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Introduction to Anthropogenic Geomorphology

Dávid Lóránt
Károly Róbert College,
Hungary

1. 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', 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. This geographical environment can be investigated from several aspects:

- in the biological (ecological) approach emphasis is put on the biotic factors of the environment or on the structure itself;
- in the geographical approach research concentrates on the abiotic factors and functions;
- the technological or planning trend focuses the analysis on the economical-technical background of impacts.

To distinguish between the first two trends and the related disciplines, the terms (bio)ecology and geoecology are in use. The two concepts differ in handling the role of abiogenic and biogenic factors. In the past decade there was an intention to define geoecology as the study of abiotic factors and of issues concerning the functioning of the physical environment, while landscape ecology investigates the biogenic factors and problems of spatial organisation, structure. The far-reaching developments in the past one or two decades made landscape ecology become a wide theorethical-practical field of research, so the adaptation of international research results and educational experience is inevitable here too. The emerging science of landscape ecology is a tool for such studies and will be the cradle for advanced studies in the future.

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 the evaluation of also regionally varying geographical potentials. **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 against geography - ever more manifest due to the scientific-technical revolution - underlined the tasks to promote efficiently the rational utilization of natural

resources and potentials, to achieve an environmental management satisfying social requirements and opportunities.

The demand for complex environmental research has grown, since this is the only way to determine the loadibility of nature and the consequence of loading, to maintain the stable equilibrium of landscape, to preserve and develop the quality of life, and to give a long-term prognosis for the purposeful exploitation of environmental resources and potentials. Applying new methods and theories, the geography of today attempts to elaborate concepts and methods primarily novel in attitude to match the complex problems. As most of the problems of environmental management are, by their essence, interconnected by causal relationships, the solutions are justified, to be sought in the framework where the complex interrelationships of the human environment can be revealed in an integrated manner. All these, of course, do not mean to give up the investigation into the individual components of the environment, but these should be coordinated by one or several programmes which guarantee the study of the inner unity and multifarious nature of environmental factors and the detection of their interactions and development trends. The resulting environmental models may provide a uniform framework for basic (theoretical) and practical purpose research. We are convinced that any of the partical factors can only be studied in entirety and successfully if its relationships are known in the environmental systems.

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. We deal with anthropogenic geomorphology and we think that in an integrative study of this type, mankind must be regarded directly as a geomorphological agent, for it has increasingly altered the conditions of denudation and aggradation of the Earth's surface.

2. Scope of anthropogenic geomorphology

'The scope of anthropogenic geomorphology does not only include the study of man-made landforms but also the investigation of man-induced surface changes, the prediction of corollaries of upset natural equilibria as well as the formulation of proposals in order to preclude harmful impacts (Figure 1). The above topics and tasks make anthropogenic geomorphology a discipline of applied character. Its achievements should also serve – in addition to promoting the implementation of socio-economic tasks – environmental protection and nature conservation' (Szabó et al., 2010).

Generally the following fields of anthropogenic geomorphology have been identified:

Mining. The processes involved and the resulting landforms are usually called *montanogenic*.

Industrial impact is reflected in *industrogenic* landforms.

Settlement (urban) expansion exerts a major influence on the landscape over ever increasing areas. The impacts are called *urbanogenic*.

