THE IMPACTS OF LAND USE CHANGE ON THE BUDAPEST HYDROTHERMAL-KARST: A STUDY OF SZEMLŐ-HEGY CAVE

LÁSZLÓ MARI & KATALIN FEHÉR

Department of Physical Geography, Eötvös Loránd University, H-1083 Budapest, Ludovika tér 2.
Hungary

Summary
Human activities have completely changed the natural conditions of Budapest. The natural vegetation has been destroyed, and the original relief modified by extensive construction work and mining. The investigated area is situated on the south-eastern part of Hármashatár-hegy mountain range and forms part of the Buda Mountains karst. In its natural state, the vegetation and soil cover provided a filter for water infiltrating through fissures. Following destruction of natural vegetation and soil cover by human activity the narrower fissures have become plugged by infiltrating pollutants and more recharge enters via wider fissures without any filtration. Changes to the land surface over the last two and a half centuries were deduced from analysis of topographic maps of different years (18^{th}–20^{th} century) and from evaluating aerial photographs and images. The caves in the investigated area were formed mainly by dissolution of limestone by thermal water ascending along faults and there has been only minor modification by descending cold waters. Various parameters have been continuously measured in the Szemlő-hegy Cave since 1987. The results have shown contamination of infiltrating water that could ultimately be dangerous for the city's famous thermal springs.

Introduction

The natural conditions of Budapest have completely changed by now, as a result of human intervention. Natural vegetation have been destroyed, and the original relief was modified by extensive construction work and mining. The investigated area, one of the Buda Mountains karst's surface, is situated on the south-eastern part of Hármashatár-hegy mountain range and it contains the most important remnants of the thermal water activity in the past 2 million years. It is bordered by the Ördögárok on the SW, by the Danube valley on E and NE and by the range of Látó hill–Apáthy cliff on NW. The uplifted area has steep slopes, but its highest point is only at 376 m (Látó hill). The base level is at 104 m asl. at the Danube, where thermal springs discharge. The pollutants of the infiltrating water are filtrated by natural vegetation, soil cover and rock fissures with large surface. The natural vegetation and soil cover are destroyed by human activity and the fine rock fissures get plugged because of infiltrating pollutants. In consequence of the plugging of these fine rock fissures' the water gets through the wider rock fissures without filtering.

Land use change

A lot of valuable information was obtained from analysis of topographic maps of different years (18^{th}–20^{th} century) and from evaluating aerial photographs and satellite images. Comparing different maps we have depicted the changes of the land cover, we could deduct the alterations of the last two centuries. The maps of the 1st military survey of this area (1785) are the first topographic maps that have any information about land cover or land use. Thought these ones also don't show the original, natural state, they are the closest ones in time among all the time cross-sections. Its surface cover categories show only the basic land uses, mainly agricultural usage, but they provide a good base for further, more complicated stages of land use. Although these maps don't have projection, so compering them with those ones with projection is difficult and can result in inaccuracy, they still can provide a good source for illustrating a tendency. We defined the main land cover or land use categories based on the topographic maps and aerial photographs. There are nine categories:

CONTINUOUS URBAN FABRIC – Structures and transport network cover most of the land. Buildings, roads and artificially surfaced areas cover more than 90 % of the total surface.

DISCONTINUOUS URBAN FABRIC – Most of the land is covered by structures. Buildings, roads and artificially surfaced areas are associated with vegetated areas. This unit consists of block of flats, individual houses, gardens, streets and parks. This type of land cover can be distinguished from continuous urban fabric by the presence of non-impermeabilised surfaces: gardens, parks, and planted areas. Buildings, roads and artificially surfaced areas cover 50–90 % of the total surface area of the unit.

SPORTS FIELD

QUARRY – Areas with open-pit extraction of construction materials (claypits, quarries).

ARABLE LAND – Cereals, legumes, fodder crops and fallow land.

FRUIT TREES, VINEYARDS – Areas planted with grape and parcels planted with fruit trees or shrubs: single or mixed fruit species, fruit trees associated with permanently grassed surfaces or/and vegetable gardens.

GRASSLAND – Pastures and natural grasslands.

