DEFORESTATION AND KARREN DEVELOPMENT IN MAJORCA SPAIN

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ABSTRACT

The development of karren landforms begins, generally, beneath a soil cover. Once the soil has been removed by erosion, former subcutaneous karren features appear at the karst surface, being reshaped by the atmospheric agents. Just then, the overimposition of the most typical bare karren features, such as flutes (Rillenkarren), meandering runnels (Meanderkarren) and heelprints (Trittkarren), produces a characteristic sharpening of the rock. In Majorca, this kind of deforestation and soil loss processes can be efficiently studied within a geographical frame in which large karrenfields are present in different topoclimatic environments.

RESUMEN

El desarrollo del lapiaz comienza, por lo general, por debajo la cubierta de suelo. Después de que el suelo es retirado por erosión, aparecen morfologías de lapiaz subcutáneo que son remodeladas en contacto con los agentas atmosféricos. Sólo entonces se produce la sobreimposicion de las morfologías típicas de lapiaz subaéreo más características, como estrías, canales meandriformes y escalones. En Mallorca estos mecanismos de deforestación y pérdida de suelo pueden ser investigados eficazmente dentro de un marco geográfico en el que los campos de lapiaz poseen una excepcinal diversidad topoclimática.

INTRODUCTION

Karren features are, probably more than dolines, the most widespread karstic landforms. If the term karren is generalized to any small-sized solutional sculpturing, as it is done in the more recent literature (SWEETING, 1972;BÖGLI, 1980; JENNINGS, 1985; WHITE, 1988; FORD & WILLIAMS 1989), every karstic terrain contains karren forms. Some of them are microscopic biokarstic features which share with the physico-chemical processes of limestone weathering a similar researching methodology. Others remain hidden under soil or buried by clastic sediments, as it happens with the typical subcutaneous karren features or cryptolapiaz (both terms can be considered synonymous). Finally, there are a great variety of karren forms, the better known, being exposed to open air so that their growth and development remain basically under the control of the atmospheric precipitations.

KARREN AND SOIL COVER IN THE EXOKARST

Most of the available literature on karren shaping processes is, nowadays, strongly biased towards those typical bare and soil-lacking karst features. These rocky environments are very characteristics of the deforested mediterranean area and also of the alpine regions, above the tree-line, where the research on karren was begun.

Obviously, the most conspicuous karren landforms are to be found on rocky outcrops on which the soil cover is less than 50 %. Even the etymology of the scientific terms lapiaz and karren reflects presumably a certain relation to the latin word lapis and the pre-indoeuropean term (stem) karra, both meaning rock. Furthermore, the sharp crests, the meandering runnels, the heelprints and flutes, that constitute the most striking karren features, are only formed when the limestone remains directly exposed to the karstic erosion of rainfall. On a larger scale, the term Karrenfeld or Karrenfield that stands for assemblages of karren landforms wider than several square kilometres wouldn,t make any sense in karstic terrains entirely covered by soil and vegetation.

Only once the pedological cover has been removed, either by natural or artificial processes,it is possible to observe the subcutaneous karren features developed on the bedrock surface beneath the soil. Artificial cuts in quarries and roads allow verification of the efficient growth of the subsoil karren (cryptolapiaz) in such an environment, characterized by the presence of high carbon dioxide concentrations as well as by a slow infiltration of water. Also, below detritic cover of glacial or periglacial origin quite similar solutional features can be formed.

The existence of subcutaneous karren features, or cryptolapiaz, was implicity assumed in several classifications of karren landforms developed on the basis of the works published by BÖGLI (1960, 1980). So three main genetic categories are distinguished: bare or free karren, half-free karren and covered karren. Later studies emphasized the role played by the subsoil corrosion in the evolution of karren morphologies in particular (GAMS, 1973) and exokarst in general (JAKUCS, 1977). Due to this, in a more explicit way, a recent publication affirmed that great areas of karren topography develop under a continuous soil and plant cover (FORD & WILLIAMS 1989); at the same time it is mentioned that many regional geomorphologic studies ignore such fact.

Among other original contributions to the knowledge about soil-bedrock interactions on karstic terrains, the subchapter titled Modifications in eroşion due to the changes in the natural plant cover of a karst region (JAKUCS, 1977) introduces a new evolutionary explanation when referring to the Aggteleki-Karszt. According to JAKUCS (1977) not only the Aggtelek karren landforms, but also the karrenfiels of the Dalmatian Karst, indicate a gradual transformation of formerly rounded and smooth shapes, produced by subsoil corrosion, towards characteristic features of sharp grooves and furrows formed in subaerial conditions. This transformation results from rock denudation, after the plant cover decay and the soil dissection advances.