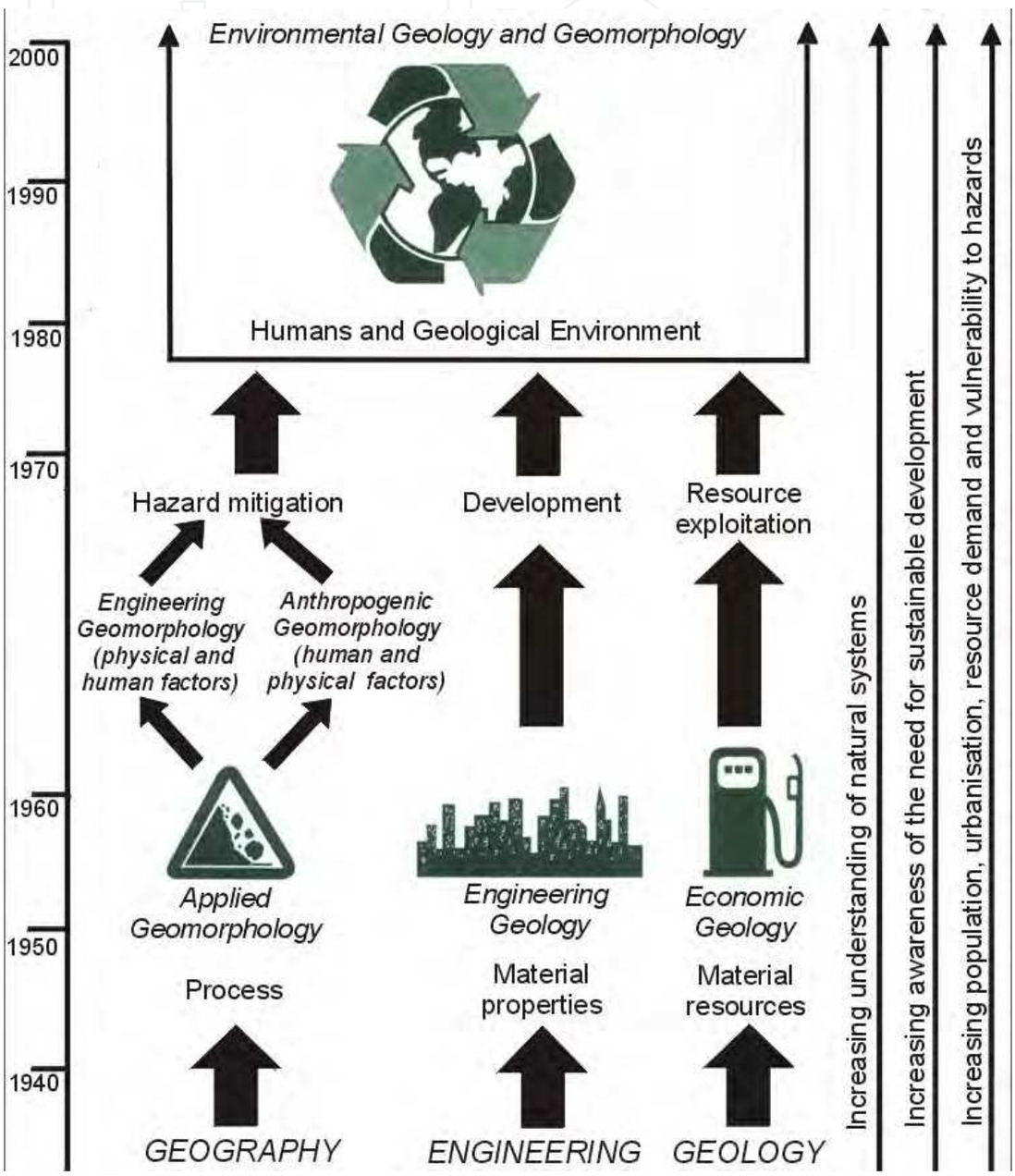
Traffic also has rather characteristic impacts on the surface.

As the first civilizations developed highly advanced farming relied on rivers, *water management* (river channelization, drainage) occupies a special position in anthropogenic geomorphology.

Agriculture is another social activity causing changes on the surface. *Agrogenic* impacts also include transformation due to forestry.

Although *warfare* is not a productive activity but has long-established surface impacts.

In contrast, the impacts of *tourism and sports* activities are rather new fields of study in anthropogenic geomorphology (Szabó et al., 2010).



(Bennett, M. R. - Doyle, P. 1999 modified by Dávid-Baros, 2006)

Fig. 1. Development and differentiate of Earth Sciences (including Athropogenic geomorphology) and its connection with the environmental problems

3. Case study: Quarrying

3.1 Introduction to quarrying

This 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 taken place due to the mining of these raw materials. The significance of this topic is supported by the presence of the so-called "mining landscapes" emerged since to the 19th century. The authors focus on the relevance of surface-forming by quarrying with special emphasis on factors influencing its spatial distribution, as well as on the characteristics and classification of mountainogenuous surface features of quarrying, giving an overview of the most important excavated and accumulated forms and form components on the macro, meso and micro levels. In the final section, some aspects of the opening and after-use of mining places are introduced by international and Hungarian case studies in order to observe how abandoned quarries can become assessed as „environmental values", and can be used as possible sites for exhibitions or for regional and tourism development projects.

