in the List of Protected Geosites or Protected Landmarks.

In the scope of the project Geological Information System (GeoIS) the database has been published on the SGIDS website: https://www.geology.sk/maps-and-data/mapovy-portal/educational-geology/important-geological-sites/?lang=en in order to disseminate the results among the public. The database is open for further inputs and for modern presentation of the geological heritage of the Slovak Republic.

## 1.6 Conclusions

The database of important geological sites provides and review of the geological heritage of the Slovak Republic. Generations of geologists active in our territory since the times of Austrian-Hungarian Kingdom have preserved highly scientific knowledge on the geological phenomena of Slovakia. The fact that in the processing and collecting of this information renowned specialists from the top national geological institutes have taken part is a guarantee of the well-balanced and justified selection of the sites of the nation- and European-wide geological heritage at the Slovak territory. We do not perceive the database of significant geological sites as being concluded; on the contrary, in the future, we count with its continuous recharge so as to provide up-to-date information to the general public, in particular in the sphere of education, the protection of nature and the geotourism. For instance, after catastrophic debris flows event of 2014 in the Vrátna dolina Valley, this exceptional geological phenomenon has been included into the database.

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# 2. Mineralogical Heritage of Slovakia – A Significant Contribution to Knowledge of Minerals in the World

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**Abstract:** Up to date, 21 new minerals have been described from 14 Slovak deposits. Another 39 minerals have provided invaluable information on the scientific knowledge and diversity of individual minerals on Earth. On the territory of Slovakia, the world's most famous locality of occurrence is mainly euchroite, scainiite, hodrušite, kobellite, mrázekite, schafarzikite, vihorlatite, skinnerite, telluronevskite and brandholzite. On a European scale, examples are precious opal from Dubník, sernarmontite from Pernek and kermesite from Pezinok. While preserving the mineral heritage, it is important to preserve, in particular, the type and rare minerals, especially in large national museums and collections, and to deposit other cotype material into other (and private) collections in order to preserve them for future generations in unforeseen circumstances.

**Key words:** mineral heritage, type specimens, extraordinary minerals

## 2.1 Introduction

Due to the large number of hydrothermal veins and their varied mineral composition, Slovakia was one of the centres of mining in Europe and in the world. Mineralogical sciences, thanks to professors at the Banská Štiavnica Mining Academy, who did not always focus in the knowledge and prognosis of mineral wealth, developed much more slowly than the technical sciences related to mining. As a result, there was a low level of mineral knowledge in Slovakia as well as a small number of new minerals first described from our territory. This was despite the fact that in the Central Slovakia in the wider area of Banská Štiavnica and Banská Bystrica, as well as in the eastern part of the Spiš-Gemer Ore Mts., there are very large concentrations of ore veins. These lodes have provided for many centuries many wonderful samples of minerals that are the adornment of many world museums as well as university or private collections. Evidence that mineralogy was not a leading scientific discipline at the famous Mining Academy in Banská Štiavnica is also the fact that no new mineral was described from this one of the largest silver deposits in Europe. For example, 7 new minerals were defined from similar deposits in Příbram, 48 from Jáchymov (both Czech Republic), and 13 from the vicinity of Freiberg (Germany), where silver was extracted. There was only one new mineral found in the vicinity of Banská Štiavnica – Hodruša-Hámre in 1972 (Koděra et al., 1970).

There are several minerals that have made Slovakia famous for heir history, some important physical properties, the size or the morphology of crystals. Many minerals are important only from a scientific point of view, occurring in microscopic form and their size does not exceed a few dozen microns. Among them are, for instance, huanzalaite from Ochtiná (Ferenc & Uher, 2007), nuffieldite, kirkiite and eclarite from Vyšná Boca and Brezno vicinity (Ozdín, 2015, Pršek & Ozdín, 2004, Pršek et al., 2008), povondraite from Bratislava (Bačík et al., 2008), pellouxite from Chyžné (Bálintová et al., 2006) and Kľačianka (Topa et al., 2012), rouxellite from Kľačianka (Topa et al., 2012), etc.). They are interesting, for example, by their rare occurrences, their exceptional chemical composition, and the like. Many of them have the second or third occurrence in Slovakia when compared with the rest of the world. This contribution, however, deals only with the macroscopically significant mineral of Slovakia, which are divided into two categories: 1. Type minerals (minerals first described from our territory); 2. Significant minerals in the world or in the European scale. A special group consists of sporadically identified minerals. This includes minerals that have been described but were probably incorrectly or doubtfully identified (e.g. camerolaite $Cu^{2+}_4Al_2(HSbO_4,SO_4)(CO_3)(OH)_{10}\cdot 2H_2O$ from Špania Dolina, launayite $CuPb_{10}(Sb,As)_{13}S_{20}$. from Dúbrava, qitianlingite $Fe^{2+}_2Nb_2WO_{10}$ from Gemerská Poloma) or they are of vague origin (e.g. poitevinite $(Cu^{2+},Fe^{2+},Zn)SO_4\cdot H_2O$) from Ponická Huta).

## 2.2 Type minerals (minerals first described from Slovak area)

**CHOVANITE $Pb_{15-2x}Sb_{14+2x}S_{36}O_x$, where x = ~0.2** (Topa et al., 2012; Fig. 2.1) – is a very rare Pb-Sb sulphosalt with oxygen and was described in 2012 especially from the deposit Dúbrava in the Nízke Tatry Mts. It also occurs on two other smaller occurrences (Malé Železné and Kľačianka in the Nízke Tatry Mts.). The mineral chovanite was named in honour of Prof. Martin Chovan (1946-), Emeritus Professor of the Department of Mineralogy and Petrology at the Faculty of Natural Sciences of Comenius University, Bratislava, Slovakia.

**COHENITE $(Fe,Ni,Co)_3C$** (Weinschenk, 1889; Fig. 2.2) and **SCHREIBERSITE $(Fe,Ni)_3P$** (Haidinger, 1847b) – were first described from the world-famous meteorite Magura, which probably fell sometime between 1830-1840 near a village of Slanica in Orava, nowadays already flooded by the Orava dam reservoir. The meteorite became famous for the fact that besides 2 new minerals in the world, a third, later discredited mineral cliftonite was

*Fig. 2.1 Aggregate of the holotype specimen of chovanite (Inv. No 7277). Cutting size 3.5 x 4 mm. Photo: D. Ozdín*

*Fig. 2.2 Up to 2 cm long longitudinal lobular aggregates of the cohenite in the Magura meteorite. Photo: D. Ozdín*

described, and especially because it was the most precious iron meteorite in the world in the 19th Century. Cohenite was named in honour of the professor of mineralogy at the University of Greifswald in Germany and an important meteorite expert Emil Wilhelm Cohen (1842-1905). Schreibersite got its name by Haidinger, to commemorate a prominent naturalist of the 19th Century, Carl Franz Anton Ritter von Schreibers, who was born in 1775 in Bratislava.

**EUCHROITE $Cu^{2+}_2(AsO_4)(OH)\cdot 3H_2O$** (Breithaupt, 1823) is the most beautiful Slovak type mineral, which was described in 1823 by F. A. Breithaupt from the Svätodušná Deposit near Ľubietová. It was named after its beautiful emerald-green colour. To date, the crystals and the intergrowths of euchroite from this site are the largest and most beautiful in the world (Kúšik, 2007a; Fig. 2.3). Another known locality of euchroite crystals is the occurrence of Poniky – Farbište (Števko et al., 2011), from where come very aesthetic aggregates of up to 10 mm large euchroite crystals, which are also the most beautiful in the world.

**FLUORARROJADITE-(BaNa)** (Števko et al., 2017a) (IMA 2016-075) is the latest new mineral in the world that has been described from the territory of Slovakia. It creates max. 2 cm large green-yellow to yellowish aggregates in quartz at Gemerská Poloma site, Adit Elisabeth. These aggregates consist of fluorarrojadite (BaNa) and "fluorodicksonite-(BaNa)" and sometimes contain the inclusion of viitaniemiite. Localities are intergrown with rodochrosite (Števko et al., 2015).

**HAUERITE $MnS_2$** (Haidinger, 1847a; Fig. 2.4) was described in the year 1847 from Vígľašská Huta – Kalinka and named after the Austrian geologists J. R. Hauer (1778 – 1863) and F. R. Hauer (1822 – 1899). The hauerites in Kalinka, along with the Italian site of Radusa, are still the largest crystals of this mineral in the world.

**HODRUŠITE $Cu_8Bi_{12}S_{22}$** (Koděra et al., 1970) was described in the year 1971 as a new mineral from Hodruša-Hámre from the Mine Rozália, where it creates mostly small-scale aggregates, rarely several mm needles in association with quartz, hematite, chalcopyrite, sphalerite and galenite. More recently, there were also found the world's largest crystals at this site. The length of the needles reaches up to 1.5 cm (Sejkora et al., 2015).

*Fig. 2.3 A qualitatively exceptional sample (10 x 6 cm) of the emerald-green euchroite from the Ľubietová – Svätodušná deposit. The size of the euchroite crystals is up to 2 cm. Finding of 2003. Photo: T. Bancík*

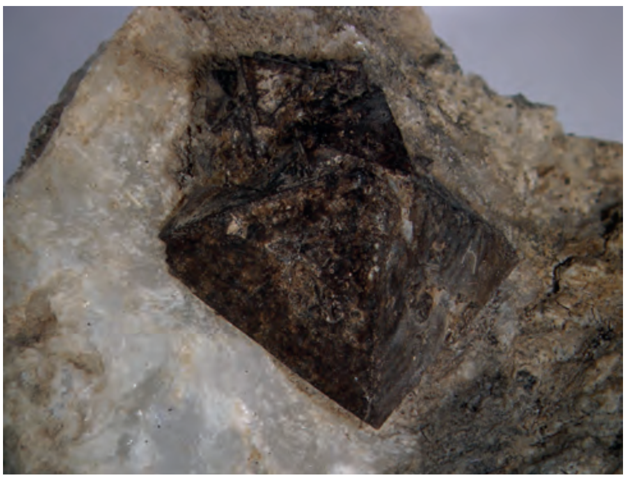

*Fig. 2.4 Idiomorphic crystal of hauerite from Vígľašská Huta-Kalinka. Crystal size 0.8 cm. Photo: D. Ozdín*

**JAVORIEITE $KFeCl_3$** (Koděra et al., 2017b) creates max. 15 μm large green-coloured crystals in inclusions of salt melts in the quartz on the Au-deposit Biely vrch at Detva. When it gets in contact with the air, it degrades immediately. This mineral was found in 3 other localities in Slovakia (Slatinské Lazy, Kráľová (near Zvolen) and Beluj; Koděra et al., 2017a), even before the approval process of this mineral came to an end.

**KORNELITE $Fe^{3+}_2(SO_4)_3·7H_2O$** (Krenner, 1888)**, RHOMBOCLASE $(H_5O_2)^{1+}Fe^{3+}(SO_4)_2·2H_2O$** (Krenner, 1891) and **SZOMOLNOKITE $Fe^{2+}SO_4·H_2O$** (Krenner, 1891) – the type location of these 3 secondary hydrated iron sulphates is Smolník. The szomolnokite received its name according to the Hungarian name of Smolník (Szomolnok). The kornelite was named after the mining engineer Kornel Hlavacsek from Smolník, and the rhomboclase was named after the rhombic shape of the crystals and the distinct cleavage (from the Greek *rhombos* – rhombic, and *klao* – cleave).

**LIBETHENITE $Cu^{2+}_2(PO_4)(OH)$** (Breithaupt, 1823; Fig. 2.5) is the best-known Slovak type mineral. Like euchroite the libethenite was described in 1823 by F. A. Breithaupt, however from the Podlipa deposit and named after the German name of Ľubietová (Libethen).

*Fig. 2.5 Superb crystal (6 mm) of libethenite in the quartz cavity from Ľubietová – Podlipa deposit. Photo: D. Ozdín*

**MRÁZEKITE $Bi_2Cu^{2+}_3(PO_4)_2O_2(OH)_2·2H_2O$** (Řídkošil et al., 1992; Fig. 2.6) – was described in 1992 from the Podlipa deposit, from the Rainer minefield in Ľubietová. At places it forms very aesthetic prismatic transparent blue crystals in the quartz or limonite cavities. Up to several millimetres large crystals are grouped into gorgeous roses. It was named after the Czech mineralogist Zdeněk Mrázek (1952-1984) who found the mineral and made its first analyzes.

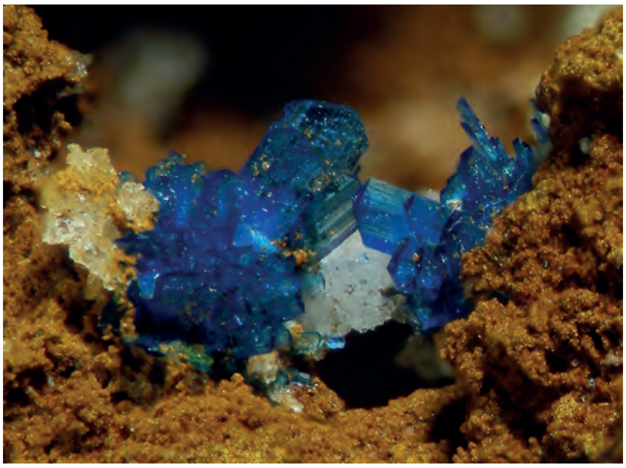

*Fig. 2.6 Mrázekite aggregate in quartz-limonite vug. Ľubietová – Podlipa deposit, mining filed Rainer, field of view 1 mm. Photo: D. Ozdín*

**OXY-SCHORL $Na(Fe^{2+}_2Al)Al_6Si_6O_{18}(BO_3)_3(OH)_3O$** (Bačík et al., 2013) was commissioned by the Commission for New Minerals at International Mineralogical Association in 2011 under the number 2011-011. Typical locations are Zlatá Idka along with the Czech site of Při- byslavice. The name reflects the recommendation of the International Mineralogical Association for designating the minerals of the tourmaline group. The title refers to the oxygen content in one of the anionic positions (oxy-prefix) and to the affinity for the tourmaline – schorl.

**RUTILE $TiO_2$** (Ludwig, 1803) is the first type mineral described in our territory. It was described from Revúca by Ignác Born in 1772 under the title "basalt ruby", but the name of rutile was introduced by Werner in the year 1803. Its name is derived from the Latin "rutilus" – reddish. For the first time in the world, the titanium element was isolated from the rutile of Revúca (Klaproth, 1795).

**SCHAFARZIKITE $Fe^{2+}Sb^{3+}_2O_4$** (Krenner, 1921) is the only type mineral from western Slovakia. Its typical location is Pernek, where it is associated with kermesite, antimonite, valentinite and sénarmontite. Its name was given after the Hungarian geologist Ferenc Xaver Schafarzik (1854 – 1927). However, samples of schafarzikite in most of the museums in the world and in private collections come from collections that were made after its re-discovery in 2002 (Sejkora et al., 2004, 2007).

**TELLURONEVSKITE $Bi_3TeSe_2$** (Řídkošil et al., 2001) and **VIHORLATITE $Bi_{24}Te_4Se_{17}$** (Skála et al., 2007) – both bismuth selenotellurides were described only after 2000 and are our youngest types of sulphides. They are grey to black in colour and can not be macroscopically distinguished from each other, or from other selenotellurides of bismuth, at the type locality, which is Poruba pod Vihorlatom. The name of telluronevskite is derived from the chemical prefix of tellurium (according to Te content) and similarity with nevskite. The vihorlatite has got the name according to the mountain range of its location.

**TETRADYMITE $Bi_2Te_2S$** (Haidinger, 1831) was described in the year 1831 from a small adit at Župkov. It is a historic site where tetradymite is the main sulphide mineral. Its name comes from the Greek *tetradymos* – fourfold.

**VASHEGYITE $Al_{11}(PO_4)_9(OH)_6·38H_2O$** (Zimányi, 1909a,b) and **EVANSITE $Al_3(PO_4)(OH)_6·6H_2O$** (Forbes, 1864) are hydrated aluminium phosphates, which were first described from Železník at Sirk. The vashegyite was named after the locality Vashegy, the Hungarian name of Železník and the evansite after the English metallurgist and mineralogist Brooke Evans (1797-1862), who collected the first samples and brought them to London for determination. In recent years, there has been a tendency to abolish evansite as a mineral because it is an amorphous mineral with a problematic chemical composition.

In addition to the above-mentioned new minerals recognized by the International Mineralogical Association, other new minerals have been published, the description of which has not yet been completed. They include, for example, the new minerals from the group of roméite from Pernek (Sejkora et al., 2012), "fluorodicksonite" (BaNa) from Gemerská Poloma" (Števko et al., 2015), As-analogue of cyanotrichite from Ľubietová (Ozdín, unpublished) or vacant mantienneite (Vavrová et al., 2006) and others.

### 2.3 Significant minerals of the world or the European significance

Among the other minerals which have made Slovakia world-famous are the so-called "Historical classics", i.e. minerals that were not first described in our territory but were known in the past in particular from our sites. These minerals include:

**ARAGONITE $CaCO_3$** is one of the most common minerals in the world. There are two exceptional locations in Slovakia, with the most beautiful aragonites in the world (Tóth, 1882). The historical site is Špania Dolina, where hexagonal and more than 10 cm large, prismatic, white or yellow crystals have been grouped in cavities into magnificent aggregates. One of the most beautiful samples is still exhibited at the Natural History Museum in Vienna. In 1840 there was found a 6.4 m long cavity with the most beautiful aragonites in the world of that-world (Ozdín, 2012a, 2013).

The second location is Podrečany, where were more than 20 cm large white crystals have been grouped into very aesthetic and more than half a meter large aggregates. Approximately 10 cm large crystals of aragonite were rarely grouped into gorgeous rosettes. The most beautiful cavity was found in 1985, from which comes a unique sample exhibited in the museum in Banská Štiavnica. Aragonite samples from Podrečany are adorned by several major museums in the world (e.g. Smithsonian in the US and others).

**AZURITE $Cu_3(CO_3)_2(OH)_2$** was long-term in Slovakia only a common mineral occurring in surface parts of ore deposits. In 2016, at the Piesky deposit at Špania Dolina a very rich unique azurite find was unearthed, partly with malachite (Fig. 2.7), from which most of the samples are deposited in museums and private collections. Several hundreds of qualitatively exceptional samples (in Slovakian terms) were found during the period of 2016 and 2017, the best of which are the prominent azurites found in the Central European region for at least 250 years. The azurite itself is characterized by great morphological variability, unprecedented quantity, as well as the size of aggregates that crystallized within the cavities and fissures of Permian sedimentary rocks (Ozdín et al., 2016).

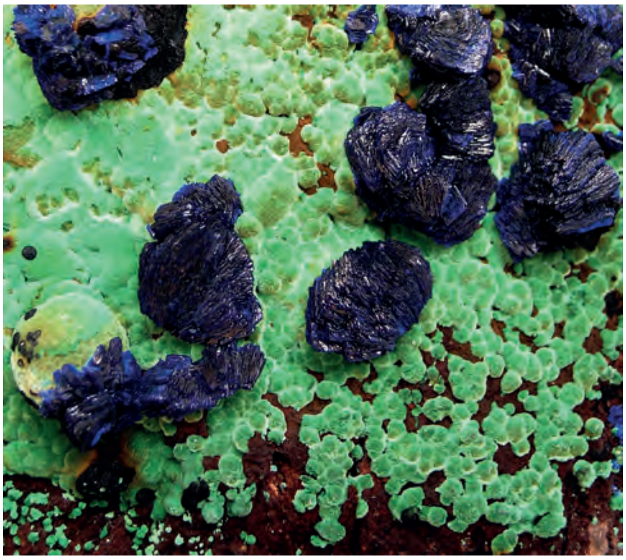

*Fig. 2.7 Aggregates of azurite composed of dark blue, glossy, table-shaped crystals grown on malachite. The slit width is 2.9 cm. The size of the largest aggregate of azure at the centre of the image is 8 mm. Photo: D. Ozdín*

**BARYTE $BaSO_4$** has in Slovakia 2 significant locations of its occurrence. The first one is Banská Štiavnica, from which up to 15 cm large leaf-shaped crystals are known (Ozdín & Krejsek, 2016), grouped into several tens of centimetres large aggregates, which are the pride of the Carpathian polymetallic veins, especially in European museums. The second location is the broader area of Rožňava, where, under the name of Betlér (Betliar), there occur very aesthetic maximum 5 cm large crystals of secondary baryte in the quartz-limonite veinstone – **wolnyne** variety (Jonas, 1820). This variety, in addition to genesis, is also characterized by great morphological variability and often glass shine. Recently, the rich druses of wolnyne were found on the Lode Mária in Rožňava, the size of which was up to 5 cm (Števko et al., 2017b).

**BOULANGERITE $Pb_5Sb_4S_{11}$ –** the largest and most beautiful aggregates composed of up to 5 cm long crystals are formed on a deposit in Nižná Slaná (Uher & Ozdín, 2004). The length of the needles belongs to the largest and its aggregates belong to the most beautiful samples of this mineral in Europe.

