MEASUREMENT OF KARSTIC INFILTRATION IN THE AGGTELEK KARST

László Zámbó

The percolation of precipitation into the karstic aquifer is one of the determining elements in karstification. This elements is called as karstic infiltration.

A monitoring system has been installed in the Aggtelek Karst in Hungary to study the process of karstic infiltration. This system is equipped with sensors and loggers and can continuously measure the parameters of the infiltration from the surface to the karstwater table.

The measuring station is in the Aggtelek National Park, which is a karst upland characterised by karren, dolines and river caves. Dolines and sinkholes are diagnostic features of karst terrain. They are topographically closed depressions with forms that may range from shaft through funnel to shallow water. Diameters range from less than ten to a little more than one thousand metres depth diameter ratios are normally between 1:2 and 1:20. Processes of mechanical collapse, of subsidence or suffusion may contribute to their formation but in true karst (as opposed to pseudo-karst) aqueous dissolution of the bedrock is either the principal process or it is the essential trigger for operation of any of the others.

In forest or grassland regions dissolution dolines typically are mantled with soil. There is often some outcropping of bedrock displaying karren forms on the steeper sideslopes, and a marked increase of soil thickness in the bottoms.

The study site is a rolling upland karst that straddles the Hungarian-Slovak border. Elevation ranges from 200 to 600 metres. Bedrocks are thick to massively bedded platform limestone and dolomites of Triassic age. Insoluble residuals are only 0.1 to 0.35%. There was quite intensive karstification during the Cretaceous, after which the strata were buried by Pannonian sands and clays (Miocene). They were lifted up as a horst block in Pliocene, when the modern period of erosion began. They display dense tectonic fracturing. In combination with the paleokarstification this has resulted in an unusually high density of final fissures that are penetrable by groundwaters.

Soils developed on the carbonate rocks are terra rossas and rendzinas (red to red-brown chromic luvisols and rendols in the terminology of the Seventh Approximation, 1960). They have an effective porosity of 30-50%. On slopes they are generally mixed and reworked to form a complex mosaic of relict and modern components.

The comprehensive instrumentation had to be limited to one site. This is a nearly circular feature 150 m in diameter and 12 m in depth. Its basal fill of soil is a further 7.5 metres in depth. The doline is situated over Béke Cave, which is 37 metres beneath it. There are now four measuring stations or experiments operating in the doline, plus a further one in the cave below.

The units of the measuring system are located in karstic vadose and epiphreatic zones along a vertical section. The first unit (which measures precipitation) is over the surface, the second unit (which measures run-off) is on the surface. Then follow five seepage measuring units in the thick soil accumulation at 0.5, 2.5, 5.0 and 8.5 metres. Finally, two units (Instrument No. 2 and 3) measure the infiltrating water of the ceiling of the Béke Cave, directly at the level of the karstic water table.

The following conclusions on the process of infiltration are based on a 3911 hour period between February and July 1995 (Figure 1), namely on a rainy section of this period (Figure 2).

1. Until the humidity of the top 5 cm soil layer is below 92-93%, and the infiltration capacity is higher than the precipitation, all rainwater infiltrates. At 92-93 humidity value run-off starts.

2. Infiltration in forested areas is 1-12 hours later than in grasslands.

3. The downward velocity of the infiltration front depends on the preliminary water saturation of the soil.

(i) At 0.5 m, infiltration can even be 44 hours later than the start of rainfall, depending on the humidity of the soil (Figures 4-5).

(ii) Over forested lands generally 12 hours, on open fields generally 3 hours are needed after the start of raining until the infiltration front arrives at 0.5 metres. In the case of recurring minor precipitation (4-5 mm) the infiltration front normally arrives at 0.5 m in 24 hours.

4. At medium humidity (40-50%), the infiltration reaches from 0.5m to 2.5 m after 15 hours, and usually needs another 17 hours to arrive at 7.5 m. ,

In humid soil (over 87%) the intensity of infiltration suddenly increases and synchronously changes with the surface swallowing.

5. Going downwards, the intensity of infiltration decreases and the process becomes longer in time. The infiltration follows the precipitation

(i) 4-50 hours later at 2.5 m (Figure 6), and

(ii) 7-14 days later at 5 m.

