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THE EFFECT OF "TERRA ROSSA " TYPE SEDIMENTS ON DOLINA MORPHOGENESIS

According to the investigation results of the last years it became obvious that the soils, humic sediments and permeable non-karstic rocks covering the surface of the karstic rocks play an important role in the karstic solution processes. The fact was also proved that under the bauxite sediments the formation of karst phenomena is also possible /investigations of Papastamatiou, Bushinski, Combes and others/. Under the terra rossa type sediments covering the karstic surface in a wide area the conditions are more favourable for the karstic solution processes.

In the course of my investigations the effect of the terra rossa type sediments, first of all of the Aggtelek karst, on the dolina morphogenesis was searched L. Jakucs and others related previously to the fact that connection may be presumed between the morphology of the dolina and the quality of the clayey sediments filling it.

The terra calcis type sediments of the Aggtelek karst are fossil relics and reactivated soil formations, respectively. The most important features of them were investigated from the point of view of the karstic processes and

the conclusion was drawn that during the development of the dolinas the terra rossa filling them are significant factors.

On the basis of the micromineralogical investigation of the dolina sediments of the Aggtelek karst the following results were established: According to the mineralogical genesis the terra rossa sediments are the redeposited substances of three rocks at least /certain part of them was redeposited several times/:

1. Minerals originating from metamorphic rocks: garnet with inclusions, kyanite, turmaline, epidote, clinozoisite, zoisite, anthophyllite, tremolite, amphibole of yellowish-green pleochroism; quartz of undulatory extinction; and partly the feldspars.

2. Minerals originating from igneous /presumably granitic/ rocks: ilmenite, titanite, biotite, chlorite, apatite, xenomorphic quartz with inclusions, partly the feldspars and partly the muscovite.

3. Minerals originating from volcanic rocks: magnetite, non-rounded zirkon, augite, partly the biotite, the idiomorphic quartz, the intact feldspars, and the volcanic detritus.

The crystalline and rounded varieties of certain minerals relate to two kinds of rocks; a younger and an older generation can be distinguished.

According to the DTA and X-ray investigations of the clay minerals of the terra rossa sediments the illite is of predominant role but small quantity of kaolinite and gibbsite also occurs.

Investigating the chemical composition of the substances the following results were obtained: SiO_2 = 42 to 66 per cent; Al_2O_3 = 16 to 42 per cent; Fe_3O_4 = 1,9 to 5,9 per cent; Fe_2O_3 = 6 to 16 per cent; MnO = 0,15 to 2,2 per cent.

The quantitative change of the humus content relates to the fact that the clays accumulated in the dolina were previously the soils of the slopes of the dolina. The humus content change between 0,733 and 2,849 per cent. Very high values /3,899 to 4,001 per cent/ were given by the terra rossa samples which, on the basis of their appearance, may be considered as the relics of the terra rossa rendzinas deposited in the dolina, and which were described by P. Stefanovits. These form in the dolina independent dark-coloured layers of several metres thickness. In other cases these formations were deposited in the dolina mixed with real terra rossa sediments of smaller humus content.

The pH-value of these sediments changed between 5,3 and 6,6. The potential acidity measured by KCl solvent showed different values between 4,2 and 5,7.

Having investigated the mechanical composition of the terra rossa sediments we stated that the quantity of the clay fraction may reach 72 per cent and within this value the fine clay fraction may reach the value of 50

to 57 per cent of the total value. The silt fraction changes between 15 and 25 per cent and the quantity of psammites remained always below 10 per cent.

Previously the presence of the terra rossa sediments covering the karst surface was explained by the phenomenon that this sediments consisting mainly of fine-grained and compact clay minerals exclude the underlying carbonaceous surfaces from the solution processes, because due to their impermeability they hinder the infiltration. The investigations made by perkolograph showed that the impermeability of the terra rossa type sediments depends on the grain size composition of the layer, on the quantity of the clay fraction, on the layer's thickness, position, organic substance content, further on the richness of the edaphic assemblage and presence of it, respectively.

Part of the terra rossa type sediments proved to be practically impermeable, in other part of them the infiltration became constant in a low level but only after certain space of time. The third part showed relatively good permeability.