A TWO-STAGES-MODEL OF KARREN DEVELOPMENT

As the available knowledge on karren development under soil has increased, the covered karren (subcutaneous karren) has ceased to be a set of solutional landforms of more or less anecdotic interest. In fact, almost every karst is or has been a covered karst. Just exceptionally, under extreme bioclimatic conditions, the exokarst evolves without any soil cover on it.

As indicated above, karstic corrosion on limestone outcrops is much more intense beneath the soil, due to the high carbon dioxide concentration registered there, and also due to the long time periods in which water remains in contact with the bedrock. It is not going too far to state the greatest amount of limestone that has been dissolved in the karrenfield over some time would have been exported when the current karrenfields were still covered beneath a layer of soil and vegetation. It is an extraordinary paradox that the most spectacular and striking landforms constituting the bare karren show potential denudation rates much lower than those corresponding to hidden subcutaneous karren. The two-stages-model for karren development assumes that the bulk of the forms observed in a karren outcrop are shapes generated when the bedrock was still buried below the soil covering. It should be remembered that, as karren sculpturing is mainly subtractive, the greater the limestone volume removed by dissolution, the greater the morphological effect will be.

When analysing thoroughly some of the main Majorcan karrenfields it is easy to find numerous hollows, pits, tubes and small cavities generated by subsoil corrosion on the sides of karren pinnacles as well as on many barren ground surfaces of karstified limestone. Such relict features of subcutaneous karren appear to be reshaped by the growth of bare karren features which modifies them substantially. Recent studies suggest that, even the bigger karren landforms, as those several-meters-high karren pinnacles of the stone forest, could have been formerly generated as covered karren (CHEN et al. 1986).

The two-stages-model for karren development assumes that under relatively steady geoecological conditions, beneath a natural plant cover and a mature soil developed in equilibrium with the climate, an intense growth of subcutaneous karren is produced. This model attributes great importance to the soil loss mechanisms because possibly these are able to override the rate of soil formation. Then, the karren morphologies generated under the soil will rise to the ground surface. Usually, the drastic increase in the rate of soil stripping corresponds to ecological crisis, as those produced by climatic changes. The deforestation provoked by man also accelerates the soil washing, as the erosion is enhanced. After soil dissection, the tops of some subcutaneous karren-pinnacles gradually emerge, being transformed by subaerial karren features. The overimposition of new solutional features generated by rainfall and runoff waters, in contact with the atmosphere, would complete this two-stages-model which can be applied in the most significant karren landscapes in warm and temperate climates.

SOME EVIDENCES FROM MAJORCAN KARST IN FAVOUR OF THE MODEL

The Serra de Tramuntana (main mountain-range of the island of Majorca) shows many evidences of the two-stages-model being valid in those karren areas located on the summits as well as in those karrenfields set on the sides and the surroundings of the mountains. All along the altitude range of the Serra, from 0 to 1400 meter a.s.l., relict features of rounded subcutaneous karren are common. At the same time, progressive transformation of subsoil-generated tubes and hollows through reshaping by typical bare karren features is observed.

In Majorca the geographical conditions are very suitable to study the relations between karren evolution and soil removal caused by deforestation processes (GINES, 1990). Due to its altitude, the Quaternary glaciations just reached to produce cold climates and small periglacial environments in the Serra de Tramuntana heights, where they could have caused recurrent bioclimatic crisis of moderate strength. Also human activity could have been an important cause of deforestation, since man settled the island for approximately 8000 years ago. Finally, the exceptional degree of karstification observed in some sectors of the Serra de Tramuntana permits to envisage a possible autodeforestation mechanism yet not stated in the bibliography: some kind of wood-subsidence promoted by vertical soil loss through large cracks widened by karstic solution.

In the Majorcan karrenfields limestones are very pure. So, a scanty amount of insoluble-minerals residuum produced during karstification generates a slow pedogenesis. If the soil formation rate is very low, any disturbance which facilitates an increase of the soil removal rate might provoke an irreversible unbalance. Climatic changes, forest destruction and easy washing of small soil particles, all along the hillslides and also through karstified fissures, are the main mechanisms which can initiate the emergence upon the ground surface of subcutaneous karren forms that appear as the soil stripping advances (Fig. 1).

