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Using the possibilities of aerial photogrammetry for the research of quarry enlargement

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Abstract

In the study we have analysed the aerial photographs of three quarries situated in the Banská Bystrica surroundings from chosen time horizons. We have elaborated photographs from the beginning of the 1960s in the first period, the ones from the beginning of the 1970s in the second period and those from the second half of the 1980s in the third period and the colour photographs from the end of the 1990s in the last period.

We delimited and digitized the quarry area in particular periods according to comprehensive analysis of aerial photographs. Quarry area polygon determined quarry dimensions and area in digital form in the specified time horizon. Consequently, the comparison was obtained from gained data in particular periods, what enabled to determine the areal enlargement of the quarry in absolute number values, presented in ha (hectares) and also in relative values presented in percentage (%).

Key words: quarry, aerial photograph, georeference and analysis of areal photographs, areal growth

Introduction

The aerial photogrammetry, as a conventional remote sensing method, has quite a long tradition in Slovakia. The official aerial photographs came into being in 1933. The interpretation of the aerial photographs has been one of the most important activities since the begin of the remote sensing utilizing. Qualitative and quantitative information on the given objects on the Earth surface are obtained from an evaluation of the characteristics of the obtained photograph. According to Húska and Tátošová (2005), in the process of evaluation of aerial photographs, the emphasis must be given to the correct interpretation of the shade (colour), size (it is necessary to take it into consideration in relation to the scale of the photograph), shape (regular geometric shapes indicate mainly the human activity), texture (smoothness of the photographed surface – e.g. grass, or buckling – e.g. wood), samples (regular spatial disposition of elements, e.g. orchard), shadows (it is possible to estimate the heigth of the objects by their shadows), position (concerning the relief etc.), associations (it is assumed that some objects are often in the presence of other objects, but it requires an experienced researcher).

Today, the widely applied method of interpretation of the multispectral imagery allows the correlation of spectral signals of objects with their generic and stock characteristics, with the use in the quantity of the applied disciplines. A similar example of a comprehensive mapping and monitoring of the impact of environmental loads on the geological factors of the environment in selected regions of Slovakia has offered by Gregor et al. (2008).

Processing method

The analysis of the aerial photographs content requires the long-time experience and the knowledge of photogrammetry. The researcher evaluating the photographs must be experienced in the field work that simplifies his or her orientation in the particular photograph. It is necessary to analyse the particular shades in black and white photogrammetry with a certainty and to confront the results often with the field work. We have based the evaluation of the photographs for the purposes of the quarry areas identification (devastated area) on methods by Feranec (1992), Feranec et al. (1997), Žihľavník (1996, 1999), Sviček (2000), Boltižiar (2004, 2005), Húska and Tátošová (2005), Bitterer (2005), Boltižiar and Olah (2009) and Hronček et al. (2011).

We have analysed black and white aerial photographs provided by the Vojenský topografický ústav (TOPÚ)

in Banská Bystrica from its archives. The colour aerial photographs were used only in the last phase in connection with the Kostiviarska quarry (Anonymous, 2002). We applied visual analysis of the analog form of the chosen photographs. We scanned the analysed photograph after the identification of the devastated quarry area in the photograph. The advantage of the aerial photographs processing consists in the fact that they have all been realized in 90° angle whereby the distortion disappears considerably (Žihľavník, 1999).

After the corners georeferencing of imageries, the position of the slide was checked by the other at least three reference points. Reference points had to be easily identificable in the field and also on the imagery. They were mainly geometrical centres of the confluence of the waterways, crossing of the different classes of communications, significant off-road shapes and quotations, etc. The area of each of the quarry has been vectorized in the software environment of Geomedia Professional. So we have scheduled the boundary of injured surfaces of the quarry. Get the exact boundaries of the campus has been complicated because of the quarry faces and vegetation process shed shade. The situation was complicated by complete cover of abandoned mining areas and with destruction by the municipal waste deponium.

In such cases, there has been a negative change of the surface area of the quarry and the field survey was necessary. After georeferencing, the scanned images (after locating them in the coordinates system), always with at least three reference points in the area of each quarry, have been vectorized in the software environment Geomedia Professional and so we have obtained the line borders of the devastated quarry area. Working with real coordinates we got real dimensions of the quarries (or of the area devastated by quarrying) and their extent. Then we overlapped the particular quarry border traverses in a chronologic way according to the chosen phases and so we could compare the particular time horizons. On the base of the comparison we have got a review of the shape changes, area expansion of the quarry plan, as well as the projection areas for all time horizons in ha (hectares). Comparing the particular time horizons, we have obtained their area expansion review in values of absolute number in ha (hectares) and in relative values in percentage (%). For the purposes of documentation, the individual sites were imagery processed, centered, cropped and enlarged to air slides with centered position of a quarry.

Aerial photographs from selected time horizons were a subject of the analyses. In the first phase we elaborated photographs from the beginning of the 1960s, in the second phase the photographs from the beginning of 1970s, in the third phase the photographs from the 2nd half of the 1980s and in the last phase the colour photographs from the end of the 1990s.

