Quarrying: an anthropogenic geomorphological approach

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Dobývanie: antropogénny geomorfologický prístup.

The study intends to give an introduction to the significance of quarrying from the point of view of anthropogenic geomorphology, indicating the level of surface forming due to the mining of mineral raw materials. The significance of this topic is supported by the existence of the so-called "mining landscapes" that emerged since to the 19th century. Authors focus on the geomorphic impact of quarrying with special emphasis on factors influencing its spatial distribution, as well as on the characteristics and classification of surface features produced by quarrying, providing an overview of the most important excavated and accumulated forms and form components, on the macro, meso and micro scales. Finally, international and Hungarian case studies illustrate some aspects of the opening and after-use of mining sites in order to observe how abandoned quarries can be turned into „environmental values", and used as possible sites for exhibitions or for regional and tourism development projects.

Key words: *anthropogenic geomorphology, mining landscapes, environmental values, regional and tourism development*

Introduction

In the past few decades interest in the environment has reached a peak as popular opinion has become aware of the extent of the human impact on natural systems. A proliferation of degrees has followed this wave of 'environmentalism', and their focus has been on natural areas and the damage caused by human impacts. Environmental geomorphology is a special interaction of humans with the geographical environment which includes not only the physical constituents of the Earth, but also the surface of the Earth, its landforms and in particular the processes which operate to change it through time.

Since the 1970s, in the research of the physical environment two, frequently intertwining trends are prominent. One of them investigates the changes in the natural environment induced by human economic intervention (which are often undesirable) along with their counter effects. The other aims at the quantitative and qualitative survey of the resources and potentials of the physical environment and at the evaluation of regionally varying geographical potentials. Researchers reviewing the geomorphological literature of the last 40 years will gain the impression that the perception of Man as a geomorphological agent is a fairly recent development. Anthropogenic geomorphology is a new approach and practice to investigate our physical environment, because in the eighties the more and more urgent demands from society towards geography - ever more manifest, due to the scientific-technical revolution. This – underlines the task to promote efficiently the rational utilization of natural resources and potentials, to achieve an environmental management satisfying social requirements and opportunities. At the same time, anthropogenic geomorphology is a new challenge for geomorphologists, since environmental problems have an effect on several branches of science.

Anthropogenic geomorphology studies the huge – and ever – number of landform associations of extreme variety, depending on the given way and aim of their creation by the human activity. The discipline also studies the surface changes induced by these forms; moreover, it predicts the consequences of disturbance of the natural equilibrium, and makes recommendations for preventing damages. Therefore, anthropogenic geomorphology can be also regarded as an applied discipline, which helps to solve both socio-economic as well as environmental and natural protection problems.

There is no need to explain in details the close relationship between mining activities and geology as well as geomorphology. However, it should be mentioned that researchers only became interested in the problems of geomorphic impact at a rather late stage of evolution of these sciences. It is well illustrated by fig. 1 that both international and Hungarian research on landscape alterations caused by raw material production only dates back to the 1960's.

Mining activities were revolutionized by developments in mining techniques and the application of steam engines since the 19th century thus the exploitation of various mineral raw materials eventuated in the emergence of "mining landscapes". As a whole, the most frequently extracted substances for the building industry embrace raw materials for the cement and lime industry, building and ornamental stones, sands and gravels as well as clays for the porcelain industry.