BIOCLIMATIC CRISIS RELATED TO GLACIATIONS

The recurrence of permafrost and cold climate phases in the summits of the main Majorcan mountains during the Quaternary might have implied the recession of the forests towards lower elevations as well as severe damages to the soil mantle. Probably, each phase of cold climate caused a real ecological crisis at altitudes over 800 metres a.s.l. in the Serra de Tramuntana mountain-range. The substitution of forests with scrubs and grass formations, more resistant to biological stress but less protective against soil erosion, produced a progressive natural soil profile degradation in the highest areas.

When the periods of cold climate came to an end the plant communities recovery was seriously hindered by the slow rate of soil formation, as the greatest part of the Majorcan highest areas is constituted by very pure carbonated rocks in which the amount of clay and clastic debris is negligible. Moreover, the soil mantle impoverishment was accompanied by the denudation of ancient covered karren. So that the resettlement of the

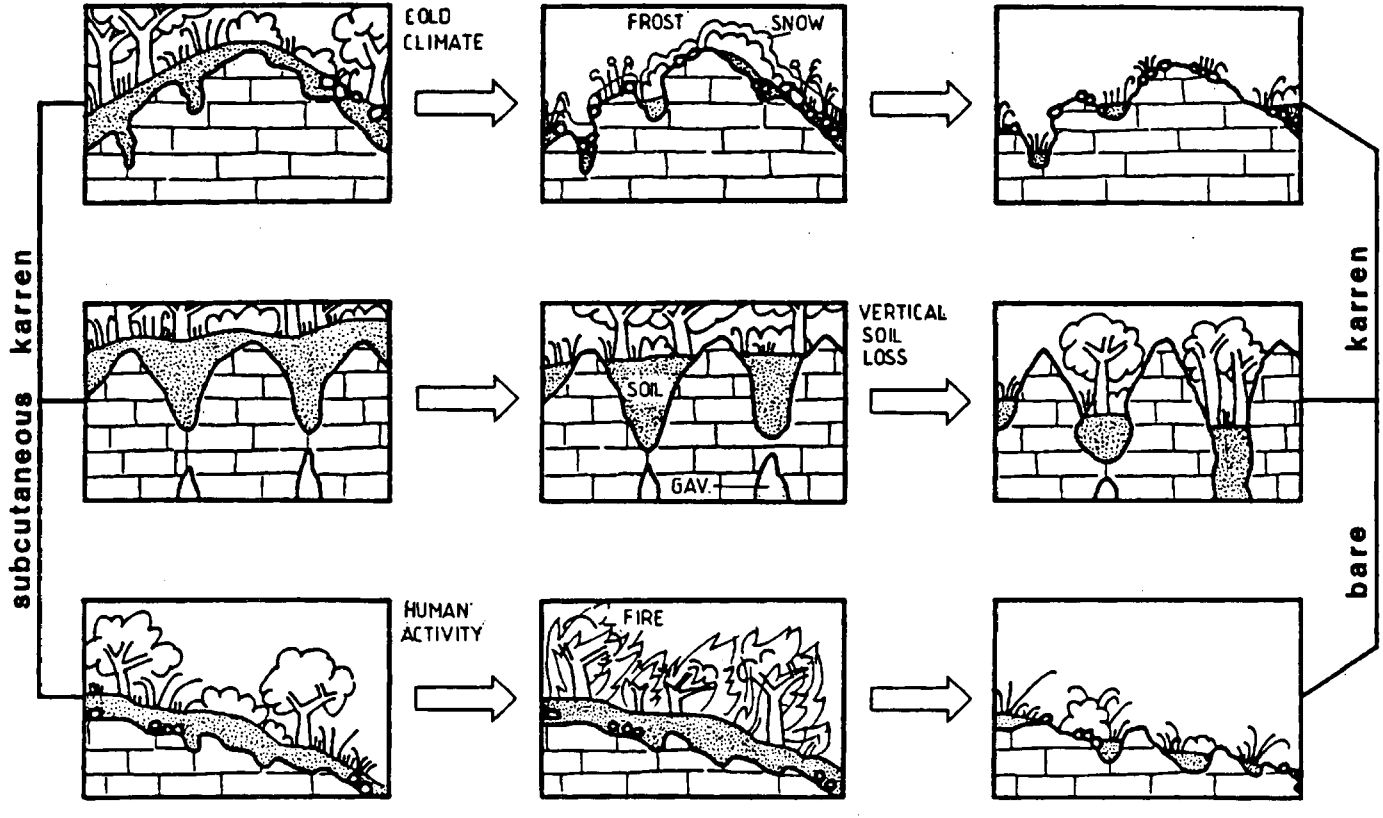

Figure 1 *Development of subcutaneous karren*

forest species resulted each time less efficient. The stony nature and sharpness of these landscapes was enhanced, specially in the areas characterized by steep slopes. Nowadays, the karren landforms located at the summits of the Serra de Tramuntana mountains (over 800 metres a.s.l.) show abundant bare karren features, with some periglacial inherited influences and with some locally dispersed remains of relict subcutaneous karren features.

DEFORESTATION AND SOIL REMOVAL CAUSED BY MAN

As a general rule human activity tends to simplify the initial complexity of the ecosystems and also tends to upset the bioclimatic equilibrium conditions that control the action of the main agents and geomorphological factors. Human settlement in Majorca, a little more than 8000 years ago, necessarily brought about changes both in the plant cover and in the predominant erosion mechanisms. It is possible that during the first four millenniums human activity had little ecological consequences. But the men of different cultures who subsequently inhabited the island produced important cattle-raising and farming changes, so causing the regression of the steady-state forests of Quercus ilex and also of the more thermophile ones of Pinus halepensis. The Roman colonization happened in 123 B.C., but the greatest agricultural changes in Majorca took place during the Muslim epoch, between the IX and the XIII centuries.

Woodfires have historically been the main cause of the plant cover decay in the Majorcan karst. To the former deforestation, due to the seeking of larger agricultural areas, it must be added the deeply rooted habit of periodically burning the brushwood in order to renew the grazing-lands. The traditional activity based on the repetitive burning of herbaceous brushwoods of Ampelodesmos mauritanica, for cattle pasturing, has become the more strong human activity in the representative karrenfields of the Serra de Tramuntana. The active soil removal produced after the deforestation and the progressive degradation of scrub formations, leads to a gradual increase of the bedrock surfaces exposed to open air. n these cases, the growth of subaerial karren morphologies is limited by the time elapsed since the dissection of the subcutaneous karren took place.