The selection criteria of the aerial photographs from the particular time horizons were based mainly on imagery entirety of the researched quarries in particular time horizons, their availability and relevant time difference between the particular imagery phases. We aimed to keep the interval of about one decade (10 years). This time horizon was defined as the most optimal not only from the aspect of opportunities to compare the quarries in a standard process and standard mining speed in a busy quarry, but also for the possibility of real comparison of quarry dimensions enlargement, the extent of successive processes in vacant quarries, possible area devastation or, on the contrary, of attempts to recultivate the mining area. The selection of the photographs of the initial time horizon analysis was limited by the fact that a full photographing

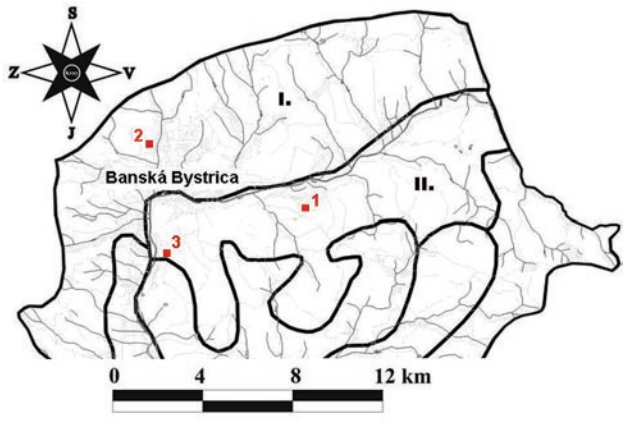

Fig. 1. Schematic draft of the analysed quarries in the northern part of the Zvolenská kotlina basin. 1 – Šalková – Kiár quarry; 2 – Kostiviarska quarry, and 3 Iliaš – Okrúhle quarry; I. – Bystrické Podolie valley; II. – Bystrická vrchovina highlands.

Figs. 2 and 3. Kiár quarry on the northern slopes of Bystrická vrchovina highlands, the waste dump is situated in the right part of the quarry (left). The view from the dump to central part of the Kiár quarry (right, photo P. Hronček).

of the area before the beginning of the 1960s was not available in the archives of the Vojenský topografický ústav in Banská Bystrica. We have checked in the field and archive research that the imagery before the half of the 20th century was faint, because the raw material mining had not been developed in the particular examined quarry areas. The particular quarries had likely not existed before this time horizon.

During the multiannual field research in the Zvolenská kotlina Basin we have identified and localized more than one hundred quarries, therefore we had to choose a key criterion in order to select them. The analyse deals with the quarries which are open in layers, where the possibility of effective economic use is present (Hrnčár, 1993) and where mining has been performed recently or the mining activity ceased in last 10 years. The selected quarries with their area belong to the largest quarries in the particular locality and they may be marked as macrosystems. As for the quarries shut down, we have supposed that there still exists a real possibility of reopening the mining (Hrnčár, 1993).

On the ground of the above defined selection criteria we mention a representative sample – three quarries in the northern part of the Zvolenská kotlina Basin. They are localized in the immediate background of Banská Bystrica. We have localized and identified them in the field on the base of field research and we have made a database with brief physical and geographical analyses (Hronček, 2004; Hronček and Milanová, 2006; Hronček and Maliniak et al., 2008; Hronček et al., 2009). We have analysed them on the base of the aerial photographs. The original aerial photographs are not published in the study because the TOPÚ in Banská Bystrica has not transferred the publishing rights on us. We have analysed quarries: 1. Šalková – Kiár, 2. Kostiviarska and 3. Iliaš – Okrúhle (Fig. 1).

Results

Šalková – Kiár quarry

The quarry is located about 800 m south-east from Šalková, the local part of the town of Banská Bystrica in the altitude 460–528 m a.s.l. It is accessible directly from the road connecting Šalková – Poniky. The quarry was opened in the 2nd half of the 20th century on the base of Middle Triassic to Upper Triassic light grey to grey dolomite with stock prognosis of 1 000 000 m^3 (Polák et al., 2003). The upper layer consists of mould clay not thicker than 0.4 m (Hrnčár, 1993). The original form of the quarry was five--plate side quarry with the main side about 70 m high and about 300 m long. The quarry plan has an elliptic shape with the longer axis of about 400 m extended in the south--west and north-east direction. The shorter axis is about 250 m long. Recently, the usable stocks from the pit part are mined during irregular season mining. The pit diameter is about 80 m and the depth about 15 m. The average mining has not reached 20 thousand tonnes and the produced rock is used after grinding as a construction and road material. Recently, the quarry has been operated by the company KARTIK s.r.o. Banská Bystrica. The present quarry shape is considerably changed by a waste dump of soil and rock material which has been stockpiled in the southern part of the quarry since 2003 (Figs. 2 and 3).

Area development

In the first phase, dated to the beginning of the 1960s (Fig. 4), the shape of the area devastated by quarrying was elliptic, extended in the south-west and north-east directions. The longer axis was 84 m long, the shorter one 60 m and the devastated area reached 0.31 ha. The side shaped quarry located on the north-oriented slope had the side of about 15 m high, which is demonstrated by the trees growing on the southern edge of the quarry side. The quarry surrounding was grown by a compact major forest stock. The field research has confirmed that the degraded area in the north of the quarry has never been a mining area degraded by quarrying. It is the Šalková – Poniky road wiggling on steep slopes with a nearby parking place. The photograph shows exactly and in detail the technical work for processing of the produced rock in the central and northern parts, the workshops and the offices were in the eastern and a dump of selected chipping fractions was in the north-eastern part of the area. It is not obvious from the picture, if there were mining plates constructed in the quarry. We can suppose their existence only in the south--eastern part of the side and this premise is supported by the shades of grey colour in the picture. The falling shadows of the trees make their exact identification difficult.

At the beginning of the 1970s (the second phase, Fig. 5) the quarry plan was almost a circle, extended a little in the south-west and north-east directions. The extension is caused by a flat spur in the north-east, where the entrance to the quarry leads from the Šalková – Poniky road. We have determined the lenght of the longer axis 140 m and of the shorter one 125 m from the traverse. The total area of the quarry with the devastated area was 1.14 ha. It was a side quarry where three minig plates can be identified that time. In the north-eastern part of the quarry the technical works, offices, workshops and a dump of gravel were localized at the entrance. Two minig plates are clear at the southern side. The quarry surround is grown by forest stock. The trees markedly shadow the surface of the upper plate.