**BRANDHOLZITE $Mg[Sb(OH)_6]_2·6H_2O$** (Fig. 2.8) was found in Pernek as the second type location in the world where it forms up to 4 mm large colourless, white to grey crystals (Sejkora et al., 2004, Števko, 2012a). This was an extraordinary, world-wide finding of this mineral that has been subjected to several reference analyzes for this mineral (Frost et al., 2009, Sejkora et al., 2010). Thanks to this finding, the Pernek's brandholzite began to expand into collections of museums and private collections around the world, as there were only a small number of samples from the original type site of this mineral in Germany, unlike Pernek. At the same time, the largest crystals from Pernek have so far been the largest samples of brandholzite crystals in the world. The scientific, museum and collectible upheaval around the Pernek finding was not enough to die away, and much more significant occurrence was found in Pezinok, on the Kolársky vrch deposit. At this site, very rich macroscopic aggregates of brandholzite were found on several hundred $cm^2$ areas with tabular crystals up to 1 cm in size (Števko et al., 2012a, b). The finds in Pezinok are so rich that they consist at least 85% of all the brand-name on earth found so far. The brandholzite here originates recently on the walls of the mining corridors and is able to crystallize within a few weeks. Therefore, at the Pezinok deposit the conditions for the formation of this mineral were determined for the first time in the world (Majzlan et al., 2016). Due to the size of the crystals and the richness of the samples, the Pezinok deposit is today the dominant locality of this mineral in the world, and from a scientific and museum point of view, it is a practically uncompromising locality.

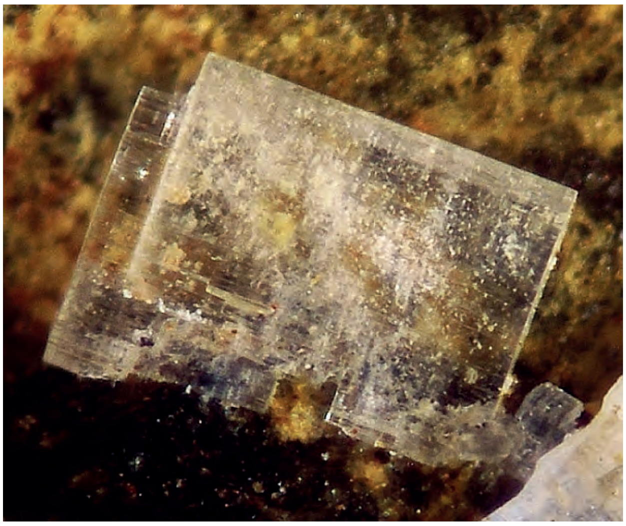

*Fig. 2.8 Euhedral brandholzite crystal from Pernek. Size of crystal is 1 mm. Photo: Daniel Ozdín*

**CALCITE $CaCO_3$** is one of the most abundant minerals in the world. From Slovakia, the calcites are most well-known from Banská Štiavnica. They are probably exhibited in all major museums in the world. Likely, the Gemerská Ves findings could make Slovakia even more famous thanks the last few years discovered phantoms of calcite (Bálintová et al., 2006). In the translucent to several centimetres large calcite there are brick-red phantoms. The phantom is a variety of any transparent or translucent mineral in which another crystal of the same mineral is seen morphologically.

**CELESTINE $SrSO_4$** was found in Špania Dolina in the calcite cavities, where it is mostly heaven-blue to blue-grey, off-white to colourless crystals. It is characterized by very strong morphological variability of the crystals (Zepharovich, 1873, Goldschmidt, 1913 – 1923), whereas the most characteristic being tabular, lanceolate, prismatic and loop-like crystals. Especially in the 19th Century they were considered the most beautiful in the world (Tóth, 1882).

**CHRYSOTILE $Mg_3Si_2O_5(OH)_4$**, which is the basic raw material of asbestos, has probably the historically most significant site in the world in the serpentinite quarry in Dobšiná, where it was mined already in 1705 (Rozložník ed., 2008). The chrysotile forms fibrous aggregates with a fibre length of up to 6 cm (Zlocha, 1978).

**COBALTITE CoAsS** has an important locality in Hnúšťa, where at the Mútnik deposit (Koděra et al., 1986-1990; Števko & Volejník, 2016) up to 1.3 cm large perfectly morphologically crystallized crystals of cobalt in magnesite, talc and chalcopyrite, were found. The size of cobaltite is unique here, and there are likely to be the largest crystals of this mineral in Europe, with the only exception of locations in Sweden.

**CORUNDUM $Al_2O_3$ var. sapphire** (Fig. 2.9) has an important European occurrence around the village of Hajnáčka. There is historically, quantitatively and qualitatively the most significant occurrence of corundum var. sapphire not only in Slovakia but also in the whole Carpathians (Ozdín, 2017). The sapphire's location has been known since the 1970s, but Szádeczky (1899) made a first description of sapphire from a sample of basalt from Kostná dolina Valley (Valley of Bones) near Hajnáčka. Subsequently, the corundum of blue, violet-grey to grey colour was found almost 100 years later when the sediments from Kostná dolina Valley were panned (Uher et al., 1999, 2012). In the years 2015 – 2017 local enthusiast Ladislav Oravec of Šurice after long searching found several dozen samples of sapphires directly in the basalt near Hajnáčka in the stone quarry above the village of Gemerský Jablonec. The largest piece of jewellery made out of Hajnáčka's sapphire had a weight of 0.265 carats.

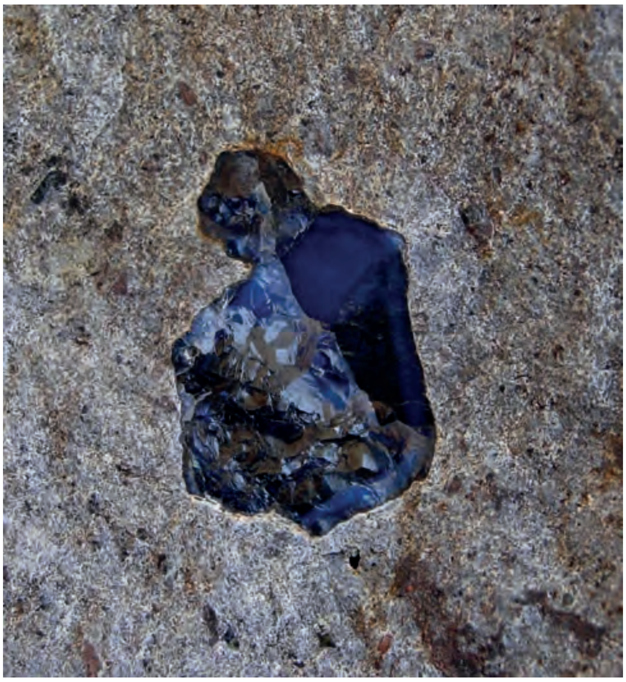

*Fig. 2.9 To date, the largest Slovak corundum var. sapphire from the quarry at Gemerský Jablonec. Its size is 1.43 cm. Photo: Daniel Ozdín*

**DEVILLINE $CaCu^{2+}_4(SO_4)_2(OH)_6 \cdot 3H_2O$** (Fig. 2.10) is one of the most valuable minerals in Slovakia, which makes wonderful table crystals grouped into more than 1 cm large globular dark green aggregates. It was first described under the name herrengrundite (Brezina, 1897) as the new mineral in the world from Špania Dolina (German Herrengrund). Later, Meixner (1940) found that it was identical to the previously described devilline, but for many decades this mineral was known as herrengrundite. In addition, Sabelli & Zanazzi (1972) solved the crystalline structure of the devilline, based on samples from Špania Dolina and not from the UK type location. Up to now Špania Dolina and Staré Hory – Richtárová are the most important localities of this mineral in the world, with the largest and most beautiful aggregates of this mineral in the world. More detailed information on the history of the description of the devilline and herrengrundite is given by Papp (2004) and Števko (2013).

*Fig. 2.10 Devilline from Špania Dolina from the collection of National Museum in Prague. Photo: D. Ozdín*

**DIASPORE AlO(OH)** is the pink aluminium oxide found in Banská Štiavnica near Banská Belá. In the 19th Century, the diaspores of Banská Belá were probably the most beautiful in the world and certainly the most famous in Europe. It was also probably the second place in the world where the diaspore was known. The diaspore was found in 1823 at the Prince Ferdinand Adit, but it was first published by world-renowned mineralogist Haidinger (1844). The largest idiomorphic diaspore crystals with lot of different crystal shapes were up to 1.5 cm in size (Szakáll et al., 2002), but individual buck-like diaspore crystals in radial aggregates were up to 4.5 cm in size (Ozdín, 2009 – 2017).

**GERSDORFFITE NiAsS** has a classic location in Dobšiná from where it was described as *wodankies* by Lampadius (1819). Later it was described corresponding to the German name of the site dobschauite (Dana, 1868). Although it is common mostly in solid and grainy dark grey aggregates, there are exceptionally large crystals up to 1 cm (Hintze, 1904), which is the maximum size of gersdorffite crystals in Europe and with the exception of one site in Morocco also in the world.

**GLADITE $PbCuBi_5S_9$ as well as KRUPKAITE $PbCuBi_3S_6$** represent Cu-Pb-Bi sulphosalts. They were discovered by the end of the 20th Century at the site of Vyšná Boca – Paurovská, where they form needles grouped into 4.5 cm large aggregates in quartz. In a short time they have been delivered to many museums in Europe, Asia and America (Ozdín, 2015).

**GOLDMANITE $Ca_3V^{3+}_2(SiO_4)_3$** is a green vanadium garnet. It has a unique chemical composition with a pronounced Cr participation in structure (goldmanite-Cr variety). So far, the Pezinok locality is the only site in the world with a chemical composition ranging from goldmanite to uvarovite (Cr-garnet). It is located in the vicinity of Pezinok, especially at the site of Rybníček. It is one of the most attractive science-collector minerals from the Western Slovakia (Uher et al., 1994, 2008).

**GUDMUNDITE FeSbS.** The crystallized gudmundite was found in 1999 in the calcite vein in front of the Sirková Adit near Pezinok. The crystals exceeded 3 mm (Ozdín et al., 2008) and are still ones of the largest in the world. Recently it was found in situ in the Sirková Adit (Ozdín et al., 2017). Due to its size and simple paragenesis, where gudmundite occurs virtually as the only white-calcite sulphide, the gudmundite from Pezinok has been exhibited by dozens of museum and private collections.

**INESITE $Ca_2Mn^{2+}_7Si_{10}O_{28}(OH)_2 \cdot 5H_2O$** (Fig. 2.11) was described as a new mineral in the world under the name of agnolith from Hodruša-Hámre (Breusing, 1900). Later it was identified with the previously described inesite (Ulrich, 1922). It is a relatively rare manganese silicate, whose aggregates at least until the first half of the 20th Century belonged to the most beautiful in the world. Also, at that time, it was probably only the second finding of this mineral in the world.

*Fig. 2.11 Agreggate of the pink prismatic crystals of inesite. Size of specimen is 3.7 x 3.4 cm. Photo: D. Ozdín*

**KERMESITE $Sb_2S_2O$** (Fig. 2.12) is one of the most beautiful Slovak minerals that make up wonderful red-wine coloured needles, grouped in particular into fan-shaped or radial aggregates. Up to now, kermesites from Pezinok are the most beautiful and largest in the world. Born (1790) described it from Krížnica near Pernek, which was the site where, along with the German Bräunsdorf, the most beautiful and most significant samples of this mineral in the world were found in the 19th Century. Later in the 20th Century, especially in the second half of the 20th Century, the most famous locality of kermesite in the world was Pezinok, where very aesthetic dark red needles reached a length of up to 8 cm (Koděra et al., 1986 – 1990) and radial kermesite aggregates were here present covering area of several hundred $cm^2$. The newer findings from the Pezinok deposit from the 20th-21st centuries were characterized by the presence of very aesthetic wine-red needle-like kermesite aggregates on the colour contrasting white colour of calcite (Kúšik, 2007 b). To date, kermesite samples, especially from Pezinok, are the adornment of most of the world's leading museum collections (Ozdín, 2012c).

*Fig. 2.12 Cavity (7 x 5 cm) with radial needles aggregates of kermesite from Pezinok (Nová Alexander Adit 2001). Photo: D. Kúšik*

**KLEBELSBERGITE $Sb^{3+}_4O_4(SO_4)(OH)_2$** is a rare Sb sulphate. In 2009, at the Au-Ag deposit in Kremnica there was found a very rich accumulation of this mineral (Števko et al., 2009). Ball-shaped and radial aggregates form maximum 4 mm large white to yellow-orange aggregates on planes up to 30 $cm^2$. Qualitatively, these samples are ones of the best in the world (Števko, 2012b) and practically the only available for museum expositions. The newer conditions of this mineral origin, for the first time in the world, have been determined from the Kremnica deposit by Majzlan et al. (2016).

**KOBELLITE $Pb_{22}Cu_4(Bi,Sb)_{30}S_{69}$** is one of the most important Slovak sulphosalts. Although this sulphosalt may be well known, little is known about the fact that has more than 35 locations in Slovakia (Ďuďa & Ozdín, 2012), which is more than all other locations around the world. The largest needles and aggregates of this sulphosalt in the world come from the Spiš-Gemer Ore Mts. deposits. On the Smolnícka Huta – Fichtenhübel deposit it formed up to 5 cm long needles (Trdlička et al., 1962), at the heap of the Pater-Noster pit at Hencl it formed up to 4 cm long needles, and at Rožňava have been rarely found up to 7 cm large aggregates of this mineral (Ďuďa & Ozdín, 2012).

**KONINCKITE $Fe^{3+}PO_4{\cdot}3H_2O$** is present at the Kociha site (Novák et al., 2003) in a larger proportion in association with vashegyite, evansite, allophane and volborthite. In Kociha's small gallery is probably the largest accumulation in the world, and its samples with whitewash aggregates are the top quality and the best in the world.

**LANGITE $Cu^{2+}_4(SO_4)(OH)_6{\cdot}2H_2O$** is a blue to light bluish- green secondary mineral, which is quite common on Cu deposits. There is one gallery (Jakub) in Ľubietová, where a large amount of this mineral is recently produced. The langite forms rich, very nice coloured crystalline coatings on the rocks (Řídkošil & Povondra, 1982). Samples from Ľubietová, especially at the end of the 20th Century and the beginning of the 21st Century have been exhibited in many world museums and collections.

**LUDJIBAITE $Cu^{2+}_5(PO_4)_2(OH)_4$** (Fig. 2.13) **and REICHENBACHITE $Cu^{2+}_5(PO_4)_2(OH)_4$** – are polymorphic modifications of the conventional pseudomalachite mineral. They were described from Ľubietová, from the deposit Podlipa (Hyršl, 1991), where they form macroscopic coating and radial aggregates, or crystalline individuals, especially grown on pseudomalachite. In the 1990s, these were the second occurrences of these minerals in the world. Both minerals emerge in hardly macroscopically identifiable but up to several centimeters large aggregates.

*Fig. 2.13 Two aggregates of ludjibaite from the site Ľubietová – Podlipa. The larger one has a size of 9.7 x 5.4 mm Photo: D. Ozdín*

**MARRUCCIITE $Hg_3Pb_{16}Sb_{18}S_{46}$** is a sulphosalt of Pb, Hg and Sb. It has long been known under the unapproved name of "gelnicite or gelnicaite". It was described in 1971 on Zenderling deposit at Gelnica (Háber & Babčan, 1971, Háber, 1980), but there was not enough material to solve its structure needed to complete its characteristics (Ozdín, 2012d). Finally, in 2007, the French-Italian team from the Buca della Vena site in Tuscany, Italy completed the description (Orlandi et al., 2007). The marrucciite of Gelnica was one of the most rewarding candidates for new mineral from our territory (1971 – 1992). It forms up to several mm large needles in association with Pb-Sb sulphosalts, antimony, cinnabar and other minerals (Sejkora et al., 2011). "Gelnicite", although not officially recognized by the International Mineralogical Association as a new mineral, has just been known for several decades from Gelnica, which is one of two sites of this mineral in the world (Ozdín, 2012d).

**NICKELSKUTTERUDITE $(Ni,Co,Fe)As_3$** has one of the classic European sites in Dobšiná, where it has been known since the 19th Century. In Dobšiná there were found ones of the largest nickelskutterudite crystals in the world, which reached 3.8 cm (Cotta & Fellenberg, 1862) or 5 cm (Koděra et al., 1986-1990).

**PRECIOUS OPAL $SiO_2 \cdot nH_2O$** (Fig. 2.14) is the only Slovak historically known gem, which was probably known in Roman times. For almost 1900 years, the precious opal was known in the world only from Dubník site in Slanské vrchy Mts. The most beautiful and largest sample of the opal from the Dubník site is exposed in the prominent part of the mineralogical exposition in the Natural History Museum in Vienna. Among the largest diamonds, ruby and sapphires it belongs to the historically best-known gems. All historically significant pieces of precious opal have been found at Dubník. Several publications, especially from the 21st Century, point to the great importance of the precious opal from the Slanské vrchy Mts. and its everlasting glory (Constantini, 2005, Semrád, 2011, 2015, 2017, Butkovič, 1970).

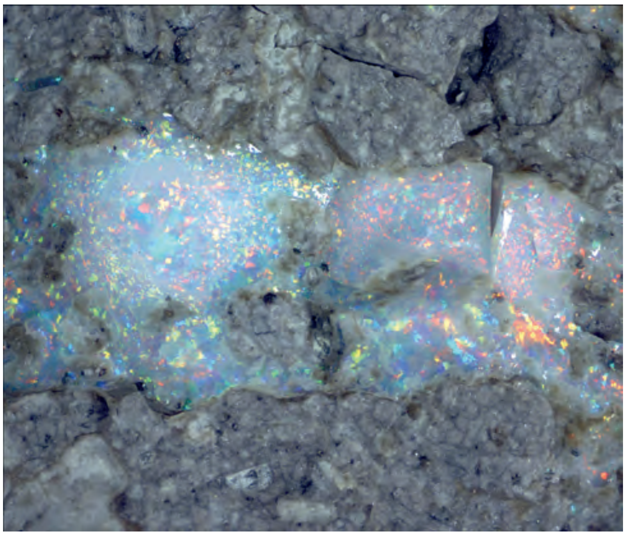

*Fig. 2.14 Vein of mosaic precious opal in andesite matrix from Červenica – Dubník deposit. Field of view 5.3 cm. Photo: D. Ozdín*

**WOOD OPAL $SiO_2 \cdot nH_2O$** (Fig. 2.15) belongs to comparatively widespread minerals and we encounter it in volcanic areas. In the case of Slovakia, there are young mountainous areas with the prevalence of intermediate andesite volcanism, which was accompanied by hydrothermal activity, whose product was also silicic acid. When effused on the Earth's surface, colloidal silicic acid incrusted mainly in tree trunks and wood opal was formed. The wood opals are mostly white, light brown to black. In the vicinity of Poľana, especially, there are specific, very aesthetic orange to red-brown wood opals with a preserved wood texture, especially in Ľubietová, Povrazník, Strelníky, Detva and Ponická Huta. The trunks of these trees reached up to 4 m in length and are locally used for grinding in gemmology (Koděra et al., 1986 – 1990, Ďuďa & Ozdín, 2012). These opals have been known at least in the 19th Century and, as they were characteristic, they have gotten to almost all of the most important European museums and collections. Even today, there have been still found new opalised tree trunks, which are valued also abroad. Wider area of Poľana is a classic wood opal site in Europe.

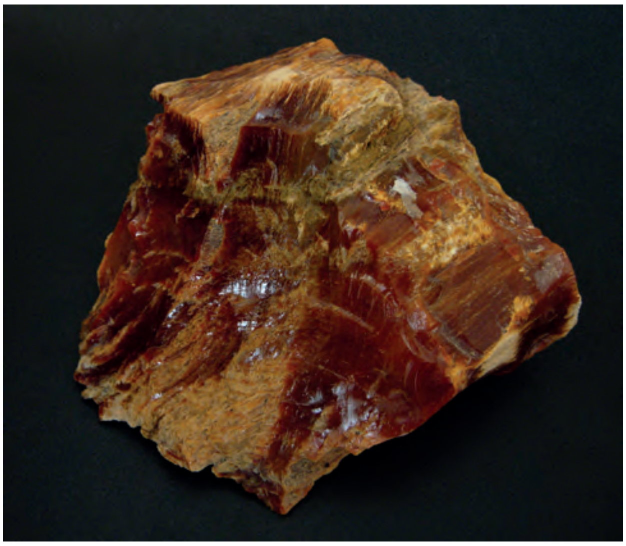

*Fig. 2.15 A characteristic red-brown wood opal (8.5 x 9.2 cm) from Strelníky near Ľubietová. Photo: D. Ozdín*

**PALYGORSKITE $(Mg,Al)_2Si_4O_{10}(OH) \cdot 4H_2O$** belongs to the visually of the least attractive minerals, but in Slovakia, especially in Jelšava, there are up to 1 m$^2$ large white aggregates grown on carbonates (Ďuda & Ozdín, 2012). It does not create characteristic crystals, but dewier skin similar to aggregates of predominantly white colour. Its aggregates are probably the largest in the world.

