THE INFLUENCE OF THE SOIL ZONE ON KARST CORROSION AND KARREN DEVELOPMENT

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Summary

Over the past two decades investigations have been directed to revealing the significance of soil zone processes on the evolution of surface karren. The soil fill was removed - as perfectly as it was possible - from two similar karren and the floors of both karren were sealed by cement. In order to reduce the effect of the cement it was covered by synthetic resin and the original soil was refilled into one of the karren while the other remained soil free. Thus measurements refer to so-called 'bare' karren, 60 per cent free from soil cover, and to so-called covered karren with a complete soil cover. The amounts of runoff from and infiltration into karren are lower than the precipitation amount on the surface both for bare and for covered karren. The deficit in the first case (through wetting and evaporation) is 23 per cent, while in the second 45 per cent (through wetting, evapotranspiration and pore water). In bare karren, infiltration occurs in pulses and ends abruptly; water from further minor events cannot reach the joints of the bedrock. The beginning of infiltration into covered karren is 1-5 hours delayed on average compared to that of bare karren, but attenuation is prolonged and in a rainy period moderate infiltration can be continual. The amount of dissolved carbonate from bare karren is usually proportional to the amounts of precipitation and infiltration. Solution takes place due to runoff from snowmelt, early summer precipitation maximum and autumn secondary rainfall maximum (at most 1500-2000 mg per two weeks), while minima are observed in the drier intervals in between. The amounts of dissolved carbonate from covered karren show greater annual variations. Maxima are over twice those for bare karren. Our observations support the conclusion that the trend of maximum solution, which reflects the joint impact of soil moisture, soil temperature and CO_2 production in the soil, controls the carbonate concentration of infiltrating water and the daily amplitude of this variation is 35-45 mg/l. During continuous infiltration there is an average of 100-110 mg/l carbonate concentration in covered karren areas.

Introduction

It has been shown that soil cover and soil deposits washed into karst passages play a significant part in the solution of karstic rocks, in the geomorphic evolution of karst terrains and development of karst features. This factor, is manifested in variable manner and degree in karst corrosion and influences the development of various karst features in all sites where soil cover or its redeposited remnants are present. Over the past two decades investigations have been directed to revealing the significance of soil on the evolution of surface karren. Focusing on the measurement of the growth and broadening of kluftkarren, a field observation station was set up in a doline on a plateau at 600 m altitude in the Aggtelek Karst, northeast Hungary. It is located on a heavily karstified doline slope of N exposure. In two parallel kluftkarren of similar size, the rainwater runoff from karren crests and peaks is received by a subsurface container system. The amount of infiltration, dissolved carbonate contents and other physical and chemical parameters are recorded on the spot or measured in the laboratory. The bottoms of the karren were originally covered by 5-10 cm deep black rendzina soils. The sides and karren crests were overgrown sporadically by bryophytes and lichens and in the karren locally monocotyledonous and dicotyledonous plants lived. A rich bacterium and Actynomyces flora thrived in the black rendzina. The 5-8 most active groups of them were identified and also investigated in other stocks. Field measurements were performed in two phases. The first lasted from March 1980 to September 1982 for 861 days, with observations at two-week intervals by installed mechanical and electronic recorders. Infiltrating water was collected for 14 days and measured and sampled. Some of the results are presented in the first part of the paper. The second phase began in January 1997 and lasted to the present day and a continuation is planned for the future. Here electronic sensors and data loggers were employed at the field station. Thus continual data collection was achieved and short-term (one-hour) changes of parameters affecting solution could be measured and details of the process of corrosion could be revealed. The first results of the second phase of investigations are presented at the end of the paper.

As the primary objective of the experiment was to study the influence of soil zone processes on karst corrosion, the soil fill was removed - as perfectly as it was possible - from two similar karren and the floors of both karren were sealed by cement. In order to reduce the effect of the cement it was covered by synthetic resin and the original soil was refilled into one of the karren while the other remained soil free. Thus measurements refer to so-called 'bare' karren, 60 per cent free from soil cover, and to so-called covered karren with a complete soil cover.