6. On slopes, at the border of decayed materials and the karstic rock, usually one hour is needed after the precipitation until the start of border surface infiltration. The velocity may be several times higher than that of the capillary infiltration. (Figure 8)

7. On karstlands which are mantled with thick (5-10 m) decayed material, at 36 m depth, the infiltration is normally 5-6 days late, while where the land is covered with thin (0.5 m) soil, it is , usually 2-2.5 days late (Figures 2-10).

8. The infiltration process becomes more and more balanced as the depth is

growing, but certain rhythmical changes in the intensity can be observed up to the karstic water table.

Changes, occasionally periodicity, in the intensity of seepage at various depths can be most easily explained by lunisolar effects, which have already been proved for movements in karstic hollows. The existence of these effects can only be presumed due to the special hydraulic rules that direct infiltration, although the mathematical analyses seem to support this.

Studying the infiltration processes at 2.5 m (Figure 11), the range of the amplitude indicated the existence of the given harmonic factor. The time period of 514 hours starting at 12 o' clock on 11 March 1995 produced 1029 data, which were analyzed by Furier transformation. With the help of this analysis it was possible to show some long periods (21, 10.5, 6.1, 3.8, 2.7, 2.12 and 1.6 days) and several short periods (Figures 12-13). A more complete explanation still needs a bigger data base and further analysis.

Measured data of karstic infiltration gave the opportunity of calculating the average value of limestone solution. On the basis of analysis carried out until now the following can be concluded.

Infiltrating water - due to lime solution - loses a part of its solution capacity in the soil cover (fixed CO_2), by solving 8.918 g/m^2/year limestone. The aggressivity of the remaining part of infiltrating water is able to solve 12.71 g/m^2/year limestone. The value of complete average limestone solution capacity - calculated to limestone denudation - is 0.01065 mm/year or (appr. 10 mm/thousand years.)