**PARNAUITE $Cu_9(AsO_4)_2(SO_4)(OH)_{10} \cdot 7H_2O$** rarely forms rich crystalline aggregates on Svätodušná deposit near Ľubietová (Sejkora, 1993, Sejkora & Kouřimský, 2005). Its aggregates forming pseudomorphoses after euchroite on areas over 7 cm$^2$ are probably the largest in the world.

**PHARMACOSIDERITE $KFe^{3+}_4(AsO_4)_3(OH)_4 \cdot 6\text{-}7H_2O$** (Fig. 2.16) was described from Nová Baňa, where this mineral formed up to 4 mm large emerald-green crystals in the cavities of limonitized altered rocks. The first finding was published by J. Krenner (1874) and one year later by Berwerth (1875) first in Hungary and after Schwarzenberg in Saxony, Cornwall in England and New York it was the fourth location in the world. At the time of their discovery, pharmacosiderites from Nová Baňa belonged to the most beautiful in the world and are exhibited in most important museum and private collections.

*Fig. 2.16 Pharmacosiderite from Nová Baňa deposit. Field of view ~ 15 mm. Photo: D. Ozdín*

**PSEUDOMALACHITE $Cu^{2+}_5(PO_4)_2(OH)_4$** (Fig. 2.17) is a relatively common mineral in the world, but Ľubietová belongs to historically known and classical localities of this mineral in the world. Especially in the 19th Century, Ľubietová and the localities of the Urals Mts. were probably the most famous pseudomalachite sites. Under various names, it was known in 1817 (Zipser, 1917). It creates beautiful, dark-green aggregates on the cracks and in the cavities of the quartz or sedimentary rocks (Hyršl, 1991). It is the adornment of almost all the historical collections of museums.

*Fig. 2.17 Pseudomalachite from Ľubietová (7 x 5 cm). Photo: D. Kúšik*

**QUARTZ var. AMETHYST and var. SCEPTRE $SiO_2$** (Fig. 2.18) is in long-term one of the most famous and most characteristic minerals of Slovakia. The sceptre quartz is a variety, where on a thinner and a longer prismatic crystal grow on a shorter and usually thicker quartz crystal on its top. The sceptre-like skeletal crystals of quartz (especially amethyst) from Banská Štiavnica still belong to the largest historical "classics" from the former Hungarian Kingdom and Europe. Their size was up to 20 cm (Uher & Ozdín, 2004). The quartz variety amethyst (Ozdín et al., 2011) was particularly rich in hydrothermal veins in Banská Štiavnica from 18th till the half of the 20th centuries. Banská Štiavnica is historically the most significant European locality for amethyst, and every world museum with specimens dated before the end of the 19th century contains its amethyst specimens (Ozdín & Krejsek, 2016). Some older, especially European museums even have tens of pieces.

*Fig. 2.18 Amethyst sceptre 5.5 cm in size from Štiavnické Bane, Göllner Adit. Photo: P. Škácha*

**ROBINSONITE $Pb_4Sb_6S_{13}$** has the most important locality in the world in a small locality called Malé Železné near Magurka in the Nízke Tatry Mts. Because it occurs in the form of macroscopic grey, fibre aggregates, often together with zinkenite (Majzlan et al., 1998) and at places it forms the dominant fill of some smaller veins (Ozdín, 2012d), it has got gradually in almost all collections around the world. If there is a robinsonite represented in some museum in the world, it is mostly robinsonite from Malé Železné. Overall, Slovakia is rich in the presence of this sulphosalt, almost 1/3 of all occurrences in the world are found in Slovakia.

**SCAINIITE $Pb_{14}Sb_{30}S_{54}O_5$** forms at Sb deposit Dúbrava the largest aggregates of this mineral across the world (Fig. 2.19), which reach up to 1 dm (Sejkora & Kouřimský, 2005). The scainiite is a grey Pb-Sb sulphosalt, found in Malé Železné (Topa et al., 2012) and in Gelnica (Sejkora et al., 2011) in addition to the type locality in the Apuan Alps (Chovan et al., 1998). In the last years, the wealthiest and most beautiful aggregates of this mineral in the world, consisting of up to 4 cm large needles (Ozdín, 2012d), have been found in Dúbrava.

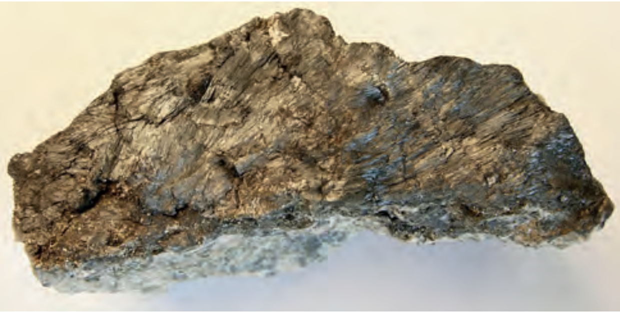

*Fig. 2.19 Exceptional sample of scainiite aggregate from Dúbrava. Size of specimen is 8.8 x 3.7 cm. Photo: D. Ozdín*

**SÉNARMONTITE $Sb_2O_3$** has a classic location in the entire Carpathians and therefore also in Slovakia in Pernek (Fig. 2.20), from where Kenngott (1852) described it as probably the second occurrence in the world and the first one in Europe termed as *Oktaedrischer Antimon-Baryt*. In Pernek, it forms the max. 3 mm large, idiomorphic, cubic, transparent, colourless crystals (Bernard & Hyršl, 2004; Koděra et al., 1986 – 1990) in association with antimony, valentinitite, kermesite, schafarzikite and Fe-carbonates.

The most significant occurrence of the sénarmontite is on the stilbnite deposit of Dúbrava, where the lenses of primary sénarmontite up to 2 m (Sejkora & Kouřimský, 2005) are present in sections Predpekelná, Dechtárka and Ľubelská (Michalenko, 1967). The sénarmontite is predominantly found a piece, of dark to light-brownish colour. In Dúbrava, the largest accumulations of the massive sénarmontite in the world are likely to occur (Ozdín, 2012b).

*Fig. 2.20 Nearly transparent, 1 mm large crystal of sénarmontite from Pernek with closed needles of stibnite on siderite. Photo: D. Ozdín*

**SKINNERITE $Cu_3SbS_3$** (Fig. 2.21) is a relatively rare Cu-Sb sulphosalt occurring mostly in microscopic proportions. On the magnesite deposit of Košice-Bankov in the last quarter of the 20th Century were found unique morphologically well crystallized up to 1 cm large crystals, which were the largest crystals of this mineral in the world. It occurs in association with chalcostite and tetrahedrite (Peterec et al., 1990, Kúšik, 2007 b).

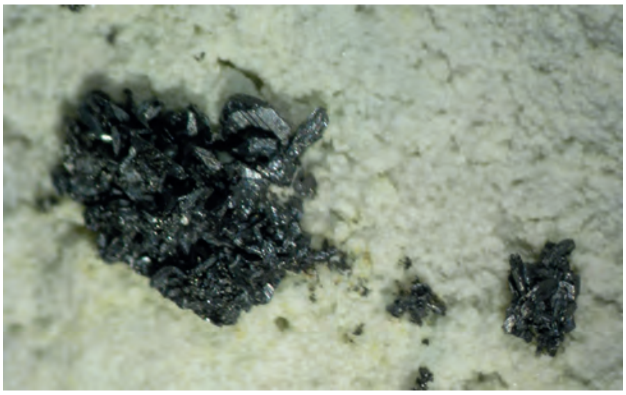

*Fig. 2.21 Characteristic skinnerite crystals from the K – 401 chamber forming intergrowths on Mg-carbonate from the Košice – Bankov deposit. Image width 2.2 cm. Photo: D. Kúšik*

**STRASHIMIRITE $Cu_8(AsO_4)_4(OH)_4·5H_2O$** was described mainly from Novoveská Huta, near the Horný Bartolomej Adit (Řídkošil, 1978, 2007), where it forms light-coloured crystalline coatings on the surfaces up to several 10 $cm^2$. At the time of its finding, it was the third occurrence in the world, and today samples from Novoveská Huta are probably the best in the world.

**TINTINAITE $Pb_{22}Cu_4(Sb,Bi)_{30}S_{69}$** in macroscopic form is one of the rare sulphosalts. In Slovakia, so far, as in the case of kobellite, are located most of the sites in the world and probably also the largest crystals of this sulphosalt in the world occur here. Five cm long needles were described in the Mária Lode at Rožňava, and at Henclová up to 3 cm long ones (Szakáll et al., 2002, Ďuďa & Ozdín, 2012). In most locations in the world, this sulphosalt occurs only in microscopic sizes up to several millimetres.

**TRIDYMITE $SiO_2$** on the site of Vechec, although it has been known for decades now, it has been discovered at the turn of the 20th and 21st centuries, that probably the largest crystals were found here, compared to the rest of the world. White pseudo-hexagonal crystals reach a size of up to 1 cm (Bernard & Rost, 1992), and interpenetration twins reach up to 1.5 cm (Pauliš & Ďuďa, 2002).

**TYROLITE $CaCu^{2+}_5(AsO_4)_2(CO_3)(OH)_4·6H_2O$** in Novoveská Huta, until the end of the 20th Century, one of the most beautiful and largest aggregates of this mineral in the world have been discovered. Generally, they are composed of fan-shaped aggregates of characteristic dark green colour with pearlescent shine in fissures of Permian sediments. Individual petal-like crystals reach up to 2.5 cm (Řídkošil, 1977) and cover an area of up to 400 $cm^2$ (Števko, 2014).

**VALENTINITE $Sb_2O_3$** has classic locations in Europe in Pernek and Pezinok (Fig. 2.22). It has long been known in Pernek before describing it from a typical locality in France, when Born (1790) had described it. It formed up to 2 cm large radial and star-shaped aggregates in association with sénarmontite, kermesite, antimony and schafarzikite. Later, the max. 2 cm large, white to grey radial aggregates occurring on thin veins and planes over 100 $cm^2$ in size were also found on the Pezinok – Kolársky vrch deposit.

*Fig. 2.22 Star-like aggregates of valentinite on the antimony ore. Image width 2.8 cm. Photo: D. Ozdín*

The localities of Pezinok and Pernek together with the Czech site of Příbram are still considered to be the old classical and most important localities of this mineral in Europe (Ozdín, 2012c).

**ZINKENITE $Pb_9Sb_{22}S_{42}$** is quite abundant Pb-Sb sulphosalt, but especially on the Dúbrava deposit it has probably the largest accumulation in the world, where its solid and feltlike grey aggregates form up to several dm large associations (Sejkora & Kouřimský, 2005) or independently fill the hydrothermal veins (Ozdín, 2012d) .

## 2.4 Conclusions

Mineralogical sites in Slovakia are still the source of new scientific discoveries and attractive samples for world-class museums and private collections. To date, 21 new minerals have been described in the world, of which 11 in the 19$^{th}$ Century, only 4 in the 20$^{th}$ Century and in the first 17 years of the 21$^{st}$ Century they are already 6. While in the 19$^{th}$ Century the new minerals from our territory had described predominantly Austrian, or German mineralogists, around the year 1900 predominantly Hungarian mineralogists, at the turn of 20$^{th}$/21$^{st}$ centuries Czech mineralogists and currently Slovak mineralogists, which only document the development of mineralogical sciences in Slovakia over the last 15 years. Among the other 43 minerals that have made Slovakia famous in the world of science, museology and collections, their distribution has been more evenly distributed over the past 200 years, proving that the interesting minerals in Slovakia have been known from the beginning of the study of mineralogical sciences in Europe to the present day, only the quality of mineralogical research Slovakia has changed over time.

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# 3. Slovak Mining Road

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**Abstract:** Among the main objectives of the Association of Mining Clubs and Guilds of Slovakia and one of the reasons why the Association was conceived in the period of 2004-06 in the relatively advanced period of the decline of ore mining as co-operation of clubs and guilds in the mining regions is the preservation of the mining heritage and active mining activity. It ought to be projected into presentations of technical level, education and mining science, metallurgy and coinage in the territory of Slovakia and in its previous state structures, preservation of mining history and maintenance of mining traditions and customs, preservation and revitalization of mining technical works in Slovakia. It is only logical that, in addition to one of the statutory obligations to terminate the mining activity "liquidation and securing", specified and fulfilled in the program of ore mining mines declared by the government of the Czechoslovak Socialist Republic in 1990 and approved by the Government of the Slovak Republic, 1991, whose final fulfilment is to return mainly the surface of mining operations to the original state for further civilian use, or reclamation as "pure nature" is, on the other hand, an initiative to preserve and promote the idea, that not all of the recession programme deserves destruction and disappearance from the surface of the earth. These mining, technological, transport, water and other construction works incorporated in the secondary transformed landscape create in many smaller and larger areas of the mining regions an organic whole with the landscape and document the history of our territory materialized in several cases at the level of the cultural heritage of Slovakia as well as in the lists of National Cultural Monuments.

**Keywords:** Slovak Mining Road, ore mining, coal mining

## 3.1 Introduction

The idea of the Slovak Mining Road was established as an initiative of mainly ore mining and iron mining regions and mining and metallurgical associations, which resumed their activity in the process of the decline of ore mining after the year in 1991. In many operations and plants, the last phase of the survey, opening, mining, and terminating the mining process is implemented as the liquidation and securing of mines, including surface structures. The above-mentioned ore and iron mining regions, owing to the use of stones and clay by the earlier settlements living in our territory, have exceeded their significance and maturity in many of the mining, related sciences and education fields of Slovakia, or Czechoslovakia and Austria-Hungary during their more than a thousand years of uninterrupted history and processing of ores. The oldest documented data on the extraction of metals in Slovakia in Špania Dolina has been estimated to 4,500 BC by the research work of the Bergbaumuseum Bochum and the Mining fraternity Herrengrund realized in 2015 – 2016. In addition to the ore mining regions, active coal, oil, and non-ore regions are also actively involved in the presentation of the mining heritage, and are represented today by major Slovak mining organizations.

With the idea of the project is to preserve and highlight selected mining and technical works and other related buildings and relics, geological phenomena and bring them into the attention of a wide range of domestic and foreign public, professionally focused experts from the world on mining, geology and history, as well as preservation for future generations. In 2005, seven active mining clubs and guilds were associated mainly with the purpose of preserving the tangible and intangible mining heritage, and created the umbrella organization Association of Mining Clubs and Guilds of Slovakia, c.a. (hereinafter referred to as "the Association"). By 2017, the Association has grown

*Fig. 3.1 Mining tools in Bartolomej Gallery – open air museum Slovak mining museum in Banská Štiavnica*

to 36 members representing practically all historical and active mining regions and significant sites of mining and processing of raw materials. Several mining and metallurgical associations, guilds and mining fraternities have built their own museums, exhibitions, instructional walkways, memorial rooms, mining houses, etc. during their modern 10 to 25 year existence (for example, the Museum of Copper in Špania Dolina, the operation of the Mining Museum in Kremnica, expositions in Ľubietová, Nižná Slaná, Rudňany, Pezinok, Marianka, the rebuilding of important galleries in Banská Štiavnica, Hodruša-Hámre, Poráč, Vyšná Boca and others).

The completion of the effort and the goal is to create the conditions for the further use of mining works and other related objects nowadays primarily for the purpose of tourism development.

## 3.2 Brief characterization of the Slovak Mining Road establishment

To achieve these objectives, the Association of Mining Clubs and Guilds of Slovakia, c.a., Rudné bane, š.p. Banská Bystrica, Faculty of BERG TU Košice – Department of Business and Tourism, Slovak Mining Museum in Banská Štiavnica and local governments initiated the project of the Slovak Mining Road (SMR). The representatives of the above-mentioned entities established a so-called SMR Task Force.

The name of the project is not taken over historically and justified by a particular stage of mining in a certain geographical axis; it is based on a linear link between the characteristic mining regions and the centres of these regions in a direction from the west to the east of Slovakia. At the same time, the name highlights the need to solve the complex question of preserving and transforming mines and operations at some points. This time limit results from the final phase of the mining liquidation and reclamation, as defined in the Mining Act, that is to say, the direct mitigation of the effects of mining activities. The title SMR should also capture part of the history of Slovakia, namely the second half of the 20th Century, when the mining in Slovakia represented thanks to the mines development, the number of active plants, the assortment of raw material extraction and the extensive geological survey, the influence on settlement, activity and employment of people in the sinusoid boom and decline an unrepeatable stage and at the end of this period there were substantial negative changes for many of the remote settlements. In the second half of the 20th Century the mining business was exclusively owned by the state through national enterprises renamed at the end of the period to state-owned enterprises. The liquidation and securing of old mining works for which the original operator is not known or does not exist, remains a responsibility of the State under the competence of the Ministry of Economy of the Slovak Republic. The Ministry executes the above mentioned activity through its state-owned enterprise Rudné bane Banská Bystrica with scope of activity on the whole territory of Slovakia, as well as in the former other enterprises of the original VHJ RBMZ (Rudné bane production unit and magnesite plants, and Spišská Nová Ves Železorudné bane mines with numerous plants in the Spiš and Gemer regions) and geological survey. The implementation of the recession program in 1993 – 2005 was exceptional by the rapid liquidation of some surface and underground facilities as a whole with subsequent reclamation and a vision of perfect and ultimate destruction of the consequences of mining activity, which is unrealistic in many cases. The intervention of mining clubs and guilds and intensive co-operation of the then management of the š.p. Rudné bane and the Ministry of Economy of the Slovak Republic in 2006 and the cooperation with the mining museums, the BERG Faculty, the Slovak Chamber of Mines and other professional organizations and self-governments (mining towns and municipalities), were a significant stimulus and change in the view of the liquidation and securing of some selected mining works and operations and the initiative to develop the tasks of the Slovak Mining Road project.

## 3.3 Characterization of SMR spatial arrangement

In the beginning, the design of the project was supposed to create the centres of the Slovak Mining Road (Fig. 3.2). These centres represent geographically, but also historically divided close or distant mining regions with varied assortment of extracted raw materials,. The basic division consists of the following SMR centres and subtitles:

1. Malé Karpaty Mts. mining – Small Carpathians Mining Road with Pezinok and Marianka centres (Au, Sb, pyrite, shale).
2. Coal mining in Slovakia – Upper Nitra Coal Basin and South-Slovakian Coal Basin with the centres of Handlová, Cigeľ, Veľký Krtíš, Malá Stracina (brown coal, lignite).
3. Mining of gold, silver and non-ferrous metals – Golden Royal Towns with centres Banská Štiavnica, Kremnica, Hodruša-Hámre and Nová Baňa (Au, Ag, Pb, Zn, Cu, Sb, rhyolite).
4. Mining of copper, gold and antimony – the surroundings of Banská Bystrica, Liptov and Upper Hron Catchment regions with the centres of Špania Dolina, Ľubietová, Vyšná Boca (Cu, Au, Sb, Fe, Hg).
5. Spiš region – copper and iron mining with centres Spišská Nová Ves, Rudňany and Smolník (Cu, Fe, Ba, Hg, Au, Ag).
6. Gemer region – mining of iron, magnesite and talc with centre in Rožňava (Fe, $MgCO_3$, Sb, Cu, Au, Ag).
7. Mining in Košice, Prešov and Slanské vrchy Mts. – with a centre in Košice (NaCl, noble opal, Sb, Fe).