In the present study two groups of factors of karren development were identified and measured:

A) triggering factors

- rainwater runoff on karren surfaces, eventually infiltrating. It was recorded in two-week intervals in the first phase and conducted under the surface through a cup meter and sampler set up in a closed space, providing electric impulses, and collected in a container in the second phase.
- amount of debris produced by mechanical weathering and reaching the karren and, mixed into the black rendzina, dissolved. Its amounts can be regarded equal in both karren and thus was disregarded in comparison.

B) influencing factors

- temperatures of soil and infiltrating water;
- soil moisture content (per cent);
- CO_2 contents of infiltrating water, which is a decisive factor in hydrogen carbonate solution, irrespective of its origin (microbial decomposition, root respiration or microclimatic water). In the analysis of CO_2 bound, equilibrium and aggressive CO_2 forms were distinguished and this allowed the measurement of dissolved carbonates and, with respect to the aggressivity responsible for further solution, the calculation of potential solution capacity.

Results

The amounts of runoff on and infiltration into karren are lower than the precipitation amount on the surface both for partly bare and for covered karren. The deficit in the first case (through wetting and evaporation) is 23 per cent, while in the second 45 per cent (through wetting, evapotranspiration and pore water). The minimum amount of precipitation to be taken into account in karren development is >1 mm at 8°C mean annual temperature and 0.02 mm per min minimum rainfall intensity. If rainfalls have parameters below the above limits, no infiltration is fed even on bare karren and they increase the precipitation deficit. The values tend to rise in the growing season and decrease at temperatures below freezing point. Over a 861 day period, 55 per cent of the precipitation infiltrated into bare karren surfaces and 23.3 per cent into covered karren. The seasonal variations of runoff-infiltration are shown in Fig. 1. In bare karren, infiltration amounts increase from April to the regular maximum in June-July and a secondary minimum is observed in August-September, a secondary maximum in October and a regular minimum in winter. There is no infiltration in winter when temperatures are below 0°C but some precipitation from frontal events may infiltrate. Infiltration shows a similar curve for covered karren but its amounts are, on average, 25 per cent less than for bare karren. Here it is typical that maxima are two-three weeks later than those on bare karren surfaces and infiltration begins with delay compared to the advent of the rainy season but with a great intensity. Infiltration on covered karren surfaces depends on the weather of the one or two weeks before the precipitation event and on the soil moisture conditions.

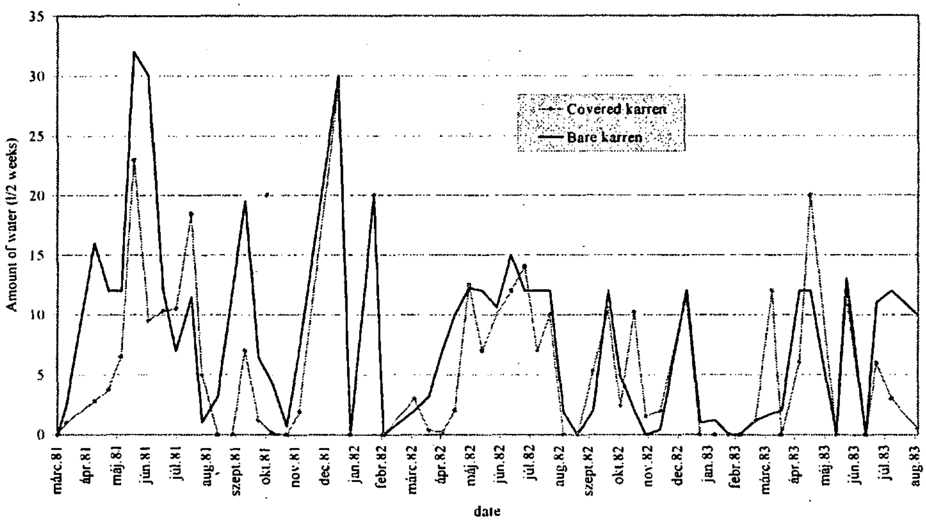

Fig. 1 Runoff water (infiltration) from the karren, 1981-1983

In bare karren infiltration occurs in pulses and ends abruptly; water from further minor events cannot reach the joints of the bedrock. The beginning of infiltration into bare karren precedes the infiltration of soil solution. The beginning of infiltration into covered karren is, on average 1-5 hours later than that of bare karren but attenuation is prolonged and in a rainy period moderate infiltration can be continual (see *Fig. 2*, 12-17 July).