BUSHY VEGETATION WITH SCATTERED TREES – Bushy and herbaceous vegetation with scattered trees. It can represent either woodland degradation or forest regeneration or even colonisation.

FOREST – Vegetation formation composed principally of trees, including shrub and bush under-storeys, where broad-leaved and coniferous species dominate.

On the bases of these maps (1st military survey, 1785; 3rd military survey, 1880; topographic maps from 1922, from 1964 and from 1985) we have drawn the land covering maps of each period (*Fig. 1–5*). Analysing these maps we can see well the quick regression of natural lands and the increase of built in parts (*Table 1, Fig. 6*). In the 18th century the 42,7 % of the territory were covered by forests or bushes, this rate decreased to 8,1 percent. Opposed to this, the rate of built-in territories was 1,6 percent in 1785 and became 85,3 percent in 1985.

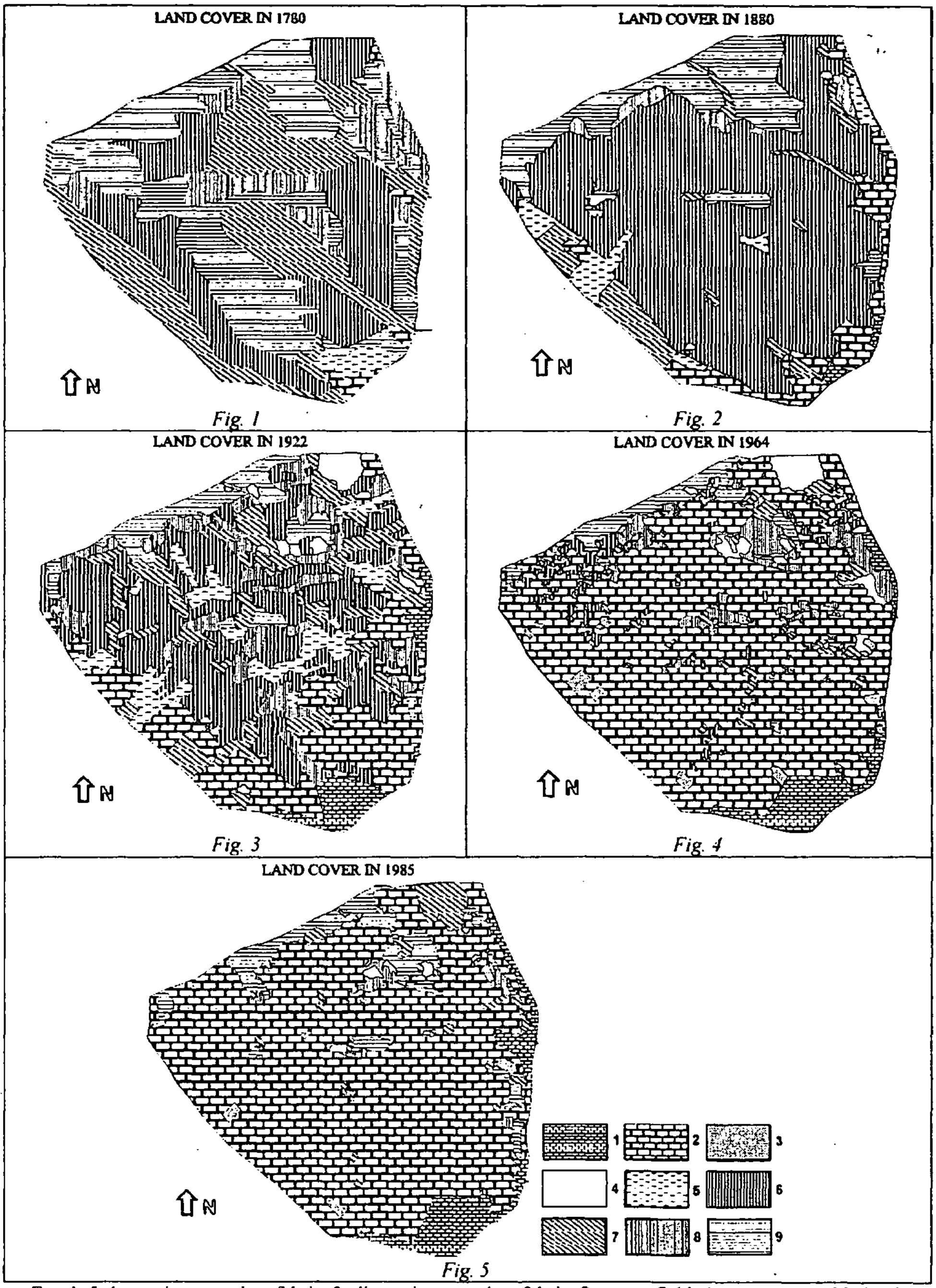

Fig. 1–5 1. continuous urban fabric, 2. discontinuous urban fabric, 3. sports field, 4. quarry, 5. arable land, 6. fruit trees, vineyards, 7. grassland, 8. bushy vegetation with scattered trees, 9. forest

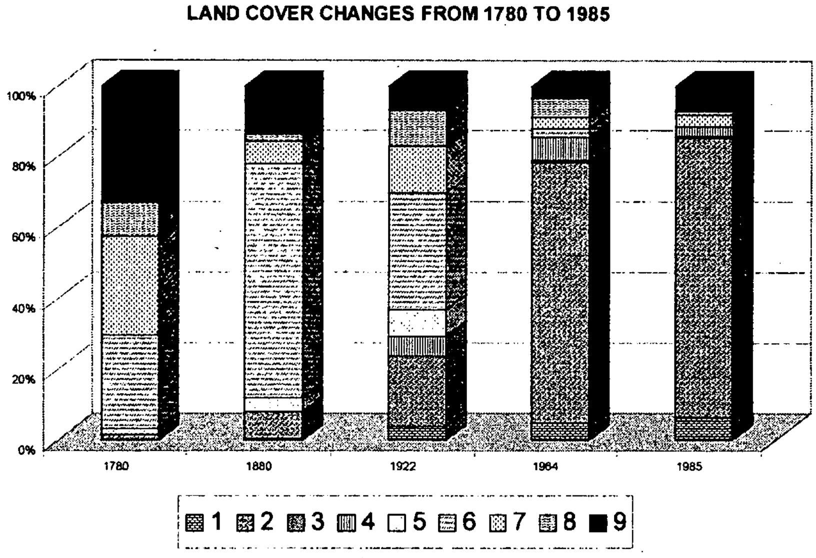

Fig. 6 Land cover changes from 1780 to 1985.
1 – continuous urban fabric, 2 – discontinuous urban fabric, 3 – sports field, 4 – quarry, 5 – arable land, 6 – fruit trees, vineyards, 7 – grassland, 8 – bushy vegetation with scattered trees, 9 – forest

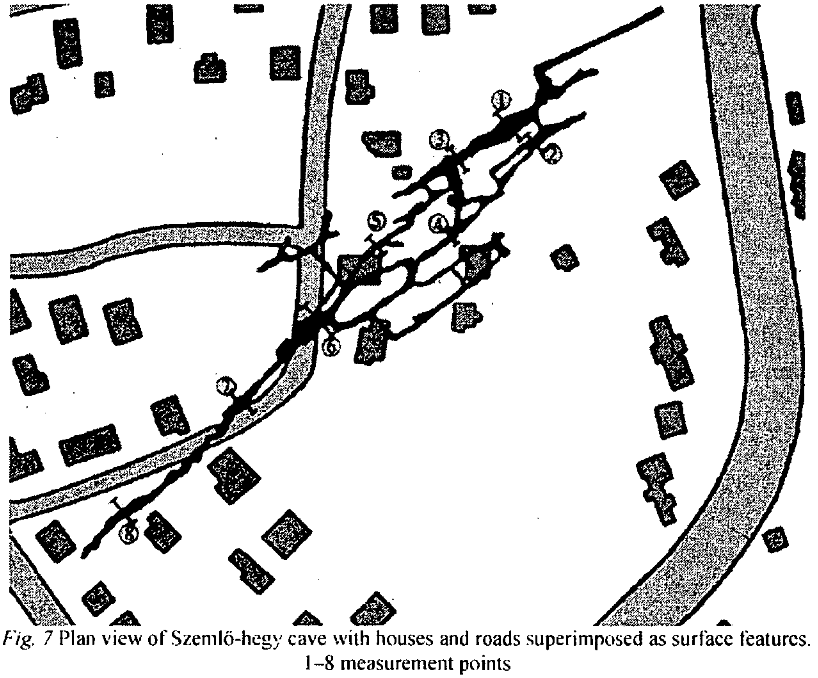

Fig. 7 Plan view of Szemlő-hegy cave with houses and roads superimposed as surface features.
1–8 measurement points
(after *Takácsné Bolner K.–Tardy J.–Némedi L. 1989.*)

