ISSN 2336-3193
DOI: 10.2478/cszma-2025-0014



Published: online December 2025, print December 2025

# The development of the landscape affected by the extraction of mineral resources in the Jeseník Region (Czech Republic)

Renata Popelková & Lenka Jarošová

The development of the landscape affected by the extraction of mineral resources in the Jeseník Region (Czech Republic) – Acta Mus. Siles. Sci. Natur. 74: 226–244, 2025.

**Abstract:** This study analyses the long-term transformation of the landscape in the Jeseník Region (Czech Republic) resulting from the extraction of mineral resources, particularly Silesian granite and Silesian marble. These raw materials, historically quarried within the Žulová Massif and adjacent areas, played a key role in the region's economic and cultural development from the Middle Ages to the 20th century. Using multitemporal aerial photographs from 1953, 1964, 1976 and 1995, combined with a 2022 orthophoto, the research reconstructs changes in quarry areas, land use and landscape structure. Historical aerial imagery was digitized, georeferenced and vectorized, enabling precise GIS-based analyses of spatial and temporal dynamics. Results show that while the total area occupied by quarries remained similar in 1953 and 1995 (approx. 31 ha), the internal structure of mining activities changed significantly: some quarries ceased operation, others expanded, and several new sites appeared. Long-abandoned quarries became predominantly reforested, with forests covering more than three quarters of former extraction areas by 2022. Only 1.39 ha of the original 1953 quarry surfaces remain active today. The study demonstrates that aerial photographs are a valuable tool for assessing landscape evolution in mining regions, enabling both qualitative interpretation and quantitative evaluation of land-cover change.

**Keywords:** landscape, mineral resources, mining, stone industry, Silesian Granite, Silesian Marble, Jeseník Region, Žulová Massif

## Introduction

The great variety of rocks in the geological structure of Silesia and North Moravia manifested itself in considerable mineral wealth. The oldest material used in the past is natural stone. In the past, the region of Silesia became famous primarily for the mining and processing of granite and marble. Granite mining in Silesia took place primarily in the vast massif of the so-called Žulová Massif, formerly referred to as the Žulová Pluton. It is a large unit built of granitoid rocks, which are predominantly intrusive igneous rocks chemically related to granite. It forms the geological basement of the eastern depression of the Vidnava Lowland and, in particular, almost the entire area of the Žulová Upland, where numerous quarries were opened. The Žulová Massif covers an area of 150 km² and, according to geophysical measurements, extends up to 6 km deep into the Earth's crust (Cháb & Žáček; 1994; Cháb et al., 2020; Pecina et al. 2006; Pouba, 1962; Hanáček, 2024).

The Žulová Massif originated at the end of the Variscan orogenic process. The massif is composed mainly of granite and granodiorite, and to a lesser extent diorite, leucocratic granite, pegmatite, and individual quartz veins. The rocks differ from one another in their chemistry and thus in their mineral composition, in their distribution within the massif, and in the type and size of the bodies they form. The largest volume of the massif is represented by granite–granodiorite, which locally interpenetrate one another. These are I-type granitoids, meaning they crystallized from magma produced by the melting of other igneous rocks in the deep part of the continental crust (Jedlička, 1997; Klomínský et al., 2018).

The granitic rocks quarried in this area are collectively referred to by the commercial name “Silesian granite.” In stonemasonry and commercial practice, two types have been distinguished since the late 19th century: light Silesian granite and dark Silesian granite. This corresponds to Scharff’s basic petrographic division into two main groups of rocks within the Žulová Masiff: the predominant group of biotite-granite rocks and the group of more mafic granodioritic to dioritic rocks (Scharff, 1920). The first type includes mainly leucocratic and mesocratic biotite granites and biotite granodiorites with a smaller proportion of the mafic minerals biotite and amphibole. The second type includes quartz diorites (fine- to very fine-grained biotite and amphibole–biotite quartz diorites, medium- to coarse-grained quartz diorites to monzodiorites, biotite and amphibole–biotite types, diorites with titanite, as well as part of the granodiorites - specifically the amphibole–biotite varieties) (Rybařík, 1994). The Sorge-type granodiorite represents, in terms of its colour index, a transitional member between the light and dark granitic rocks of the Žulová Masiff and is usually assigned to the second group (Scharff, 1920).

Both the more common light granite and the less common and more sought-after dark granite were processed. Apart from granites, Silesian marbles are a very well-known and important raw material. These were mined in numerous quarries in the vicinity of the Žulová Masiff with centres in Horní Lipová, Supíkovice and Velké Kunětice. Silesian marble was famous for its colourful variety, so in addition to the more common grey-white or dark marble, rarer brownish, reddish or greenish marble was mined. Due to its excellent properties and due to its similarity to Italian white marbles, the calcitic marble of Supíkovice is referred to as “Silesian Carrara”. It is one of our highest quality decorative stones, characterized by hardness and good polishability.

The vast granite massif served as a source of construction material already in the Middle Ages, as can still be seen today in the oldest secular and church buildings in the Jeseník Region (e.g. the early Gothic portal of the Church of St. Catherine in Vidnava or the stone elements of the cemetery Church of St. Cross in Javorník-Ves). The first written record of the use of the Jeseník marble dates from 1419, when a tombstone for Bishop Wenceslas od Wrocław was made of Kunětice marble. Even in the following centuries, Jeseník granite and marble entered the market not only in the local region, but also in the adjacent lowland areas of the Principality of Nysa (Otmuchov, Nysa, Pačkov). However, the systematic extraction of local stone only occurred in the course of the 19th century, when not only utilitarian objects (gutters, troughs, door and window frames, stairs, etc.) began to be produced from granite in large quantities, but marble also began to be used for the more demanding production of monuments and altars (Hečková, 2022; Popelka, 2006).