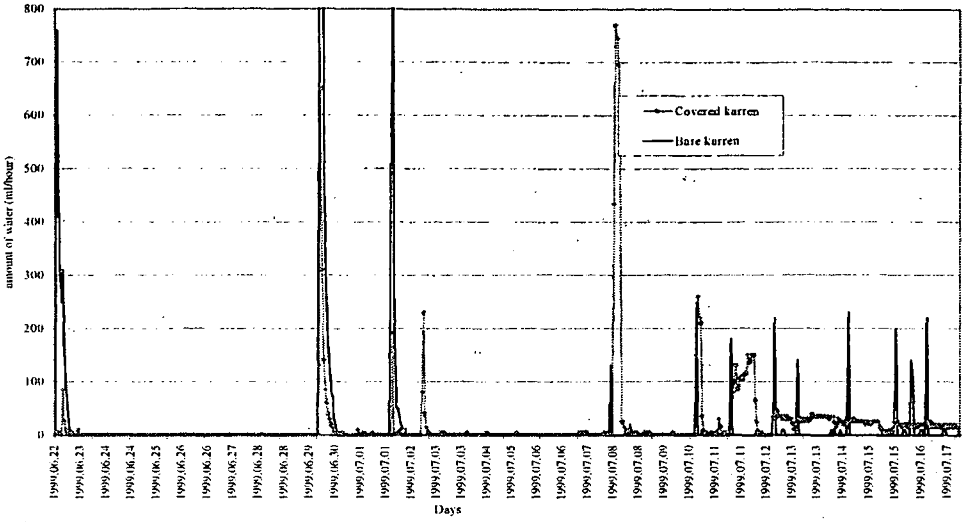

Fig. 2 Runoff water (infiltration) from the karren, Summer, 1999.

When the soils are moist (96-100 per cent soil moisture) even small rainfall amounts infiltrate. Where there is a clay cover infiltration is initially rapid but with swelling it slows down and attenuation is prolonged. The change of infiltration and soil temperature is particularly characteristic in covered karren (*Fig.3*).

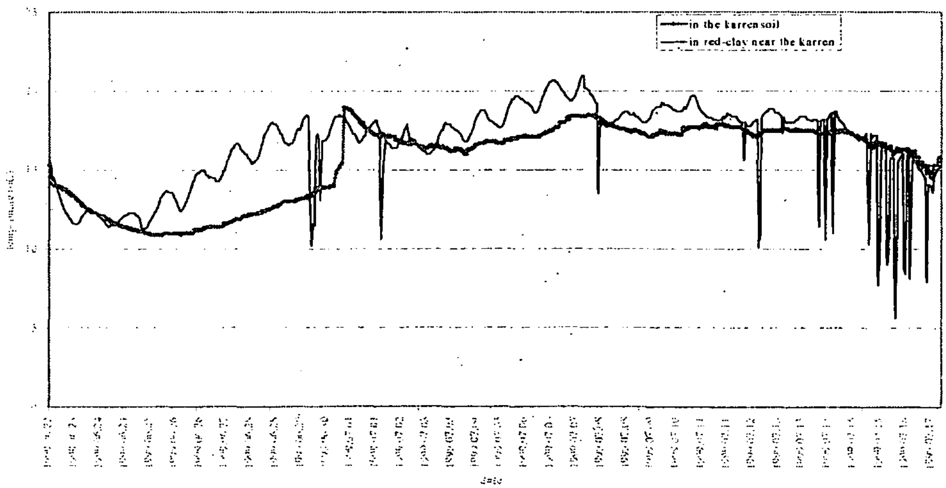

Fig. 3 Soil temperature

In non-frontal weather conditions, the soils of karren covered by black rendzinas shows a sinusoidal daily temperature curve, e.g. in summer 3-4°C daily variation is observed. Intensive infiltration after rainfall events cools the soil down by 7-8°C on average. Cooling is simultaneous with the beginning of intensive infiltration and during prolonged low-intensity infiltration soil temperature resumes its normal daily curve. This indicates that infiltrating water does not cool down soil particles for a long time and thus soil microbial activity and CO_2 production is not reduced but, with the increased CO_2 solution by cold water, the solution capacity of infiltrating water grows (*Fig. 4*).