The close relationship between mining activity and geology as well as geomorphology is not required to be explained in details, however, it should be mentioned that researchers only became interested in the problems of surface forming in a rather phase during the evolution of these sciences. It is well illustrated by *Figure 1* that scientific works on the research of landscape alterations caused by raw material production, can be traced back only from the 1960s to a greater extent both in the international and the Hungarian literature.

Mining activities were revolutionised by developments in mining techniques and the application of steam engines from the 19th century thus the exploitation of various mineral raw materials eventuated in the emergence of "mining landscapes". As a whole, the most generally mined raw materials for the building industry embrace the raw materials for the cement and lime industry, building and ornamental stones, sand and gravel as well as clay materials for the porcelain industry. This 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 taken place due to the mining of these raw materials.

3.2 Surface-forming by quarrying

It can be claimed that the spatial distribution of quarrying, in general, is even in a sense that if geological conditions provided, settlements in which surroundings in any time of the history a quarry of any scale has not been opened can hardly be found in mountainous areas. When quarrying also aims to reach markets to a greater distance, instead of the factor mentioned above, market regulatories (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 determinant 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 mountainogenuous landforms on the one hand as well as in the rate of the expansion of areas effected by mining activity.

The site selection of quarries is, in addition to the geological conditions, also predominantly influenced by the topography of the area. Quarries are exploited by longwall face mining at mountainous or hilly terrains whereas at flat areas deep mining is applied, however, occasionally intermediate types can also be developed. Exceptionally, closed work is applied, too, as in the case of Fertőrákos (NW-Hungary). As far as quarries with longwall face mining are concerned, it is the topography that undergoes the most visible transitions as in some cases, face walls of several hundred meters in length and some ten meters in height can be resulted, even at more levels depending on the applied techniques of mining *(Figure 2)*.

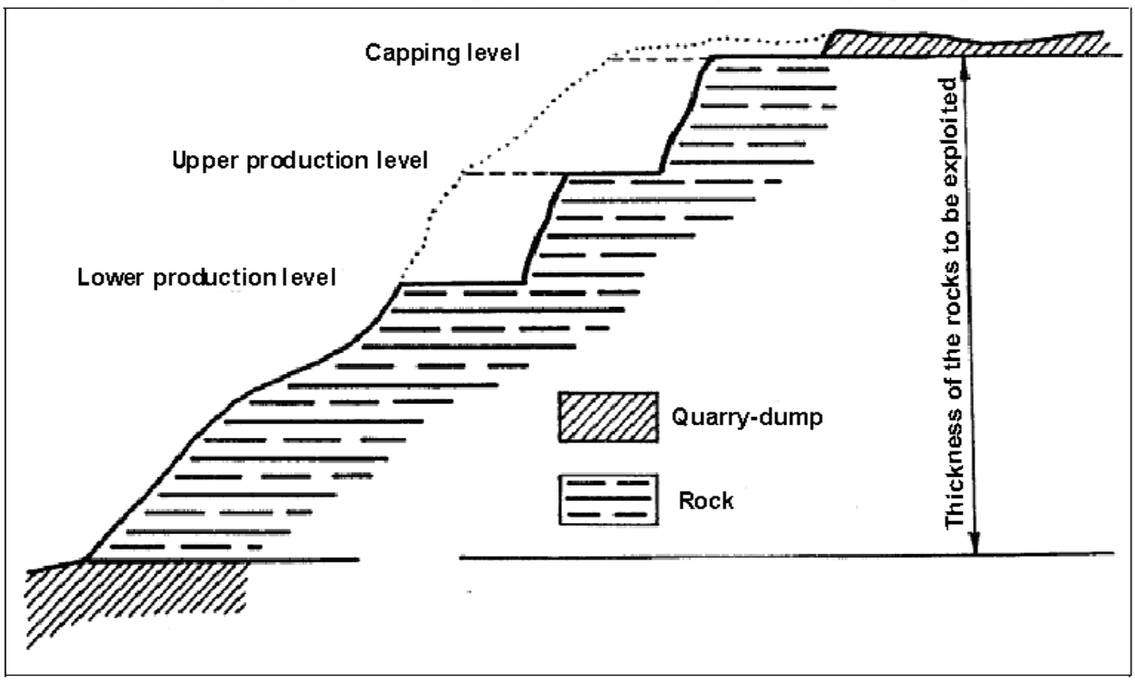


Fig. 2. Sitting of a quarry of several production levels (Ozorai, 1955)