From the 1860s, we can already talk about the beginnings of the industrial production of stone products organized on a business basis (the most famous entrepreneurs include Albert Förster and Hermann Franke). The rational use of mineral resources was due to professional stonemasonry schools which, due to the stonemasonry boom, were founded in 1885 in Supíkovice for marble processing and a year later in Žulová for granite processing. At the end of the 19th century, more than 3,500 people made a living by processing stone in the Jeseník region alone, and they worked here at 160 industrial enterprises dealing with stone mining and processing. At that time, a large part of the local stone products were exported, especially to neighbouring Germany, but also to the USA and Australia. The concentration of high-quality stone processors meant that, from the 1880s, not only local raw materials were processed in the region, but also stone imported from Scandinavia (mainly Swedish vein) or from Italy (Carrara marble) for the production of luxury goods.

The boom in granite and marble mining and processing in the area of the foothills of the Rychleby Mountains, the Žulovská Downs and the Zlaté Hory Highlands continued despite the decline in stone production in the period of economic turbulence in the first third of the 20th century and despite the further decline during World War II and the subsequent departure of the stonemasons when the Germans were expelled from the Jeseník region. Stone production after World War II did not reach the pre-war volume and quality. Artistic production was completely left behind, and the purposeful production of paving stones and other building materials was given the green light. Although granite and marble are currently mined in the Jeseník region only to a very limited extent, the tradition of mining and stone processing is still of great importance to the region today (Gába, 1986; Popelka, 2006).

The quarries in the studied area were and still are not only important sites for the extraction of granite and marble, but also interesting mineralogical localities. Thanks to the quarrying of stone, it has been possible to study not only the geological structure of parts of the Žulová Massif, but also the origin and development of minerals (Losos & Brož, 2002). Černá Voda – Nový lom quarry (Fig. 1, 2) represents one of the most characteristic artificial exposures of biotite-bearing granodiorites to granites in the Žulová Massif. The quarry is dominated by light gray, equigranular granitoids. Intensive mining activity has enabled detailed geological investigations, yielding numerous significant insights. The site ranks among the most important localities for sulfide hydrothermal mineralization within the Žulová Massif. These mineralizations occur primarily in association with pegmatite, aplite, and quartz veins, as well as in otherwise unmineralized granite fractures. Notably, the locality hosts some of the finest molybdenite occurrences in the Czech Republic (Losos, 1998; Štelcl & Vávra, 2014).

**Fig. 1:** New Quarry, Černá Voda, 2012. Photo by L. Jarošová.

**Fig. 2:** New Quarry, Černá Voda, 2024. Photo by L. Jarošová.

Mining continues at several quarries in the Žulová area. Fine-grained granodiorite is currently extracted at the Jašek quarry, while light biotitic granite to granodiorite is actively quarried at several sites operated by Slezský kámen a.s., including the Petrov (Fig. 3) and Huttung quarries. Southeast of Žulová, several smaller inactive quarries are present, such as Transgranit (also known as Ostrůvek), Lihovar, and Starost (Fig. 4, 5). The rocks quarried at these sites comprise leucocratic monzogranite and dark gray granodiorite, referred to as Sorge-type granodiorite (Scharff, 1920). These exposures provide clear examples of magmatic differentiation within the granite–granodiorite series.

Another remarkable quarry within the Žulová Massif is the Vycpálek Quarry. The abandoned stone quarry (Fig. 6) is among the most interesting mineralogical sites in our country. It is a unique locality where crystals of "floating garnet" (grossular, variety hessonite) occur within marble layer that appear in the uppermost part of the quarry wall, directly overlying biotite granite. At the same time, the quarry contains tactites typical for the Žulová Masiff area. The beginnings of quarrying date back to the 1860s and 1870s, and operations ended in 1969. The quarry is being devastated by uncontrolled mineral collecting, often involving the use of explosives. The original vegetation in the upper part of the quarry is being damaged, leading to subsequent erosion and the loosening of outcrops (Fig. 7).

**Fig. 3:** Petrov Quarry, Žulová, 2024. Photo by L. Jarošová.

**Fig. 4:** Starost Quarry, Žulová 2025. Photo by L. Jarošová.

**Fig. 5:** Starost II Quarry, Žulová, 2025. Photo by L. Jarošová.

**Fig. 6:** Abandoned flooded Quarry Vycpálek, Vápenná, 2005. Photo by L. Jarošová.

**Fig. 7:** Upper part with „floating garnets“ destroyed by mineral collectors, Vycpálek Quarry, Vápenná, 2009. Photo by L. Jarošová.

In the quarry near Vápenná, crystalline limestones were intensively mined over the course of the last two centuries. Numerous fissure-karst cavities with sparse speleothem decoration were encountered in the quarry walls. Due to the dense fracturing, the local limestone was unsuitable for stonemasonry, and from the second half of the 19th century it was therefore quarried and exported for the needs of sugar factories, ironworks, and glassworks. Mining here ended in 1973. The landscape and karst features of the area have been significantly altered by intensive limestone extraction, which left behind a relatively extensive complex of abandoned quarries (Fig. 8). The area lacks surface karst features, but underground phenomena are relatively abundant. All the limestone quarries in the vicinity of Vápenná exposed and completely or partially removed a number of them during mining, ranging from narrow karstified fissures to large caves with speleothem decoration. Among the largest caves are Roušarova, Pec a Velký dóm (Král, 1959; Morávek, 2009; Vocilka, 1977).

