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PLAIN KARST AND THE BASIC LAWS OF ITS DEVELOPMENT

Karst is a wonderful phenomenon of our planet. Being the product of complex hydrochemical processes under certain natural conditions, karst presents a complex geological history of the development of the earth crust in the platform and fold structure of the continents, a characteristic system of subsurface cavities, frequently arranged in a stage pattern in a geological section. The amazing and grandiose systems distinguishing the karst landscapes of Europe, North America and Asia are particularly striking.

The global spread of karst, its occurence on differnt continents, in different climatic-landscape zones, at different altitudes, from low-lying planes to high altitude regions is accounted for by the wide spread of soluable rock, both exposed and buried: limestone, dolomite, chalk, marble, gypsum, anhydrite, mineral salts /salt karst/. According to G.A.Maximovich /1963/ the rock subject to karst processes amounts to up to 40 million km² or one third of land.

On the earth surface karst processes form a characteristic karst relief of the surface and subsurface run-off, a peculiar geological composition of rock with great masses of breccia. Karst cavity filling contains valuable and various ores, rare mineral deposits. Oil, natural gas, bauxite and other deposits tend towards karst rock.

The typological peculiarities of karst in mountain and plain areas were described by L.Savitsky /1909/. He distinguished two types of karst in Western Europe: Mediterranean and mid-European or exposed and mantled, respectively. These terms have been widely used in literature. A closer scrutiny of the typological definitions of karst, however, reveale their limitations.

If we take into account the fact that Mediterranean karst is an example of mountain karst, while mid-European reflects the features of plain karst, it is quite logical to accept the following names of geomorphological types of karst: mountain and plain karst /Stupishin, 1967/.

The author suggests geomorphological classification of karst with an account made for 16 features: geostructural, morphometric, lithological, karst rock thickness, the degree of karst deposit exposure, the depth of karst rock bedding, age, the age regenerations of karst, the stratigraphy of karst rock, the activity of karst processes, climatic, the degree of flooding /hydrological/, morphological, geomorphological, botanical, evolutionary /Stupishin, 1967, pp. 22-24/.

This paper deals with the singularities of plain karst and the main laws of its development. I.P. Gerassimov and Ya.A.Meshchryakov /1967/ have shown the principal features in the development of the Earth's relief. They distinguished two principal morphostructures of land, viz., the morphostructure of plain-platform areas and that of mountains areas /orogenic/.

The theories put forward by I.P.Gerassimov and Ya.V. Meshcheryakov /1967/ on land plain and mountain morphostructure confirm from the geomorphological viewpoint the suggested geomorphological classification of karst.

Plains constitute over 64 per cent of land, primary plains formed by practically horizontal layers of sedimentary rock accounting for 47 per cent, while denudation and socle plains representing peneplain territories of old folded structures account for 17 per cent /Gerassimov, Meshcheryakov, 1967/.

In the Soviet Union karst in socle denudation plains occurs in the Kazakh Preublic /Stupishin, 1968/. It is old and has been investigated in connection with the evaluation of the bauxsite content of the old karst relief of Central Kazakhstan. "In the great plains of the earth, however, stratum and recent accumulative surfaces predominate rather than peneplains. Their flat character reflects the platform type of relief-forming rock position" /Gerassimov, Meshcheryakov, 1967, p. 19/.

Mantled karst /as understood by Gvozdetsky, 1954, p. 330/ is typical of plain karst, since karst rock is usually covered by non-karst deposits of various lithological composition, origin, age and thickness. However at tectonically elevated spots small areas of exposed and turf-covered karst may occur.

Although the covering deposits are not subject to karsting, tney reflect with sufficient clarity the existence of subsurface karst developing in soluable rock. Its occurence is manifested on the day surface by various holes: sink holes, cavities and, often, by solution lakes. In rare cases karst rock is exposed in the hole walls. Thus the so-called "reflected karst" is typical of plain karst /Stupishin, 1967/. The term "reflected karst" stresses the dependence of surface hole shape on the subsurface karst, mantled in the case of plain karst by non-karst cover deposits of considerable thickness.

A relatively small thickness of the upper rock stage is characteristic of plain karst. It is determined by fluvial downcutting /normally 40-60 m in the Volga-Kama case/. This thickness of karst rock determines the insignificant depth of sinkholes.

Karst frequently occurs in river valleys, this phenomenon complicating the surface of aggradation terrace filling. Karst is particularly frequent at terrace joints and between the upper terraces and water divide slopes. In terrace surface areas karst occurs in superimposed erosion hollows, shallow valleys, gorge systems, forming in some places solution lakes, up to 30-40 m deep /Middle Volga

region/. Karst forms are also observed on right bank slopes of river valleys, where covering non-karst deposits are washed considerably and soluable jointy rock comes close to the surface. Longitudinal fracture trenches of gravitational karst origin are typical of such slopes. These trenches may be dozens of kilometres long, dozens of metres wide and up to 40 m deep /Middle Volga region, Angara region, Eastern Siberia/.