Difference had to be made between the two kinds of appearance of the terra rossa type sediments:

1. The type, rich in edaphic assemblages and intergrown with roots and which is of relatively high humus content and of more loose sturcture showing recent soil features, is permeable for water and capillar

network can be found in it. The slopes of the dolina are covered for the most part by terra rossa type sediments of this type. The separating ridges between the dolinas and the upper layer of the dolina floor filled with clay /1 to 1,5 m thick/ as well as the slopes of the dolinas are covered by this type of terra rossa sediments. This is called in the following Type A.

2. Only the upper part of the terra rossa accumulations of thickness /2,5 to 25 metres/ is of soil structure. In the lower part the clay is poor in humus, and in the grain size composition the ratio of the clay-, and colloidal fractions is increased. In the overwhelming majority of the cases this type of terra rossa is of impermeable behaviour /Type B/.

According to our investigations the terra rossa of Type A is permeable for rainwater and the sediment is relatively permeable. During the infiltration the lime aggressivity of the water considerably increases. This phenomenon can be explained first of all by the fact that the terra rossa of Type A is densely intergrown with roots. In the course of the roote respiration these produce CO_2 and the CO_2-content of the air of the soil caves is multiplied comparing it with that of the fresh air. In addition to the CO_2-production of the roots considerable significance is attributed to the CO_2-production of the biosphere of the soil, first of all to the microorganism. According to all probabilities the CO_2-quantity originating in the course of the functions of life of the monoplastids and microbes forms considerable part

of the CO_2-quantity being in the soil and in its air. As to our hypothesis CO_2 may originate during the decomposition and transformation of the organic substance of the terra rossa layers being rich in organic substance and humus is greater than that of the layers being poor in organic substance. The more detailed investigation of this phenomenon is in progress but it can be stated that the higher CO_2-content, which is significant from the point of view of the karstic solution, could be registered, as well.

The structure of the terra rossa of Type A, rich in humus and roots, is more loose than that of the Type B, and this fact explains at the same time the relative permeability of the first type.

On the complex effect of these the lime-solving capacity of the water infiltrating the terra rossa of Type A is much greater than that of the water of rainwater. Therefore it can be stated that this type of terra rossa intensifies the solution processes of the underlying limestone so that it highly surpasses the measure of solution of the free limestone surfaces.

The accumulation of the terra rossa of Type B may be considered impermeable. Its structure is very compact, roots and higher humus content can be found only in the uppermost layers. It was observed that in the strata of the thicker dolina sediments the organic substance content decreases downwards and below 2 metres its quantity varies only between 0,7 and 1,2 per cent. The rainwater, either becoming aggressive in the upper zone binding the CO_2, cannot infiltrate the thick filling up, leastways in considerable quantity concerning the solution.

In several cases of our investigations the lowermost part of the thick layers was moist. In these cases, however, the water got the terra rossa by lateral infiltration above the limestone floor.

It can be stated, therefore, that the terra rossa accumulations of Type B surpassing the critical thickness of 1,5 to 2 metres exclude more or less the underlying limestone surfaces from the solution processes and contrary to the thin terra rossa accumulations of Type A they hinder the karst formation of the underlying rocks.

The opposing effect of two kinds of the dolina sediments mentioned above /according to the qualitative and quantitative appearance of the terra rossa/ on the karstic solution processes of the limestone surface is of important conclusions.

In the areas investigated the major part of the dolinas developed as sumps. The originally cone-shaped depression of steep slopes came into existence in such a way, partly by means of capture. Further they became the mesh of the terra rossa cover and of the terra rossa type sediments carried by rainwaters.

The terra rossa dolina sediments could display their effect in the way mentioned above.

1. The terra rossa sediments of Type A accumulated in the bottom of the dolina in thin layer either intensify the solution processes of the dolina floor or maintain the former rate of deepening. The most rapid solution may take place in the place of the leakage of

considerable water quantity, in the deepest point of the dolina, so that the reversed cone, resp. cone-frustrum type shape of the dolina remains until the accumulation of the terra rossa carried by water surpasses the critical thickness of 1,5 to 2,5 metres, and becoming impermeable it decreases the solution processes in the deepest points of the dolina.

A part of the terra rossa got the dolina is washed into the fissure and solution cave system of the limestone because the clay forms colloidal solution with water and can be easily transported. The finest clay fraction /the quantity of which is frequently more than 50 per cent/ gets the deeper parts of the karst /it can be found also in the roofs of the caves in a depth of 80 to 100 metres from the surface/ and it is deposited only in the most narrow fissures.