**Fig. 8:** Old limentone Quarry Vápenná, 2023. Photo by L. Jarošová.

## Monitoring the transformation of the landscape

How did stone mining affect the shape of the Jeseník region landscape? There can be various answers to this question, which depends primarily on the information sources we use. At present, aerial photographs, the use of which offers numerous advantages, are a very frequently used source of information about the development of the landscape. Above all, they allow a detailed view of the landscape, in such detail that even detailed maps usually do not allow. The possibility of compiling time series that perfectly express the dynamics of landscape changes is another great advantage. Last but not least, they provide the possibility of creating overlapping operations that allow the phenomena observed to be precisely quantified. In this way, primarily qualitative (thematic) information is obtained from the images, e.g. landscape structure, vegetation cover, distribution of settlements and others. Qualitative information thus needs to be reconstructed using other information sources.

Aerial images provide a bird's-eye view of the Earth's surface and allow observing landscape features in their spatial context. (Lillesand et al., 2015). Aerial photographs are also suitable historical material providing information about the landscape in the past. Together with contemporary images of the same territory, they can be used to derive the development of the landscape in the time horizon observed. The advantage of aerial photography is that they provide a non-generalized view of the landscape. Therefore, they show the comprehensive current status as of the date of imaging. This feature is of great importance especially in areas where the dynamics of landscape changes are high (e.g. mineral extraction areas). N. Niepce, WHF Talbot and LJM Daguerre are credited for the invention of photography in 1839. (Lillesand et al., 2015) The first known photograph taken from a height is associated with the French photographer Tournachon (Nadar), who, in 1858, took a photograph of a small town near Paris from a height of about 80 meters from a balloon. In addition to balloons, various kites were also used as carriers in the beginning. (Dobrovolný, 1998) Photography using cameras placed on pigeons was patented by J. Neubornne in 1903 (Halounová & Pavelka, 2005).

Also, shortly after the invention of the airplane at the beginning of the 20th century, the first attempts were made with photography from this carrier (Dobrovolný, 1998). The first aerial photographs were those of LeMans in France (1908) and Centocelli in Italy (1909) taken by W. Wright. The great development of aerial photography was noted during the period of both world wars. More than a million aerial reconnaissance photographs were taken during World War I alone. (Lillesand et al., 2015) Subsequently, aerial photography was also used for topographic mapping, including agriculture and forestry Halounová & Pavelka, 2005).

The first photographs of our territory (part of Prague) were taken from a balloon by J. Plischke in 1906 and 1908 (Dobrovolný, 1998). The foundations of aerial photography in our country were laid before World War II. Part of the territory was photographed (Halounová & Pavelka, 2005).

Since the 1930s, when aerial photography of the landscape began to be used in the Czechoslovak Republic, aerial photographs have been one of the main sources of information about the landscape. In the period of 1936–1938 and in 1946, only a small number of pictures were taken. Between 1947 and 1956, aerial surveying images were used for the first time on a larger scale for photogrammetric evaluation in the process of making maps in a scale of 1: 25 000. In the period mentioned, almost the entire territory of the country was photographed mainly in a scale of 1: 23,000. Later, the entire territory of the country was photographed regularly every 5–7 years, due to the updates to topographical maps.

Between 2003 and 2011, a third of the territory of the Czech Republic along the meridian belts was photographed every year. Since 2012, aerial surveying of the territory of the Czech Republic and the creation of orthophotos have been carried out in a two-year period, when about a half of the territory of the Czech Republic is photographed every year. The Czech Office for Surveying, Mapping and Cadastre periodically updates a set of colour orthophotos in the dimensions and layout of map sheets of the State Map of 1: 5 000 (2 x 2.5 km) for the territory of the Czech Republic. Orthophoto is a georeferenced orthophotographic representation of the Earth's surface (ČÚZK, 2022).

Lipský (2000) states that monitoring landscape changes over time is based on monitoring changes in individual landscape components, their area representation, size, shape and spatial configuration. A change in the representation of individual landscape types leads to a change in the ecological stability of the territory. Knowledge from the historical development of the territory can be applied in the design of optimization of landscape restoration and landscape care.

It is also possible to monitor the spatiotemporal changes of the landscape by simple visual comparison of classic aerial photographs from different years (Fig. 9). In this way, however, it is not possible to accurately detect changes in the boundaries of individual areas, to record their attributes (properties), and it is also more difficult to determine the dimensions of these areas. Therefore, it is advisable to convert the background material into digital form by scanning it and then use the tools of geographic information systems (GIS) to monitor the changes in the area. However, it must be said that visual image interpretation, which is the basis for processing in GIS, is neither simple nor, often, even unambiguous. (For aerial imagery analysis for areas affected by deep coal mining, see Mulková & Popelková 2013).

Aerial images enable effective monitoring of landscape changes, the dynamics of changes and their direction, the extent of landscape devastation, etc. In combination with the possibilities of GIS analyses, these changes can be quantified relatively accurately and efficiently, and qualitative developments in time and space can also be captured.