Szemlő-hegy cave

The Buda karst caves are under a densely built-in territory, where not only precipitation brings in dangerous substances, but also communal sewage water endangers the karst. Szemlő-hegy cave is dissolved in an Upper Eocene limestone (Szépvölgy Limestone) and marl (Buda Marl) along three longer and three shorter NE–SW fractures and some minor tectonic lines perpendicular to them (*Fig. 7*). Thermal waters ascending along faults dissolved the cave and descending cold waters only played a modifying role. Foot level of the passages is at 160 m asl, while its discovery entrance is at 206 m asl. The total length of the system is 2200 m. Karstic infiltration is subordinate on the area, because impermeable marls cover it; moreover accelerated urbanisation further decreased it.

Table 1 Land cover between 1780-1985

	1780 %	1880 %	1922 %	1964 %	1985 %
continuous urban fabric	0	0.4	3.7	4.8	6.3
discontinuous urban fabric	1.6	7.6	20.1	73.5	79
sport field	0	0	0	0.7	0.5
quarry	0	0.1	5.5	6.7	2.6
arable land	1.5	3.8	7.5	0	0
orchard, vineyards	26.4	66.1	32.9	2.2	0
grassland	27.8	6.4	13.3	3.2	3.5
bushy vegetation with scattered trees	9.8	1.9	10.4	5.4	1,1
forest	32.9	13.7	6.6	3.5	7

Table 2 Typical extreme values of dripping waters in caves

		Hungarian average	Szemlő-hegy cave
PH		7,5–7,8	7,1–8,1
Electric conductivity	μS/cm	620–790	586–1360
Total hardness	mgeé/l	5,0–9,0	4,7–13,8
Ca^{++}	mg/l	90–160	66–228
Mg^{++}	mg/l	0,5–19	7–34
HCO_3^-	mg/l	200–480	96–260
Cl^-	mg/l	3,0–30	9–200
NO_3^-	mg/l	0,5–90	1–380