In cases when the rock material to be exploited can be found under the ground level on a flat or on a declivate surface, we are constrained to open a quarry sunk under the surface. These types of quarries are sometimes created through the lowering of mine floor of quarries with longwall face quarrying. The occurrence of a very thick upper layer may necessitate the siting of the quarry actualised below the ground surface, thus in such cases exploitation takes place from underground shafts or rooms. Apart from this, the characteristics of the mined (metamorphic, igneous, sedimentary) rocks are of decisive relevance as well as the adherence of the various mine safety regulations. All of them may have an influence on the evolving forms too.

3.3 Characteristics and classification of the surface features of quarries

As a result of quarrying activity, it is the landscape morphology that undergoes the most visible changes *(Table 1)*.

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

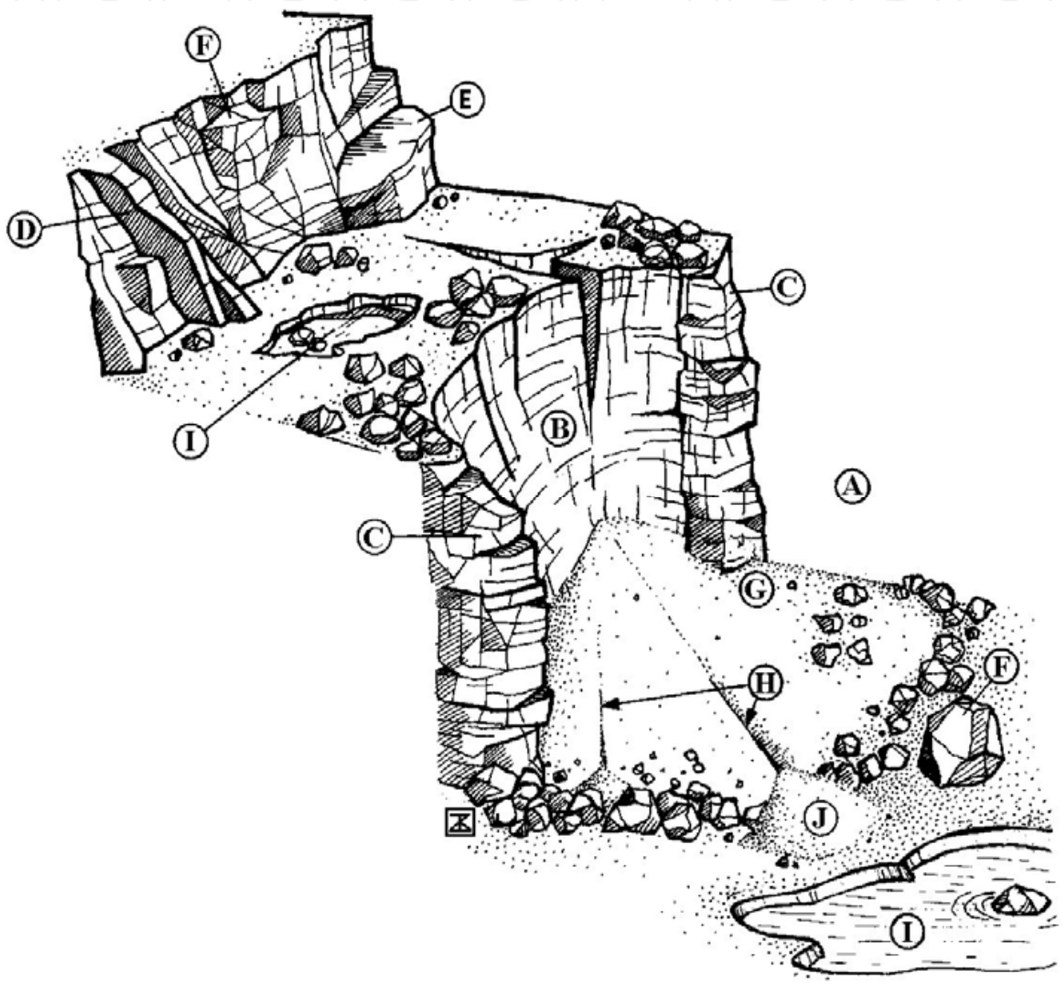
a.) excavated (negative) forms,
b.) accumulated (positive) forms,
c.) and forms destroyed by quarrying activities can be classified into another group on the basis of the geotechnics of quarrying activities. This virtually means the levelling of the surface, which is called planation activity in geography.