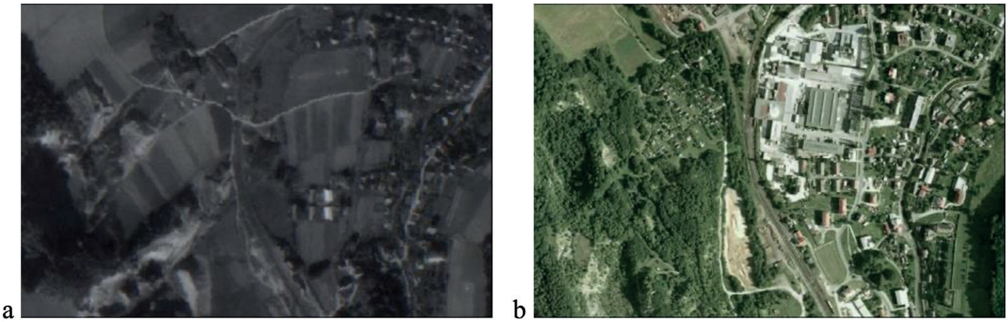



**Fig. 9:** Comparison of the same part of the municipality of Vápenná village in different years: a - section of a black-and-white aerial (1953), b - section of a colour aerial photograph (2003). No scale. Photo from 1953 provided by VGHÚř Dobruška, © GŠ AČR. Image source from 2003: (PVS CR, 2006)

### Area of interest

In order to capture the transformation of the landscape of the Jeseník region, which was influenced by stone mining, we chose the area on the border of the Žulovská Downs and the Rychleby Mountains. The Žulová region is located in the northeastern part of the Czech Republic, not far from the border with Poland. It is located in the Olomouc Region and in the district of Jeseník, which was formerly part of the district of Šumperk. The spatial delimitation of the area of interest is shown in Fig. 10.

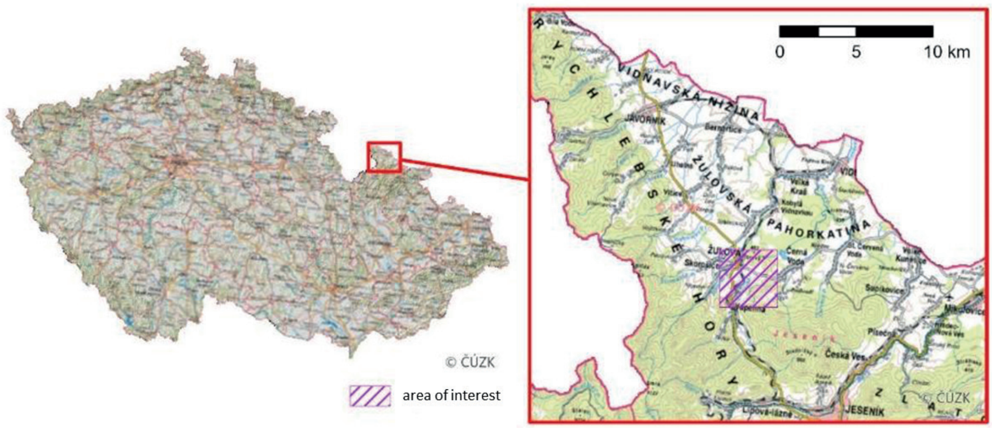



**Fig. 10:** Location of the area of interest in the Czech Republic. Data source: (ČÚZK, 2022)

The area of interest is located northwest of the town of Jeseník. It covers parts of the following municipalities: Žulová, Vápenná, Černá Voda and Skorošice. It was chosen to include the area in which mineral extraction took place in the second half of the 20th century. There were active quarries in the area of interest in the 1950s: Jašek Quarry, Petrov Quarry, Quarry near Žulová, Upper Quarry, New Quarry, Hutung Quarry, Jan Vycpálek Quarry and Vápenná Quarry.

## The data used and work progress

The work progress can be divided into several consecutive steps:
**preparatory phase** – acquisition of aerial photographs and other necessary data, selection of evaluation parameters and suitable analyses, field survey

**data processing** – preparation and processing of aerial photographs, visual image interpretation of aerial photographs, vectorization of modified source data, modification of data created

**data analysis** – multitemporal analyses of the landscape with a focus on surface mining of mineral resources
evaluation of data obtained and analyses performed: evaluation of the state and development of mineral extraction, monitoring of changes in the landscape, presentation of results

Historic black-and-white aerial photographs from 1953, 1964, 1976 and 1995 were used to monitor the landscape in the area of interest. The analogue data obtained was first converted into digital form. Black-and-white aerial photographs were scanned at 600 DPI to distinguish very small details in the images. The resolution was determined based on a compromise between the quality of the image scanned and the volume of the resulting data.

Subsequently, it was necessary to georeference the historical aerial photographs. Due to the nature of the area, manual georeferencing was used using identical, so-called photo points, which were searched both in the data, which was transformed, and on the map, which is already georeferenced. Elements for which we do not expect a spatial shift (churches, corners of buildings, road intersections, etc.) serve as photo points. When georeferencing the data, emphasis was placed on the even distribution of the photo points.

The original, unedited aerial photographs contain a number of geometric distortions created by central projection during imaging. These deformations do not allow their direct use, for example, for measuring distances and areas. Therefore, it is necessary to carry out geometric corrections of aerial photographs. Geometric corrections were performed in PCI Geomatica software, the OrthoEngine module. Due to the fact that there are no exact data from the calibration protocol for older aerial photographs, a polynomial transformation of the first and second order was applied. The polynomial transformation is based on the collection of identical points (e.g. corners of buildings) and the calculation of transformation equations to convert the position of the pixels to the appropriate coordinate system.