In the extraglacial zone of the Russian Plain stratum elevated step-like denudation plains /erosion-denudation planation surfaces/ are common. In these plains water-divide and water-divide-slope karst frequently occurs. It is characteristic of gentle and long slopes which face a river valley. In the case of the washing out and small depth of non-karst deposits on slope surfaces linear zones of hole karst forms /sink holes, cavities/ can be observed. It has been noted that the spread of karst cavity chains on slope surfaces is often associated with the jointing in soluable mountain rock.

Karst also occurs in accumulative low plains. This is a frontal apron karst in the Russian Plain /"Russian Polessie"/ which is characterized by numerous solution lakes as well as by the combination of karst, suffosion and aeolin forms of relief.

Thus in the Russian Plain which is considered to be a typical sphere of the spread and development of plain karst three main types of karst landscapes should be distinguished: I/ karst landscapes of river valleys; 2/ karst landscapes of old denudation planation surfaces; 3/ karst

landscapes of Anthropogen superimposed accumulative plains. Each of the distinguishable karst landscapes is characterized by morphologo-hydrographic and landscape singularities, by a combination of karst objects.

In karst areas one may come across the following karst types of relief: 1/ karst bed-land which is a basin-type relief with outlying hills, the outliers of primary surface; 2/ karst hummocky topography with ringed karst trenches. It is found in small tectomic structures /brachy-anticline/, composed of joint, soluable rock. Brachy-anticlines complicate the structure of platform ramparts, e.g. the Vyatka or Oka-Tsna; 3/ karst-valley topography is characterised by the regenenation of surface drainage, its transformation into a subsurface one, by the complication of a valley floor by karst cavities with sinkholes, by the presence of slope gravitation-karst belts and trenches; 4/ karst-ravine-gorge topography represents regeneration under the influence of the karst of small erosion forms /ravines and gorges/. Blind karst ravines and gorges having basin form which constantly recurs are typical; 5/ karst-lake topography. It is characterised by the presence of a large lake basin /one or more/ with steep banks complicated by karst cavities of the funnel type.

Each of the distinguishable karst topographies is characterised by local geographical landscape singularities.

Favourable orographic conditions and rugged plain topography in humid climate contribute under the conditions of karsting to the infiltration of a considerable part of surface drainage. The insignicant tiltin of soluable rock, normally constituting a few dozen minutes contributes to the

development of karst over large areas. However the mechanism of karst processes is considerably complicated by the presence of non-karsting cover deposits which are subject to stoping, subsidence and washing-out over the sink centres and along the joints into karst cavities.

Karst in plains is subjected to the structural pattern of rock. It is confined to the platform deformation of sedimentation layers. It normally occurs within positive rampart structures /placanticlines/ which are characteristic of anteclises or large positive platform structures. Easily soluable rock: limestone, dolomite, gypsum, anhydrite is exposed or lies close to the surface within the limits of the Oka--Tsna, Vyatka-Volga, Soka-Sheshma, Zhiguli Ramparts. It is stripped in river valleys. Karst disappears in the zones of tectonic strata warping due to the overlapping of karst rock by the clastic deposit layers of considerable thickness. Besides, the low surface of tectonic sag is characterised by the downcutting of the river system dissecting the surface layers.

The analysis of the spread of karst within the limits of platform structures and ramparts testifies to the unevenness of the territorial spread of karst which more frequently develops on the slopes of the positive structures of the third order /brachyanticlines/ complicating the structural field of ramparts. As many as 120 karst holes /bedding caves, cavities/ per 1 km² have been observed /TASSR, MASSR, Gorky Region, etc/. Anticline structure slopes of the lower order are composed of jointy carbonate-gypsum deposits of the Kazan stage of the Perm system. The favourable strata gradients and increased jointiness of soluable rock facilitates the active development of subsurface and surface karst on the sides of tectonic structures. The area of these struc-

tures is found to be 50-70 km² at the relative elevation of the arch of up to 50-70 m. An important factor for the development of karst within the limits of small structures is the downcutting of modern or old river valley structures.

The lithological singularities of karst rock section are vital for detecting the strata in which active karsting takes place. In the east of the Russian Platform /Middle Volga region/ there are the following variatins of combined sections of karst rock: I. Homogeneous carbonate section composed of limestone or dolomite strata. Karsting is confined to the most readily soluable stratum, e.g. "sugar-like-limestone" /Zhiguli/. This stratum is affected by cavities /caves, grottoes/. 2. Heterogeneous carbonate section composed of the alternating strata of dolomites and limestones. Limestone being more readily soluable, particularly when it has macrocrystalline structure, is affected by cavities. This carbonate breccia is formed in the geological section, the dolomite breccia being cemented by secondary calcite, appearing as a result of the solution of the macrocrystalline limestone layers /Samara Bend/. 3. Carbonate-sulphate section composed of jointy limestones or dolomites overlaying waterproof gypsums. In the case of a deeply downcut river valley /the Oka, the Volga, the Kama/ karst processes are confined to the contact surface between carbonate rock and gypsum.