In the case when only terra rossa sediments of relatively small quantity get the dolina from the sediment-collecting area and certain part of this gets the fissure system; the thickness of the sediment in the dolina-floor reaches the critical measure either during a long time or by no means. In this case the deepening of the dolina continues vertically and the original cone-shaped form which is ever growing, is preserved. The downward deepening of the deepest point is promoted by the terra rossa of Type A lying on the bottom, and in such a way by the lapse of a reasonable time a dolina of large-sized filler cross section develops. Such precedents of the dolina evolution can be seen on the surface of the Nagyoldal of the Aggtelek Karst and in numerous other places.

In those cases the slopes are covered by thin clay layer, the transportation is slow, the catchment basins are relatively small, the dolinas are vertically developed and the cone-shape remained constant up to the present. According to the bore-holes the terra rossa sediment of the dolinas do not surpass the thickness of 1,5 to 2,5 metres in general, they are decidedly terra rossa sediments of Type A, and are rich in humus /dolina form No. 1./.

2. When the accumulation of the terra rossa sediments reaches the critical thickness the morphological development shows another way. The clay accumulated in greater quantities becomes Type B and due to its partial or total impermeability the water infiltration weakens at the deepest points of the dolina. The rainwater infiltrates further the contact with the compact limestone and in the narrowing edge of the dolina sediment where it does not surpass the critical thickness mentioned above. The stronly corroding water which gets across the thin terra rossa contacts the limestone at the edge of the dolina and not at the deepest point of it. The fissures of the limestone are enlarged and dissolved by this water. This leakage form may be called lateral leakage. The water acts mainly on the place of infiltration hence the deepening as well as the solving devastation are here the strongest. Certain part of the water disappears in the fissure system and certain part of it, however, goes forward under the overlying clayey strata towards the deepest point of the dolina floor, but its corrosion capacity is decreased because it reached the saturated stage. This water only uses the fissures system formed previously in the bottom of the dolina, but is it unable to widen the fissures, moreover it promotes the clogging ot them. In the course of its way it drenches

the lowermost strata of the dolina, as it was stated in numerous cases. After a longer space of time the laterally leaking water weakens and corrodes the limestone in such an extent that, with gradual break down, the deeper bottom surface of the dolina widens. In function of the progression of this process and of the deposition of further terra rossa sediments the zone of intense corrosion moves laterally outwards. The relative flattening and levelling of the dolina floor may be called the planation of the dolina bottom.

By the lapse of a reasonable time this evolution form becomes predominant in the dolinas of thick sediment mass and the original cone-shape of the dolina transforms into a wide bowl-shaped form. The dolinas of the southeastern part of the Aggtelek Karst represent this morphological type. The thickness of the terra rossa sediments in them is between 5 to 20 metres, except the marginal parts. Their sediment-collecting area is relatively large and the transportation of the sediments is rapid. The deeper zones of the dolina sediments consist of terra rossa sediment of Type B.

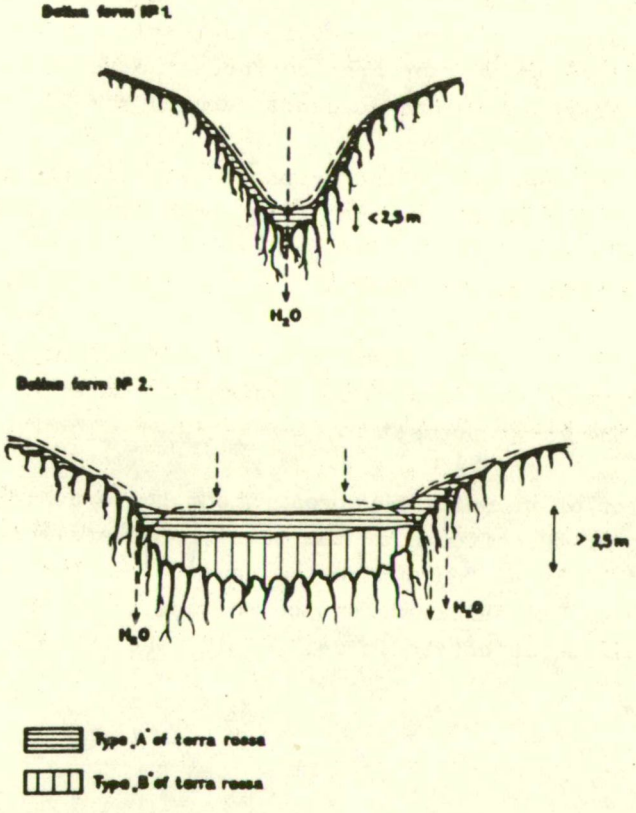
The sections of the filling strata relate to the lateral post-deepening. These strata are curved, they wedge and are sometimes interrupted and change in quality according to the fact that what part of the accumulation is the deposition place of the fresh terra rossa sediments. In case of deepening of other kind the filling strata ought to continue towards the margin of the sediment. The bowl-like appearance is further called dolina form No. 2.