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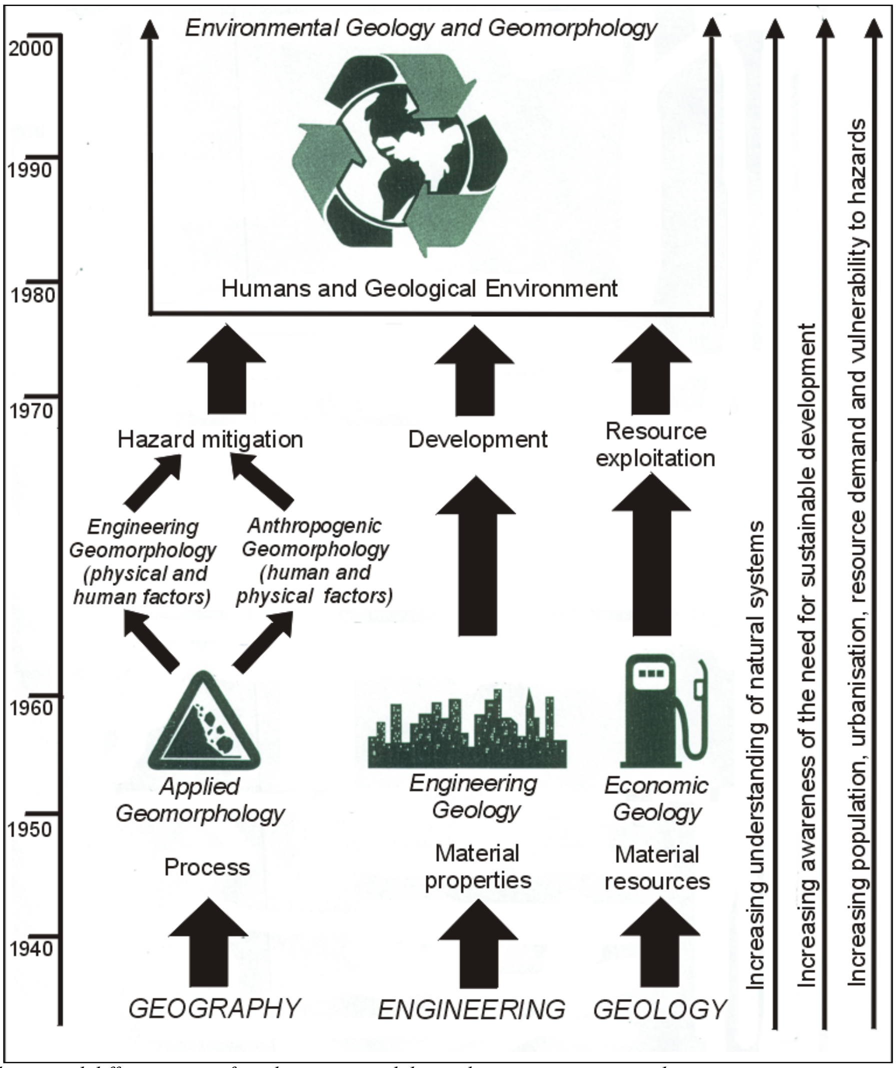

Fig. 1. The evolution and differentiation of earth sciences and their relation to environmental issues.
(after Bennett & Doyle, 1999, modified by Dávid & Baros, 2006)

This study intends to give an introduction to the significance of quarrying from the point of view of anthropogenic geomorphology, indicating the degree of surface transformation which took place due to the mining of raw materials.

Geomorphic impact of quarring

It can be claimed that the spatial distribution of quarrying in general, is fairly even in the sense that if geological conditions allow it, there are hardly any mountain settlements without a quarry of any scale opened in their surroundings during their history. When quarrying also aims to reach markets at a greater distance, market pressures (economically exploitable supplies, transportation expenditure and possibility, etc.) become more important, thus in some cases, quarrying can show a rather high concentration in space. The level of socio-economic development being decisive for the quantity and quality indicators of the material flow between user and its environment, has undergone continuous changes during history. This is reflected by the extent of the montanogenic landforms (ie. those produced by mining) on the one hand as well as in the rate of the expansion of areas effected by mining activity.

In addition to the geological conditions, the site selection of quarries is also controlled by the topography of the area. Longwall face quarrying prevails on mountainous or hilly terrains whereas in flat areas deep mining is applied. However, intermediate types also occur occasionally. Exceptionally, closed work is applied, too, as in the case of Fertőrákos (NW-Hungary). As far as longwall face quarrying is concerned, it is the topography that is transformed to a visible extent, face walls of several hundred metres length and of some ten metres height may result, depending on the applied technology (fig. 2).