A colour orthophoto from 2022 was used to determine the current landscape cover. The orthophoto did not need to be edited, it was displayed in the ArcGIS Pro software in the S-JTSK coordinate system through the ArcGIS map services of the Czech Office for Surveying, Mapping and Cadastre.

The occurrence of mineral extraction areas and the structure of the landscape was determined by visual image interpretation of the aerial photographs processed. Visual image interpretation of aerial photographs enables the determination and description of the appearance and properties of premises and phenomena shown in the images using direct interpretive signs and indirect interpretive signs (shape, shade, size, colour, tone, texture, structure, etc.), based on the knowledge of the relationships between the individual elements (Čapek, 1978). Certain types of surface (vegetation, bodies of water, rocks, etc.) reflect a part of the incident solar energy in different ways, which affects the resulting amount of reflected electromagnetic radiation recorded, thus giving individual types of surface a different, easily distinguishable character (Ciolkosz et al., 1999). It is therefore possible to successfully analyse aerial images based on this knowledge and experience (Mulková & Popelková 2013). Visual image interpretation is best learned through the experience of watching many aerial photographs, supplemented by local knowledge of the environment and processes observed. (Lillesand et al., 2015). In the photointerpretation of mainly black-and-white aerial photographs, complications may arise in the recognition of some areas appearing in the photograph. For example, differentiating vegetation (type of vegetation or type of forest, method of land use) is problematic. In such cases, it is necessary to use supporting data, e.g. cadastral and other maps from the relevant years, archival documents and other available documents relating to the territory. From aerial photographs transformed into coordinates, it is possible to obtain the data needed to monitor changes in mineral extraction areas in the selected time horizon. Through visual image interpretation and subsequent vectorization at a scale of 1: 5 000 in ArcGIS software, data capturing the landscape of the area of interest in the monitored years was obtained from aerial photographs. Due to the character of the territory, the following categories of landscape use were monitored:

mineral extraction areas

industrial premises

residential development

permanent grasslands (meadows and pastures)

arable land

forests and groups of trees

water bodies

The result of a visual image interpretation of the entire area of interest in 1953 is shown in Fig. 11. Line features are also recorded here: roads, field and forest roads, railways and waterways.

Multitemporal analysis of historical aerial photographs enables a qualitative evaluation of landscape development as well as quantification of the magnitude of changes in the landscape. A qualitative description of the landscape mosaic focuses primarily on its content. It is therefore a qualitative description of the units that make up the landscape (Guth and Kučera, 1997). The quantitative approach deals with quantitative evaluation, i.e. the ability to measure and calculate various values related to the landscape structure.

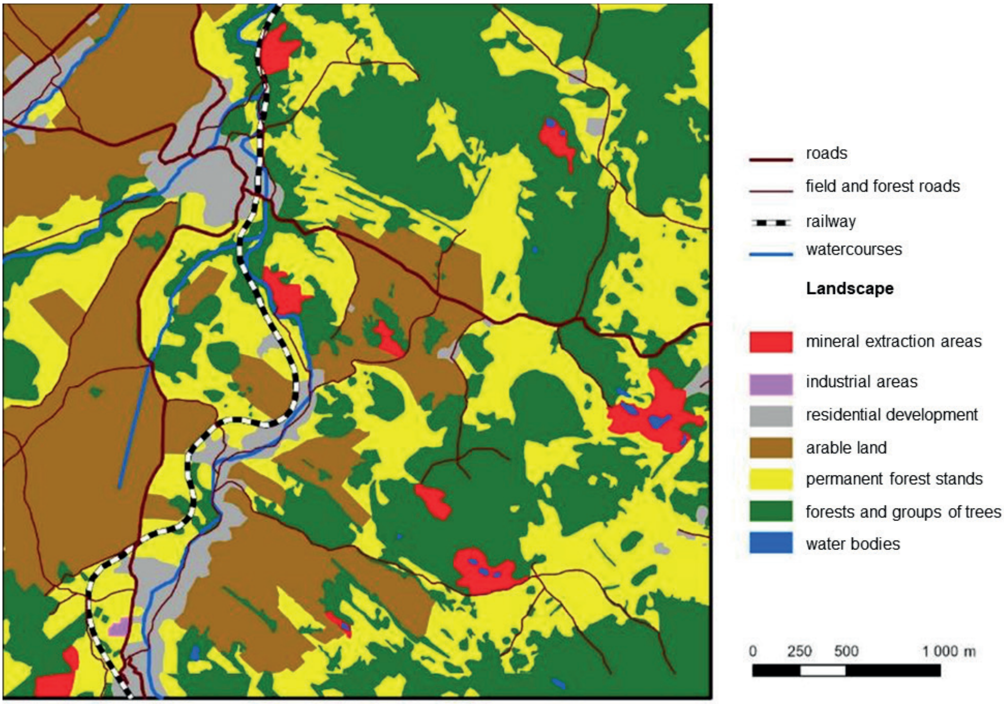



**Fig. 11:** Use of the landscape in the entire area of interest in 1953.

Maps were created from the data derived in ArcGIS software, and a quantitative evaluation of the data in the form of tables and graphs was also performed.

Using the analytical tools of GIS software applied to the layers created, it is possible to monitor the development of the landscape. The so-called overlay operations, which search for places meeting or not meeting certain conditions, can be used, for example, to compare the occurrence of specific types of landscape use in different years (e.g. it is possible to compare the occurrence of mineral extraction sites in 1953 and 1995).