The original intention consulted during the development phase in 2007 with the Ministry of Economy of the Slovak Republic consisted in the central financing of the Slovak Mining Road project through the EU funds in the

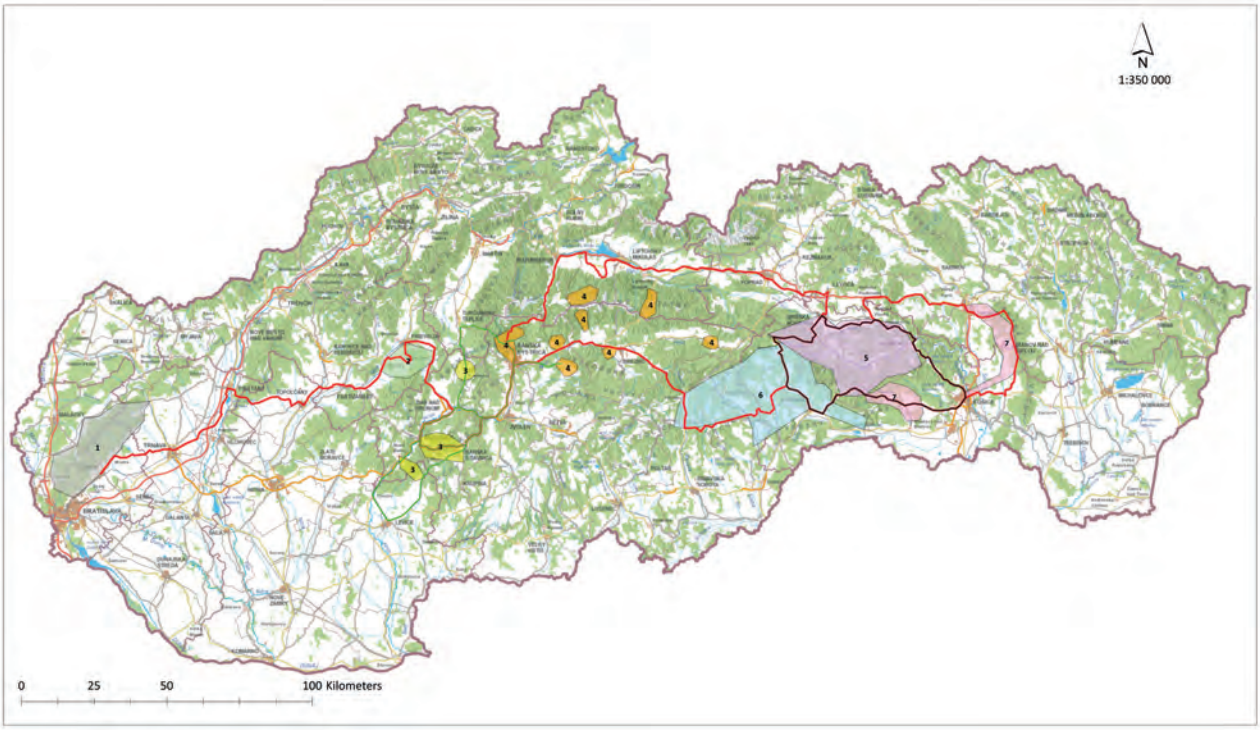


*Fig. 3.2 Slovak Mining Road (1. Malé Karpaty Mts. mining – Small Carpathians Mining Road, 2. Coal mining in Slovakia – Upper Nitra Coal Basin and South-Slovakian Coal Basin, 3. Mining of gold, silver and non-ferrous metals – Golden Royal Towns, 4. Mining of copper, gold and antimony – the surroundings of Banská Bystrica, Liptov and Upper Hron Catchment regions, 5. Spiš region, 6. Gemer region, 7. Mining in Košice, Prešov and Slanské vrchy Mts.*

2007 – 2013 funding period and the concept of the project as a national project for the preservation and transformation of mining works and plants. After clarifying the conditions for the provision of these subsidies in January 2008, it was clear that it is not possible to fulfil the defined conditions (in particular settlement of ownership relations, etc.) in a number of criteria. Therefore, the implementation and the main role of the Association lies in the level of promotion of the project as a whole and creation of the conditions for partial realization in the regions, active cooperation in the tasks of the programme. In order to realize this intention, the Association in cooperation with the company Rudné bane, š.p. has agreed to cooperate on the promotion of Slovak Mining Road sites through a website, information boards and a prepared printed guide to mining-technical monuments and mining museums in Slovakia. The individual centres and locations presented on the SMR map as the main sites are planned for the SMR info-panels. These locations are marked by a numeric code expressing the route and the centre. In addition to the basic info-panels, the boards are also located on important mining-technical monuments in the country.

*Fig. 3.3: The first SMR table in the former royal town of Smolník*

During 2008 – 2016, the SMR Task Force carried out documentary work on the selection of sites, a description of the mining-technical sights and related cultural monuments in the regions and localities concerned, thus making a list of the sites. Despite the fact that in Slovakia there are about 300 mining towns, municipalities and sites with mining or metallurgical activity and history, the list of 2017 consists of 96 sites selected. The primary criterion for inclusion of a site in the SMR list is, in addition to historical data, the current state of preservation of the object, so that it could be tangibly presented to-date.

In 2009, the first SMR table (Fig. 3.3) in the former royal town of Smolník was officially unveiled and consecrated on May 1, 2009, which launched a concrete work on bringing the sites and objects of the mining and metallurgy to the foreground.

The SMR info-panels have an agreed type of a headline and a left edge. In the locations where the SMR copies at the same time the sites of the Iron Route – especially in the Gemer and Spiš area, the upper edge of the board in the right corner also bears the logo of the Iron Route – now under the name of the Slovak Iron Road (hereinafter referred to as "SIR").

In 2011, during the 3rd meeting of the Mining Towns and Municipalities in Rožňava, the Chairman of the Association of Mining Clubs and Guilds of Slovakia, and the Chairman of the civic association Slovak Iron Road signed a cooperation agreement. An important purpose of the agreement is the joint promotion of the sites which are identical in the Gemer and Spiš regions with respect to the extraction and processing of the iron ores all over Slovakia as the SMR sites.

The final update of the list of SMR and SIR sites in 2017, which should conclude a site presentation plan for a longer period of time, based on the criteria described above, including the updating of the centres in each region, is as presented hereinafter. The centres of the regions are the sites where a mining museum or an info-centre are located where further data on a mining region can be obtained.

## 3.4 Regions and centres of the Slovak Mining Road (centres marked in bold)

### 3.4.1 Malé Karpaty Mts. mining – Small Carpathians Mining Road

Mining in Malé Karpaty Mts. region (the most important sites are depicted in Fig. 3.4) has historically not been as important as in other areas, but it was an important part of the economic prosperity of the region. The earliest documented mining in the area was precious ore mining, the origins of which date back to the 14th Century, when the Charter of 24.6.1339 was granted by the Hungarian King Karol Róbert of Anjou to Šebuš and Peter, the counts from Svätý Jur and Pezinok who operated the gold mines, provided the 15th of the yield of the gold will be transferred to the royal court (Wittgrúber et al., 2001). The documented annual gold production was 300 – 2,000 grams, which was delivered to the Kremnica Mint (Bergfest, A., 1951). The first valid account of the amount of gold extracted comes from 1778, namely 1,267 grams of pure gold (Wittgrúber et al., 2001). The end of gold mining in this area is dated to 1861, when the last gold was shipped to Kremnica. In recent years, the mining has been limited to the panning of the material of old heaps.

Historically, the second oldest mining in the region was the antimony mining, the beginnings of which date back to the late 18th Century when precious metal mining was already in decline, and local miners tried to replace their business by prosperous minerals. Antimony, which

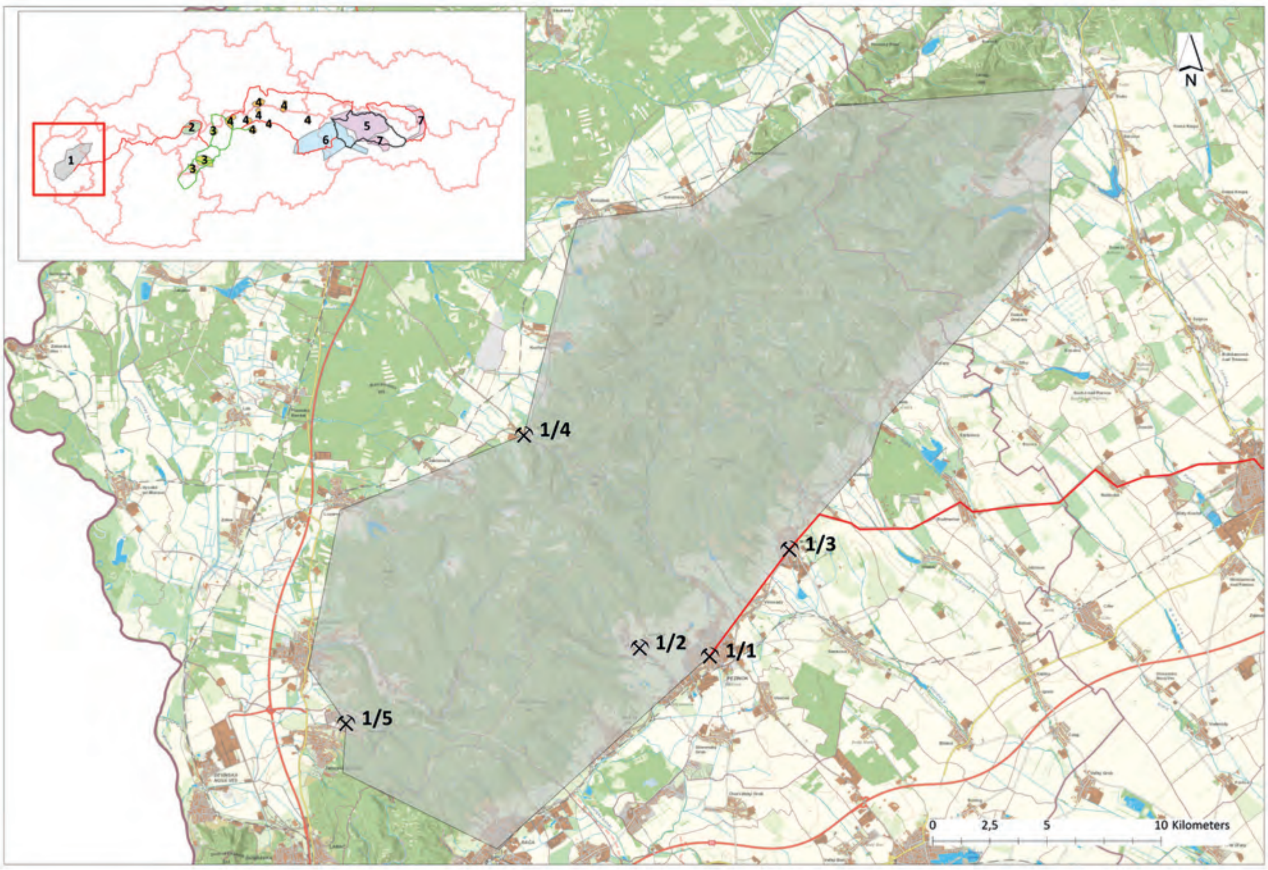


*Fig. 3.4 SMR sites of Small Carpathians. 1/1 Pezinok, 1/2 Limbach, 1/3, Modra, 1/4 Pernek, 1/5 Marianka*

was the source of pigment production earlier, but it importance has grown in this period as a metal that was added as an additive to alloys (e.g. the military industry). Since in the Small Carpathians sources of antimony mineralization, have been genetically linked with pyrite-pyrrhotite volcanic-exhaling mineralization, they were used historically together. Firstly, in 1790 in Pernek the Barbora Upper and Lower Galleries were developed (Wittgrúber et al., 2001). Later on, the Zubau and Pavol Galleries were also excavated. The 1790 report also mentions the galleries around Kuchyňa, namely Trojičná and Puklišova Galleries, but they were merely the exploration galleries. Work on the deposit on the Kolársky vrch near Pezinok also started (Fig. 3.5). Here, in the years 1809 – 1810, 11.1 t of antimony concentrate was extracted and processed, in the Pernek region at the same time, it was only about 3 t of antimony concentrate.

The large mining boom focused on the extraction of pyrite ores was connected with the construction of the first sulphuric acid plant in the then Hungarian Kingdom, which was built in Cajla in 1848. However, its operation was relatively short since it had stopped in 1896. There were several reasons for this development, the low quality of local pyrite ores was the main cause of frequent operational disorders (Bergfest, A., 1951). The mining excavation in the Pernek had halted in 1922, and the extensive geological exploration study associated with the restoration of the old mines as

*Fig. 3.5 Budúcnosť Adit with information boards of local mining road, Kolársky vrch Hill.*

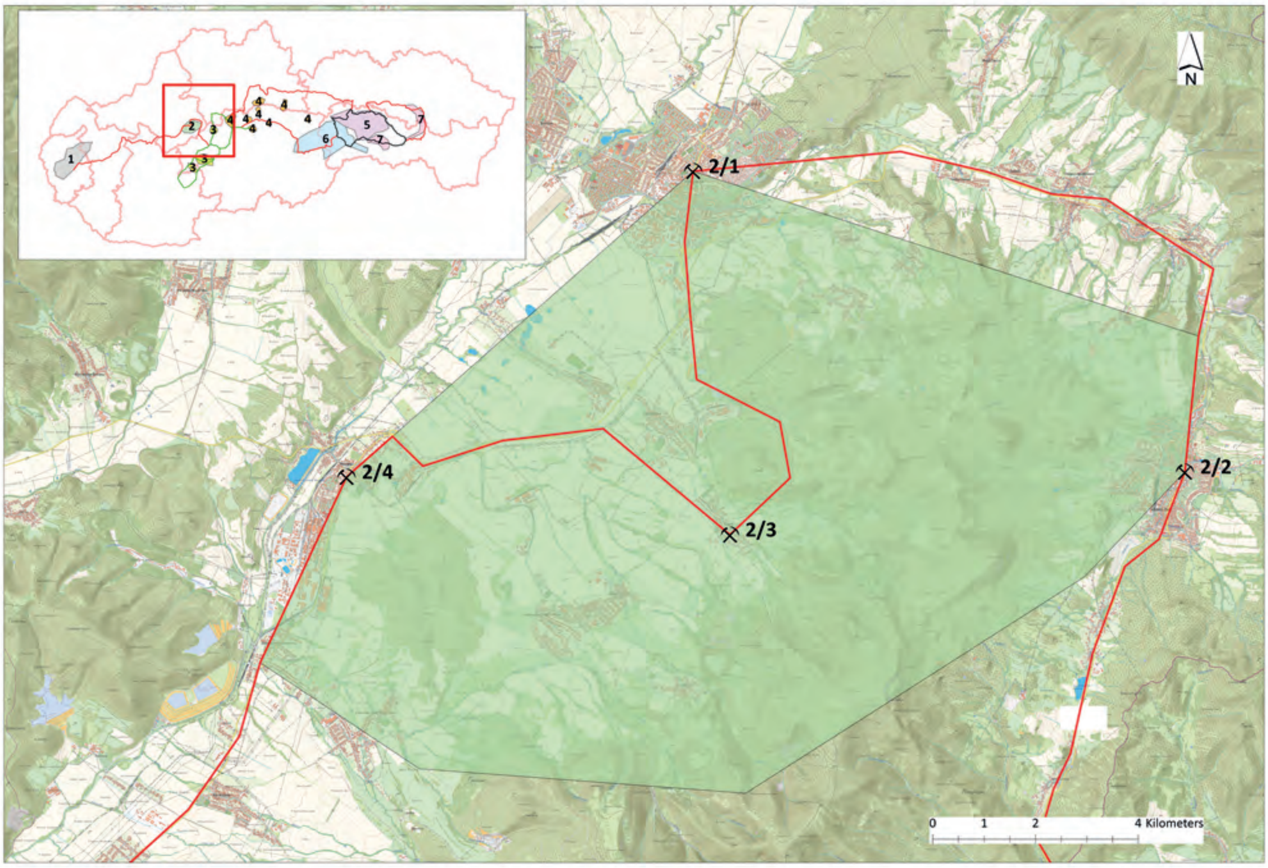


*Fig. 3.6 SMR sites of coal mining in Slovakia. 2/1Prievidza, 2/2 Handlová, 2/3 Cigeľ, 2/4 Nováky, 2/5 Veľký Krtíš – Baňa Dolina, 2/6 Malé Straciny, 2/7 Modrý Kameň*

well as the excavation of the Stanislav research pit carried out in the 1950s did not yield satisfactory results and the mining on the deposit did not recover. In the Pezinok area, the antimony ores were mined with less breaks until 1991, when the mining was stopped and the mining works were slowly liquidated.

The youngest mining industry, which is part of the SMR, is the mining associated with the excavation of the Lower Jurassic black roofing shales around Marianka, which was developed by the founding the enterprise of the French financier Paul Eugene Bontoux in 1859 (Kráľ et al., 2011). From the very beginning, this company exclusively devoted to the production of roof coverings, but later it also went to the production of slate school tables, which supplied the whole Hungarian Kingdom, and part of the production was directed to export to the Balkans, but also to Egypt, America and elsewhere. Evidence of the high-quality work of the company was the award of silver medal for shale products at the IV$^{th}$ World Exhibition in Paris in 1867. With the advent of producing lightweight coverings that replaced the slate roofs, however, the plant gradually declined and during the World War I it completely stopped the operations.

### 3.4.2 Coal mining in Slovakia – Upper Nitra Coal Basin and South-Slovakian Coal Basin

The origins of exploitation and extraction of coal in our lands are associated with the processing of gold-bearing ore by roasting with the addition of mineral coal (the most important sites are depicted in Fig. 3.6). This procedure was firstly used in Kremnica in the treatment process at the end of the 17$^{th}$ Century and it is assumed that coal originated from the nearby Ortúty site (Zámora et al., 2003). But the very beginnings of the search and subsequent industrial coal mining in Slovakia fall to the end of the 17$^{th}$ and the beginning of the 18$^{th}$ Century. All this was related to the finding of an alternative to wood (the lack of wood near mining centres) as an energy raw material in the mining and processing of precious metals, copper and iron mainly in the Central Slovakia region. These facts led to efforts to find coal deposits in Slovakia and to make attempts to use it in mining and metallurgy. The Viennese Court Chamber supported the search for mineral fuel deposits through various appeals, regulations, rewards, and so on. In 1722, the English mechanic, Isaac Potter, built a new steam-powered wood-fuelled fire-engine in New Baňa. On the basis of the experience gained, until 1758 another 6 fire fire-engines were built in the Banská Štiavnica Ore District. The fuel consumption (wood) was very high for these machines. Therefore, a great effort was made to find coal deposits in the Central Slovakia Ore District. This effort was also supported by the Vienna Court Chamber, which promised 100 ducats of reward to the one who finds coal and delivers it to the smelter plant in Banská Štiavnica. This situation caused the first time to mention the coal deposit in Handlová. Another wave of discovery of coal deposits was stimulated again by the Vienna Court Chamber. In 1751, it ordered all subordinate offices to search for deposits of coal and peat and to test for these types of fuel. In 1766, it promised a reward of 100 ducats to anyone who finds a coal or peat deposit. Already in the same year, an application for permission for coal mining in Badín was filed. In 1768, the first coal deposit survey was carried out at Obyce. In the 18$^{th}$ century almost all major coal deposits in Slovakia were known. However, their regular mining did not occur at that time. For the coal deposits in the Habsburg Empire it should be noted that the coal was not among the reserved minerals for quite a long time. Until April 2, 1782, the Vienna Court Chamber issued a decision to proceed as it did to other minerals when granting the coal mining. The coal mining approval should be granted by the mining courts. However, on June 20, 1788, it issued a decree according to which the deposits of coal which would be found in Hungary and Transylvania in the future should be completely exempt from consent to mining them by the mining courts, and should be left to the landowners who could freely dispose of them. Such a legal status was in force until the adoption of the General Mining Act in 1854. Although it was favourable for the Hungarian nobility, which owned most of the land, it had negative consequences for the development of industry especially in Slovakia. It caused not only technological delays in metallurgy and iron smelting, but it also affected the overall decline of these industries. In the first third of the 19$^{th}$ Century there were a number of sins in Slovakia that evidenced the gradual rise of the industrial revolution. Already in the 1820s, for example, modern steam engines started to be built in the Central Slovakia mining region, and they were gradually introduced in other areas of Slovakia. Therefore, the pressure to acquire the mineral fuel has risen and forced the exploration of coal deposits. The first well-known exploration of the coal deposit in Handlová and the first coal mining in Slovakia after 1837 in Badín belonged to this period. Already in the 1850s the efforts have been made to excavate other major coal deposits in Slovakia, which in some cases led to the start of regular mining. In 1854 Ján Pálffy, the owner of the coal mine, started the quarrying of coal in the Handlová deposit. Early 1850s the extraction was started in the Obyce-Jedľové Kostoľany deposit. In 1873, the extraction proceeded to the systematic extraction of the Badín coal mine depression. A great effort to extract the coal deposits led to the further development of the industry and the construction of the railways, and a major impetus was the issue of the General Mining Act on November 1, 1854. This law declared coal as a reserved mineral and thus made its extraction independent of the consent of the landowner. Overall, however, the Slovak coal in the 18th and 19$^{th}$ centuries contributed very little to the development of industrial production in Slovakia. It was because there was no quality coal in Slovakia, the coal deposits were distant from the major metallurgical centres, and the mining was complicated due to the unfavourable legal relations, which, for a short period of time, did not reflect the miners' needs (Hronček & Herčko, 2014). In the last quarter of the 19$^{th}$ Century only 3 bigger coal plants were operating in Slovakia, in Handlová, Badín and Obyce. Minor mining operations were also carried out in the South Slovakia coal basin around Veľký Krtíš. The most important were the coal mines in Handlová, where the origins of the coal mining were associated with the name of the Bojnice Count Ján Pálffy, who secured in 1858 – 1861 the right to mine the coal in the mining fields Karol, Konštantín, Ján, Barbora, Anna and Laura in the north-east edge of the deposit, where the coal seam is just below the surface. However, their greatest development began in the early 20th Century after extensive drilling. Since 1919 the company was operating under the name of Handlová Coal Mines, stock company, Bratislava. Since its inception in the new Czechoslovakia, the Handlová deposit has secured a substantial part of coal mining in Slovakia. Already in 1910, the construction of a thermal power plant in Handlová began, which gradually increased its capacity and until 1953 it was the largest thermal power plant in Slovakia. In 1938 the stock company Handlová Coal Mines opened mining fields in the vicinity of Modrý Kameň and in 1940 began lignite mining in Nováky (Zámora et al., 2003).