In the third phase of the 2nd half of the 1980s (Fig. 6) the quarry was shaped by the onward mining in the southern direction to an ellipse extended in the north--south direction. The north-south axis was 390 m long and the shorter – east-west axis was 330 m long. The quarry with its dimensions and the area of 3.31 ha took a character of a large quarry. In the picture two high mining plates connected with three lower plates may be identified thanks to the falling shadows in the southern part of the side quarry area. A large technical works with a transporter designed to process the produced rock was located in the northern part of the quarry. Offices and workshops were located in the eastern part of the quarry. The field research has confirmed that the circle-shaped devastated area in the

north of the quarry entrance related to the maintenace of the Šalková – Poniky road. Deciduous forests are growing in the surrounding of the quarry. The trees are shadowing the upper plate in the south-west part of the quarry. In the southern part of the quarry the shadows are falling on the ground without the upper layer.

In the last analysed – fourth phase – dated to the end of 1990s (Fig. 7), the quarry plan was complex and it may be qualified as an ellipse. It is considerably pushed in the north-west part. This is caused by the nearby Šalková – Poniky road which showed to be a very restrictive factor of the lateral extension of the mining area in that direction. The mining area of 4.14 ha is 310 m long in the SW–NE direction and its width is 240 m. It is a side quarry with the side oriented to the north and divided into 6 mining plates. Sunlight is delineating the plate edges in the photograph. In the northern part of the quarry a grinder with a trasporter designed for production of standard gravel fractions can be identified. In the eastern part of the quarry workshops and offices are located. The quarry surround is grown by deciduous forest and we have checked this fact in the field, too.

Comparison of particular development phases

Traverse made by vectorization of the aerial photograph falling into the time horizon of the beginning of the 1960s (i.e. the first analysis phase) limits the original core of the quarry of 0.31 ha. This quarry may be approximately identified with the original core quarry which opened the layer at the beginning of the 2nd half of the 20th century. Before the quarry was opened, the layer had been mined below on the slope, where it was better accessible. A new quarry was opened at the present place after building a solid surface of the Šalková – Poniky road. Starting of quarrying in this layer related to the housing construction and particularly to the industrial building in the eastern part of the town of Banská Bystrica. The onward minig caused that its area reached 1.14 ha in the second analysed phase at the beginning of the 1970s, which represents 268 % increase, i.e. total by 0.83 ha. The mining gradually shifted in the south and south-west direction and in the 2nd half of the 1980s the quarry area had 3.31 ha which means further increase by 190 %, i.e. by 2.17 ha. As a paradox, the Šalková – Poniky road, which led to its opening, became a restrictive factor of its enlargement at the break of the centuries. The vertical progress of the mining in the southern direction against the slope slowed down. Later, the quarrying has oriented in vertical direction into the core of the layer which has led to the pit creation in the 1st decade of the 21st century. In the last analysed phase dated to the end of the 1990s we have determined the quarry area of 4.14 ha, which means the enlargement by 25 %, i.e. 0.83 ha. Comparing the particular phases we may state that the quarry entrance has not changed, which was predetermined by the quarry position on the northern slope. The position of the technical works in the quarry also has not changed during 50 years. On the base of the aerial photographs, it is obvious that the technical works have been rebuilt considerably and modernized (Fig. 8).

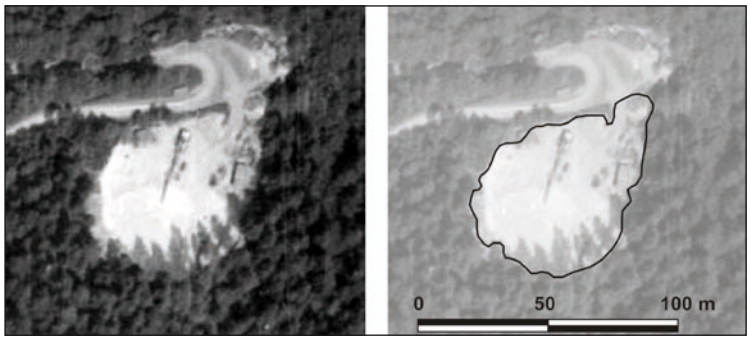

Fig. 4. Aerial photograph of the Šalková – Kiár quarry at the beginning of the 1960s, graphically compiled according authors Hronček et al. (2009, left) and graphically elaborated ground plan of the Šalková – Kiár quarry at the beginning of the 1960s (right).

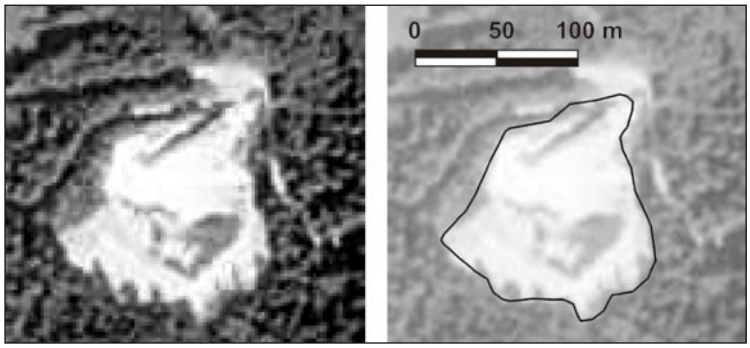

Fig. 5. Aerial photograph of the Šalková – Kiár quarry at the beginning of the 1970s, graphically compiled according authors Hronček et al. (2009, left) and graphically elaborated ground plan of the Šalková – Kiár quarry at the beginning of the 1970s (right).