As a result of the lateral evolution the lower part of the dolina cuts back more rapidly than its middle part, therefore the slopes are frequently slightly bulging. The process of bulging of the dolina sides reacts upon the devastation of the terra rossa cover of the dolina sides, i.e. on the bulging surfaces this process become accelerated and the limestone becomes barren and on this surface the karr-formation prevails.

In the course of the widening process the dolinas elogante in the indicated directions. Between the dolinas approaching each other first of all in the direction of the common lithoclases the separating ridges become lower and break down so that several dolinas may merge into one another. The relics of the ridges between them can be always found. When the clayey filling of the dolina begins to spread over the separating ridge, its corrosion accelerates for a short time until the overlying layer reaches the thickness of 1,5 to 2 metres. Due to the greater thickness of the overlying sediment the relics of the ridge preserves and it can be found at a later phase, too, on the uvala bottom surface formed in the course of merging.

In numerous places of the area investigated the phenomenon occurs that on the slopes above the present dolinas the terra rossa of Type B forms relatively thick /5 to 8 metres/ series and the former depression filled by it got vertical position comparing to the present dolina. On the basis of the fact mentioned above the explanation of this phenomenon is obvious. Where the evolution of the former karst surface formed dolinas and which were

filled up by terra rossa sediments the possibility of further deepening comes to an end. In the course of the lateral widening the place of the new break downs was put over the neighbouring areas where the thin overlying stratum promoted their formation. In certain cases the over-deepening became possible comparing the level to the former bottom surface, because the newly developed dolina having smaller sediment collecting area was filled up more slowly and the sediment of the older dolinas getting vertical position was transported into the over-deepend dolina only later, due to some kind of difficulty. The surroundings of Lake Vörös and other places show excellent precedents.



Numerous measurements were done to recognize the indirect double role of the terra rossa sediments played in solving the limestones. It must be emphasized that the solution-promoting effect of the terra rossa sediments occurs when this cover replaces the soil for the most part. The chemical changes of the water-infiltrating it and forming lime-aggressive compounds are hardly known. According to our measurements while the CO_2-content of teh air of the uppermost 30 centimetres of the terra rossa soil is only 0,1 to 0,5 per cent now in a depth of one metre this reaches 1 per cent. On the basis of this it may be presumed that the carbonic acid content of the infiltrating water increases down to a certain depth and its aggressivity is greater at those places where the soil is of 0,5 to 1 metre thickness but is permeable /on the overwhelming majority of the karst surfaces the thickness of the terra rossa sediments does not surpass the 30 to 40 cm/.

Differences are in the carbonic acid content of the soil-air according to the quality of vegetation, too. The terra rossa sediments covered by forests showed higher carbonic acid content, in general.

The effect of the terra rossa accumulations being not soil but thicker rock strata proved to be a fact dwarfing the karst formation.

A lot of transitions appear among the opposing effects and, what of the effects of the terra rossa sediments will prevail depends on the manifestation of other factors. For instance the thickness can be neither determined exactly which could be authentic in determining the prevalence of

on or another of the effects /positive or negative/ of the terra rossa sediment.

The effect of the terra rossa sediments in only one factor in the morphological evolution process of the dolinas. This effect may be promoted or hindered in closest complexity by other factors /petrographical, tectonic, pedological, hydrological, biological, geomorphological, phylogenetic, etc./. Therefore it is not to be expected that all the dolinas covered by terra rossa sediments can be assigned exactly to one of the morphological types described above. The development either prevails variably /in negative and positive forms/ in the course of its movement processes or the effect of the terra rossa sediments does not prevail and its role as evolution factor can be determined only in the given period and comparing with the effects of the other factors.

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