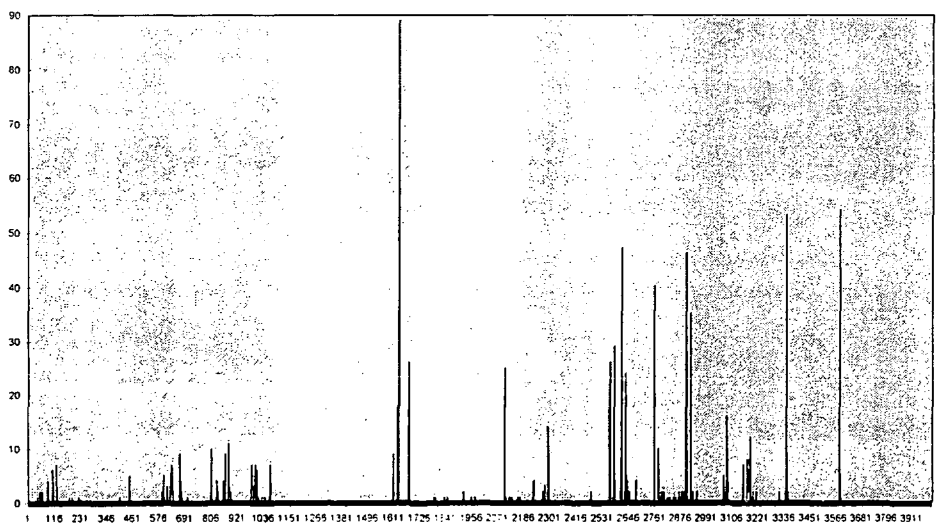

Figure 1

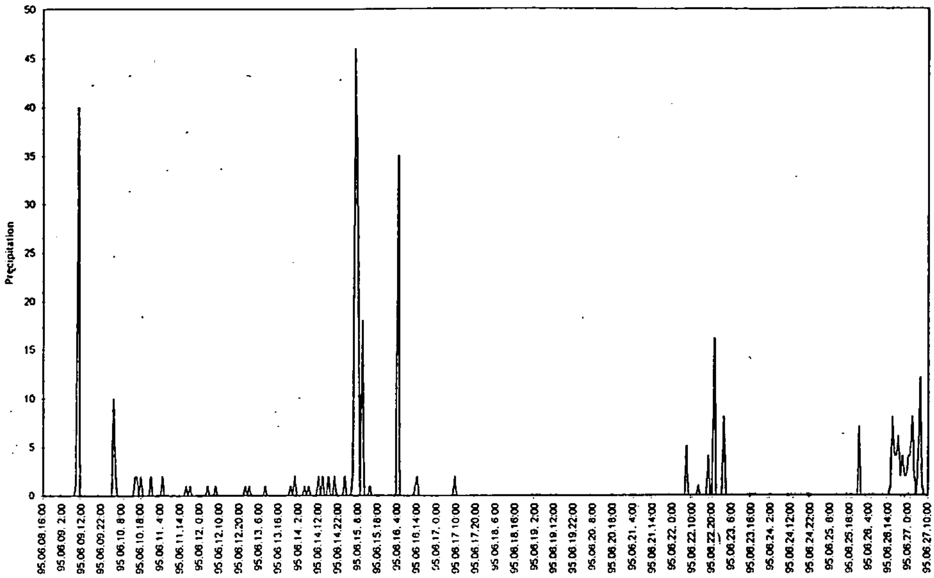

Figure 2

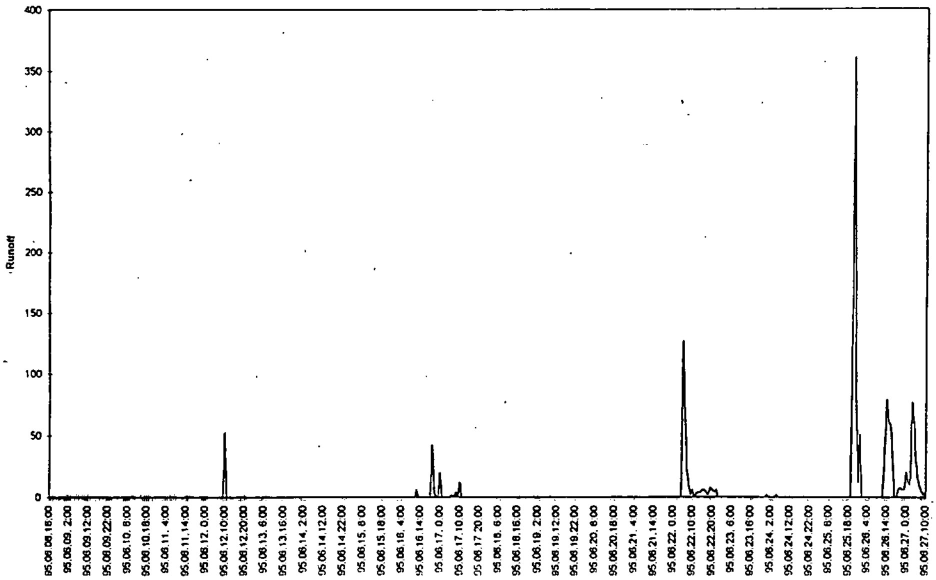

Figure 3

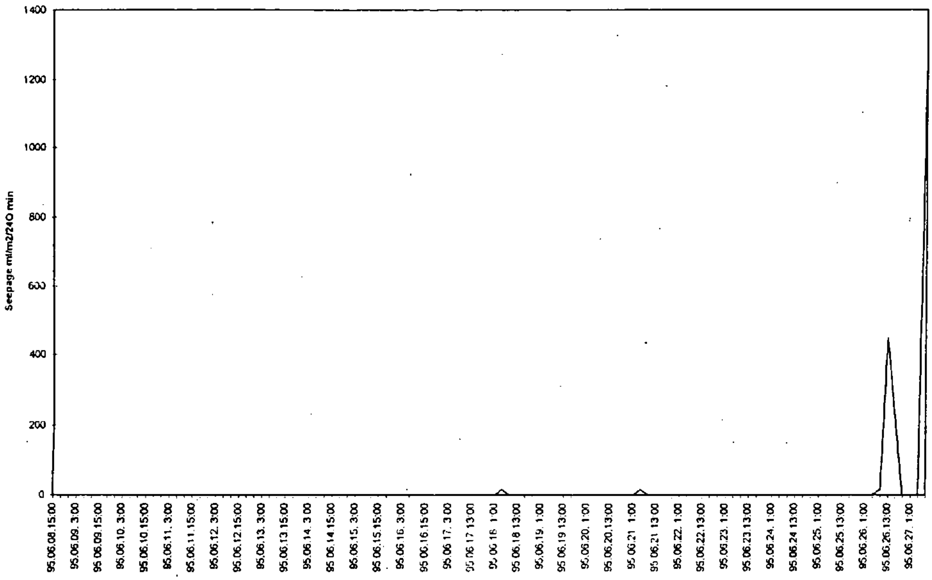

Figure 4

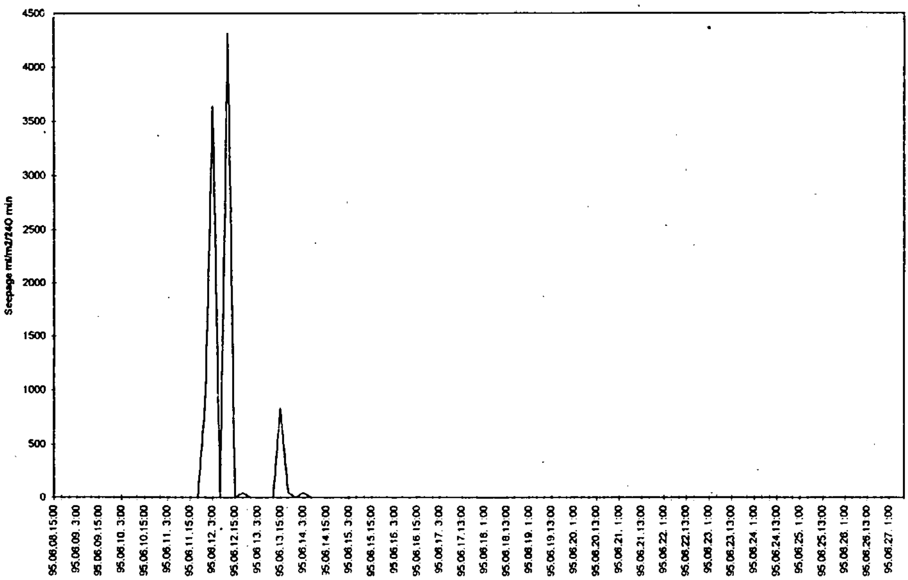