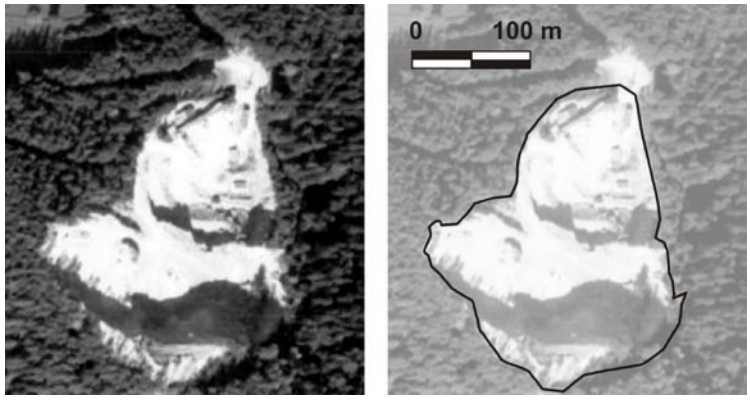

Fig. 6. Aerial photograph of the Šalková – Kiár quarry at the second half of the 1980s, graphically compiled according authors Hronček et al. (2009, left) and graphically elaborated ground plan of the Šalková – Kiár quarry at the second half of the 1980s (right).

Kostiviarska quarry

The largest quarry of the Zvolenská kotlina Basin is located on its northern border at the western skirt of Kostiviarska, the local part of the town of Banská Bystrica (Fig. 9). It is located on the eastern slope of the ground elevation Laskomer (632 m a.s.l.) at the right side of the Bystrica valley.

The side quarry is located between 412 m a.s.l. and 568 m a.s.l. The vertical elevation difference of the quarry is 156 m and its side is divided into five plates. The quarry with almost an elliptic plan is 1.4 km long along the north-south axis and 0.5 km along the shorter axis. The total devastated area is about 0.5 km^2. Today, the quarry is vacant, shut down and it has been partly recultivated. Cement raw material of the yellow and brown to grey colours, consisting of limestone and marly limestone complex of the Krížna nappe of the Lower Cretaceous age, was mined in the layer (Hrnčár, 1993; Polák et al., 2003). The quarry was opened as a raw material base for the newly built cement works in Banská Bystrica at the beginning of the 1950s. The quarry had been busy until 2002 and it was shut down in this year.

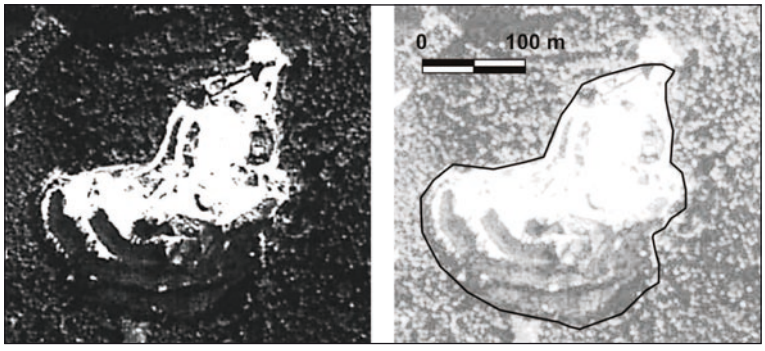

Fig. 7. Aerial photograph of the Šalková – Kiár quarry at the end of the 1990s, graphically compiled according authors Hronček et al. (Hronček et al., 2009, left) and graphically elaborated ground plan of the Šalková – Kiár quarry at the end of 1990s (right).

Fig. 8. Comparison of areal growth of the Šalková – Kiár quarry at the second half of 20th century according to polygons of particular analysed periods.

Fig. 9. Aerial view on the Kostiviarska quarry in 2009 (photo Z. Filadelfi).

The area development

As early as in the first phase at the beginning of the 1960s (Fig. 10), the whole area after quarrying in Kostiviarska had a character of a large quarry despite the fact that it was busy only several years. The quarry was located in the northern part and technical works with a loading station of a cableway were located in the southern part. The devastated area – as a quarrying relict – was located on the eastern slope of Bystrica valley and its plan was markedly extended in the north-east direction. Its lenght was 1 150 m, width 400 m and the area was 25.57 ha. The side quarry was 310 m long and 350 m wide along the slope. Four mining plates are visible in the picture. It is not clear if all of them were mined or only prepared for mining by removal of hanging wall rock. Technical works with a number of paths securing the access to the plates were in the southern part of the area. Permanent grassland – grazing – grew in the quarry surround. Grazing in the south-east of the quarry grew gradually by pioneer types of plants which reach tree-height today.

In the second phase at the beginning of the 1970s (Fig. 11) the limited traverse of the area took an elliptic plan with some spurs where technical works were located. The quarry area was 1 300 m long in the north-south direction and 400 m wide in its widest place. The total devastated area with relicts after quarrying was 38.68 ha. The side quarry in the northern part of the area was 325 m long and 360 m wide and it was divided into 4 mining plates. Each of the plates was accessible by individual road which the lorries used to transport the produced rock for processing in the southern part of the area. In addition to the paths in the quarry and the technical works, also the loading station of the cableway in the eastern part of the quarry may be well identified. Permanent grassland – grazing – grew in the surrounding of the quarry, where the tree stock meshed, particularly in the north-east and south-east near the Bystrica river flat.