The coal mining in Slovakia has acquired its importance and its development after the WWII. Socialist industrialization required the provision of the necessary fuel-energy base. Limited import possibilities of noble fuels and energy have led to high requirements for the development of mining in all coal mines of the Czechoslovak Republic and thus also in Slovakia, despite the fact that, besides the Handlová deposit, the coal from other deposits did not reach high the caloric values (Hronček & Herčko, 2014). The nationalized stock company HUB under the name Handlová Coal Mines, n.p., also administered the coal mines in Obyce, Veľká Tŕňa and Čakanovce. Opening works started in Nováky in 1940 and developed after 1950s and the Nováky Coal Mine was established with the mines Mier, Lehota and Nováky, renamed in to Youth Mine in 1957. From the original Handlová operation, the mine Cigeľ split in 1959 as an independent company (Zámora et al., 2004). After a variety of organizational changes, the coal mining company with its headquarters in Prievidza operates under the name of Hornonitrianske bane Prievidza, a.s. Interesting examples of the coal mining history are exposed in Museum of Ján Procner in Handlová (Fig. 3.7).

### 3.4.3 Mining of gold, silver and non-ferrous metals – Golden Royal Towns

It is difficult to determine when the precious stone mining began in this most important mining region (the most important sites are depicted in Fig. 3.8). It is assumed that the Celts, whose coinage was based on gold and especially silver, could exploit these rich finds (Kolníková, 2012). Based on the finds (Roman coins, terra sigillata and Roman glass) from Banská Štiavnica, the location of the Staré mesto (Old Town), where the very beginning of underground mining in this mining region is likely, we can assume that there was a relatively extensive mining of precious ores during Roman times. We do not have the direct reports on the mining and processing of precious ores by Slavs. But considering the popularity of these metals by the Slavs and the material documents for processing and producing jewellery (Bojná, Nitra, Bojnice, Pobedim), we assume that well-known ore deposits such as Kremnica, Banská Štiavnica and others were exploited. The exploitation of ore deposits continued even after the demise of Great Moravia, when Slovakia became part of the early-feudal Hungarian state. It looks like the ore mines produced so many precious metals that they were not only able to conceal domestic consumption but also exported. This is evidenced by Nestor's Kiev Chronicle, which mentions the import of Hungarian silver to Kievan Rus in about 969. Undoubtedly, the mining of precious stones in the Banská Štiavnica area was of utmost importance. It is assumed that 50% of the extracted silver originated from the Banská Štiavnica Ore District. This silver served as a basis for the coinage of Hungarian silver coins (Kúšik, 2015). During the 10th Century, significant mining of precious metals ores was in the Banská Štiavnica area. The record from the year 963 on the arrival of Czech miners in Banská Štiavnica has been preserved (Lichner, 2002). In the Charter of 1156, this territory is termed "Terra Banensium" – the land of miners. Later in 1217 it is mentioned as "Bana". But the seal of the 1275 document contains already the name Štiavnica (Schemnitz). Historians explain this by saying that the name of Bana refers to the Staré mesto – Glanzenberg and Štiavnica was a settlement in a valley that is identical to today's centre of Banská Štiavnica. The production of gold and silver in the 11th Century can be considered very interesting due to the high content of metals in the surface parts of deposits and the easy accessibility of the ores (Kúšik, 2015). The boom of mines brings a change of settlement to the city that in 1238 received from King Béla IV

*Fig. 3.7 Handlová – Museum of Ján Procner*

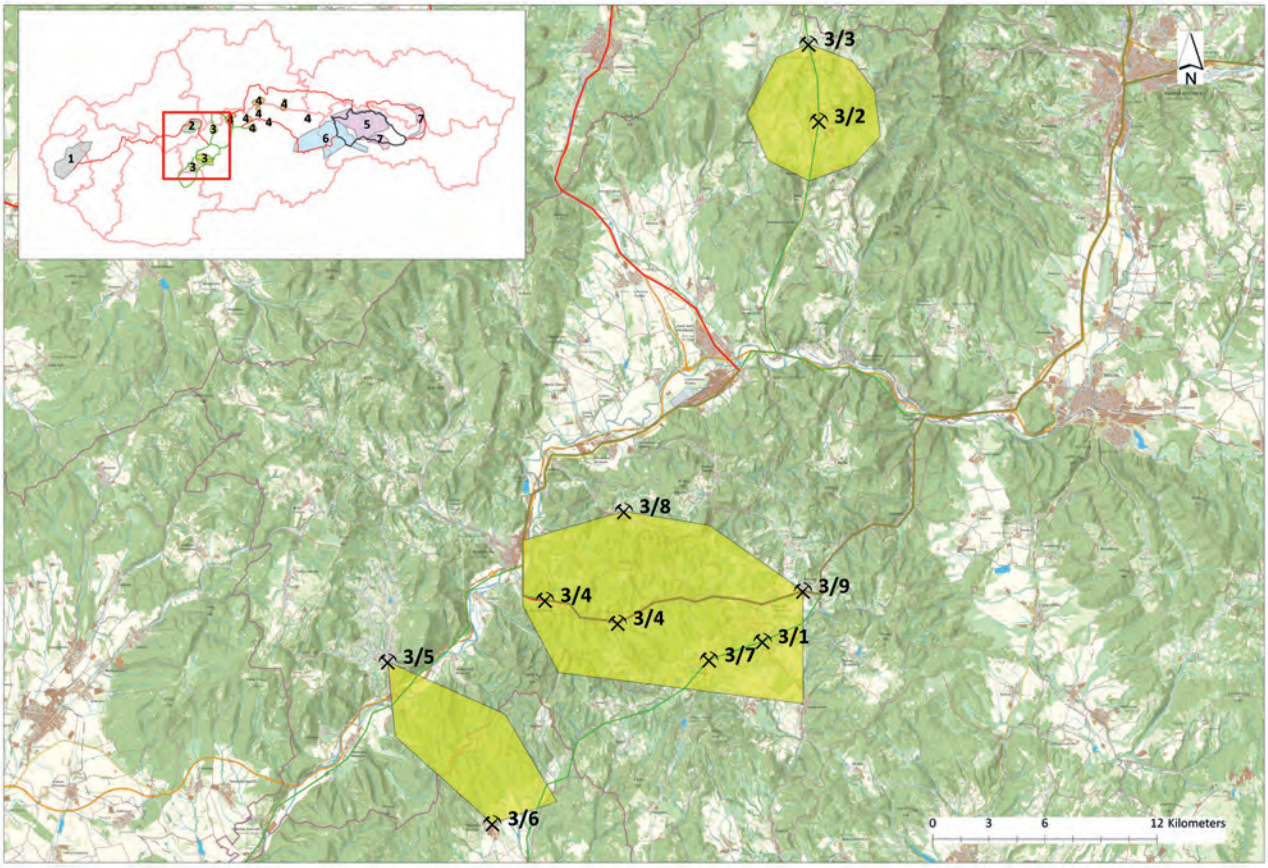


*Fig. 3.8 SMR of mining of gold, silver and non-ferrous metals. 3/1 Banská Štiavnica; 3/2 Kremnica, 3/3 Kremnické Bane, 3/4 Hodruša, 3/5 Nová Baňa, 3/6 Pukanec, 3/8 Vyhne, 3/9 Banská Belá*

the city privileges and mining rights. The significance of mining is also emphasized in the 1275 town seal, where the coat of arms of the city, besides the walls, contains symbols of mining tools (as illustrated in Fig. 3.1), such as pick and hammer (Lichner, 2002).

The first written records proving the existence of Kremnica are from the 14th Century. In 1328, Charles I, also known as Charles Robert of Anjou granted special privileges the "guests" concentrated in the Cremnych Bana settlement – coiners from Kutná Hora; that encouraged its intense development. Thus, the settlement was given the privileges of a free royal city and mining mint rights under the Kutná Hora law. At Kremnica, however, there was already developed mining business with total annual production estimated at 130 kg of gold per year (Beránek, 1977). Shortly after the arrival of the miners, the first coins – the Hungarian Groschen – were minted in 1329. Eight years later, the mint production included also the golden florins. Later, they became known as Kremnica ducats. It is believed that Kremnica's mining history began much earlier. However, there is no documentary evidence linking to the beginning of mining on this deposit. However, the only direct evidence was found by a detailed geological survey of the Šturec deposit. It was the rest of the wooden pillar from the old mines in Šturec, which was dated to 1050 by the $^{14}C$ method. The depth of the find below the surface shifts the beginning of mining for at least 100 years back. According to other authors, the mining activities began in the 8th or 9th centuries, eventually in the beginning of the 11th Century, when in 1004-1008 the miners from Harz settled in the region. The most likely beginning of the Kremnica mining is the end of the 9th to the beginning of the 10th Century. The document from the year 1385 mentions, for example, a hereditary gallery that was 4 km long. This fact points to the long-term use of the deposit. The oldest codified mining law in the territory of Slovakia dates back to the thirties of the 13th Century. It was probably the law of the Štiavnica Mines, which was given the privilege by the King Béla IV. However, the document defining the mining law was probably destroyed during the Tatars' invasion in 1241 – 1242. Until now only the German language copy from 1466 has been preserved. All mining towns in the territory of today's Slovakia adopted it either as a whole or at least some parts. Most decision-making on mining was given to free mining towns. King Stephen I (997 – 1038), the founder of the Árpád dynasty, established the royal mining chamber, which was the forerunner of the Chambers of Mines.

Since the second half of the 13th Century, a significant development of mining occurred in Slovakia. All major deposits and numerous smaller occurrences were exploited, exploring the possibilities of extraction and treatment of precious metals ores first. All ore deposits in Banská Belá, Hodruša (Fig. 3.9), Štiavnické Bane, Pukanec and Nová Baňa areas were mined. Since the 14th Century mining our territory experiencing a great boom, but with the deepening of mines and the tracking the ore columns to the depth water problems occur in most mining areas. This led in most of the areas to construction of drainage galleries and the construction of pumping equipment, treadmills. At the same time, the deepening of mines also reduced the quality of ores and the mining was more complex and required the involvement of more miners, thereby increasing the cost of mining. In every mining town, according to King Charles Robert's order, they built a royal house, Kammerhof, in which the Chamber Count was seated. The miners were obliged to exchange gold and silver in Kammerhof, and the Chamber Count was the only one authorized to determine the fineness of the metals. On April 7, 1388, Banská Štiavnica held the founding meeting of the Union of Central Slovakia Mining Towns, which was tasked with jointly solving the problems of mining towns. In Banská Štiavnica, water reservoirs for surface water capture started to be used to propel water wheels (Kúšik, 2015) at the end of the 15th Century.

In the 14th and 15th centuries, the exploitation of precious metals ores in Kremnica reached a maximum and the annual production of gold exceeded 400 kg, representing a third of the total production in Hungary and a tenth in the world (Beránek et al., 1977). The prosperity of the city in the 14th Century is documented by its rapid expansion. In Kremnica, the waterworks were built to supply water. The oldest of them was built in the 15th Century.

At the beginning of the 16th Century there were 426 individual mining centres around Banská Štiavnica. The technique of work has changed by improving mining. The rock was first transported in backpacks, then dragged on the rims, later wheel-bags were used, and then took over from Tyrol the carts they had modified for the Banská Štiavnica conditions; these mining carts were also called the Hungarian carts. Vertical transport was secured by a simple device with a winch, later using a treadle wheel, horse winder or water wheel. The water was needed to build up artificial water reservoirs. In the period 1500 – 1638 there were only 4 water reservoirs /Veľká Vodárenská, Malá Vodárenská, Brennerštôlnianska, Evička/. The water was pumped by the rope container, the ventilation was natural, or the blasts were used. Lighting went from primitive rays and torches to oil burners. The development of mining also required some specialization of workers. The professions were created as miners – breakers /rock disintegration/, loaders /rock loading into transport vessels/ and runners /they transported the rock to the destination/. Special squads provided water pumping. Specialists worked on ore treatment and compaction. Several mines from smaller miners who were unable to maintain mining financially were gradually taking over by the state. In the 17th Century a separate mining administration was established, for the mines belonging to the state, so-called Mines Administration on Vindšachta. Although in the 17th and the beginning of the 18th Century Banská Štiavnica was challenged severely – the Turkish raids, the anti-Habsburg noble uprising, the plague epidemic in 1709 – 1710, which killed about 6,000 people, the Banská Štiavnica mining continued to progress. The year 1690 was the richest year of the Banská Štiavnica mining area when 29,000 kg of silver and 605 kg of gold were produced in the smelters. The ores mining moved deeper-and-deeper, the mining work became technically more demanding, more systematic mining techniques and

*Fig. 3.9 Knocking Tower in Banská Hodruša*

*Fig. 3.10 Portal of Bieber Hereditary Adit*

more complicated finishing and metallurgical processes were needed. The rock was still disconnected manually (using a pick and a hammer), exceptionally with fire. On February 8, 1627, Kaspar Weindl from Tirol made the first underground mining blast in the world with black powder in the underground of Horná Bieberova Gallery (Fig. 3.10; Kúšik, 2015).

Handheld drills were also used. Mining water was pumped from the level of hereditary adits to the surface by vessels, leather bags and piston pumps. The first mention of piston pumps is from 1604 in the Brenner works. There, for the first time in 1619, a horsepower treadmill was used to drive piston pumps. However, human and horsepower did not meet the increasing need for ever deeper mining. Greater emphasis was put on improving the construction of treadmills and the use of water energy. At the beginning of the 18th Century, in 1700 – 1701, the chief engineer Adam Unger built a water-powered wheel pump. Flooding of the galleries was an increasing problem and there was a threat of mines closure. The engineer Matej Kornel Hell helped to rescue them. He constructed water pumps in the Magdaléna Shaft at Vindšachta and in the Horná Bieberova Gallery. Development required better and better processing of ores. The method of treatment in the stamp mills was applied, that belonged to the most important treatment ores processing in Banská Štiavnica. The increasing need for more propellant water required an expanding network of artificial water reservoirs – the "ponds" that secured energy for mining machinery, water pumps, hoisting and treatment equipment and smelters. This sophisticated water management system of artificial water reservoirs, powered and interconnected by collecting, conducting and drive ditches, not only saved the Banská Štiavnica mining, but on its energy base developed a mining pumping technique, which was also a model for other mining sites in the world. Two major personalities, engineer M. K. Hell and Samuel Mikovíni, who was appointed in 1735 for imperial-royal geometer and the first professor of the mining school in Štiavnické Bane, had a large share in this development. In the near Nová Baňa, after a short epoch of boom (14th-15th centuries), the town, experiencing the internal unrest in Hungary and anti-Turkish wars, had suffered one blow of fate after another – the destruction of the city by the Turks in 1664, the anti-Habsburg uprising and the plague epidemic, which made the city almost extinct in the 17tth Century. The mining water problems also negatively affected the further development of mining. The flooded mining works were to save by the atmospheric fire engine, built in 1722 by the English designer Isaac Potter (the model of the machine is located in the Hron Regional Museum in Nová Baňa). It was the first steam engine on the European continent (Kúšik, 2015). In Banská Štiavnica at the end of 18th Century. the construction engineer Jozef Karol Hell proceeded with the construction of additional reservoirs. In 1738 he built the first weft pumping machines. J. K. Hell put in operation in 1755 his invention – Hell's Air Pump Machine, where he used a completely new driving element – compressed air in addition to water. The machine had a revolutionary design and overtook its time. However, the atmospheric steam /fire/ pumping machines were still largely used. In the Banská Štiavnica ore district they were built in the greatest number in Europe and were assembled completely in Slovakia. At the end of the 18th Century more economical Hell's water-column machines started to be used. A major breakthrough in the mining of precious ores in Banská Štiavnica was the completion of the inauguration of the Hereditary Adit of Joseph II (Voznická), which began to be drilled in 1782 and completed 96 years later, in 1878. This hereditary drainage gallery, which drains the deposit up to level of the 12th horizon, has a length of 16,210 m and at the time of its construction it was a unique mine work on an European scale (Kúšik, 2015). This gallery has greatly facilitated the mining in the region, since only horizons below its level pumped were pumped, so the mining costs were not so high. At the beginning of the 19th Century, Hell's water-column machines were perfected by professor of the Banská Štiavnica Mining Academy, Jozef Schitko. In the course of the 18th and 19th centuries, the ores treatment achieved a high technical standard in Banská Štiavnica. In their reports, many experts and foreign travellers included Banská Štiavnica among cities with excellent technics and technology of ore processing. Emperor Maria Theresa adopted the proposal of John Tadeus Peithner, and by decree of December 13, 1762, ordered the establishment of a Mining Academy in Banská Štiavnica. It was the first college of this focus in the world, and Banská Štiavnica became the centre for the development of mining science and technology in Europe (Kúšik, 2015). The first lecture at the Mining Academy was presented on October 1, 1764. The professors (Jacquin, Poda, Delius, Scopoli) of this school are associated with many European and world lead-

*Fig. 3.11 Farewell to the Old Year in Glanzenberg Hereditary Adit*

ers in science and technology. The Mining Academy later merged with the Forestry Institute and thus established the Mining and Forestry Academy in Banská Štiavnica. The Academy trained a number of mining experts who were involved in introducing new methods and practices in mining practically all over the world. In Kremnica, in the second half of the 18th Century, with the drainage of mines (Deep Hereditary Adit) and the opening of deeper ore bodies, the production of precious metals began to grow. In the years 1748 – 1800, an average of 635 grzywnas of gold and 20,809 grzywnas of silver were obtained. But early in the 19th Century the Kremnica mines again struggled with great difficulty and were unprofitable. The mines reached into the deeper parts that were not drained by the Deep Hereditary Adit, and had to be pumped, ventilated and the hoisting of the extracted ore was too costly. In 1841, work began on the excavation of the Main Hereditary Adit, which was completed in 1899. It reached a length of 15,481 m (Kúšik, 2015).

After the end of the World War I and the creation of Czechoslovakia, in 1923 – 1931 the Banská Štiavnica and Hodruša plants interrupted their operations, as a result of the reconstruction and rehabilitation of partially suspended mining and metallurgical operations. Of the original 1,500, only 600 miners were employed. Preliminary work on the opening of the richest ore pillars on Špitaler and Grüner's veins was carried out, the shafts František, the blind Emil and Mária were deepened because of the ventilation. Later on, they began work on the Maximilián Shaft and the Svätotrojičná (Saint Trinity) Gallery and the Pacher Gallery. The system of stamp mills and gravitational treatments was also rebuilt. In the year 1930 in the František Shaft modern flotation treatment plant was built, which alternately processed precious and polymetallic ores. Around the year 1930, a mining operation was started with the mining of precious metals ores on the Grüner Vein and the polymetallic ores on the Špitaler Vein. During the monitored period, a total of 405,000 t of ores were exploited, of which 187 ths. t were precious metals ores and 13,920 t of lead concentrate were produced. The water reservoirs mostly lost their original purpose, ceased to provide energy water and began to serve fishermen and tourists. The Hodruša plants conducted an exploratory program focused on the Schöpfer Vein at the Lower Plant and the Finsterort and the Východná (Eastern) veins at the Upper Plant. At the same time, in Vyhne the work proceeded on the Pod Šiváröou veins. As the quality of the ores did not reach the expected parameters, in 1939 the Rozália Vein started to be explored for copper ores. In the year 1922 the plant in Kremnica took over Ing. Aurel Lehotzký, who was a native of Kremnica and a graduate of the Banská Štiavnica Mining Academy. He worked out a redevelopment plan for the plant, which focused on the more promising veins in the shafts Ferdinand, Ludovika and Anna. The ore was treated by amalgamation associated with flotation and subsequent leaching in the cyanization facility. In the period under review, 495 ths. t. of precious metals ores were mined out, from which about 2 tons of gold and 4 tons of silver were produced. Thanks to the use of the Turček Water Pipeline, the mining plant was self-sufficient in the production of electricity. By rebuilding the hydroelectric system (the Ferdinand Shaft (Fig. 3.12), the Anna Shaft and the Shaft IV), the electricity was also supplied to the public network.