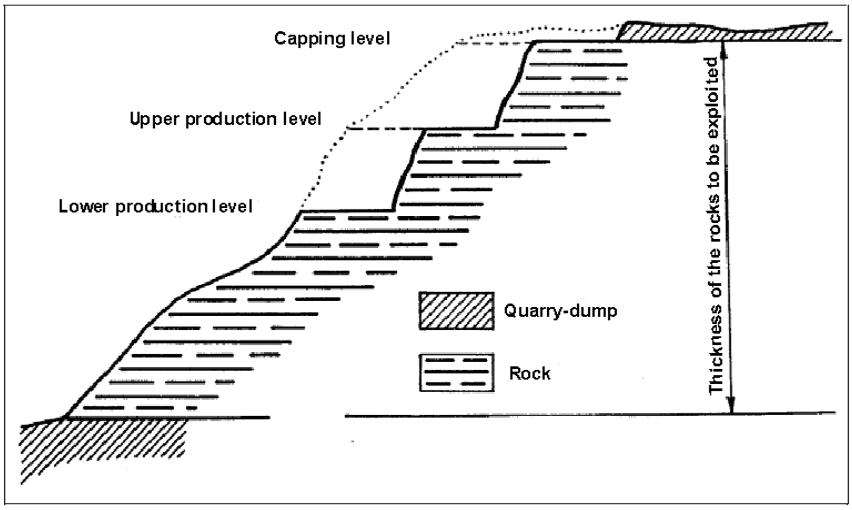

Fig. 2. Siting of a quarry of several production levels (Ozoray, 1955).

In cases when the rock material to be exploited is found under a flat or sloping surface, a quarry sunk in the surface has to be established. Such quarries are sometimes created through the lowering of the quarry floor by longwall face quarrying. If the overburden is too thick, extraction takes place from underground shafts or cavities. Apart from this, the characteristics of the quarried (metamorphic, igneous, or sedimentary) rocks are of decisive relevance as well as the adherence to the various mine safety regulations. All of them may also have an influence on the evolving features.

Classifying the geomorphic impact of quarring

As a result of quarrying, the landscape may undergo visible changes (Tab. 1).

Tab. 1. Form-shaping role of quarrying activities (Dávid, 2000).

<table>
<tr><td colspan="12">A. categories By the nature of surface features</td></tr>
<tr><td colspan="6">EXCAVATED FORMS</td><td colspan="6">ACCUMULATED FORMS</td></tr>
<tr><td colspan="12">origin and size</td></tr>
<tr><td colspan="6">EXCAVATED MACROFORMS
(surfaces with material deficit = caverns)</td><td colspan="6">ACCUMULATED MACROFORMS
(mine dumps)
cone-shaped
truncated cone-shaped
terraced</td></tr>
<tr><td colspan="12">quarrying technology</td></tr>
<tr><td colspan="3">Simple excavated type:
excavation pit
delph</td><td colspan="3">Complex excavated type:
horizon mining</td><td colspan="3">Simple accumulated type:
single quarry dump</td><td colspan="3">Complex accumulated type:
quarry dumps in groups</td></tr>
<tr><td colspan="6">EXCAVATED MESOFORMS
mine wall
debris apron
mine floor</td><td colspan="6">ACCUMULATED MESOFORMS
plateau
slope</td></tr>
<tr><td colspan="12">MICROFORMS</td></tr>
<tr><td colspan="4">Excavated microforms:
rock buttress and pillar
pinnacles
rock benches
small shallow ponds</td><td colspan="4">Microforms created as a result of natural processes:
mass movements
linear erosion</td><td colspan="4">Accumulated microforms:
heap
boulder</td></tr>
<tr><td colspan="12">B. categories By the type of geotechnic activity</td></tr>
<tr><td colspan="12">LEVELING</td></tr>
<tr><td colspan="6">ABRADING</td><td colspan="6">FILLING UP</td></tr>
</table>

Forms created as a result of mining can be classified into three main groups (Dávid, Patrick, 1998 a,b; Karancsi, 2000; Dávid, 2000):

a) excavated ('negative') forms,
b) accumulated ('positive') forms,
c) forms destroyed by quarrying activities can be classified into other groups on the basis of geotechnical criteria. This virtually means the levelling of the surface, which is called planation in geography.