In the next – third phase – dated to the 2nd half of the 1980s (Fig. 12), the quarry area plan was considerably extended in the north-south direction with some spurs for the technical and service works. The longer axis of the traverse

limiting the area devastated by quarrying was 1 410 m long and the maximal width in the northern part, where the quarry is located, was 520 m. The total area devastated reached 47.11 ha. The side quarry was 870 m long and divided into 5 mining plates with the maximal width of 130 m at the second plate. Permanent grassland – degraded grazing – grew in the surrounding of the quarry. Shrubbery and trees of a line and fragment shape mashed in the grazing. The aerial photograph shows in detail the system of the access roads, the devastated areas, technical works and service buildings. Pioneer plants of the coming succession mashed between the devastated places in the southern part of the quarry.

The last – fourth – analysed phase relates to the aerial photographs from the end of the 1990s (Fig. 13). The limited quarry area plan was markedly extended in the north-south direction. It was 1 430 m long and not wider than 520 m in the northern part, where the quarry is located. The total devastated area reached 46.73 ha. The side quarry was 900 m long and divided into 5 mining plates. As the cement production decreased that time, causing also the decrease in the mining volume, the quarry area began to be grown by plants from its surrounding. Initial phases of succession began in the non-recultivated quarry area. Permanent grassland – degraded grazing – grew in the surround of the quarry. Shrubbery and trees began to predominate over the grazing. The aerial photograph shows in detail the devastated areas in the southern part of the quarry in which plants mashed between the system of the access roads, technical works and service buildings.

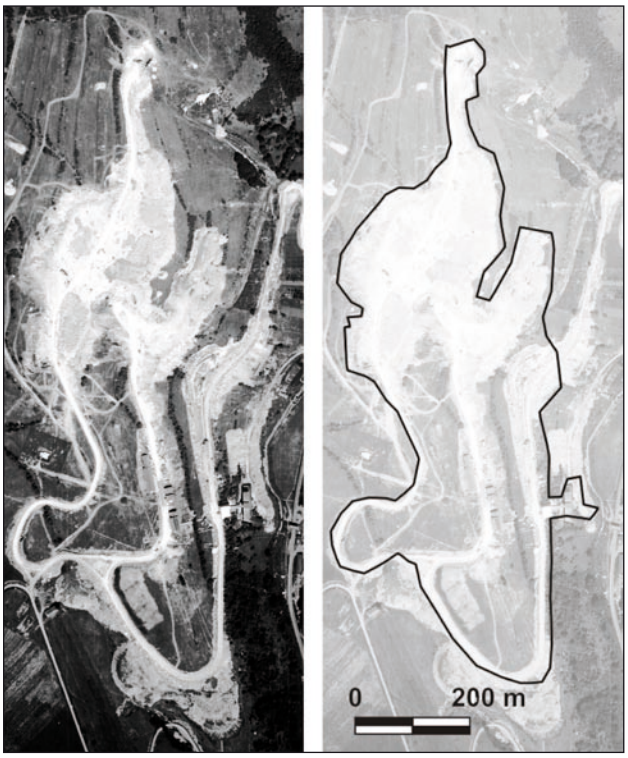

Fig. 10. Aerial photograph of the Kostiviarska quarry at the beginning of the 1960s, graphically compiled according authors Hronček et al. (2009, left) and graphically elaborated ground plan of the Kostiviarska quarry at the beginning of the 1960s (right).

Comparison of the particular development phases

During the analysis of the aerial photographs of the first phase from the beginning of the 1960s (Fig. 14) the Kostiviarska quarry was one of the largest quarries of the Zvolenská kotlina basin and reached gradualy the dimensions of a large quarry. Its area was 25.57 ha. The shape of the emerging quarry depended on the layer shape and position on the eastern slope of the right side of the Bystrica valley. In the next phase at the beginning of the 1970s the area extended in the north direction and so did the area of the quarry. The borders of the southern part of the area, where the technical works, service buildings, access road system and the loading station of the cableway were located, did not change considerably during the examined period. At the beginning of the 1970s after a decade of an intensive quarrying, the total quarry area was 38.68 ha, that is 51.3 % increase, i.e. by 13.11 ha. In the next phase the intensive mining continued mainly in the vertical direction into the depth of the layer and moved slowly in the horizontal north-west direction. In the 2nd half of the 1980s the quarry area devastated by the intensive quarrying reached 47.11 ha, that is 22 % increase, i.e. by 8.48 ha. The last research phase from the end of the 1990s is characterized by the decrease of raw material mining for the cement works at the end. As a result, the shape of the devastated quarry area did not change considerably, but its area was reduced. The reducing of the area resulted

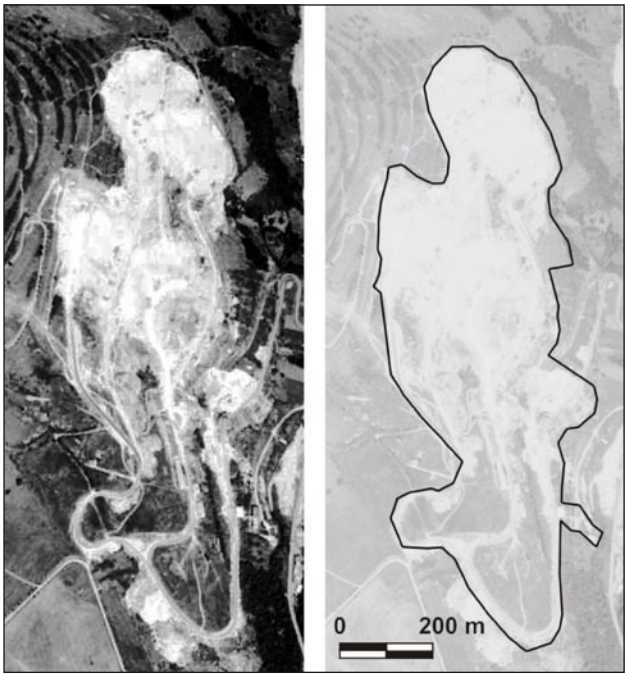

Fig. 11. Aerial photograph of the Kostiviarska quarry at the beginning of the 1970s, graphically compiled according authors Hronček et al. (2009, left) and graphically elaborated ground plan of the Kostiviarska quarry at the beginning of the 1970s (right).