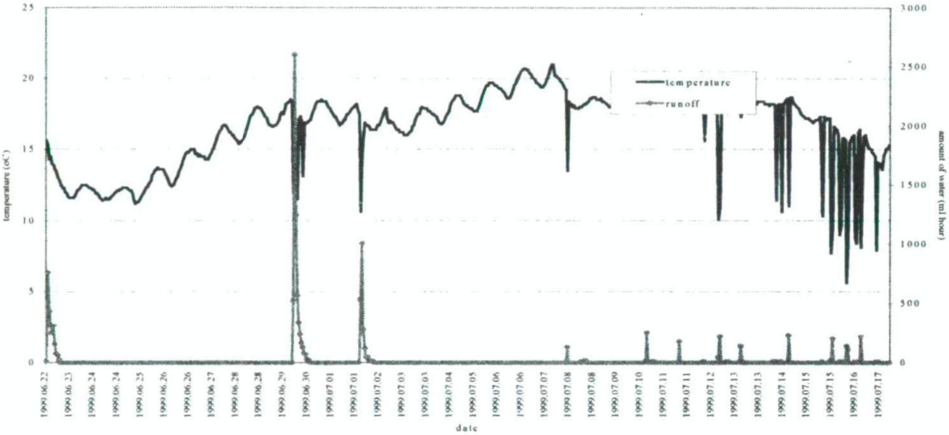

Fig. 4 Surface temperature and runoff water from the bare karren

The influence of infiltration on temperature cannot be observed so clearly where the soil cover is clayey. The carbonate solution capacity of infiltrating water, assuming prevailing hydrogen carbonate corrosion, corresponds to the amount of dissolved CO_2. The annual curve of solution on bare karren (*Fig. 5*) is more moderate than on covered karren.

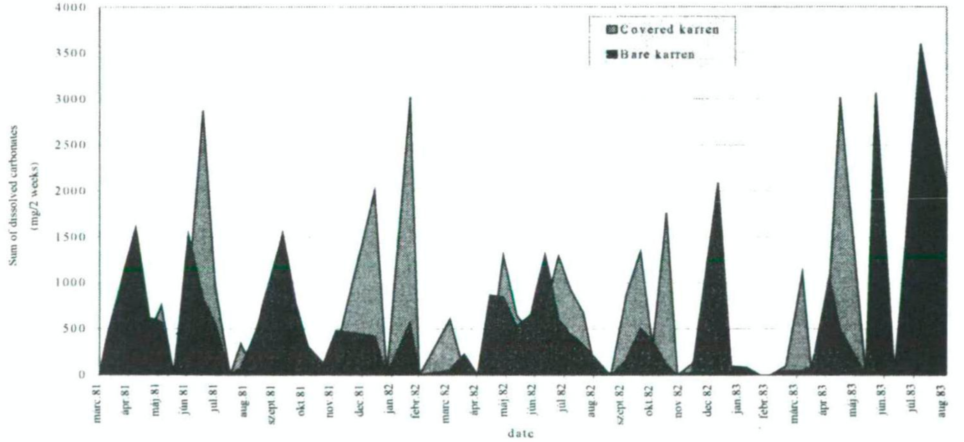

Fig. 5 Sum of dissolved carbonates in water draining from the karren, 1981-83.

The amount of dissolved carbonates in water draining from bare karren is usually proportional to the amounts of precipitation and infiltration. Solution takes place due to runoff from snowmelt, early summer precipitation maximum and autumn secondary rainfall maximum (at most 1500-2000 mg per two weeks), while minima are observed in the drier intervals in between. In covered karren, the amounts of dissolved carbonates show greater annual variations. Maxima are over twice those for bare karren. Corrosion in covered karren is not a linear function of precipitation but adjusts to interactions of soil biological activity and infiltration. Consequently, optimum solution is not always controlled by precipitation amounts and extreme values may occur in any month (including February). It is characteristic that during frozen soil conditions and in totally dry periods corrosion stops entirely. Continual observation allowed the formulation of several relationships between infiltration and carbonate solution (*Fig. 6*).