The formation of subsurface cavities is due to the leasching of a gypsum waterproof layer, by active subsurface karst water. As a result gypsum caves are formed in the river valley slopes /Syukeevo, TASSR, BASSR/ and lakes /the Vyatka river valley, Kirov region/. 4. Suphate section with thin dolomite interlayers. The presence of thin dolomite interlayers allows the water to penetrate the gypsum deposit and to dissect it. As a result of gypsum leaching cave karst cavities appear over the contact surfaces with dolomite.

5. Chalk section with clay interlayers /Ulyanovsk region/. Clay interlayers are waterproof. They produce karsting stages of small depth preventing the development of a deep and thick karst.

Climatic, geographic and landscape conditions play an important role in the development of karst. Geographic landscape zoning connected with the balance of warmth and humidity is well pronounced on vast plains. Seven landscapes and geographical zones are distinguished in the case of the Russian Plain: tundra, forest-tundra, forest, forest-steppe, steppe, semidesert, desert. In accordance with these zones we should distingusih landscape-geographical types of karst. This approach is quite justified. It reflects the contemporary principles of physical-geographical zoning of the USSR territory /1968/. Thus G.Chabot distingusihed /Gvozdetzki, 1954, p. 331/ in accordance with the climatic-landscape principle "Mediterranean" karst temperate climate karst, torpical karst, humid subtropical karst and desert karst. The latter type /both plain and mountain/ is common in the Soviet Central Asia. Humid subtropical karst is well represented in Georgia /Black Sea area/. The climatic-landscape type of karst peculiar to the USSR is the one common in the "ever frost" area in Eastern Siberia /Paramuzin, 1953, Gvozdetzki, 1954/. C.Kossak /1952/ adheres to the same principle of classification as Chabot. The intensity of karst processes depend on climate humidity, the best conditions for the development of karst being, according to G.Kossak, in the typical Mediterranean areas.

Climate-landscape vertical zoning is absent from plains. However, even insignificant elevations create, because of greater humidity, better conditions for the formation of surface run-off and, indirectly, for the development of karst processes.

In the geological composition of the sedimentary cover, thanks to the calm tectonic territory development, the "levels" of old karst with old an buried crusts of weathering and with the forms of old buried karst /paleokarst, Stupishin, 1967/ are preserved. The old karst levels reflect the long-term continental stages of territory development. Continental gaps in the Paleozoic Volga-Ural anteclise are established in the pre-Famonnian, pre-Visean and, partly, Upper Permian, pre-Upper Jurassie periods and, with scouring, in the Neogene and Quaternary periods /Stupishin, Otreshko, 1967/. In view of the carbonate collector problem the knowledge of karst in the Paleosoic sections is beoming increasingly important and has already become an important subject of investigation on the part of oil, gas and other mineral resources prospectors.

Lower Mesozoic karst occurs in the Middle Volga valley /the Smara Bend/. Perm carbonate rock is characterised by extremely old karsting. Old karst zones with an overall thickness of 40 m are distinguished. The working out of karsting zones took place under the conditions of slow tectonic rising of territory during Triassic and lower Jurassic and the corresponding lowering of underground water level. Surface and subsurface forms of old karst have been studied. Karst fields of 4 km^2 with a depth of downcutting of up to 50 m, are notaworthy. Subsurface karst cavities-tunnels located 70 m below the surface are observed. They are filled with blueish-green clay containing tree-trunk gragments and pyrite druses. Humid and warm climate in lower Mesozoic period resulting in the growing of old coniferous and tree--like ferns is established by the geomorphlogical and paleobotanical method. In the crust of weathering of lower Mesozoic karst rock with high alumina content is formed /zhigulites/.

Karst is particularly wide-spread due to Alpine Orogenesis. Three big phases of neotectonic movements are characteristic of the east of the Russian Platform /Nikolayev, 1962/. As a result of neotectonic movements deep valleys of neogene scourings were downcut into the thick layer of Paleozoic soluable rock. Then they were filled with a thick layer of sand and clay formation of the akchagyl stage /Pliocene/. Terraced accumulation-erosion were worked out o in the Quaternary period. The formation of neogene-Quaternary karst is an important geological phase which created the basic features of the modern development of plain karst confined to river valleys.

The economic utilization of plain karst areas presents a very intersting problem. Karst subsurface waters characterised by a constant and voluminous discharge /over 200e/ /sec/ are successfully used for water supply of many cities and towns /Kazan, Arzamas and others/. Iubular springs coming to the surface from the deep levels of jointy carbonate--sulphate rock of the Permian system /Izhminvod, Sergievskminvod and Bakirovo spas/ possess balneological properties. Valuable building materials are to be found in karst areas and large quarries are situated there /Middle Volga region/. Oil and gas deposits are contained in karst carbonate rock of carboniferous age.

The well-known bauxite deposits in the north-west of the Russian plain are associated with the old karst cavities of Lower Paleozoic /Silurian period/. Large and numerous solution lakes are of fishing industry and as tourist attractions. Karst cavities are the sites for artificial reservoirs and are used for sports. Karst phenomena are criteria in prospecting for various raw and construction materials. Karst also has a number of negative features which must to taken into account during construction work. Observations carried out in cave laboratories are of great theoretical and practical interest.

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