<table>
<tr><td colspan="4">FORM-MAKING ROLE OF QUARRYING ACTIVITIES</td></tr>
<tr><td colspan="4">A. On the basis of surface features</td></tr>
<tr><td colspan="2">EXCAVATED FORMS</td><td colspan="2">ACCUMULATED FORMS</td></tr>
<tr><td colspan="4">on genetic basis and size</td></tr>
<tr><td colspan="2">EXCAVATED MACROFORMS
(surfaces lacking in materials = caverns)</td><td colspan="2">ACCUMULATED MACROFORMS
(mine dumps)
cone-shaped
truncated cone-shaped
terraced</td></tr>
<tr><td colspan="4">on the basis of mining techniques</td></tr>
<tr><td>Simple excavated type:
excavation pit
delph</td><td>Complex excavated type:
horizon mining</td><td>Simple accumulated type:
single quarry dump</td><td>Complex accumulated type:
quarry dumps in groups</td></tr>
<tr><td colspan="2">EXCAVATED MESOFORMS
mine wall
debris apron
mine floor</td><td colspan="2">ACCUMULATED MESOFORMS
plateau
slope</td></tr>
<tr><td colspan="4">MICROFORMS</td></tr>
<tr><td>Excavated microforms:
rock buttress and pillar
pinnacles
rock benches
small shallow ponds</td><td colspan="2">microforms created as a result of natural processes:
mass movements
linear erosion</td><td>Accumulated microforms:
heap
boulder</td></tr>
<tr><td colspan="4">B. On the basis of the type of geotechnic activity</td></tr>
<tr><td colspan="4">PLANATION ACTIVITIES (PLANATION)</td></tr>
<tr><td colspan="2">ABRAIDING</td><td colspan="2">FILLING UP</td></tr>
</table>

(Dávid, 2000)

Table 1. Form-making role of quarrying activities

The morphological study of forms of quarrying was undertaken in three categories, distinguished on a genetic basis and size (*Figure 3*). It should be noted, however, that there are several different types of classification for these forms (*Erdősi, 1966, 1969, 1987, Karancsi, 2000*). An aspect may be for example the location of the quarry compared to geological formations and surface macroforms (*Erdősi, 1987*), as well as metric categories for the order of magnitude can also be created taking the characteristics of the given area into account (*Karancsi, 2000*).



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

Fig. 3. Schematic layout of a quarry (Dávid-Karancsi 1999)

Macroforms are the most obvious landscape-forming remnants of mining having also an influence on landscape assessment. Excavated macroforms developed as a result of mining can virtually be regarded as surfaces lacking materials (caverns). Accumulated macroforms are the so-called mine dumps. Excavated macroforms created as a result of mining are composed of smaller elements (excavated mesoforms). Mine walls, mine floors and debris

aprons can be distinguished in almost every mine. The morphological components of accumulated macroforms (the so-called mine and other dumps) 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 mining techniques and technology, and working rate, the characteristic features of the forms in all three categories are also determined by the geological characteristics of the area (structure, bedding), the feature of the rocks and the natural processes affecting them.

Excavated (negative) forms

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

The other type of excavated forms is multi-levelled horizon mining (complex excavated type). The appearance of complex excavated forms is characteristic of modern times. The technical condition for the appearance of these forms was the increase in the capacity and efficiency of excavating equipment, and the geological conditions were the presence and exploration of thick stratums.