WOOD SUBSIDENCE PROMOTED BY KARSTIFICATION

In some strongly karstified limestone plateaux from the Serra de Tramuntana mountain-range, such as the one surrounding Lluc, tall karren pinnacles outstand over the Quercus ilex forest. It seems as if the forest would have sunk down among the deep spaces which exist between the karren pinnacles, accompanying the gradual soil, lowering. It would be more appropriate to talk about a "subsidence" or a settling of the natural soil-forest mantle as a whole, rather than to refer to an authentic deforestation.

The bizarre landscape resulting from this karstic process of "wood subsidence" is enough to produce intransitable groups of rocky edges and almost vertical pinnacles which rise above woodlands confined among them. On top of these limestone-pinnacles the bare karren features are remarkably developed, while 10 or 20 metres below them, at the foot of the pinnacles, the subcutaneous karren features are predominant.

The several limestone plateaux, where such a noteworthy karrenfields present moderate slopes, show well developed joint systems and furthermore they seem to have undergone a very long karstic evolution (that perhaps comes from the end of the Tertiary, according to BÖGLI, 1976). Probably a long time ago, when the limestone platform was being karstified, the surface was buried by ancient soils coming from the decay of clays, marls and volcanic rocks of the Upper Triassic (Keuper). It seems as if the intense karstification was enough to produce a substantial solutional enlargement of the main cracks until the rate of vertical soil loss through major fissures exceeded the slow current rate of soil formation on the almost pure karren-bearing limestones. From that moment on, the deepening of both the soil and its natural plant cover provoked a progressive rise of karren pinnacles above the level of the forest.

CONCLUSIONS

It is necessary to extend the karstic research on the physico-chemical and pedological processes that are involved in the development of the karren morphologies which are formed under a soil cover. Further studies should be performed in order to know the morphometry, the most significant characteristics and the distinctive diagnostic features related to the subcutaneous morphogenetic environment. It is also interesting to make carefully observations on the several phases of the sequence: deforestation - soil removal by erosion - and overimposition of bare karren features. Detailed studies of the different deforestation mechanisms, as well as of the time-span during which each one of them has been active on the Majorcan karrenfields, could allow the acquisition of approximate estimations of the rates of soil loss and karstic denudation.

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