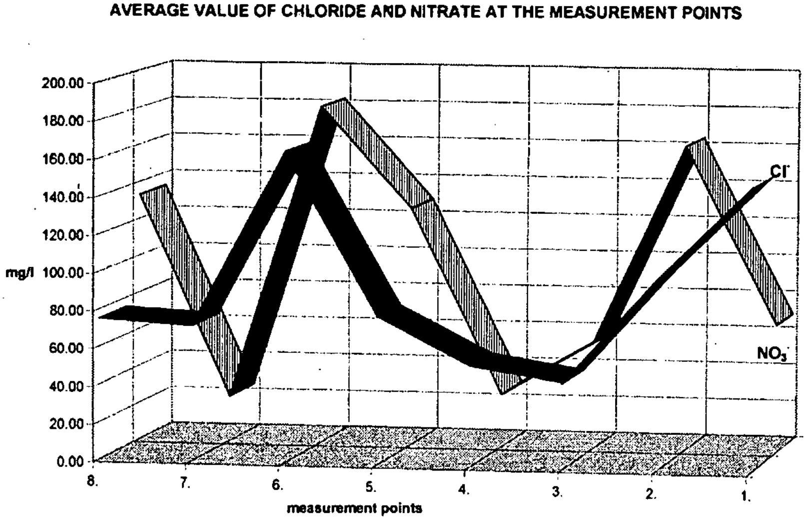

Fig. 8 Average chloride and nitrate ion concentration at the sample points

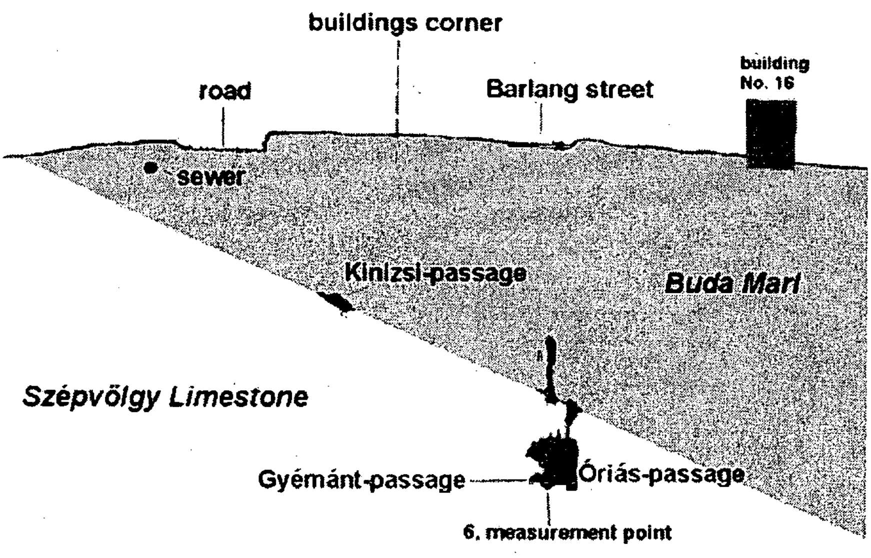

Fig. 9 Cross-section of Szemlő-hegy cave taken from measurement point 6. (after *Horváth J. 1995*)

Infiltration water quality

The chemical composition and quality of the infiltrating waters became known from analyses carried out in the caves from dripping waters. We collected water samples regularly since 1987, and analysed by the method of drinking water standard. The examined parameters: total hardness, calcium-content, magnesium-content, alkalinity, constant hardness, chloride, nitrate, nitrite, ammonia, phosphate, sulphate, potassium, sodium, pH and electric conductivity. We collected water samples from eight measurement points, from the passages of the cave (*Fig. 7*). The values of dripping waters compared to average values of Hungarian karst areas with those of Szemlő-hegy cave, we can experience that the total hardness and the concentration of Ca and Mg moves in wider range (it depends partly on the quality of the rock cover). The content of chloride and nitrate and the extreme values of electric conductivity indicate unambiguously the contamination that originated from the surface. The content of hidrocarbonate is less here, its place is partly taken up by the anions coming from contamination (*Table 2*).

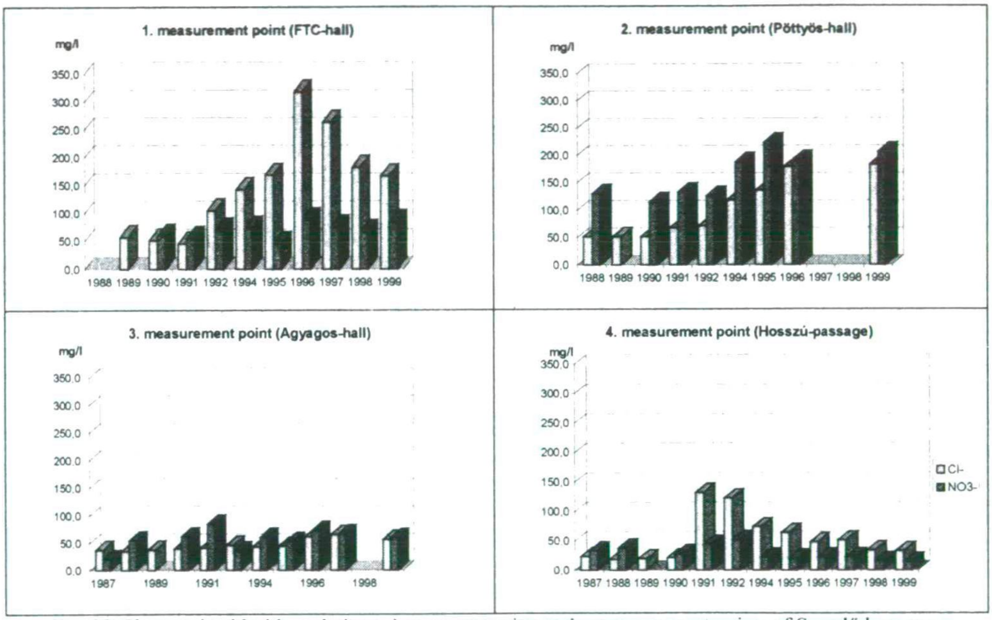

Fig. 10 Changes in chloride and nitrate ion concentration at the measurement points of Szemlő hegy cave