The form components of excavated mesoforms:

Mine wall: the steepest form component, whose angle of inclination with the mine flat is determined by the mining techniques (blasting, hand or power excavation) as well as the rock quality; normally it is nearly vertical. The mine floor is usually surrounded by mine walls on three sides.

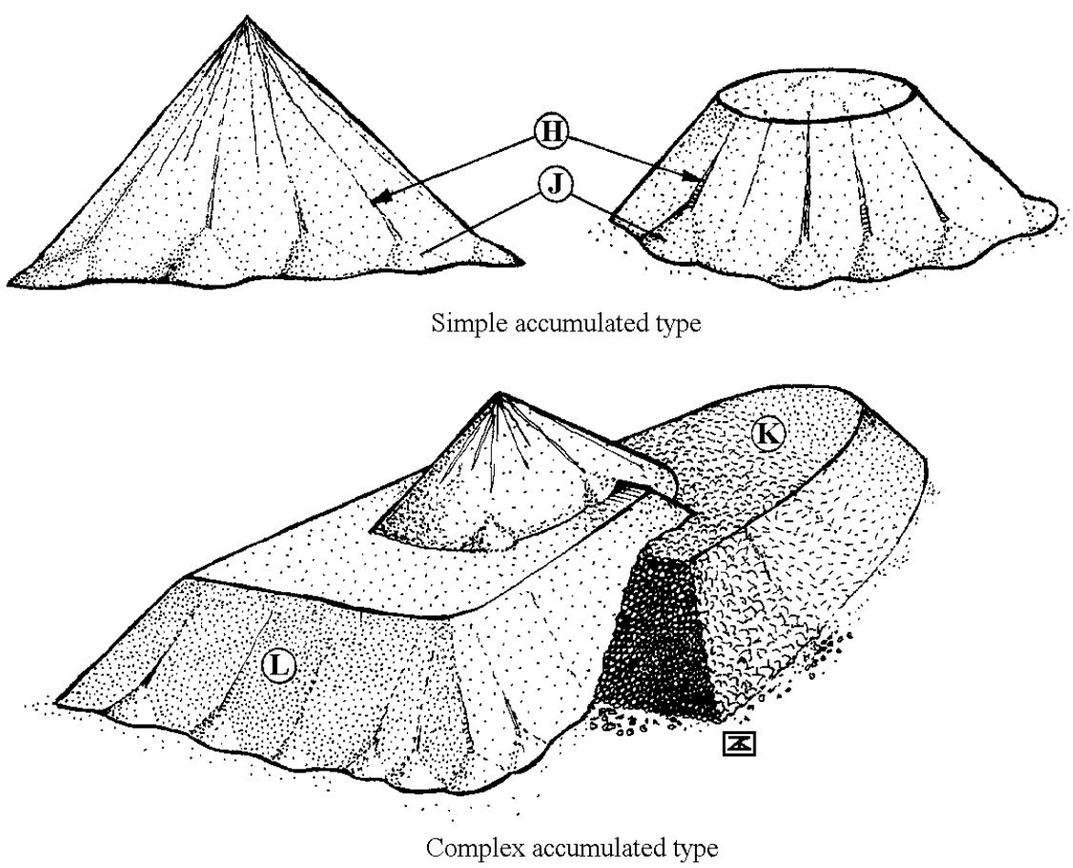
Debris cones, debris aprons: a form component with a smaller angle of rest lying at the foot of mine walls whose material partly derives from mine working and partly from natural processes (rockfalls). They are initially developed by accumulation but as their origin, they are linked to excavation activities. With the amount of material in debris cones grown, they may coalesce to form a continuous debris apron.

Mine floor: an approximately flat ground surface surrounded by mine walls and debris aprons, in which form elements of a great variety (accumulations of the quarry material, quarry heaps, pillars, etc.) can be found.

The most common excavated microforms of mining are rock counterforts, rock benches, out-weathered quarry columns, pinnacles and pillars. These latter ones basically are the transitions between excavated and accumulated forms as being the positive remnant forms of quarrying. These forms can resist the damaging effects of natural processes we find only a little material derived from rock falls in front of them. In front of the wall sections next to them there are well-developed talus sloped originated in mass movements. Precipitation derived small shallow ponds can evolve in the holes of mine floor.