Figure 5

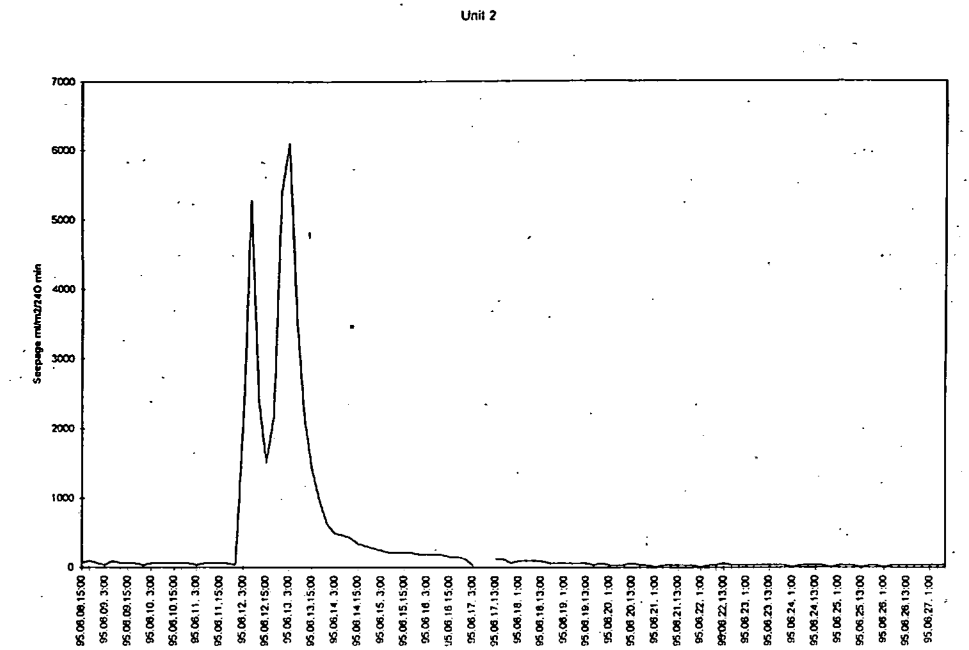

Figure 6

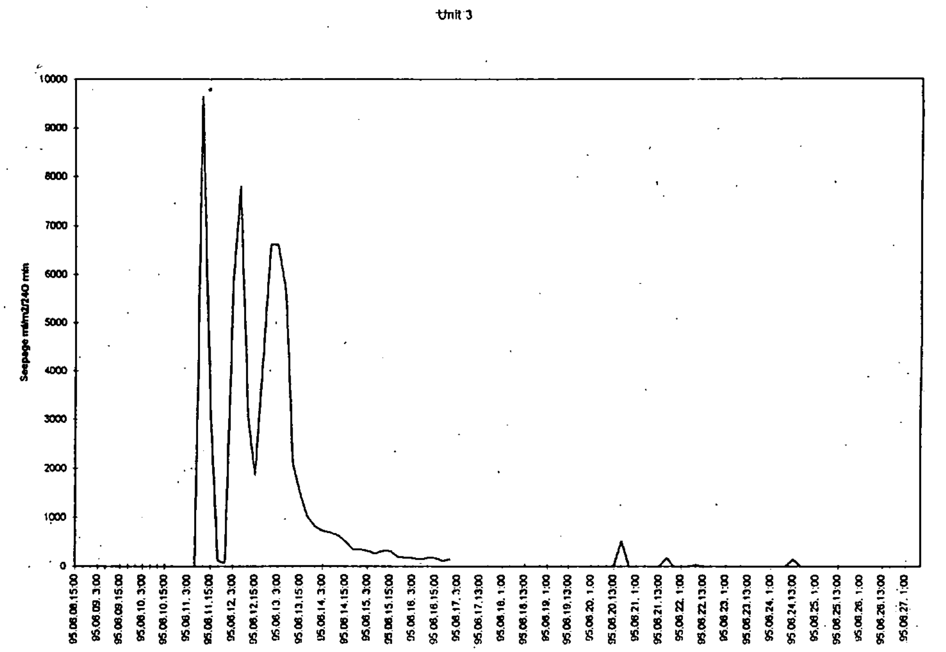

Figure 7

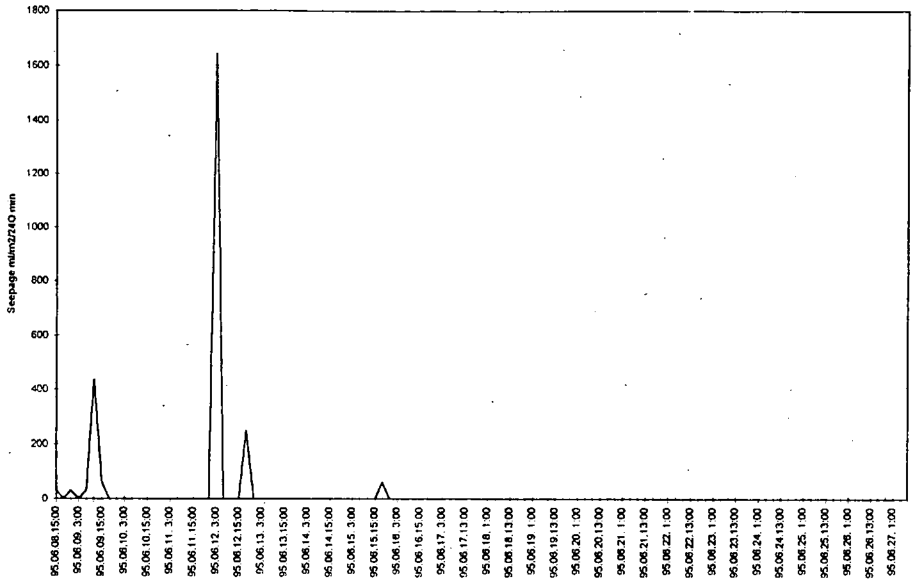

Figure 8

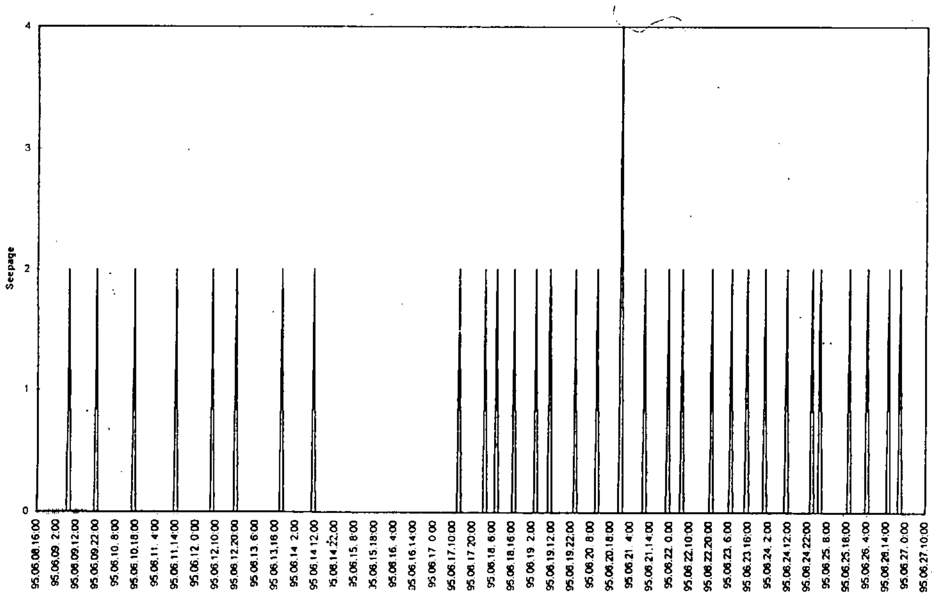

Figure 9