After the end of the Second World War and after the change of social conditions, the newly-established enterprise Rudné bane, n.p., Banská Bystrica covered the plants in Banská Štiavnica, which in the post-war years also mined precious metals ores mainly on the Grüner Vein and the polymetallic ores were mined out on the Špitaler Vein. Until 1952 the exploratory work was done unsystematically, according to current needs. The intensive geological survey began in 1952, but it was not enough to offset the differences until 1965, and so irregular development of the mines had a long-term effect on the deposit economy. After the construction of the Nová (New) Shaft in 1973, a new conceptual solution was developed for the exploitation of the Banská Štiavnica ore district. It was decided to carry out an extensive geological survey in depth along the whole ore field, including the Piarg part of Štiavnické Bane and the whole Hodruša ore district. The estimated potential of the ore deposit was 5 million tons of geological reserves. The excavation of the Roveň Shaft began in the southern part of the deposit, which had to be an ventilating shaft and had to make accessible the ore units in the southern part of the ore field. An important achievement was the development of the New Drainage Gallery (NOŠ), which ought to help the Old Voznica Gallery, which was no longer able to drain the entire district. The gallery development started in 1978 and was

*Fig. 3.12 Ferdinand Shaft in Kremnica*

completed in the year 1989 in a circular profile of 3.4 m. The Banská Štiavnica plant was the largest plant of the Rudné bane š.p. Between 1946 and 1947, 17.5 thousand t. of precious ores were processed. After the transition to the extraction of polymetallic ores, 4,078.4 thousand of these ores were extracted in the period 1946 – 1990, of which 44,736 t of lead, 5,064 t of copper, 787 kg of gold and 39,460 kg of silver were produced. The zinc concentrate was processed separately, of which 56,470 tons of zinc and 10,871 kg of silver were produced (Kúšik, 2015). During the greatest development of the plant 1,500 – 1,600 workers worked in the field of mining. After 1989, the votes against the high production costs in the ore mining industry increased and in 1991 the Decision of the Government of the SR on the concept of utilization of selected mineral resources in the SR stated that the mines in Banská Štiavnica should attenuate the mining till 1995 and to carry out disposal of unnecessary mining spaces and facilities. In 1992, the mines went to private hands and the company Hell, s.r.o. continued with mining until 1993. In 1994, without any detailed analysis, the mines had been liquidated and the promising programme for the mines and the city ended and the industrial sector that gave rise to the city and its development disappeared (Lichner, 2002). However, the miners` ceremonial customs have been preserved (Fig. 3.11). The Hodruša-Hámre plant extracted the precious metals ores until the year 1950. In the period 1946-1950, a total of 47 ths. T of ore were extracted. Then the plant turned to the mining of copper ores in the mine Rozália. During the monitored period, 1,857 thousand tons of the copper ores were mined out in the plant. The copper concentrate was supplied to Krompachy smelter plant. At the beginning of the 90-ies after the termination of polymetallic ores mining, a precious metals deposit was discovered in the northern part of the deposit. Since 1992, the mining is taking place here up to the present day. The Kremnica plant with precious metals ores mining in the Anna Shaft; in 1959, the mining industry ended here. Similarly, in 1966 the Ludovika Shaft (Fig. 3.13) was closed, and in 1970 the mining on the richer veins of the ore section of the Ferdinand Shaft ended based on the Decision of the then Ministry of Mining. Between 1959 and 1965, the precious metal ore was extracted in Šturec. In the early 1980s, gold prices rose rapidly in the markets. This stimulated renewed interest in exploration and possible renewal of the ore mining in the Šturec area. In the years 1983 – 1986, a semi-operating line was built, and the machinery for the treatment facility was modified and along with the leaching plant for the cyanisation process. The plant developed a proposal to increase the mining capacity of 30 ths. t. ores a year, but no implementation took place. On the semi-operating line between 1987 and 1990, a total of 34,710 tons of ore was processed, with the yield of 46.5 kg of gold and 328 kg of silver. In the period 1946 – 1970, a total of 922.3 ths. t. of precious ores were extracted from the deposit (Kúšik, 2015).

*Fig. 3.13 Ludovika Shaft – Mining Museum in Kremnica*

**3.4.4 Mining of copper, gold and antimony – the surroundings of Banská Bystrica, Liptov and Upper Hron Catchment regions**

It is very probable that the Špania Dolina – Piesky deposit was exploited already in the Eneolithic Period. Beneath the old mining spoil tips at the site Piesky near Špania Dolina, stone tools (stone mills) were found, where copper ore was crushed and hammered into flour. It is reported that about 300 stone mills of different sizes were found in the Piesky saddle (Kvietok et al., 2015). At the same site, there were also the remains of a roasting fireplace where the ore was roasted before compaction. The instruments and fireplace probably belong to the Early Bronze Age (Kúšik, 2015). However, the town of Banská Bystrica was granted the privilege of a free mining royal town only in 1255 under the reign of Béla IV. The owners of the mines, the so-called waldbürgers and their mining rights to search for and extract gold, silver and other metals throughout the territory of Zvolen County – were declared by the Decree of Béla IV already in the year. 1242. The granted privileges also brought relief from all taxes, and the only duty was a royal "urbura"; the payment equalled 1/10 extracted gold of 1/8 extracted silver or other metals (derived from the Banská Bystrica privilege from 1255). In the Banská Bystrica ore district (the most important sites are depicted in Fig. 3.14), the deposits produced a lot of silver, which was obtained from the tetrahedrite ores. Of course, the mining in the local mines situated in Špania Dolina (Fig. 3.15), Piesky, Staré Hory – Richtárová (Fig. 3. 16) and Ľubietová was mainly focused on copper ores containing silver (so-called black copper). In the 14th Century, most of the black copper production was exported to Venice, where they were already able to

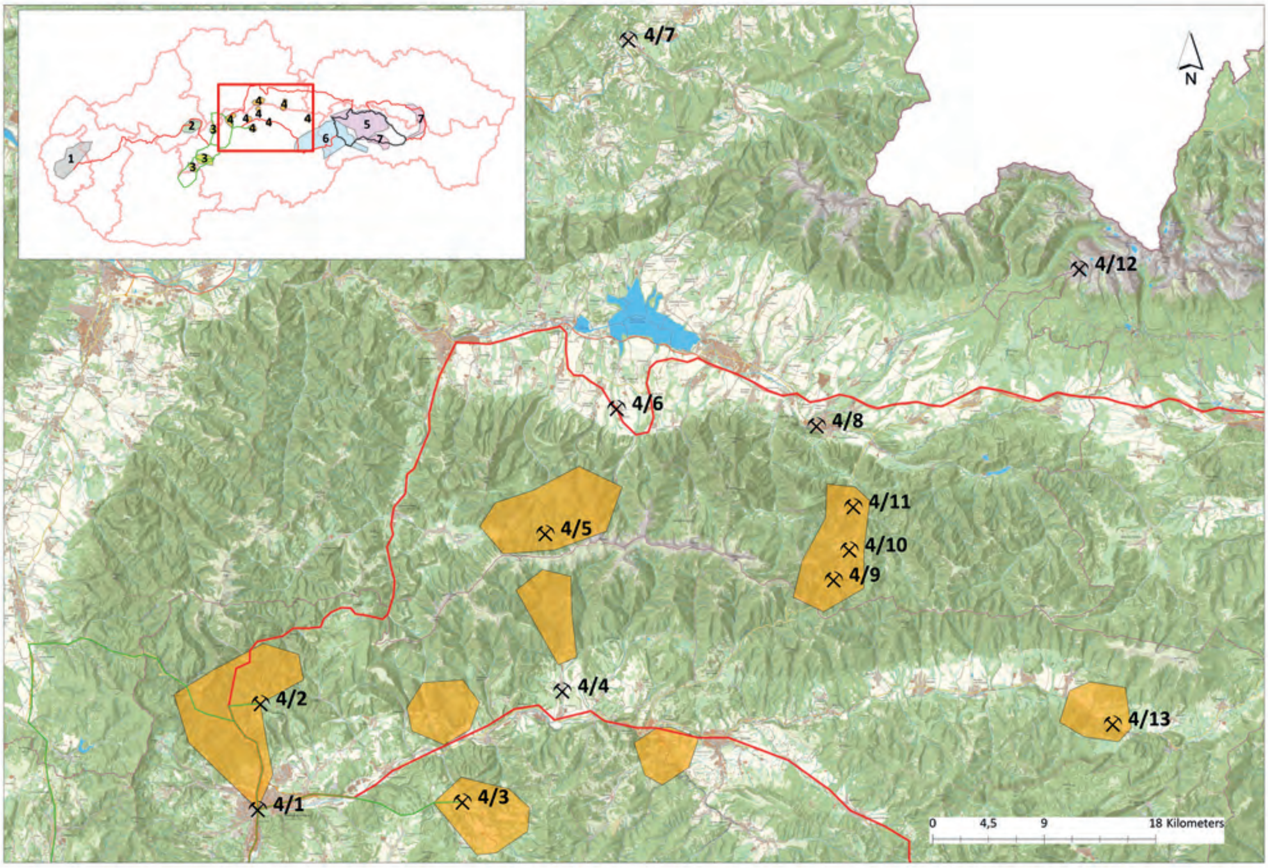


*Fig. 3.14 SMR – Mining of copper, gold and antimony – the surroundings of Banská Bystrica, Liptov and Upper Hron Catchment regions. 4/1 Banská Bystrica, 4/2 Špania Dolina, 4/3 Ľubietová, 4/4 Jasenie, 4/5 Magurka, 4/6 Liptovská Dúbrava, 4/7 Podbiel – Františkova huta, 4/8 Liptovský Hrádok – Vážnica, 4/9 Vyšná Boca, 4/10 Nižná Boca, 4/11 Malužiná, 4/12 Kriváň-Vysoké Tatry, 4/13 Valkovňa*

separate silver at the time. The secret of producing copper with its lesser content in ore brought to this area a Krakow burgher man Ján Thurzo at the end of the 15th Century. In 1494 he created together with the Upper Germany merchant house of the Fuggers, the grandiose business and enterprise company "Ungarische Handel". During the first half of the 16th Century, the company controlled all the copper markets. In the period 1496 – 1546, the company recorded the maximum development of the copper ores extraction with high Ag content, for which the ore had an extraordinary price. Interesting fact is, that in AD 1533, the Portuguese trade vessel Bom Jesus sunk off the coast of southern Namibia. Amongst the excavated materials recovered from the presumed shipwreck of the Bom Jesus, of paramount importance are 1845 copper ingots, showing the trademark of the Fugger company (Hauptmann, et al., 2016). In the 16th Century, the Banská Bystrica "Ungarische Handel" copper company was the largest copper producer in the world. In the area of Ľubietová, which in 1379 was granted the free mining town rights by the Charter issued by King Louis I of Hungary, with acknowledged privileges of 1382, the Medieval mining was profitable. It was only in the first half of the 15th Century, when Ľubietová was plundered and fired by the Hussite army, the mining here declinde until the Thurzo-Fugger company mentioned above took control over the local mines. The medieval copper mining in the mid-17th Century was concentrated mainly in the Banská Bystrica and Ľubietová districts. But it slowly moved to the Eastern Slovakia region. The Thurzo-Fugger company ended its activity in 1545 and the mines were taken over by the Empire. After Bockai and Bethlen's uprising, the Banská Bystrica copper company was in a desperate state. The mines were mostly flooded and the miners broke up. The situation improved somewhat when the state signed a contract with the entrepreneurs W. Paller and L. Henckel, who provided the money for mining operations. The production slowly began to rise. However, the copper companies began to compete in the markets first with Sweden, and later also with Japanese copper. In 1642, the state rented the mines to the Viennese merchant brothers Joanelli. But they had rather plundered the mines, and the had exploited mining community what caused their dissatisfaction. Following the rebellion of George I Rákóczi in 1645, a plague epidemic and hunger broke out and miners who did not receive wages, run away. In the second half of the 17th Century, the plant was restarted, and the state, which at that time operated the mines, introduced measures to make extraction more efficient and the production of copper rose again. However, the exhaustion of ore reserves was obvious. The shafts were over 350 m deep, the production costs increased, and the production declined. In the next period (18th – 19th centuries), the copper mining in Banská Bystrica region /Špania Dolina, Ľubietová/ still survived, but the mining of the copper was already dominant in the Spiš-Gemer region. Nevertheless, in this area, significant mining-technical works were built and used; som of them are historical monuments in the present. In the 16th Century the construction of Špania Dolina Mining Water Supply was built, one of the most important historical and technical works of that time in the vicinity of Banská Bystrica. The water for the drive of the hoisting equipment was supplied with this mine water, which had a total length of about 33 km and the water was supplied from distant Prašivá Hill. The so-called "cementation waters", which began to be utilised in the 17th Century, were very interesting. This phenomenon is already described in the work of the alchemists, Paracelsus, as well as classical scientists – montanists such as J. Agricola, travellers doctor E. Brown, J. G. Becker and F. E. Brückman, physicist I. Newton and A. F. Marsigli (Grecula et al., 2002). This water was trapped in the underground in special tanks into which the old unusable mining iron was deposited on which the excreted copper was precipitated. By the late 18th and early 19th Century, the copper mining was also under the influence of foreign competition. Still in the middle of the 19th Century about 50-70 tons of copper were extracted annually in Špania Dolina and about 800 people were employed there. Gradually, the mining fell, and the mines were finally closed in the year 1888. The famous history of Špania Dolina today reminds so-called "Špania Dolina glasses" scattered across European museums and private collections. These rare pieces of art were gifted to great visitors. They were made by Banská Bystrica goldsmiths from sheet metals produced from "cementation waters" in Špania Dolina. They were decorated with gold and precious stones. They have characteristic inscriptions engraved, such as: I was iron, I have become copper, gold is covering me. In the 20th Century, attempts were made to restore copper ore production around the Špania Dolina deposits. Certain re-discovered parts of the veins were mined in the 1960s. Since 1964, old heaps from the Richtárová Valley and the Piesky deposit were extracted for the industrial accumulation of copper ores in them. The ore was driven by a new-built traffic junction to a plant in Špania Dolina. The processing of rocks was gradually stopped and in 1986 the facility turned to the treatment plant of the Hg-ore from Malachov, from a deposit in which the mercury was mined in the 14th Century. Several stages of the geological survey were carried out along with the extraction from old heaps, the remains of which can be found mainly on the site of Piesky. This ended the famous epoch of the copper mining around Banská Bystrica.

Iron ore mining was of great practical significance also for the Hron Catchment in the vicinity of Hronec, Poniky, Ľubietová, Železná Breznica, Vyhne and Horné and Dolné Hámre. The production in this area was mainly responsible for the supply of precious ore mining facilities. But new iron smelters were founded, for example, at the end of the 17th Century in Tisovec and Ružomberok. The ores were still largely obtained from the surface areas of the gossan-type deposits. Generally, however, the ores in the Hron Catchment had lower metal content than the Spiš-Gemer ores. At the end of the 17th Century, the first blast furnace was built and put into operation in this area, in 1692 in Ľubietová (Kúšik, 2015). In the 18th Century, a huge iron complex was established in Hronec. In the first half of

*Fig. 3.15 Miners` Church and houses in Špania Dolina*


*Fig. 3.16 Old Haliar Hereditary Adit*


*Fig. 3.17 Mining cart: Welcome to mining village of Vyšná Boca*

the 19th Century, the construction of a strip mill under the hummock of Brezová was ordered by G. Schweizer – the Chamber Count in Banská Štiavnica. At the end of the 19th Century, Podbrezová Iron Works belonged to the largest and most prosperous factories in Hungary (Zámora et al., 2003).

Relatively prominent in this area is also the mining of precious metals ores. The first mention of this mining was in the 13th Century, when the precious metals ores in the Nízke Tatry Mts., in Vyšná Boca (Fig. 3.17), Partizánska Ľupča-Magurka, were mined. In the vicinity of Hybe penning was reported. However, in the 16th – 17th centuries mines in this area are reported as less profitable (Kúšik, 2015). The revival took place in the 19th Century, when a hereditary adit was excavated at Magurka. Since the ores contained antimony, it also became a by-product of the gold mining. The end of the gold mining in this locality came in 1923.

The development of antimony mining in the Nízke Tatry Mts. region dates back to the late 17th Century, but especially to the 18th Century, with the revitalization and flourishing of mining of the entire area of the Nízke Tatry region and, in particular, with the prospecting and extraction of stibnite ores. The restoration of mining works occurred after the year 1806, and with the breaks, the Liptovská Dúbrava deposit was mined until 1993. Before and during the Second World War, until the 1947, only those ores were mined, from which a concentrate with a metal content of more than 40% Sb could be obtained. The great revival of the exploration and mining of the Sb-ores occurred in the 50 – 80s of the 20th Century. Concentrations quality with a content of 54.12% Sb achieves global parameters (Grecula et al., 2002).

### 3.4.5 Spiš region

The beginnings of mining in this region (the most important sites are depicted in Fig. 3.18) are not clearly documented by discoveries directly in mining centres, but indirect evidence may be the archaeological finds from the Hornádska kotlina Basin, indicating local metallurgical processing of metals. Some authors put the mining beginnings in the region of mining and iron metallurgy into Halstatt Period (iron) (Daniel et al., 2011), some are considering the Bronze Age in terms of extraction and processing of precious metals ores and copper due to the existence of significant centres of the Bronze Age at Spišský Štvrtok in Myšacia Hôrka and found depots of bronze and gold products, which were probably produced directly in the settlement (Vladár, 2012). Since the second half of the 13th Century, the Spiš region had experienced a significant development of mining. At that time, silver was mainly mined in Gelnica, Smolník and Spišská Nová Ves. Even in the 14th to 15th centuries, the precious metals ores were mined in this area and their production had to be high when King Charles Robert of Anjou made Smolník in 1328 the seat of one of the two coin chambers in our territory; the second one was in Kremnica (Kúšik, 2015).

The copper ore mining was also very well developed in this area. Significant mining facilities were in Gelnica, Smolník and Spišská Nová Ves. Particularly noteworthy was the production of cementation copper in Smolník. This phenomenon is already described in the work of the alchemists, A. Smoczký, as well as classical scientists – geographer D. Fröhlich, physician D. Geyger, F. E. Brückman, and A. F. Marsigli and others (Grecula et al., 2002). In the 17th Century, this region was already dominant in the mining and processing of copper ores. But even in this area, periods of deep decline alternated with periods of relative prosperity. During this period, the most important enterprise in the Spiš region was the Smolník plant, less Gelnica and Švedlár plants. In the 19th Century, the decline of the copper ore mining in Spiš started with overrunning of the European market with cheap and quality copper from newly-discovered American deposits; the Spiš copper could not compete with the price. These circumstances lead to the gradual disappearance of the copper ore mines and smelters throughout the region in the second half of the 19th Century. The recession also affected the ancient mining towns of Gelnica and Smolník, where, for example, copper mining ceased to exist at the end of the 19th Century and only pyrite for the production of sulphuric acid (Jančura, internet source) was exploited. At the beginning of the 20th Century, the copper ore mining was the most developed on the Slovinky deposit. Originally it was a plant that focused on complex siderite ores with a relatively high copper content of 4%. After the liquidation of the ironworks of Krompachy, it was decided that the iron component would not be recovered from the deposit. After stopping the iron ore processing, the possibilities of recognition the copper component at the market were sought. After the founding of the copper smelter in Krompachy, the mining operation

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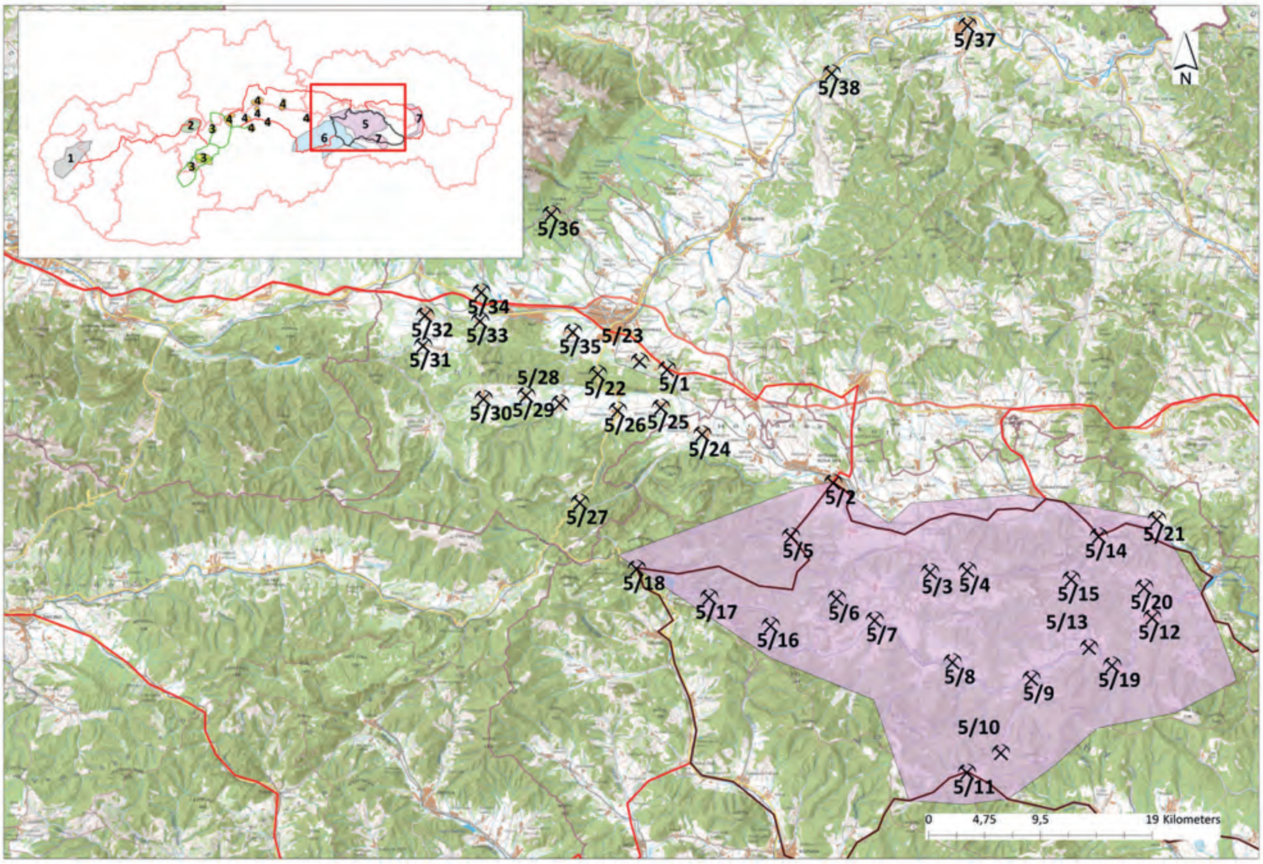


*Fig. 3.18 SMR in the Spiš region. 5/1 Kišovce-Švábovce, 5/2 Spišská Nová Ves, 5/3 Rudňany, 5/4 Poráč, 5/5 Novoveská Huta, 5/6 Hnilčík (Roztoky, Bindt, Grétla), 5/7 Nálepkovo and Henclová (Stillbach), 5/8 Švedlár and Stará Voda, 5/9 Mníšek nad Hnilcom, 5/10 Smolnícka Huta, 5/11 Smolník, 5/12 Gelnica, 5/13 Helcmanovce, 5/14 Krompachy, 5/15 Slovinky, 5/16 Hnilec, 5/17 Mlynky, 5/18 Stratená, 5/19 Prakovce, 5/20 Žakarovce, 5/21 Kluknava – Štefanská Huta, 5/22 Poprad – Kvetnica, 5/23 Gánovce, 5/24 Hrabušice, 5/25 Spišský Štiavnik, 5/26 Hranovnica, 5/27 Vernár, 5/28 Spišské Bystré, 5/29 Kravany, 5/30 Vikartovce, 5/31 Šuňava, 5/32 Štrba, 5/33 Lučivná, 5/34 Mengusovce, 5/35 Spišská Teplica, 5/36 Vysoké Tatry, Tatranská Javorina, 5/37 Stará Lubovňa-Jakubany, 5/38 Podolínec, Vyšné Ružbachy*

was restarted in 1938 and continued with the use of copper ores. In the period 1919-1944, 1,043 thous. t. of the copper ore was extracted, which represented 97.7% of the Slovak production. After the World War II, the Smolnik plant was exploiting the pyrite-copper ores, which were mined already in pre-war years. The pyrite ore was treated to a coarse-grained concentrate which was suitable for burning in furnaces for the production of sulphuric acid in all Slovak pulp –mills and paper-mills. The pyrite roaster-grains, which contained more than 50% of Fe, bought the Vitkovice Ironworks, which extracted from them the copper and silver. The mining of these ores was carried out until 1989. During the period under review, 4,980.7 thousand tons of the pyrite-copper ores was recovered on the deposit. The Slovinky plant in the post-war period appeared to be non-perspective and the management of the national enterprise decided not to invest in the renewal of this plant. Only in the year 1948 a report on the evaluation of the efficiency of mining and metallurgical processing of metals (Cu, Au and Ag) was developed. This report triggered a series of situations that led to the re-establishment of the plant and the launch of an extensive exploration programme. From 1950 to 1990, 8,437 ths. of the copper ores were extracted here (Kúšik, 2015).