### The development of mining of mineral resources in the monitored area of interest

Fig. 12 shows the mineral extraction areas in 1953. Polygons (areas) where mining (active quarries) took place in the monitored year are shown here: Jašek Quarry, Petrov Quarry, Quarry near Žulová, Upper Quarry, New Quarry, Hutung Quarry, Jan Vycpálek Quarry and Vápenná Quarry.

In order to determine the development of the mining areas monitored, individual layers were analyzed, which express the state of mining of mineral resources in the respective years. Fig. 5 illustrates the mining situation in the area of interest in the following years: 1953, 1964, 1976, 1995 and 2022.

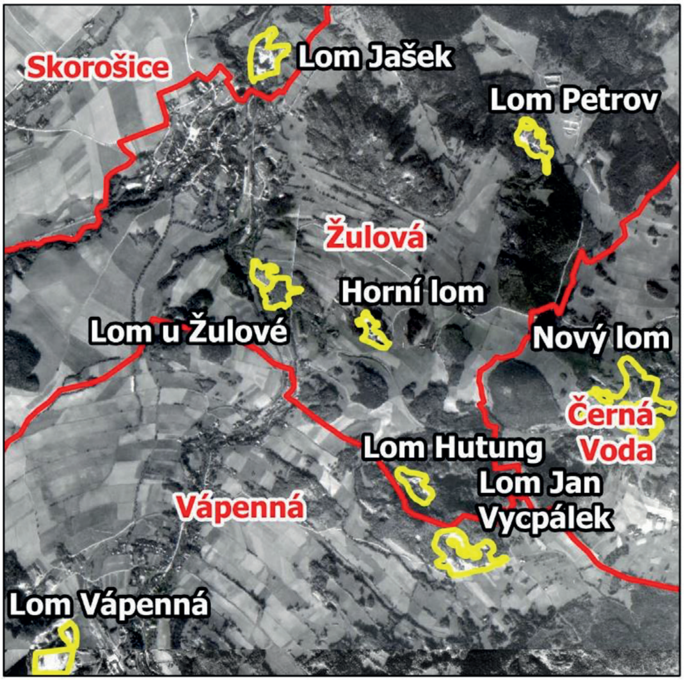



**Fig. 12:** Areas of mineral extraction (yellow line) shown in a section of an aerial photograph from 1953 showing the selected area of interest. The red lines show the boundaries of the municipalities. Aerial photo provided by VGHÚř Dobruška, © GŠ AČR.

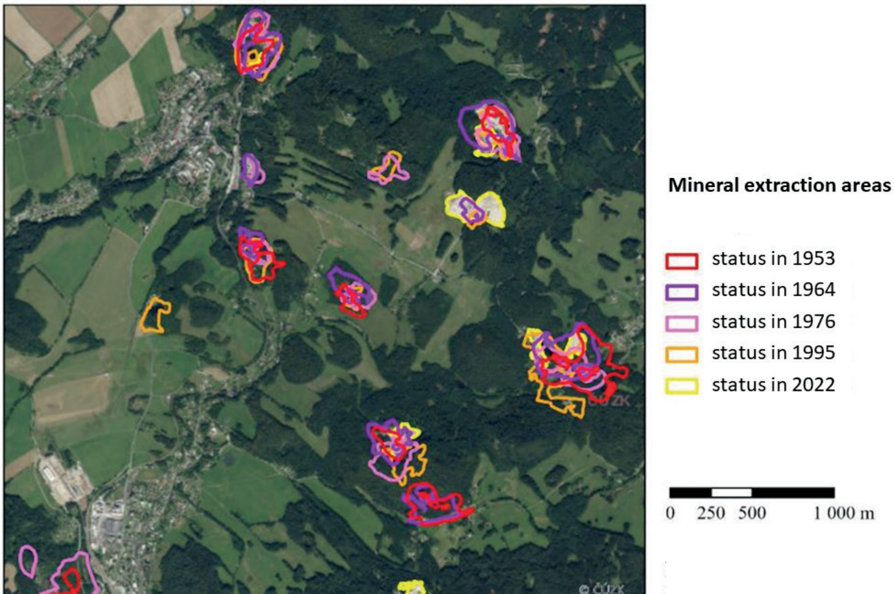



**Fig. 13:** Areas of mineral extraction in the selected area in 1953, 1964, 1976, 1995 and 2022, Source of orthophoto from 2022: (ČÚZK, 2023)

Mining areas, waste dumps and processing areas are part of every mineral extraction site. Most often, there is a change in the dimensions of the mining areas and waste dumps. It can be seen from Fig. 13 that the size and location of individual mining areas have changed for the following quarries: Quarry near Žulová, Upper Quarry, New Quarry and Huttung Quarry. In the area of interest, all mining sites remained active except for the only one, which is Jan Vycpálek Quarry. Fig. X shows the premises of this quarry in 1953 and 1964. In 1976, Jan Vycpálek Quarry was no longer in operation. From these data obtained from aerial photographs, it is therefore possible to deduce that Jan Vycpálek Quarry disappeared between 1964 and 1976.