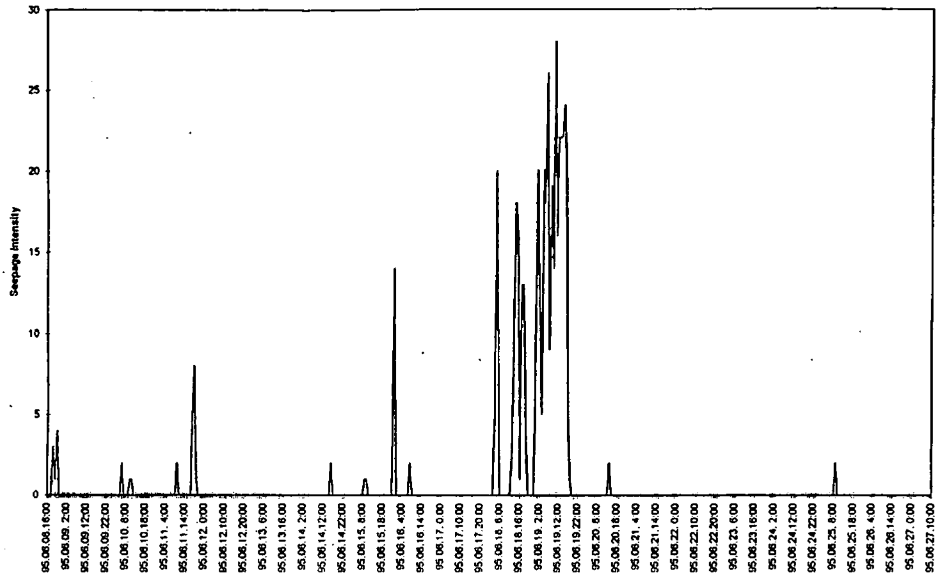

Figure 10

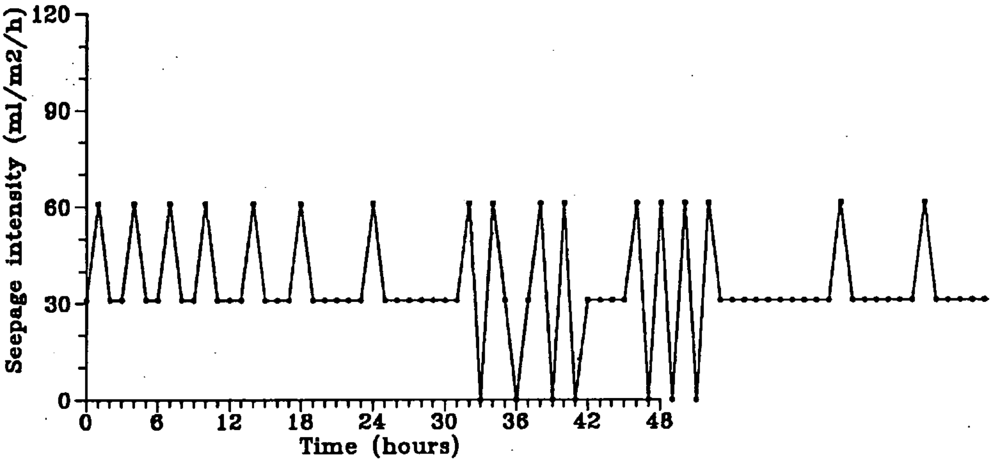

Figure 11

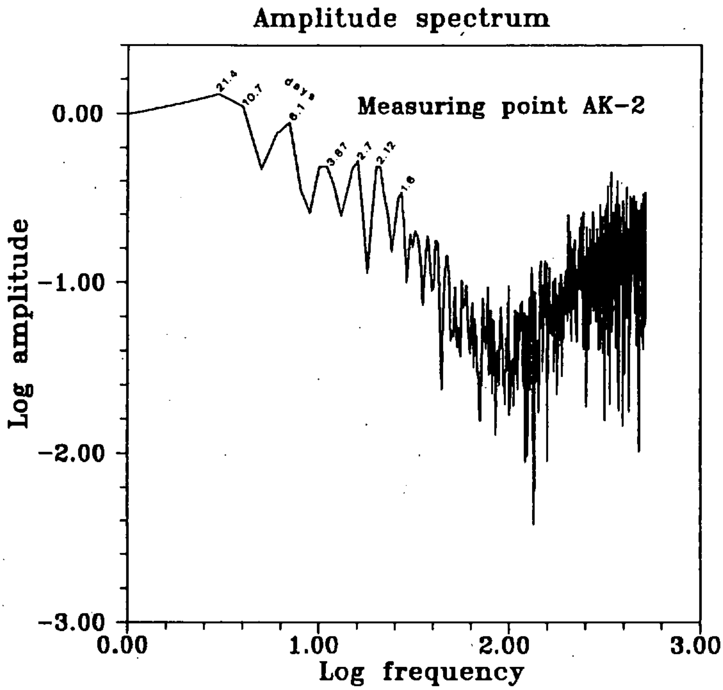

Figure 12

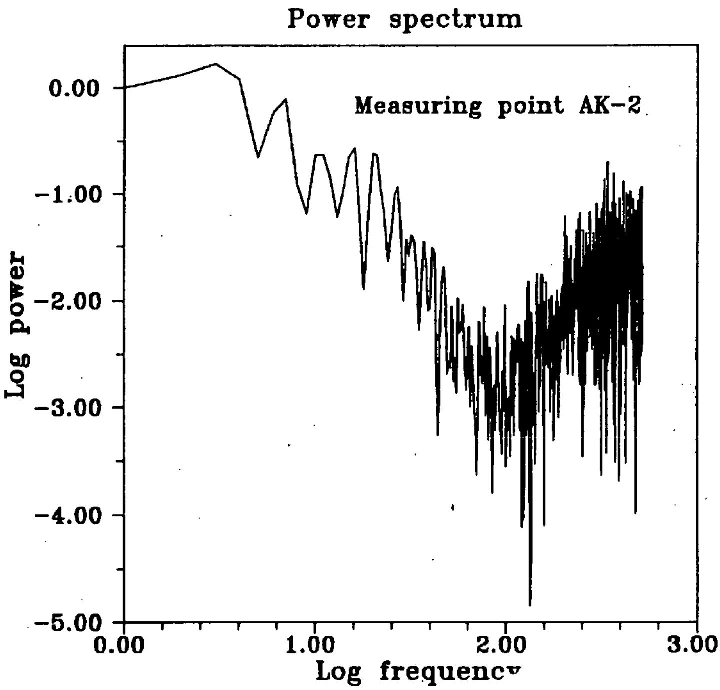

Figure 13

REFERENCES

FORD, D.C. - WILLIAMS, P.V., 1989: Karst Geomorphology and Hydrology. London, pp. 1-600.

MAUCHA, L., 1977: Study of tidal movement of karst waters and karstic rocks. Annales Geophys., Tom. 33, Fasc. 1/2. Grenoble, pp. 151-156.

WHITE, W.B., 1988: Geomorphology and Hydrology of Karst Terrains. Oxford, pp. 1-464.

ZÁMBÓ, L., 1993: Karsztmorfológia (In: Borsy, Z.. Általános természetföldrajz), Budapest, pp. 544-593.

Address of author:

László ZÁMBÓ
Department of Physical Geography
Eötvös Loránd University
Budapest, Hungary