As we have already indicated in the introduction, the iron ore mining has a very long history in the Spiš region. Since the end of the 13th Century, rich iron ores were predominantly obtained from the surface deposits of the gossan-type. But also by moving to the lower parts of the deposits due to the above-mentioned interconnectedness with the copper ore mining, the iron production was very important. At the end of the 17th Century a second blast furnace was built in this area, namely in 1710 in Hnilec. However, since the middle of the 19th Century, the iron ore mining and the iron production were vigorously developing as opposed to the development of the copper ore mining industry. This development stems from the industrial revolution and the need for iron as a raw material for commodity mass production. The mining, heat treatment and iron metallurgy were driven by large companies integrating all these industrial activities. For the Spiš region, the construction of the Košice – Bohumín railway line and the subsequent construction of numerous mining railways, enabling the rapid and relatively inexpensive transport of ore or agglomerate to the massive metallurgical factories in the Ostrava region, or in Silesia where there is enough energy raw material – coal, was crucial. The old deposits of Roztoky, Grétla, Bindt, Mlynky (Fig. 3.19), Poráč-Rudňany,

*Fig. 3.19 Miners` houses – Mlynky-Rakovec*

Žakarovce and others received investments in the opening and modernization (mechanization) of mines, treatment of ores and agglomeration furnaces (Jančura, internet). After the First World War, however, the situation changed diametrically, and iron ore mining was experiencing difficulties in finding markets for the outgoing ores, since the total demand for iron ores was significantly lower than in the pre-war years. The ore mining was limited in our territory. During this period, mining was carried out mainly on the deposit in Koterbachy (Rudňany), but also on the deposits Roztoky, Grétla, Bindt and Mlynky (Grecula et al., 2002). After the World War II all operations were gradually closed, the Rudňany deposit was the last mined, where during the boom and subsidies of the ore mining the investment was still made at the Markušovce plant. But subsequently, in the 1990s, as a result of social change, the decline of ore mining and the passage to market conditions, the iron ore mining in Spiš disappeared. Only the Poráč mine was in operation, with the baryte extraction.

Since the 14th Century, the deposit Gelnica-Zenderling benefited from mercury. In the 19th Century, the mercury ores were also mined at the complex ores deposit in Koterbachy (Rudnany), where the mercury was a by-product of the siderite mining. In the Gelnica-Zenderling deposit (Kúšik, 2015) the mercury mining also continued.

The mining of manganese ores started at the Kišovce deposit at the turn of the 19th – 20th centuries, first from the surface, for the needs of local ironworks. Later, in 1908, the Vítkovice ironworks began to with the underground mining. However, the development of mining occurred during the First World War (1916) as the import of manganese ores was interrupted. In the inter-war years, the manganese ores mining decreased again, the original level was reached only in the World War II; in 1943 it doubled. The majority of the production was provided by the Kišovce Švábovce deposit, during the World War II there were also mined the deposits in Michalová and Čučma. After the World War II, the plant in Švábovce covered two deposits of the manganese ores in Švábovce and Kišovce. The end of the mining on these deposits was mainly affected by the cheap ores supplied by the world's largest producer of manganese ores, the USSR. Over the monitored period, a total of 3,430 ths. of the manganese ores were extracted (Kúšik, 2015).

### 3.4.6 Gemer region

Iron ore mining has a very long history in this area (the most important sites are depicted in Fig. 3.20). The finding of a Roman kiln in 1896 (Rákošská Baňa), as well as the finds of iron slag in the earth kilns, called the wolf holes, shift the boundary of the use and compaction of the iron in this area into the time of La Tène Period (Frák, 1987). The iron ore mining began to appear in the written reports from the 13th Century. However, the great development of the ferrous mining occurred only in the 14th Century. This was also related to the development of precious metals and copper mining and metallurgy as they needed iron to produce working tools, stamp mills and various pumping and transport equipment. The iron ores were located on the territory of present-day Slovakia in large quantities and in numerous places, but the deposits of the Gemer region were particularly profitable. In the first half of the 14th Century, there was a major change in the iron production. A water wheel for furnaces and hammer forge was introduced. Extensive mining of the iron ores was in the middle of the 15th Century at the Železný vrch deposit near Dobšiná. An important iron area was also formed around iron-bearing deposits Železník, Rákoš and Hrádok (Kúšik, 2015). An important factor in the development of the iron ore extraction was the fact that the iron produced did not come under the royal tax "urbura", that is, transferred to the present times, the iron ores were not reserved minerals. The iron ore mining was at a loss at the end of the 18th Century. The mining administration attempted to push for change so that the iron became a reserved mineral, and the state could collect the taxes. However, this change was achieved definitively at the beginning of the 19th Century. During that period the state attempted to promote the iron ore mining, owned the ironworks in Tisovec and partially in Sirk (Železník). But the decisive position in the mining industry was still in private hands. The most important miners of that time include the noble families of the Andrassy and the Coburgs. The largest concentration of iron-and-furnace and hammer forges was in the Gemer region near the rich deposits. At the Gemer region, at the end of the 18th Century, about 70% of the then Slovak territory iron production was produced (Kúšik, 2015). Significant deposits of the iron ores were at this time at the Gemer region in Železník, Rákoš and Dobšiná. The large deficiency of the iron ore production was the fact that it focused only on the production of pig iron (lack of secondary manufacturing). Most of the production was exported to the western countries

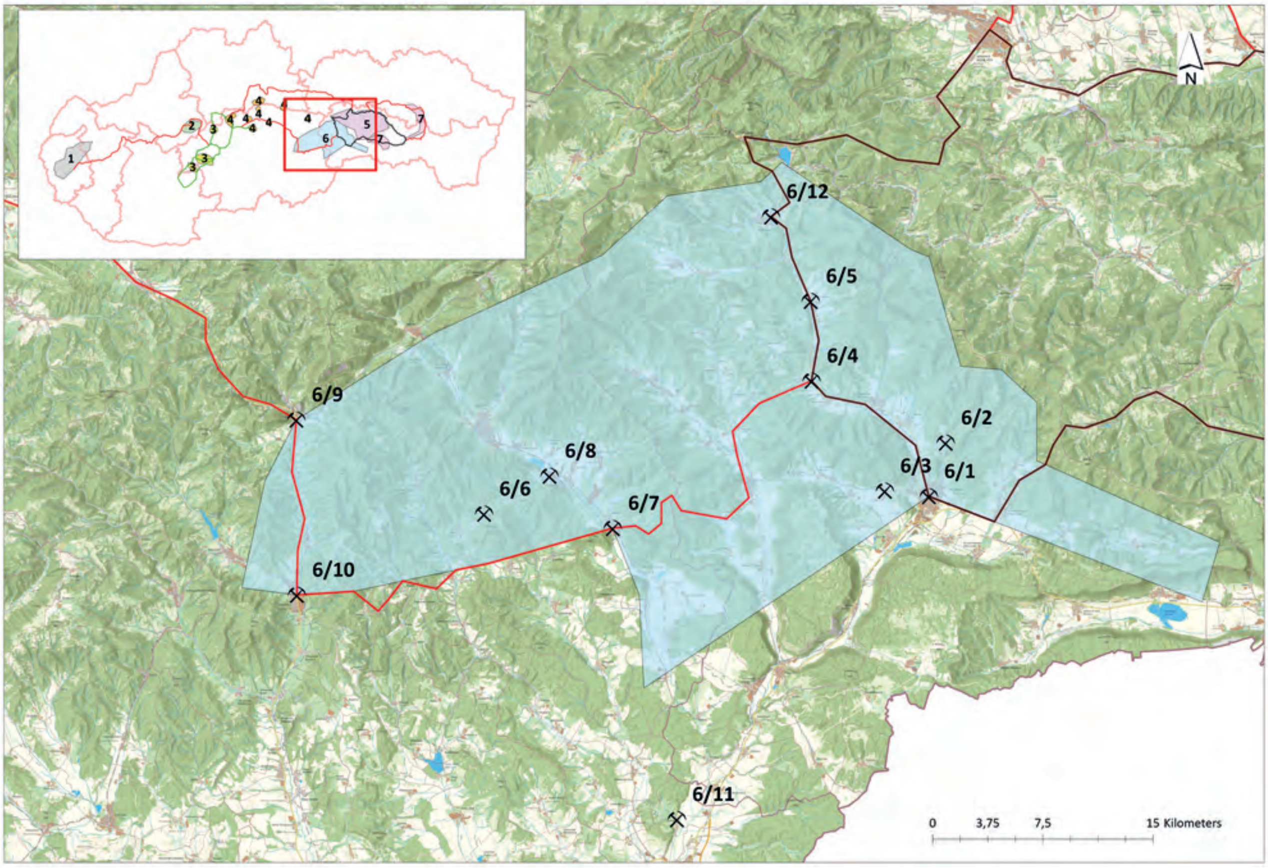

*Fig. 3.20 SMR in the Gemer region. 6/1 Rožňava, 6/2 Čučma, 6/3 Rudná, 6/4 Nižná Slaná, 6/5 Vlachovo, 6/6 Železník, 6/7 Jelšava, 6/8 Lubeník, 6/9 Tisovec, 6/10 Hnúšťa, 6/11 Gemer*

of the monarchy, from where various iron products (from Austria and the Czech Republic) were imported. At the beginning of the 20th Century, the extraction of the iron ores took place mainly on the deposits of Dobšiná, Nižná Slaná-Vlachovo (Fig. 3.20), Železník, Rákoš, Sirk, Rožňava, Nadabula. After the Second World War and the change of the social establishment, the newly-founded enterprise Železorudné bane, (n.p.) Spišská Nová Ves covered the extraction of siderite ores and mercury in Rudňany. The total amount of the siderite ore extracted during the reference period, which includes the years 1945 – 1990, was 30,615 ths. t. The Dobšiná plant, despite the rich tradition and the extensive ore field, had the problem to provide for a larger number of quality ores, so the plant was cancelled in 1958 and the mining stopped in 1969. During the period under review, 1,363 thousand tonnes of the iron ore were extracted. Before the nationalization the Železník plant consisted of two or up to four mining enterprises. The nationalization of the industry enabled to bring together all parts of the deposit. In 1946, the Rákošská Baňa plant was also added to the ironworks. In 1957, exploration work was carried out to clarify the geological structure of the Železník Hill with the deposits of Železník in the north and Rákoš in the south. The extensive exploratory work, however, did not show sufficient reserves of the ores to ensure the prosperity of the plant. This was the end of the iron ore mining in the year 1965. At the Železník deposit in the monitored period 3,450 ths. t. of the iron ore were extracted. Between 1975 and 1987, the Rákoš deposit was still mined because of the mercury ore, but the operation was unprofitable. The Rožňava plant, which also included the sections Drnava, Malý Vrch, Dolný and Horný Hrádok, and the aforementioned plants after the cancellation were one of the largest iron-ore plants in Slovakia. On all known deposits, an intensive geological survey was carried out in post-war times, which secured the reserves of ferrous mineral ores in Rožňavské Bystré, Rudník, in the central part of the ore field on the deposits of Bernardy, Sadlovský, Štefan and Mária mine. The Maria Vein was explored on the Maria mine, where in 1981 a vein structure called Strieborná (Silver) was discovered, which earned her name for a high silver content in tetrahedrite (150 – 400 g/t). This was examined in detail from 1985 to 1991 and the great promise of this ore-mineralization has been confirmed. The iron ore mining was terminated in the whole ore district in 1993. In total, during the period under review, 9,988.34 ths. t. of the siderite ores and 2,422.7 ths. of the siderite-tetrahedrite ores were extracted, i.e. a sum of 12,411 thousand tons. The plant in Nižná Slaná thanks to an intensive geological exploration on the Manó deposit, which resulted in the reserves calculation in the year 1966, which confirmed at the extraction of 700,000 thous. t. annually a lifetime of 45 – 50 years. The further geological survey verified the depth of the deposit as well as the promising eastern part of Kobeliarovo. The positive results of the survey included the Nižná Slaná district as the most important iron ore region of the Spiš-Gemer ore district. During the monitored period, 16,471.8 thousand tonnes of

*Fig. 3.21 Blast furnace Etelka near Nižná Slaná plant*

the iron ores were extracted in this area. The operation was stopped in 2008 (Kúšik, 2015).

Since the 14th Century, at the deposit in Dobšiná cinnabar was extracted, from which mercury was obtained. In the 18th Century, the mercury was acquired on a smaller scale at a deposit in Nižná Slaná (Kúšik, 2015).

The antimony ores and gold were mined near Čučma since the end of the 17th Century. However, the main development of mining occurred only at the end of the 18th and early 19th centuries. The mining was terminated in 1952 (Rozložník et al., 2013).

Cobalt-nickel ores were mined in Dobšiná since 1780. Initially, there was a problem with the application of ores (used only for dyeing). At the beginning of the 19th Century, the ores began to be exported to England, Germany and Belgium. The mining of cobalt–nickel ores from the Dobšiná deposit represented up to 75% of mining throughout the Austro-Hungarian monarchy. After 1875, the mining began to cease and later ended (Kúšik, 2015).

The beginnings of magnesite mining in our territory are linked to the end of the 19th Century. The stimulus was the necessity to obtain refractories for blast furnaces. The magnesite as an unfamiliar stone was encountered by the workers who built the railway line Jesenské-Tisovec in 1871 between the towns of Hnúšťa and Hačava. Then there was a targeted search for this mineral, which resulted in the discovery of the magnesite deposits near Ratková, Jelšava, Lubeník, Ochtiná, Bankov near Košice, Ružiná and Cinobaňa. In 1900, the plants of the company Magnesit Industrie Aktien-Gessellschaft (MIAG) were built in Hačava and Jelšava The so-called Horný Hačavský (Upper Hačava) plant used magnesite extracted on deposits in Ratkovská Suchá and Burda. The raw material was first transported by horse-drawn vehicles, later a cableway from Burda to Hačava was built. In 1909, the Danish firm Schmidt from Copenhagen installed the rotary kiln for magnesite clinkering, which was the first of its kind in the world. At the Jelšava plant, which was supplied from the Dúbrava deposit, the magnesite was just burned and assorted and thus dispatched to the Kobányi (Budapest) brick works. Later, other companies started to extract and process magnesite, and the plants were founded in Hačava Dolný závod (Lower plant), Chyžná Voda-Lubeník and Bankov near Košice. The magnesite mining was negatively influenced by the nostrification law after the creation of the Czechoslovak Republic, as all magnesite plants were in private hands. At the same time, the destruction of the Slovak ironworks industry after the First World War had an impact on the development of the magnesite industry. Sales to this market represented only 2 – 3% of total sales. The Czech companies were mostly supplied with refractories from Austria. Only 7 – 8% of total sales were sold to this market by the Slovak magnesite works. The Austrian magnesite industry also gained a dominant position on a worldwide basis thanks to the Cartel Agreement of the main suppliers of refractories, which established disadvantageous quotas for producers in the Czechoslovak Republic. For export to overseas, our manufacturers also competed with the magnesite products from Greece and Yugoslavia, thanks to cheap shipping. The deposits in Hnúšťa-Ružiná, Košice-Bankov, Lubeník, Studená, Hačava, Hnúšťa-Horná Magnezitka (Upper Magnesite Plant), Ratkovská Suchá, Burda, Ploské, Sirk, Jelšava and Ochtiná were mined in this period. The production was exported to entire Europe. Of the total there were sold 8.5% of unprocessed magnesite, 76% of clinker and only 15.5% of final magnesite product. This also reduced the prosperity of using such a rare raw material (Kúšik, 2015). During the World War II, approximately 2.6 mil. t of crude magnesite were extracted. The Slovenské magnezitové závody, n.p., Košice (Slovak Magnesite Plants) have begun renewing the mining of destroyed factories after the retreating German troops destroyed mainly surface objects of plants (generators, magnesite burning furnaces, electric power sources and others). In the war years, a geological service (search and exploration) was neglected, data on possible magnesite reserves was missing, since the magnesite did not belong among the reserved minerals. By the Regulation SNR No. 46/1947 the magnesite was declared a reserved mineral. Between 1953 and 1965, a geological survey was carried out on all magnesite deposits. The mostly rich deposits were Jelšava-Dúbrava, Burda-Poproč, Košice-Bankov, Podrečany and Lubeník-Studená. The International Magnesite Cartel ceased to function in the war years, and after the war it was legally dissolved in 1947. This has conditioned the development of the magnesite industry in Slovakia. In 1963, the government of Czechoslovakia decided on the development of the magnesite industry in Slovakia, when it was decided that the Jelšava plant would produce clinkers and the Lubeník plant would produce the building materials. Unfortunately, the trends that have been taken to improve the quality and economy of mining and production have not been maintained, which has had a negative impact on the development of the magnesite industry since 1990. In the period under review, since 1959, surface mining has been transferred to underground mining of the magnesite. The Slovak magnesites are of lesser quality, they are demanding for treatment and subsequent processing after firing. Because of this, the Slovak magnesite industry was hardly resistant to natural-quality Chinese and North Korean magnesite. During this period, the production took place at the plants in Hačava, Jelšava, Košice, Lovinobaňa and Lubeník (Kúšik, 2015). During the monitored period 86.6 mil. t. of the magnesite were extracted.

already lost. The main metal was silver, the production of gold and antimony was always relatively small, other metals (Pb, Zn) were not extracted. Overall, about 126,000 kg of Ag, 78 kg of Au and 3,300 t of Sb were mined out on the deposit (Koděra et al., 1986 – 1990). The mining terminated in 1924, during the Second World War, temporary work was restored in the period 1940 – 1944. At the end of the 1970s, reserves and possibilities for further exploration were verified. Two types of veins were distinguished (Rozlozsnik in Koděra et al., 1990), in the new ones three types of veins (Varček and Kodera et al., 1990): from the oldest to the youngest – l. quartz-siderite with a sulphide association poorer in jamesonite and rich in Cu-minerals