On the basis of the vector layers created, overlay operations allow monitoring the development of mining of mineral resources in the selected time horizon. Fig. 14 shows the evaluation of the change in mineral extraction areas from two time periods: 1953 and 1995. Two vector layers were the basis for analytical processing: mineral resource extraction sites from 1953 and mineral resource extraction sites from 1995. After the overlay operation applied, it is possible to distinguish three types of areas in the resulting layer. The light red polygons show areas where the quarry was active in 1953, but by 1995, mineral extraction was no longer taking place. Areas of mining that had been preserved for more than 40 years (they appear on aerial photographs from both years at the same time) are shown by hatched polygons. The dark red areas are premises of mineral extraction that appear only after 1953 (the 1995 photo shows an active quarry, but the use of these areas is different in 1953).

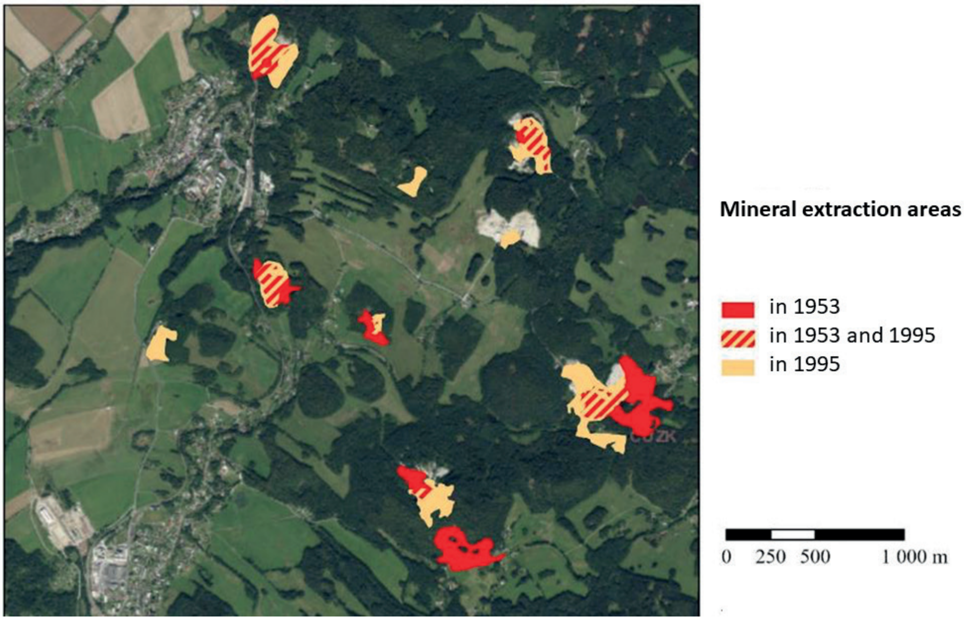



**Fig. 14:** The state of mining of mineral resources in the selected area in 1953 and 1995. Source of the 2022 orthophoto: (ČÚZK, 2023)

The contents and perimeters of individual polygons were also determined. Table 1 shows the total areas of all monitored quarries (in hectares) in 1953 and 1995. The last column of the table shows the area of the premises, which were recorded in the same place in both monitored years (areas of the hatched polygons from Fig. 14).

**Tab. 1:** Dimensions of quarries (in hectares) in the monitored area in 1953 and 1995.

| **Quarry Name** | **Area (in hectares)** | | |
|---|---|---|---|
| | **in 1953 only** | **in 1995 only** | **in both years** |
| Jašek Quarry | 0,53 | 3,44 | 2,89 |
| Petrov Quarry | 0,28 | 2,36 | 1,95 |
| Ralux s.r.o. Quarry | - | 0,75 | - |
| Boží hora Quarry | - | 1,20 | - |
| Quarry near Žulová | 1,05 | 0,88 | 2,27 |
| Ehrlich Quarry | - | 1,92 | - |
| Upper Quarry | 1,11 | 0,38 | 0,30 |
| Nový Quarry | 6,96 | 6,32 | 2,88 |
| Lom Hutung | 1,43 | 3,05 | 0,50 |
| Jan Vycpálek Quarry | 5,38 | - | - |
| Vápenná Quarry | 3,28 | - | - |

It is interesting that in each year observed (that is, in 1953 and in 1995), the premises of mineral raw materials extraction in the selected territory occupied a total area of approximately 31 ha. In the course of more than 40 years, however, mining changed in two thirds of the mineral extraction area. During this time (between 1964 and 1976) a large quarry disappeared: Jan Vycpálek Quarry with an area of 5.38 ha and Vápenná Quarry (3.28 ha) also disappeared between 1976 and 1995. Of the remaining quarries, Upper Quarry experienced the greatest surface losses, the area of which was halved between 1953 and 1995. The area of New Quarry also decreased. On the contrary, Jašek Quarry, Petrov Quarry and Huttung Quarry saw the largest increase in the monitored period. The area of each of them has almost doubled. New quarries have also appeared in the area of interest: Ehrlich Quarry, Boží Hora Quarry and Lom Ralux s.r.o, (Ralux Quarry) From the last column of Table 1, as well as from Fig. 6, it can be seen that the largest area of mineral extraction sites that remained in the same place during the period of 1953–1995 (2.9 ha) was seen at two quarries: Jašek Quarry and New Quarry. Significant areas were also preserved in Quarry near Žulová (2.27 ha) and Petrov Quarry (1.95 ha).

With the use of overlay operations, it is also possible to find out from which type of landscape use a particular type arose (e.g. a quarry was created in a place where 70 years ago there was arable land, etc.) or what the current landscape use is in areas where in 1953 mining of mineral resources took place. These changes between individual categories can also be quantified. The evaluation of areas where mineral raw materials were extracted in 1953 provide an example. In these polygons, the changes in landscape use that took place until 2022 were identified and quantified. Fig. 15 shows how the 1953 mineral mining landscape is used in 2022.