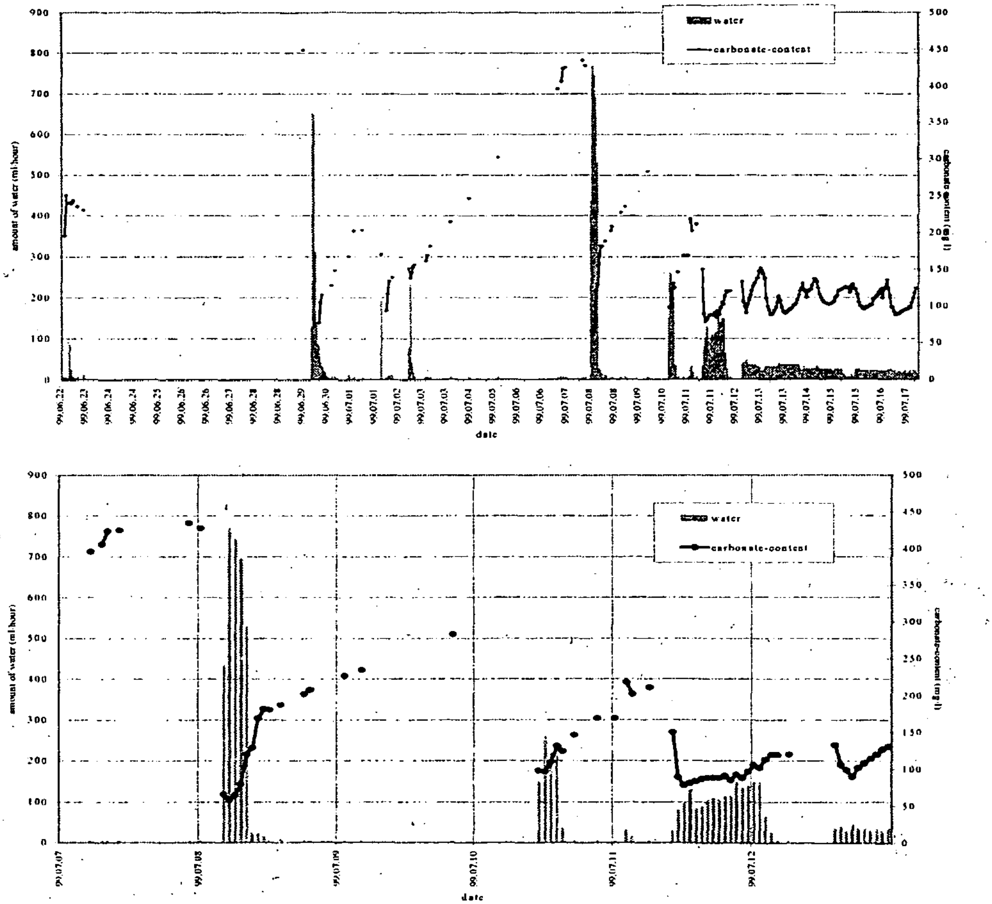

Fig. 6a-6b Amount of water draining from the covered karren and its carbonate-content
A: 22.06. - 17.07.1999, B: 07.07. - 12.07.1999.

There is generally an inverse relationship between the amount of infiltration and the carbonate content of water. In the various phases of infiltration during a rainfall event, however, this means a regularly changing relationship. Within a phase of infiltration:

1. At the beginning of rainfall, the carbonate concentration of infiltrating water is reduced to its minimum, 50-80 mg/l.
2. During a prolonged rainfall event, the initially low carbonate content increases slightly (to 80-130 mg/l).
3. During the infiltration of minor rainfalls after a major event, carbonate content reaches 2-8-fold higher values than the minimum, 130-450 mg/l.
4. In the case of uniform and prolonged infiltration, carbonate content shows a daily cycle with an amplitude of 80-140 mg/l.

Detailed study of uniform infiltration allows three conclusions to be drawn (*Fig. 6b*):

1. With the intensification of infiltration, the concentration of dissolved carbonates increases in the water and the other way round.
2. The relationship between the amount of infiltration and carbonate concentration is inverse but not linear.
3. Uniform, constantly low-intensity, infiltration involves constant carbonate concentration if factors achieve an equilibrium under optimum solution conditions.

The variations of major factors of solution, temperature and infiltration, soil moisture content and the resulting level of biological activity in the soil, that cumulate in the potential carbonate solution capacity of water are shown by the curve of carbonate concentration observed for constant low infiltration (*Fig. 7*). During uninterrupted but slight infiltration, the carbonate concentration of water shows a sinusoidal curve. Concentration changes in a daily cycle, probably influenced by root respiration and temperature. The regular daily cycle of concentration is disturbed temporarily by cooling during infiltration but when infiltration acquires its normal rate, the trend of concentration is restored.