The water samples from different parts of the cave are very different. We illustrate the spatial distribution of contamination by the average concentration values of each measurement points with special regards to chloride and nitrate ions – mainly coming from sewage and from road salting in wintertime (*Fig. 8*). The cross section by the 6th measurement point shows the stratification of the limestone and marl, and the connection between the cave and the surface (*Fig. 9*). The strata dip is 20°. The infiltrating water gets down to the cave faster on the boundary of two strata than through the micro-cracs, so the filtration of the joint systems doesn't succeed. The outstanding nitrate ion concentration indicates the contamination (1st measurement point in 1996, 4th measurement point in 1991, 5th measurement point in 1988 etc.). (*Fig. 10–11*). The consistently ascending chloride ion concentration of 7th measurement point indicates the reduction of filtering force of rock fissures because the fine rock fissures get plugged by infiltrating pollutants. The contamination of the phosphate coming of different chemicals (detergent, artificial fertiliser etc.) appears on three points (№ 1., 5., 6.) while the nitrite appears only two points (№ 5., 6.) showing the parts of the cave which get the biggest contamination.

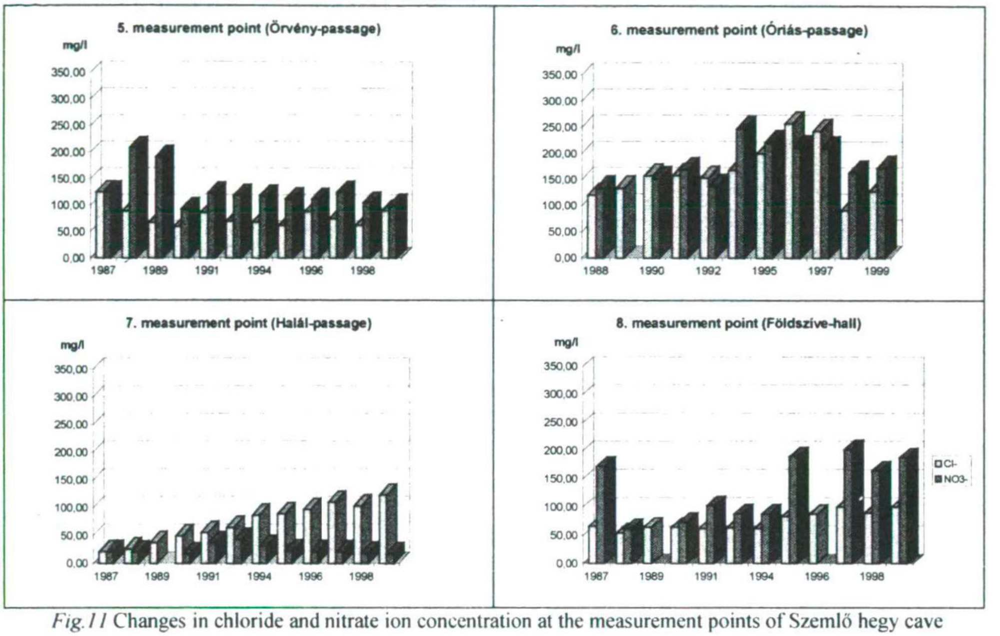

Fig.11 Changes in chloride and nitrate ion concentration at the measurement points of Szemlő hegy cave

References

Takácsné Bolner K.–Tardy J.–Némedi L. 1989.: Evaluation of the environmental impacts in Budapest's caves on the basis of the study of the quality of dripping waters – Proceedings 10th International Congress on Speleology, Budapest, pp. 634–639

Horváth J. 1995.: Cross section of Szemlő-hegy cave – manuscript

Maps: 1st military survey 1785. scale 1:28800

3rd military survey 1880. scale 1:25000

Topographic map 1922. scale 1:25000

Topographic map 1964. scale 1:10000

Topographic map 1985. scale 1:15000