The geomorphological study of quarrying features was undertaken in three categories, distinguished by origin and size (fig. 3). It should be noted, however, that there are several different approaches to classification (Erdősi, 1966, 1969, 1987; Karancsi, 2000). One of them, for instance, is by quarry location relative to geological formations and surface macroforms (Erdősi, 1987). Another takes into account the characteristics of the given area (Karancsi, Z. 2000).

Macroforms are the most obvious traces of quarrying. Excavated macroforms may be regarded as surfaces with material deficit (caverns). Accumulated macroforms are called mine dumps. Excavated macroforms are composed of smaller elements (excavated mesoforms). Quarry walls and floors and debris aprons are distinguished in almost every extraction site. The morphological components of accumulated macroforms are plateaux and slopes (accumulated mesoforms). The surfaces of mesoform components can be divided into smaller and larger excavated depressions (possibly out-weathered sections) or accumulated elevations that are called microforms. In addition to the influence of quarrying technology and working rate, the properties of features in all three categories are also controlled by the geological characteristics of the area (structure, bedding), the nature of the rocks and the natural processes affecting them.

Excavated (negative) forms

The most common and simple type of excavated form is an excavation pit or a delph in the surface. Excavated macroforms of quarrying origin usually appeared before accumulated forms, therefore examples of them can be found in the first period of quarrying history. They are found next to almost every town and village in mountainous areas. Mainly in the form of small quarries.

The other type of excavated forms results from multi-levelled horizon mining (complex excavated type). It is increasingly typical in modern times. The technical condition for its occurrence was the increase in the capacity and efficiency of excavating equipment, while as far as geological conditions are concerned, it was favoured by the presence of thick strata. For this type of surface mining operation is necessary to provide a safe general slope angle (finish angle).