Accumulated (positive) forms

Accumulated macroforms are called quarry dumps. They are formed through the accumulation of materials currently of no value from an economic point of view. During outcast mining, dumps of various origins are heaped. By the burden-removal of layers covering the useful material, a significant amount of so-called sheating dump is created. This material (interstage and plant dump) can also be a result of the exploitation and processing of the material, i.e. during griding 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 are distinguished in quarrying. In addition to these, temporary dumping of the quarry material also has to be mentioned as part of this group. They can be found singly (simple accumulated type) or in groups (complex accumulated type).



Legend: H-water groove, J- debris cone, K-plateau, L-slope

Fig. 4. Typical forms of quarry dumps (Dávid-Karancsi, 1999)

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.

Form components of accumulated mesoforms

Plateau: the approximately 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. The plateaux of truncated cone-shaped dumps are usually smaller.

Slope: the sloping ground surface which surrounds the plateau or the peak in the case of a cone-shaped dump. Its angle of dip can vary within wide limits depending on the mode of accumulation, the dump material and the original ground surface.

The most obvious microforms of dumps, formed through natural processes, are rainwater grooves cut into slopes, which lie radially on cone-shaped or truncated cone-shaped dumps. The dump material carried by rainwater settles in small alluvial cones at the foot of slopes. Plateaux with approximately flat ground surface may be dissected by rainwater grooves cutting back into them.

The accumulated microforms of mine floors, formed as a result of mining activities, are the larger heaps and boulders cutting up the approximately flat ground surface.

Planation activities (planation)

Quarrying does not only have a form-making effect 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 a denudated surface. There are visible and advanced precedents of this in Hungary as seen on Photo 1.

3.4 Some aspects of the opening and after-use of mining places

Until recently, it has also been claimed that abandoned quarries both in Hungary or abroad were coupled by basically negative, unpleasant association of ideas, as antecedents has so far met mostly the "scars in the landscape" *(Photo 2)*.

However, an evolving new estimation can also be slowly observed, of which by abandoned quarries are regarded as „environmental values", assessed and used as possible sites for exhibitions or for regional and tourism development projects. The case studies below intend to give a short but detailed overview to two interesting examples.

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 towns, and connected to them facilities suitable for entertainment (parks, multiplex cinemas, gaming-rooms, concert halls, discos, galleries, art centres, etc.) are also developed (*Bennett-Doyle 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 *(Photo 3)*.

Tokaj – Patkó Quarry

The quarry hosted an event of large scale on 30th June 2002 functioning as a „Festival cauldron". The event took place due to the fact that the Tokaj-Hegyalja Region was awarded World Heritage status in the category of cultural landscapes, thus programs were organised in the quarry strip pit to celebrate it *(Photo 4)*. The quarry since has been regularly used as a site for events.

Photo 1. Excavation of the Bélkő near Bélapátfalva (N-Hungary)

Photo 2. Scars of the andesite quarry at Sás-tó near Gyöngyös in the Mátra Hills (N-Hungary) made visible by clear-cutting with Mt. Kékes in the background

Photo 3. The Bluewater Shopping Centre near London with the mine wall of the Blue Circle Chalk Quarry in the background

Photo 4. Concert in the Patkó Quarry (Tokaj, N-Hungary)

4. Conclusion

Anthropogenic geomorphology is a new challenge for geomorphologists, since environmental problems have an effect on several branches of science. We teach anthropogenic geomorphology as an activity system, therefore, we believe in the equality ranks among the various fields of science in environmental protection and we assign an important part to anthropogenic geomorphology in the structure of our education.

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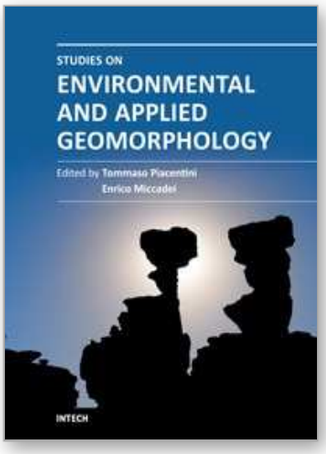

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Phone: +86-21-62489820
Fax: +86-21-62489821