from the progressive succession at the expense of the area devastated by mining, which had appeared as obvious light places in the photograph before. The quarry did not change its shape, but it began to be grown by plants. At the end of the 1990s, the area of the limited traverse identical with the quarry area borders devastated by mining was 46.73 ha. This area had not changed until 2002 when the mining ceased and in comparison with the last analysed period it shows a decrease by 0.8 %, i.e. 0.38 ha.

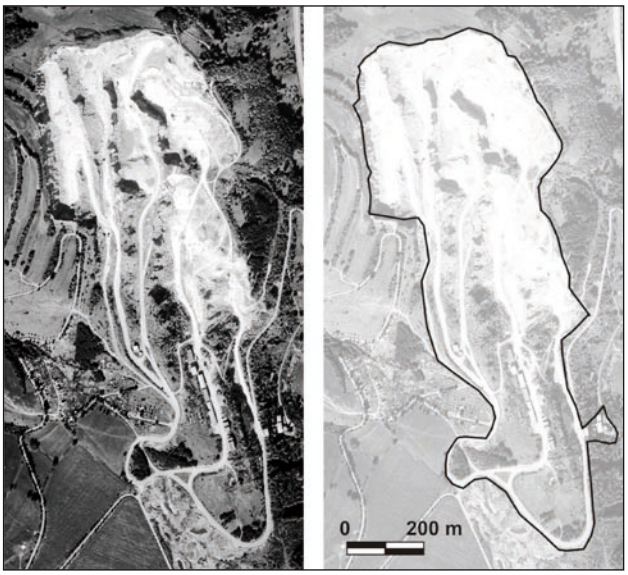

Fig. 12. Aerial photograph of the Kostiviarska quarry at the second half of the 1980s, graphically compiled according Hronček et al. (2009, left) and graphically elaborated ground plan of the Kostiviarska quarry at the second half of the 1980s (right).

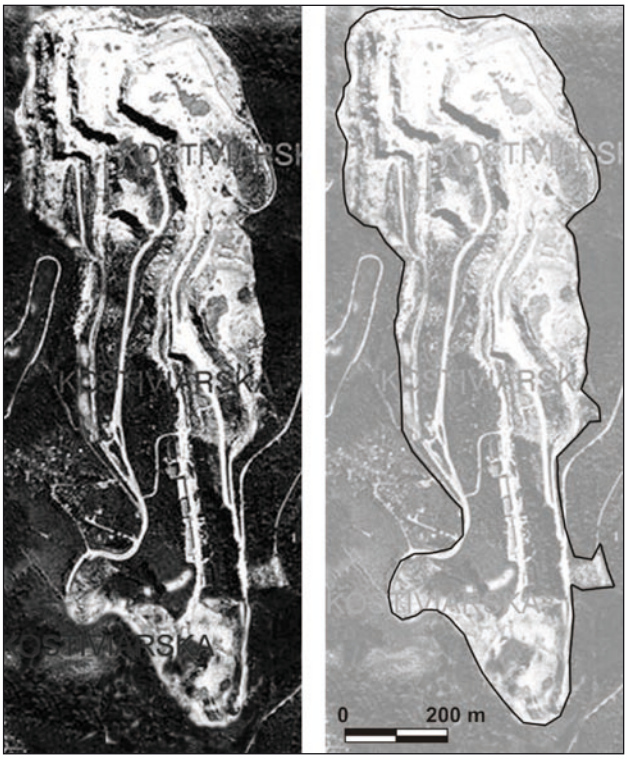

Fig. 13. Aerial photograph of the Kostiviarska quarry at the end of 1990s (© Anonymous 2002, left) and graphically elaborated ground plan of the Kostiviarska quarry at the end of the 1990s (right).

Iliaš – Okrúhle quarry

The quarry is located about 0.5 km in the east from Iliaš on the southern slope of the ground elevation Okrúhle (485 m a.s.l.) on the right side of the Dolina valley (Fig. 15). The quarry was opened in the Middle to Upper Triassic dolomite bed with the stock prognosis estimated to 600 000 m^3 (Polák et al., 2003; Polák, ed., 2003). The layer was opened by the former local agricultural cooperative in the 1970s. Recently, the MHRČ s.r.o. company from Banská Bystrica has performed the mining activities and the annual mining volume is between 250 000 and 300 000 tonnes.

The side quarry is to be entered by a forest pitch road from Iliaš. The lowest (entrance) part of the quarry lies in 352 m a.s.l. The highest point of the quarry side lies in 380 m a.s.l. The main quarry side is about 500 m long and divided in two main plates which are 15–20 m high. The quarry width does not exceed 200 m. The quarry is markedly extended in the north-west and south-east direction (Hrnčár, 1993).

Area development

In the first phase, which we dated to the beginning of the 1960s (Fig. 16), the quarry plan had a compact and almost circular shape. The devastated quarry area located on the right side of the Dolina valley was slowly extended in the north-west and south-east directions. The photograph shows the side character of the quarry with one mining plate. By means of vectorization we have found the dimensions of the quarry at the beginning of the 1960s. The quarry diameter was 120 m and took an area of 0.68 ha. The aerial photograph shows besides the devastated area also the access paths which entered the quarry from the west. It is also possible to interpret the sliced parts of the ploughland on the south-western slope of the valley. Shrubbery pioneer plants are visible in the north-west and south-east which points to the degraded grazing. Permanent grassland can be visible in the north side of the quarry.