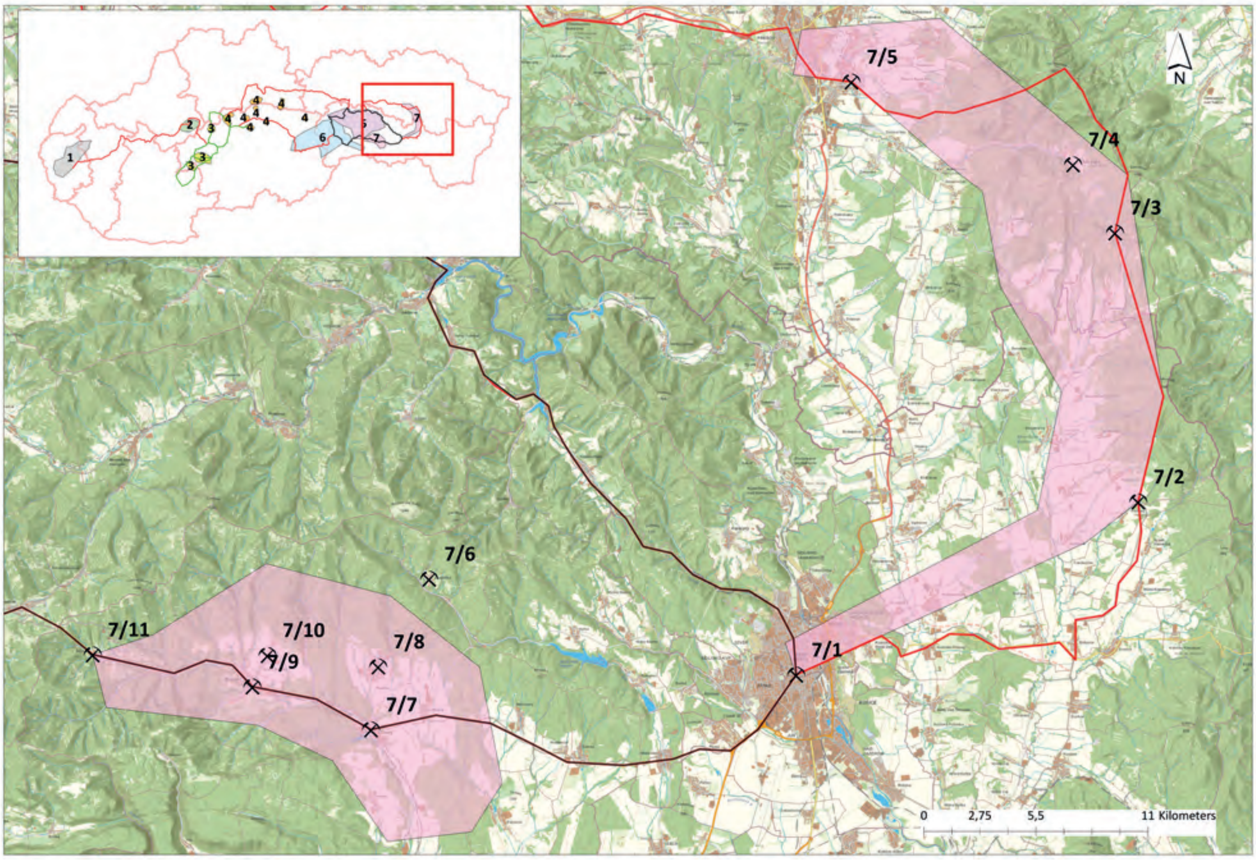


*Fig. 3.22 SMR – Mining in Košice, Prešov and Slanské vrchy Mts. 7/1 Košice, 7/2 Herľany, 7/3 Opálové bane, 7/4 Zlatá Baňa, 7/5 Prešov-Solivar, 7/6 Zlatá Idka, 7/7 Jasov, 7/8 Poproč, 7/9 Medzev-Luciabaňa, 7/10 Vyšný Medzev, 7/11 Štós*

### 3.4.7 Mining in Košice, Prešov and Slanské vrchy Mts.

The first written document of precious metal mining is from this area (the most important sites are depicted in Fig. 3.22) from the second half of the 13th Century, where Zlatá Idka and Jasov are mentioned in the list of King Béla IV of Hungary. In the area of Zlatá Idka, Jasov and Poproč, the gold was originally obtained from the Ida Brook, later from the upper, near-subsurface parts of the veins. At the time of Matthias Corvinus (15th Century) gold coins were minted in Košice from the Zlatá Idka gold. The privilege of mining was granted to the village of Zlatá Idka in the year 1439. The biggest flowering of the mining was in the decade. 1863 – 1873, when the average annual production of Ag was 2,800 kg. Since 1895 the mining industry was

(veins Anton, Jozef), 2. quartz-sulphidic with abundant jamesonite and inferior representation of siderite, antimony and gold (most of the main veins), 3. quartz-sulphide with abundant stibnite and increased content of Au (veins František, Štefan, Jeremiáš and other small veins).

The first documented data on the acquisition of precious and non-ferrous metals in the vicinity of the Zlatá Baňa came from the 14th and 15th centuries. The mining of Pb-Zn-ores and gold developed in the 17th and 18th centuries, during the first half of the 19th Century almost all the deposits were abandoned. However, more accurately documented gold mining was carried out only from the end of the first half of the 18th Century until the beginning of the 19th Century, but it was totally unsuccessful. The interest in polymetallic ores was restored only in the second half of the 20th Century. The technical work carried out since 1975 has confirmed an in-depth continuation of the vein-stockwork structures, whose surface parts were of interest in the past, and consequently industrial deposit accumulations of polymetallic ores (Koděra et al., 1986-1990) were discovered at the Zlatá Baňa deposit.

Iron ore mining was also significant in this area, especially in the surroundings of Medzev, Štós and Poproč. This is the Štós – Luciabaňa vein zone, of the E-W direction, with a total length of 18 km, attributed to the siderite formation of the south siderite stripe of the Spišsko-gemerské rudohorie Mts. This vein band binds to the tectonic failure line in the rocks of the Gelnica group, is of a linear character, and the ore veins are concentrated at the crossing points of longitudinal tectonic structures with transverse and diagonal structures. The transverse tectonics of the normal fault character is intensely manifested only in the eastern part on the deposits of Fortúna and Rúfus in the village of Poproč. The mineralization is not uniformly distributed over the entire length of the vein zone; it has the character of lenses and ore columns (Koděra et al., 1986 – 1990). The Rima plant in Luciabaňa produced during the inter-war period 1,227.1 kt of iron ores (Grecula et al., 2002). After the World War II, the Luciabaňa plant, as a stand-alone plant, ceased mining in 1962 and the production was stopped in 1969. During the period under review, 1,964 kt of iron ore was extracted (Kúšik, 2015).

Written reports document the salt springs at Prešov since the 13th Century. In 1348 three salt springs were mentioned. The brine from the salt springs was extracted by the Šóš family, which owned the land on which the salt springs surged. Since 1572, the salt mining was running underground, as the state administration took over the exploitation from the Šóš family, which did not want to give up. However, the dispute over saline springs lasted until 1592 and ended with the victory of the state. Later (in 1586), the state administration leased the plant until it was completely destroyed during the Bockai's uprising. In the year 1616 the plant was leased to the city of Prešov. By the end of the 17th Century, the deposit had been opened by 3 shafts and several galleries. The production of rock salt was steadily increasing. Only at the end of the rebellion of Franz II. Rákoczi the plant started to decline. In the middle of the 18th Century, the salt was still obtained in both ways, from the brine and by the extraction of halite. However, in 1752 the Solivar mines (Fig. 3.23) were flooded with the salt water, and the extraction of the halite was over. The brine was continuously pumped through the Leopold Shaft using the winder. At the end of the 18th Century, two salt cooking facilities with evaporating tanks were built. Production increased and profits were high. E.g., in 1790 the production of the Vienna cent of salt was worth 17 kreutzers and 2 denarii, the selling price was 1 gold and 40 kreutzers. About 80% of the production was sold on the domestic market, the remainder being exported. But the mining failed to cover the demands of the market, which had to import salt from Poland and Transylvania. The salt mining continued in the Solivar plant, which was named in 1925 Solivar President Masaryk after the establishment of Czechoslovakia. The plant was completely rebuilt and the salt cooked on the principle of vacuum cooking. Since the flooding of the mine in 1752 the salt was extracted in the form of a brine and there was no direct contact with the deposit, a survey was conducted to clarify the structure of the deposit. However, the 4 exploration wells carried out in 1922 did not sufficiently elucidate the deposit geometry. After the World War II, the Prešov plant was still in operation, in which the brine was obtained in two ways. The first was a classic old way from the brines drawn by the Leopold Shaft and evaporation in the tanks. This method was operational until 1970, when the shaft object as well as the cooking facilities were handed over to the Technical Museum. The second method was the use leaching by drilling an extensive exploration network, which continued with the 1939 survey. From the total of 15 boreholes, 11 boreholes were used for leaching. From 1947 to 1990, the total of 1,870 thousand tons of salt were extracted on the deposit. The salt mining was completed in 2009 by the company Solivary a.s. Prešov after many centuries of tradition of the salt mining in the region. Another deposit that was discovered during the oil exploration in 1959 was Zbudza with supplies of 1.5 billion tons of salt. A deep 192.6 m shaft and 2 km of mining corridors were excavated on the deposit. However, the production in Chemko Strážske plant was not carried out, and so in 1970 the mines Zbudza were liquidated (Kúšik, 2015).

*Fig. 3.23 Leopold Shaft – house of winder for the removal of mine water, Slovak technical museum Košice – exposition Solivar Prešov*

***Fig. 3.24** Dubník – opal mines, exposition in Jozef Adit*

The first mention on possible extraction of expensive opal at Dubník (Fig. 3.24) was made in 1603 in the licensing letter for Štefan Kecer granted by the Emperor Rudolf II (Semrád, Kováč, 2003). We can confirm the mining of the only Slovakian gemstone – noble opal from Dubník, from the second half of the 18th Century (under the reign of the Empress Maria Theresa). In the years 1750 – 60, Count Vecsey and his secretary Szukovicz made exploration pits here. In the year 1787 the state administration showed an interest in the opal mines, but already at the beginning of the 19th Century it put the mines for rent. Gradually, several tenants were replaced during the 19th Century, the members of the Goldschmied family of Viennese entrepreneurs were dominantly active in the opal mines. The most famous expensive opal found at Dubník was the so-called Harlequin, or Vienna Imperial Opal, which was found in 1775 and weighs 2,970 carats or 594 grams, and is currently exhibited at NHM in Vienna. In the beginning of the monitored period, the Dubník deposit of precious opals was allocated to Soľná Baňa. However, the directorate of Soľná Baňa did not manage the Dubník deposit issue and it was the beginning of the end of the opal mines. Then Czechoslovakia rented the opal mine for 10 years to the Bittner-Belangenay company in France in 1922. However, the company was unable to continue opal mining and thus ended its activity in the same year (Kúšik, 2015).

## 3.6 Promotion of the SMR project

Another work of the Association members in cooperation with the Slovak Mining Chamber, local authorities, the Ministry of Economy of the Slovak Republic and the Ministry of Culture of the Slovak Republic is the inventory, documentation and publication of printed colour publications on mining sites and the description of milestones and the development periods of mining and metallurgy in the regions.

To describe the phenomena of montane heritage at selected sites, the Association has developed the following manual and procedure:

Cultural, natural and industrial heritage – mining science:

1. Geology and mineralogy;
2. Outcrops of veins, oldest stopes and mines on the surface, exploration pits;
3. Mining and metallurgical units (mining plants, smelters, foundries, etc.);
4. Mining-technical works (shafts, hoisting towers, hereditary adits, “muntlochs” = entrances into galleries, ...);
5. Other related operations (plant administrations, test rooms, laboratories, workshops, transformer stations, power stations, heating plants, all buildings and facilities located in the yard, or near the mining facilities courtyards);
6. Mining railways, trails, cableways, waterworks (ponds, ditches);
7. Architecture of the region – the mining ones in particular (knocking towers), mining settlements – mining houses, colonies, urban (waldbürger houses, mining authorities and directorates, mining schools buildings), defensive – fortifications – parts of castles and chateaux related to the mining production, distribution and storage of raw materials, churches and other buildings with mining exhibitions;
8. Other attractions (geology, caves, other technical monuments of the region);
9. Additional information related to the mining and its history.

Typical mining elements in the architecture of the mining regions are completing the character of the landscape modified by mining, and in exceptionally rare preserved localities, the undistorted scope and harmony of the historical industrial architecture with the other elements of the natural and cultural heritage of the landscape.

At present, the resources for reimbursement the costs of realization of the goals and objectives of the project “Slovenská banská cesta” (Slovak Mining Road) are supported in the regions above all by active mining and geological exploration and other organizations, subsidies of mining towns and municipalities, by the involvement in other Higher Territorial Units in the calls and projects, own funds at the level of individual associations, guilds, and fraternities. Centrally, sponsored projects are sponsored by the Association, which are largely reimbursed within the meaning of the Law 71/2013 Coll. in the calls of the Ministry of Economy of the Slovak Republic.

The Association of Mining Clubs and Guilds of Slovakia, in the context of the presentation of the mountainous heritage of the Central European region, cooperates with the relevant national brethren organizations in the Czech

Republic, Hungary, Poland, Austria and Slovenia in order to create a joint project for preservation and presentation of the montane heritage.

### 3.7 Conclusions

The idea of the implementation of the project "Slovak Mining Road" was initiated by the mining regions and mining and metallurgical associations, which resumed their activity in the process of the decline of ore mining after the year 1991. In 2005, the seven active mining associations and guilds have joined together to preserve tangible and intangible mountainous heritage and created the umbrella organization – the Association. By 2017, the Association has grown to 36 members representing practically all historical and active mining regions and significant sites of mining and processing of raw materials. Several mining and metallurgical associations, guilds and mining fraternities have built their own museums, exhibitions, instructional walkways, memorial rooms, mining houses, etc. during their modern 10 to 25 year existence. The design of the SMR project has already created 7 centres at the beginning. These centres represent geographically divided mining regions. The Association in cooperation with the company Rudné bane, š.p. promotes the SMR sites through a website, information boards and a printed guide to mining-technical monuments and mining museums in Slovakia is being prepared. The individual centres and locations presented on the SMR map as the main sites are in the plan for installing the SMR info-panels. In addition to the basic info-panels the boards are also located on important mining-technical monuments in the regions. Currently, 96 locations are selected in the list by 2017. The first SMR table was officially unveiled and consecrated in the former royal town of Smolník on May 1, 2009. The presentation of the mining industry and the mining and metallurgical heritage in the SMR information means do not serve only active mining operations and mining-technical historical works, but also the material monuments related to the mining activities in the regions and built in elements of architecture (e.g. mining knocking towers, mining houses, church buildings with mining motifs elements, mining colonies, etc.) and all kinds of mining expositions and educational walkways. We believe that the SMR project will help us to better promote a significant part of our montane history, mining-technical historical works, traditions and unique architecture, thus contributing to the expansion and improvement of tourism in the regions concerned.

MAY LORD GIVE US SUCCESS!

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# Instructions to authors

**General instructions**

The Editorial Board of the Slovak Geological Magazine accepts manuscripts in English language.

The Editorial Board accepts or refuses a manuscript with regard to the reviewers` opinions. The authors are informed about a refusal within 14 days after receiving the decision of the Editorial Board. Accepted manuscripts are prepared for a publication in an appropriate issue of the magazine. The author(s) and the publishers enter a contract establishing the rights and duties of both parties during editorial preparation and printing, until the time of a paper publishing. Simultaneously with article the editorial office must receive the corresponding author‘s proclamation that no part of the manuscript was already published and figures are original as well. Copied figures must be legalized by obtaining the copyright. The proclamation must contain the name of author (authors), title and the address of residence.

**Text layout**

**The text** should be arranged as follows: full name of the author(s); title of the paper, number of supplements (in brackets, below the title, e.g. 5 figs., 4 tabs.); key words - maximum 6 key words arranged successively from general to special terms; abstract (max. 300 words presenting principal results, without references); in a footnote of the first page, name of the author(s) as well as her/his/their professional or private address.

The extent of the article is limited to 30 manuscript pages including references, figures and explanations. Publishing of longer articles must be agreed by the Editorial Board.

The text of the paper should be logically divided. Text must be sectionalized by headlines, the position of the main headlines is in the centre of the page, associated headlines start from the left side of the page. The hierarchy of headings can contain maximum three levels (1 - highest level, 2 - lower, 3 - lowermost), being indicated by pencil at the particular heading. Text of the article has to contain the introduction, characterization (state) of investigated problem, used methodology, obtained data, discussion, conclusion and references.

The references in the text should be used preferably in parentheses. Names of cited authors in the text are written without first names or initials (e.g. Matula, 1969); the names of the co-authors are divided (e.g. Mišík & Sýkora, 1981). The name(s) is followed by a comma. If there are more authors, the first one, or the first two only are cited, adding et al. and publication year.

**Mathematical and physical symbols** of units, such as m, oC should be preceded by a space, e.g. 20 m, 50 oC, etc. In the case of % and ‰, the exemption shall be made: 10%, 2‰. SI units are preferred. Abbreviations of the units such as second, liter, etc. should be written without a period. Compass readings may be substitute by the abbreviations E, W, NW, SSE, etc. Brackets (parentheses) are to be indicated as should be printed, i.e. square brackets, parentheses or compound. Dashes should be typed as double hyphens.

Text of the article must be sent to Editorial office printed in two copies with line spacing 2, as well as on CD. Please for using preferable MS Word editor for PC. Figs. and Tabs. must be delivered in digital form in separate files. Paragraphs are marked with 1 tab space from the left margin, or by a typographic symbol. Greek character in the text must be visualized in the text by its name [e.g. Ʊ (omega)]. Indices and exponents should be properly marked.

**Figures and tables**

The high quality of illustrations is required. Their aim is the most effective documenting and explaining the text. When drawing them by hand or computer their maximum width 81 mm (width of column) or 170 mm (width of page) must be taken into account. Properly adapted figure (dimensions of letters, thickness of lines) can be reproduced also in the scale 1:1, but there is recommended to prepare figures in larger scale. The pen-drawn figures must be prepared by black ink using the template for figures. The minimum acceptable size of capitals and numbers in camera-ready figure is 2 mm. Maximum dimension of illustration in journal is 170x240 mm. Overlapping of illustrations should be avoided.

Figures compiled using the computer must be printed by high resolution laser printer (min. 300 DPI). For figures drawing the editorial office recommends the Corel Draw software. The very thin lines (hair lines) as well as automatic filling of objects are not allowed. The filling must consist from separately set objects. The raster-type filling of planes is either appropriate.

Each illustration including photographs must contain graphic (metric) scale. Grouped figures, e.g. photographs and diagrams must be compiled as one figure with separate parts designated a, b, c, etc. They are referred to as one picture.

Photographs must be sharp, preferably black & white, contrast, in the form of JPG or TIFF files having resolution of at least 600 DPI.

All figures must contain their number, description and name of author; in the case of maps and sketches an arrow indicating their orientation, and scale.

The explanations used for a series of several maps and profiles should correspond to that in the first figure. Description to figures should be inserted in the text on their proper place.

Each illustration and table must be referred in the text.

The high quality colour illustrations can be published after agreement by editorial office. The costs incurred will be charged to the account of the author (50 EUR for one page).

The Publisher reserves the right to return the graphic supplements back to author after language correction, resp. demand him to replace them by the higher quality ones.

Tables are submitted on separate page. Their layout is accepted in a size of up to A4. More widespread tables are not accepted.

Data are incorporated into table only when there is no possibility to incorporate them into text. The numbering of tables shall be gradual. Short explanation to a table should be included on the same sheet. If the text is longer, it should be typed on a separate sheet.

The author is asked to mark in the text where the figure or the table should be inserted.

References

The list of references should only include the works cited in the text. The references are stated in alphanumeric order, with hanging indent in the second and following lines. The denotation "in press" can be used only in the cases of acceptance of reviewed version of article by editorial board. The denotation "personal information" can be cited only in the text (e.g. Kováčik, pers. information, 2008). When referring the data by other author not being the co-author of referred publication, in the text he is cited in the following form: (Gerda in Kubka, 1975), though in the list of literature is stated only Kubka J., 1975.

**Examples of referring:**

Book

Gazda, L. & Čech, M., 1988: Paleozoic of the Medzev nappe. Bratislava, Alfa, 155.

Journal

Vrba, P., 1989: Shear zones in the metapelite complexes. Mineralia Slov., 21, 135 –142.

Anniversary volume

Návesný, D., 1987: High-potassium rhyolites. In: Romanov, V. (ed.): Stratiform deposits of Gemericum. Spec. publ. Slov. Geol. Soc. Košice, 203 – 215.

Manuscript

Radvanský, F., Slivka, B., Viktor, J. & Srnka, T., 1985: Vein deposits of the Jedľovec nappe of Gemericum. Final report from the project SGR-geophysics. Manuscript-archive ŠGÚDŠ Spišská Nová Ves, 28.

**Proofs**

The authors are obliged to correct the errors, which are due to typing and technical arrangements. The first proof is sent to author(s). The second proof is provided only to the editorial office. It can be sent to authors upon request.

The proofs must be marked clearly and intelligibly, to avoid further errors and doubts. Common typographic symbols are to be used; their list and meaning will be provided by editorial office. Each used symbol must also appear on the margin of the text, if possible on the same line where the error occurred. The deadline and conditions for proof-reading are subject to the contract, which is governed by the Chairman of the Editorial Board.

**Final remarks**

These instructions are obligatory to all authors. Exceptions can be made by the Editorial Board or the Scientific Editor. Manuscripts not complying with these instructions shall be returned to the authors.

The Editorial Board reserves the right to publish preferentially invited manuscript and to assemble thematic volumes.

The manuscripts should be sent by e-mail to the address:
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