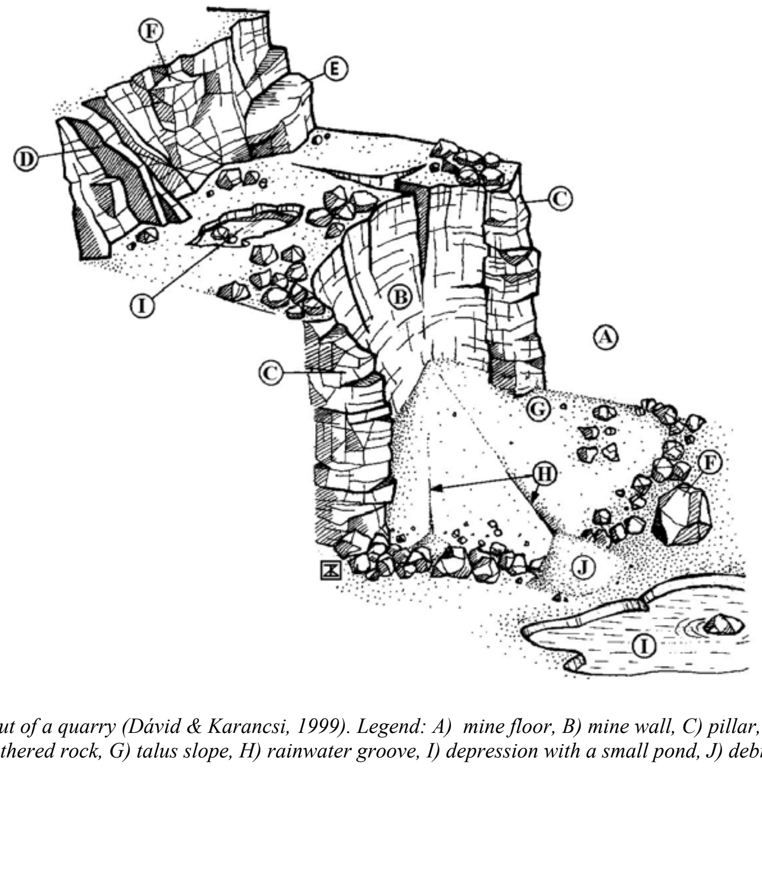

Fig. 3. Schematic layout of a quarry (Dávid & Karancsi, 1999). Legend: A) mine floor, B) mine wall, C) pillar, D) rock buttress, E) rock bench, F) out-weathered rock, G) talus slope, H) rainwater groove, I) depression with a small pond, J) debris cone

Excavated mesoforms are composed of the following elements:

Mine wall: the steepest component, whose angle of inclination to the floor is determined by quarrying technology (blasting, hand or power excavation) as well as by rock quality. It is normally subvertical. The quarry floor is usually surrounded by walls on three sides.

Debris cones, debris aprons: components with smaller angles of repose lying at the foot of quarry walls. Their materials partly derive from quarry working and partly from natural processes (rockfalls). They are initially developed by accumulation but their origin is linked to excavation activities. As material is accumulating in debris cones, they may coalesce to form a continuous debris apron.

Quarry floor: an approximately flat ground surface surrounded by walls and debris aprons, including a range of features (accumulations of quarry material, quarry heaps, pillars etc.).

Common excavated microforms of quarrying are rock counterforts, rock benches, out-weathered quarry columns, pinnacles and pillars. The latter are basically transitional features between excavated and accumulated forms as being the positive remnants of quarrying. They may resist the damaging effects of natural processes and talus slopes of various size are found in front of them. Precipitation water may collect in small shallow ponds in the depressions of the quarry floor.

Accumulated (positive) forms

Accumulated macroforms are called quarry dumps. They are formed through the accumulation of waste, which is currently of no value from an economic point of view. During open-cast mining, dumps of various origins are heaped. By the removal of the burden above the material to be excavated, a significant amount of so-called sheating dump is created. This material (interstage and plant dump) can also be a result of the extraction and processing of the material, i.e. during grinding or crushing. The granulometric composition of quarry dumps is rather diverse, being influenced not only by geological conditions but also by the method of processing. There can also be different shapes of dumps, as curve-, fan- and round-shaped dumps created at the end of bankfills. In addition, temporary storing of the excavated material also has to be referred to this group. They are found isolated (simple accumulated type) or in groups (complex accumulated type).