Conclusions

The observations support the conclusion that the trend of maximum solution, which reflects the joint impact of soil moisture, soil temperature and CO_2 production in the soil, controls the carbonate concentration of infiltrating water and the daily amplitude of this variation is 35-45 mg/l. During continuous infiltration there is an average of 100-110 mg/l carbonate concentration in covered karren areas. The results from the total measurement period indicate that in bare karren the further potential solution capacity due to increased infiltration with reduced dissolved carbonate amounts promotes karren deepening, while in covered karren, the increased solution under the soil points towards karren widening. Summarising, the deepening rate of bare karren is 1.3 mm per ka, while the deepening rate of covered karren is 1.0 mm per ka.

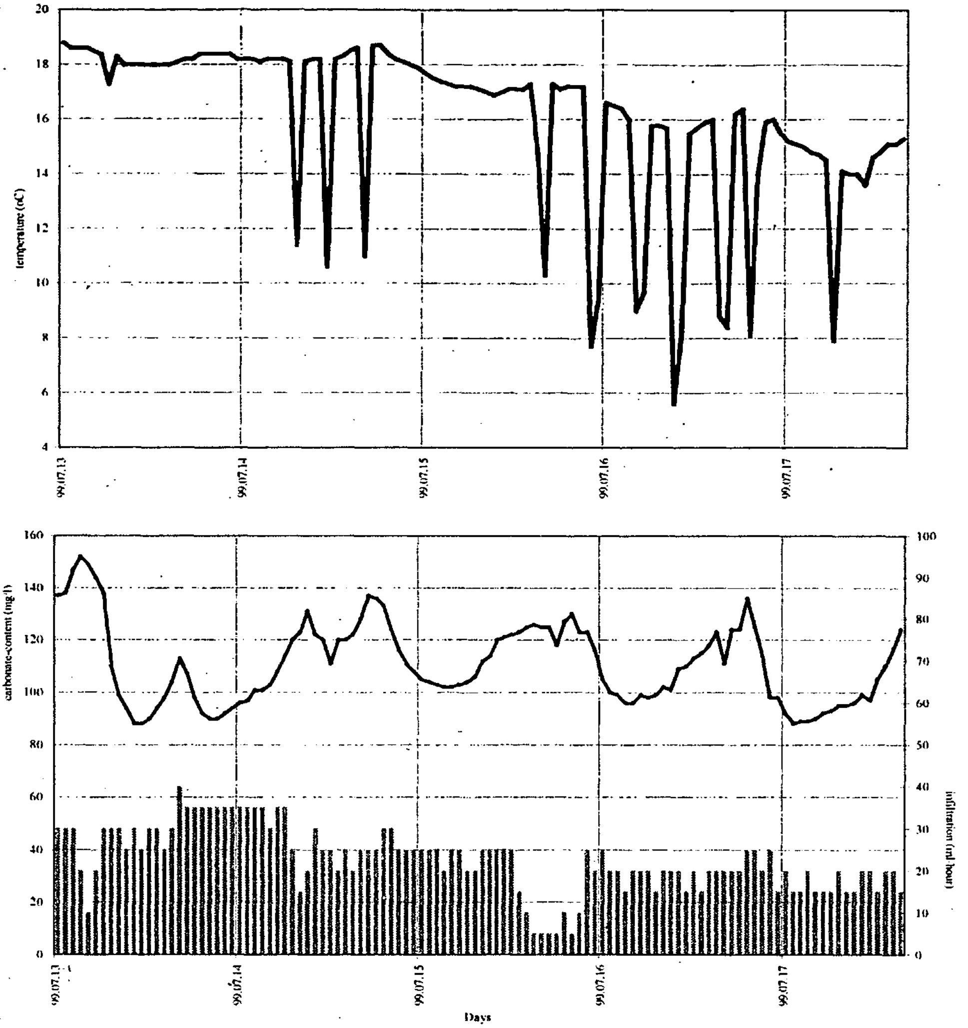

Fig. 7 Soil-temperature, carbonate-content and infiltration from the covered karren.

Acknowledgement

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