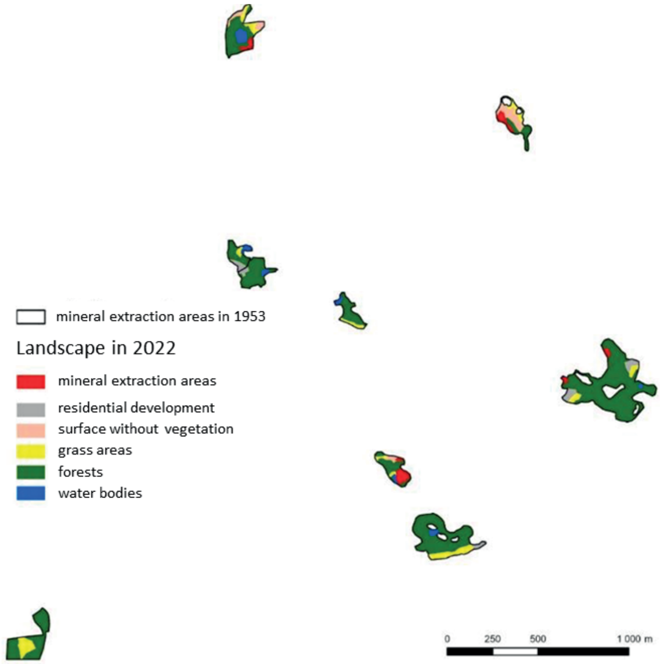
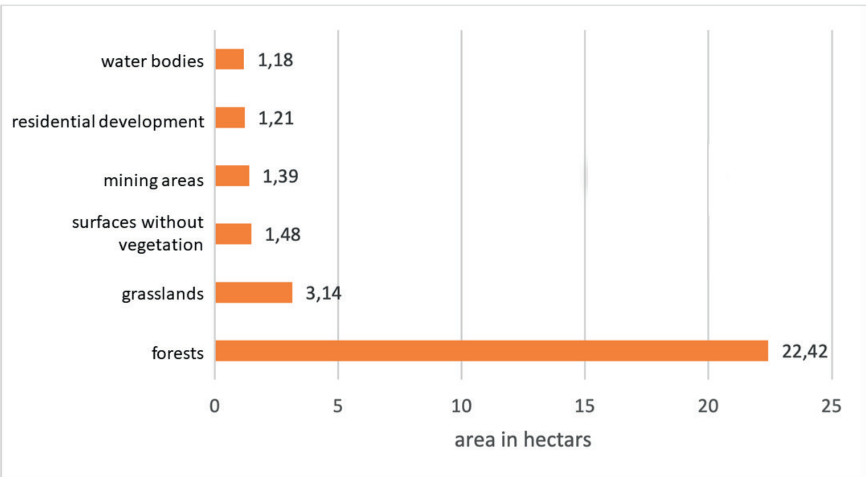



**Fig. 15:** The use of the landscape in 2022 in areas where mineral resources were mined in 1953.

The quantification of changes in the mineral extraction area category from 1953 to other land use in 2022 is demonstrated by Graph 1. The total areas (in hectares) of individual categories from 2022, which were used for the extraction of mineral resources in 1953, are listed here.

**Graph 1:** Comparison of total areas of individual categories of landscape use in 2022, which were created in the period of 1953 – 2022 from mineral extraction areas



The former mining areas from 1953 in the area of interest are most often overgrown with vegetation. Graph 1 and Fig. 15 show that the original areas of mineral extraction are mostly overgrown with forests. Forests in the monitored areas occupy more than three quarters of the area of the total amount of changes. A tenth of the original mining area is covered by grass areas in 2022. In some areas (in 5% of the monitored area), mining has been terminated, but, until now, the surfaces remain without vegetation. Development and water bodies appeared in almost the same area (about 4% of the monitored area). From 1953 to 2022, only 1.39 ha of mineral extraction sites were preserved in the same place.

## Conclusion

After surface mining, specific phenomena and shapes remain in the landscape. All mineral extraction areas are made up of mining areas, waste dumps and raw material processing areas. In the area of former mining, a depression is formed, which remains in the landscape in the form of rock outcrops or is filled with water (often without drainage). Waste dumps, on the other hand, become elevations that tend to be overgrown with different vegetation than the surrounding area, as it is a loose and unconsolidated material (the parent substrate of the surrounding area is solid).

The given example of monitoring the development of mineral extraction shows that aerial photographs are a very suitable source of information for a detailed assessment of spatiotemporal changes in the landscape. It is possible to monitor and quantify not only the areas of individual categories and their changes. It is also possible to find out what types of landscape use a specific area was created from or what type it was transformed into and what their dimensions are.

**Acknowledgements:** The study was financially supported by the Ministry of Culture of the Czech Republic by institutional financing of long-term conceptual development of the research institution (Slezské zemské muzeum, MK000100595).

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**Author's addresses:** Renata Popelková, Department of Physical Geography and Geoecology, Faculty of Science, University of Ostrava, Chittussiho 10, CZ-710 00 Slezská Ostrava, Czech Republic. E-mail: renata.popelkova@osu.cz

Lenka Jarošová, Slezské zemské muzeum (Silesian Museum), Nádražní okruh 31, CZ-746 01 Opava, Czech Republic. E-mail: geologie@szm.cz, orcid iD: 0009-0007-4369-2421