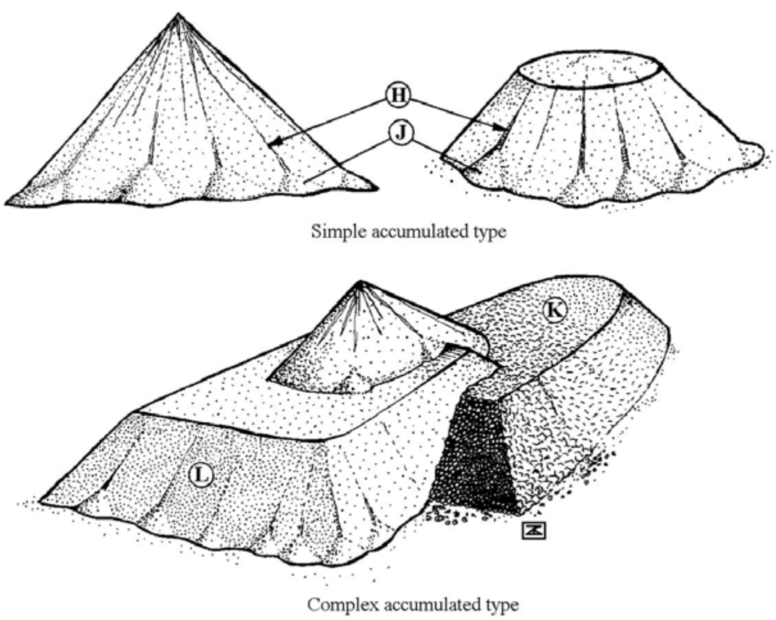

Fig. 4. Typical forms of quarry dumps (Dávid & Karancsi, 1999). Legend: H) gully, J) debris cone, K) plateau, L) slope.

The shape of a positive form is determined by several factors: the original ground surface, the mode of accumulation and the physical features of the dump material. Cone-shaped, truncated cone-shaped and terraced dumps are the most common.

Common components of accumulated mesoforms are

Plateau: the relatively flat ground surface surrounded by the slopes of dumps. Its extent is determined by the type of the dump. The largest plateaux can be found on terraced dumps, while the plateaux of truncated cone-shaped dumps are usually smaller.

Slope: the sloping ground surface which surrounds the plateau or the peak in case of a cone-shaped dump. Its inclination varies depending on the mode of accumulation, the dumped material and the initial ground surface.

The most obvious microforms of dumps, formed by natural processes, are gullies cut into slopes. They are arranged radially on cone-shaped or truncated cone-shaped dumps. The dump material carried away by rainwater settles in small alluvial cones at footslopes. Flat-topped plateaux may be dissected by headward eroding gullies. The accumulated microforms of quarry floors, formed as a result of quarrying, are larger heaps and boulders dissecting the approximately flat ground surface.

Planation

Quarrying does not only construct landforms but it can also result in planation. With the spreading of dump material over natural or artificial dips (slopes, valleys, pits or depressions), they may be filled. Another possibility is the excavation of whole mountains during quarrying activities, resulting in huge landscape scars. A remarkable instance in Hungary can be seen on fig. 5.

Fig. 5. Excavation of the Bélkő near Bélapátfalva (N-Hungary).

Use of quarring sites after decommissioning

Until recently abandoned quarries both in Hungary and abroad has raised negative, unpleasant associations as 'scars in the landscape' (fig. 6).

Fig. 6. Scars of the andesite quarry at Sás-tó near Gyöngyös in the Mátra Mountains (N-Hungary) exposed by clear-cutting with Mt. Kékes in the background

However, a new assessment is also encoun-tered according which abandoned quarries are regarded as 'environmental values' They are apprecia-ted as possible sites for several uses (exhibition sites or scenes for regional and tourism development projects). The case studies below intend to provide a brief overview.

Fig. 7. The Bluewater Shopping Centre near London with the wall of the Blue Circle Chalk Quarry in the background.

Bluewater shopping centre

In recent years, many precedents, mainly from Great Britain show that commercial centres (hyper and supermarkets) are constructed in old quarries outside cities and next to them facilities for entertainment (parks, multiplex cinemas, gaming-rooms, concert halls, discos, galleries, art centres, etc.) are also developed (Bennett, M. R., Doyle, P., 1999).

The most outstanding example for this is the Blue Water Shopping Centre located in Dartford at Junction No. 2. of the London Ring Road M25, marketed as the largest entertainment centre of this kind in Europe. This investment compelling both in its outside and inside appearance has been built between 1995 and 1999, in the area of the abandoned Blue Circle Chalk Quarry (fig. 7).

Patkó Quarry, Tokaj, NE-Hungary

The former quarry hosted a large-scale cultural event on 30 June, 2002, functioning as a 'festival cauldron'. The event took place on the occasion that the Tokaj-Hegyalja Region was awarded the UNESCO World Heritage status in the category of cultural landscapes. Cultural programs were organised in the quarry to celebrate it (fig. 8). Since then it has been regularly used as a site for similar events.

Fig. 8. Concert in the Patkó Quarry of Tokaj.

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