We dated the second phase to the beginning of the 1970s (Fig. 17). The quarry plan shape did not change considerably despite the fact that its area enlarged to 1.82 ha. The plan began to extend more in the north-west and south-east directions and took elliptical shape. The longer axis was 200 m and the shorter one 120 m long. Two mining plates may be identified in the quarry. The access paths are also clearly visible. There are apparent landscape changes in its surround due to the collectivization changes. In the south-west, ploughland represented a part of large-scale areas. The old original grazings appear as a continuous scrub in the north-west and south-east. A continuous shrubberry and tree plants bordered on the quarry side in the north-east in the place of the former grazings.

Fig. 14. Comparison of areal growth of the Kostiviarska quarry in the second half of 20th century according to polygons of particular analysed periods.

In the third phase dated to the 2nd half of the 1980s (Fig. 18) the quarry was markedly extended in the north--west and south-east directions. Its longer axis was 720 m and the shorter one only 120 m long. The devastated quarry area was 7.70 ha. It was a complex quarry area with well built access roads. The side was divided in three mining plates one above the other and the technical works were in the centre of the quarry. Mown meadows were found in the south-west and degradated grazing in the west and east of the quarry. A continuous forrest stock was in the north.

We dated the last – fourth – phase to the end of the 1990s (Fig. 19). The quarry area was extended in the north-west and south-east directions with the axis 570 m long. The shorter axis was 180 m long. The total devastated quarry area reached 8.44 ha. Technical works with a transporter for gravel production, offices, workshops and a stock of produces gravel are clearly visible in the south-western part of the quarry. The original grazins in the south-east and north-west of the quarry got the character of an almost compact forest stock. We have localized a small grazing area in the east of the quarry. The landcape was mosaic-like in the south-east of the quarry and on the left of the valley where grazings were combined with mown meadows.

Comparison of the particular development phases

On the ground of the vectorization of the quarry borders in the aerial photograph from the first phase at the beginning of the 1960s (Fig. 20) and by its comparison with the second phase dated to the beginning of the 1970s, we may state that the quarry enlarged on account of the right slope of the valley in the north-east direction. However, there were no considerable shape changes, but the quarry area enlarged from 0.68 ha to 1.82 ha, that is 167 % increase, i.e. by 1.2 ha. In the next phase (the 2nd half of the 1980s), the area enlarged markedly. The quarry area enlarged to 7.70 ha, that is 323 % increase, i.e. by 5.88 ha. The shape of the enlarged quarry area was predermined by the reliefs of the valley and the layer where the raw material was mined. The quarry plan extended considerably in the north-west and south-east directions. In the last phase (the end of the 1990s), the quarry area and shape did not change markedly, because the mining progressed in the vertical direction – in the depth of the layer. We have checked the mining direction by the field research. The quarry area enlarged to 8.44 ha, that is 9.6 % increase, i.e. by 0.74 ha. The exact georeferencing of the vectorized quarries showed some little inaccuracies in the north-west created by the growing over of the old quarry parts and in the south-eastern part, where a weak quarry side shift is visible, compared to its deepening that has been checked by the field research.

Fig. 15. Aerial view on the Iliaš – Okrúhle quarry, located in the Dolina valley in 2009. Photo Z. Filadelfi.

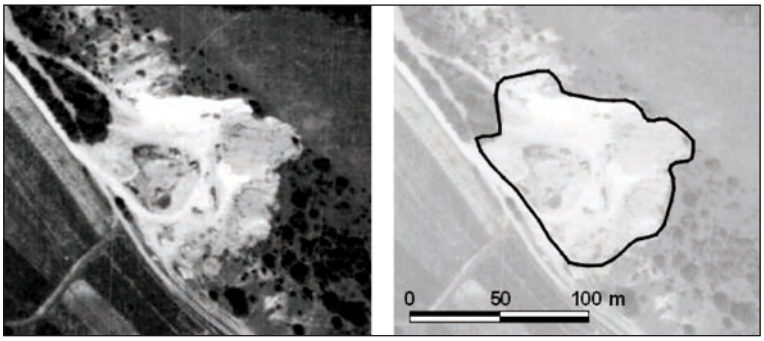

Fig. 16. Aerial photograph of the Iliaš – Okrúhle quarry at the beginning of the 1960s, graphically compiled according authors Hronček et al. (2009, left) and graphically elaborated ground plan of the Iliaš – Okrúhle quarry at the beginning of the 1960s (right).

Conclusion

Based on the content analysis of the aerial photographs we have limited the quarry areas (devastated areas) in particular phases. We have used the digitalized quarry area traverse to determine the dimensions and the area of the quarries in particular time horizons in the GIS environment. We have compared the data obtained in particular phases and on this ground we have set the quarry area enlargement in absolute number value in ha (hectares) and in relative values in percentage (%) as well.

Followingly the obtained information has allowed us to state that the quarries were opened in a spontaneous way and the mining reached its maximum at the end of the 1960s and 1970s. The produced raw material was used as a building material during the vast building of the town of Banská Bystrica. The mining increase in the Kostiviarska quarry related to similar activities. Kostiviarska quarry was considered as a raw material base for the cement works in Banská Bystrica.

As per analyses of the enlargement of the quarry area, the dimensions of the area or the area devastated by raw material minig may be determined exactly. Direction of the mining – horizontal or vertical into the layer depth – may be also determined. It is also possible to determine the shifting of the quarry side in relation to the slope, the cardinal points, as well as to the permanent grassland in the quarry surrounding, or to the water-course base, other road nets, etc. Following the analysis of the aerial photographs, it is possible to determine the changes of the shape charecteristics of the quarry, the number of the plates in the particular time horizons, the time of creation of the pit part, the changes of the quarry dimensions, etc. The following comparison of quantitative and qualitative morphological characteristics of the quarries in particular phases increases the amount of obtained information in a geometric way. These properties can be examined in the context with other conditions of exploitation (the geological structure, ecological limits, political, economic and socio-economic development, etc.).

The information obtained by the analyses of the aerial photographs will result – in comparison with the field research and archive results – in a number of additional new derived

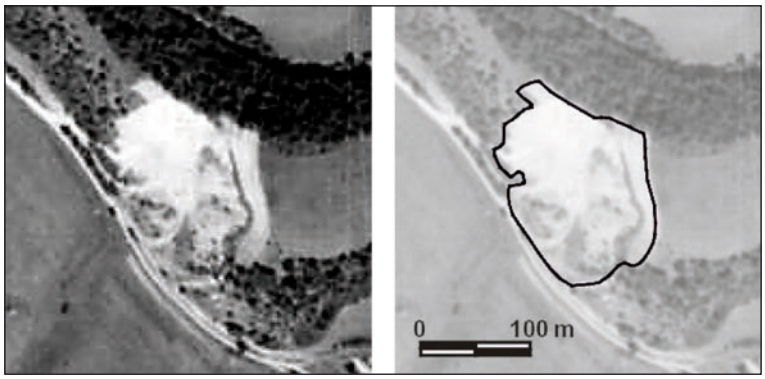

Fig. 17. Aerial photograph of the Iliaš – Okrúhle quarry at the beginning of the 1970s, graphically compiled according authors Hronček et al. (2009, left) and graphically elaborated ground plan of the Iliaš – Okrúhle quarry at the beginning of the 1970s (right).

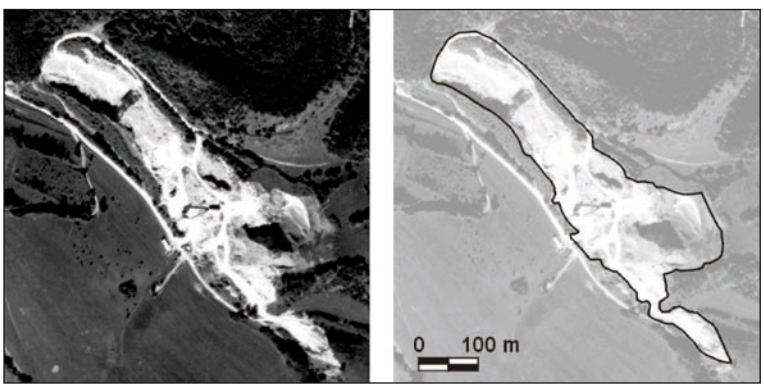

Fig. 18. Aerial photograph of the Iliaš – Okrúhle quarry at the second half of the 1980s, graphically compiled according authors Hronček et al. (2009, left) and graphically elaborated ground plan of the Iliaš – Okrúhle quarry at the second half of the 1980s (right).

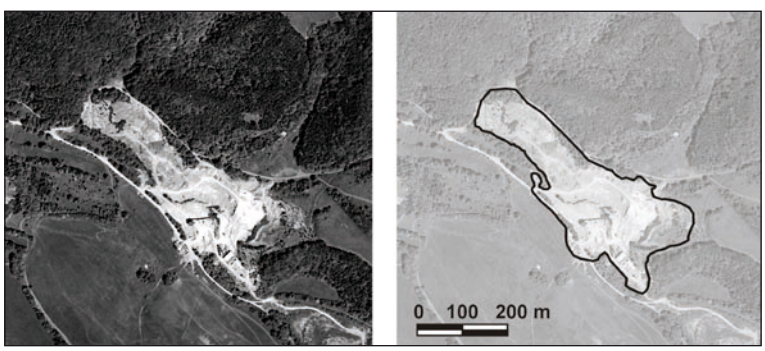

Fig. 19. Aerial photograph of the Iliaš – Okrúhle quarry at the end of 1990s, graphically compiled according authors Hronček et al. (Hronček et al., 2009, left) and graphically elaborated ground plan of the Iliaš – Okrúhle at the end of the 1990s (right).

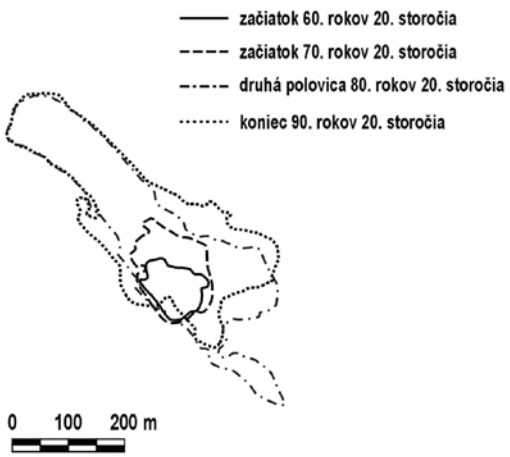

Fig. 20. Comparison of areal growth of the Iliaš – Okrúhle quarry at the second half of 20th century according to polygons of particular analysed periods.

knowledge, particularly for the nature protection, landscape planning, recultivation and secondary use of the quarries and the area devastated by the raw material mining. Equally important are the results of the research in relation to the assessment of the possibilities for development of geotourism, the potential of natural-technical systems for the use in the education and the historic documentation.

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