FEATURES OF KARST DEVELOPMENT IN VALLEY EUPHRATES (REGION OF THE HALABIYA COMPLEX, SYRIA)

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ABSTRACT

In the valley of the Euphrates River the sulphate-marl massif of the top part of the lower farce (N_1f_1) composing bed and slopes of right and left sides of the river valley is subject to karst process. The same thickness participates in a geological structure of watershed plateaus on both coast.

In the karstological relation the territory is unique. Here under the conditions of the karst massif structure 4 types of karst are allocated from "armored" to "open" (naked). On hydrodynamic features, in the studied territory the karst forms developed and developing in the conditions of the draining influence of close erosional incisions. The territory is characterized by a spatial combination practically of all known karst hydrodynamic situations.

The morphological range of superficial karst forms is limited. On surface of watersheds and on slopes of the valley of Euphrates the polygenetic forms – karst-erosive waterless valleys in the plan having a dendritic appearance (wadi) widely represented. The majority of superficial, underground and transitional types of the karst forms – niches, grottoes, channels of pressure head (freatic) and a free-flow (vadose) overflow of underground waters is dated for various elements of valleys of wadi.

The most part of the karst cavities opened when drilling wells is dated for slopes of the valley of Euphrates. It is the most probable that it is cavities of channels of overflow of underground waters along a valley board. The opened cavities concerning their high-rise situation are divided into two groups. The cavities of the first group in the hydrodynamic relation confined to the area of modern seasonal fluctuations in groundwater levels, and the second group of cavities is confined to the area of the vertical downward hydrodynamic circulation, which was removed from the scope of the hydrodynamic activity.

On the basis of the analysis and generalization of various factors of development of the karst forms within the valley of the Euphrates River 4 types of situations of development of the recorded karst forms are allocated. Each of the allocated types and subtypes are characterized by morphological and morphometric parameters.

Key words: karst forms, genesis, karst massif, hydrodynamics

INTRODUCTION

On hydrodynamic conditions, according to typification of A.G. Lykoshin [1, 2, 3], in the studied territory in general, the karst developed and develops under the draining influence of the close erosive cuttings (near-valley karst), option of a subhorizontal bedding of the karst rocks (complex influence of a regional drain – the valley of the Euphrates River and local erosive cuttings – waterless valleys). In view of the scheme of hydrodynamic zonality of karst massifs in platform areas offered by G.A. Maksimovich [4] and detailing a hydrodynamic situation, within the studied territory the following hydrodynamic zones of the massif and conditions of development of the karst forms corresponding to them are allocated:
– a zone of near-surface circulation of underground waters (fracture-karst waters) in intensively jointed layers of gypsum which are coming to a surface or lying under rather thin cover eluvial deposits in a near-valley zone and on gentle slopes of the valley;

– a zone of the vertical descending circulation of underground waters (inside of subvertical intra sheeted and secants cracks) with elements of a subhorizontal overflow (on surface of the layers of clay and marlaceous structure, inside of the bedding cracks in sulphatic thickness);
– the zone of seasonal fluctuations of levels of underground waters – is closely connected with change of water levels in the local erosive cuttings in the near-valley zone and in the Euphrates River);
– the zone of horizontal circulation of underground waters focused from the massif to the valley of Euphrates with unloading of waters in alluvial deposits of the valley;
– the zone of subvalley (under the bed of the river) circulation of underground waters is focused in the direction of the valley, the stream channel. Uses fractures of various genesis in the soluble rocks, forming in them channels of subvalley drain.

GEOLOGICAL STRUCTURE

Within the studied territory on both river banks the karst massif is put by gypsum and marlaceous deposits of the top part of the lower farce (N_1f_1). The karst is developed in the gypsum layers. The surface sulphate-marl thicknesses is covered by alluvial gravel and pebble deposits. General thickness of gravel and pebble deposits 10-17m. The stratigraphy of gravel and pebble deposits remains problematic. These deposits are identified as a Pliocene-Mezopleistocene (N_2-aQ_{II}). Pliocene deposits are blocked by covers of basalts of focal distribution ($_{\exists}Q_{II-III}$). Within the studied territory covers of basalts have thickness 7-12m and are located on a surface of the near-valley zone and part of water separate plateau. Layers of basalt of various temporary generation are divided by pro-layers of a sedimentary origin. The ratio of pro-layers and layers of basalt assumes from 3 to 4 stages of formation of a basalt cover in the Quaternary Period. The layer of eluvial loam thickness to 6m, lying on a surface of a basalt plateau finishes the geological section (fig. 1).

Figure 1. Right bank of the Euphrates River. Roof of gypsum (N_1f_1) covered by eluvial-deluvial loam, basalt fragments ($_{\exists}Q_{II-III}$)

Figure 2. Contact zone of basalts and gypsum. Basalt-gypsum breccia. Units of fine-crystalline gypsum invest basalt fragments

It is obvious that outpouring of basalts caused high-temperature impact on the spreading deposits. As a result layers of sulfates of the top part of thickness of the lower farce were exposed to partial assimilation. As a result of high-temperature impact on sulfate-marl massif (a transpiration of the sulphatic and carbonate vapors) the high content of sulfates in loams between basalt layers, and also high content of sulfates and carbonates in Pliocene deposits under basalts was created.

Important feature of contact zone of basalts and the spreading rocks is that in this zone and, especially on the direct contacts "basalt-gypsum" the crust of secondary powdery crystal gypsum as result of boiling up of primary surface after high-temperature influence (fig. 2) was created. This feature of contact zone is important, first of all, from the hydrogeological point of view. In combination with an eluvial dense gypsum crust on a surface of plateau and erosive slopes the assimilation crust on sites of basalt cover distribution is an additional obstacle of the transfer of surface runoff to groundwater runoff.

TECTONICS AND JOINTING

Since the end of Neogene and throughout the Quaternary Period of geological history the territory developed in the conditions of the unstable tectonic mode. The mode was characterized by alternation of stages short-term vertical (positive) motions and stages of stabilization of tectonic movements with weak negative motions. Variability of the tectonic mode is confirmed by a structure of thickness of basalts where gypsum-sandy-argillaceous sedimentary layers divide thickness of basalts. It should be noted that in general for a site of researches the block tectonics which feature is motions with various amplitude of the tectonic blocks relatively each other is characteristic.

Tectonic blocks are divided by crushing zones, zones of system joints, subvertical faults of normal (seldom tear) type. Within the studied territory the borders between tectonic blocks in near- slope part of the Euphrates River valley and on its slopes are fragmentary traced by waterless valleys – "wadi" – from the North African designation of erosive cuttings with seasonal or temporary waterways.

The tectonic blocks limited by joints or faults make a structural-tectonic basis of the massif (fig. 3). In turn these rather large blocks are broken by cracks as endogenous, tectonic, and exogenous origin, forming in general a difficult network. The part of this network spatially focused in the direction to the valley of the Euphrates River was and is hydrogeologically active, optimum for development of erosive and erosive-karst processes.

Morphology of wadi valleys allows with high degree of probability to assume their karst-gravitational (corrosion and failure) origin at a stage of origin of the valley with its subsequent karst-erosive study in the direction of the localized surface and groundwater runoff. Erosive "blind" valleys of wadi at the initial stages were created by karst falls. Formation of karst falls is provoked by sharp change of level of local basis of erosion (vertical block motions) on border of the Neopleistocene and the Holocene after final formation of thickness of basalts.

Carstified gypsum layers of thickness of the lower farce (N_1f_1) are broken by cracks of various genesis – litogenetic intersheeted (bedding plane cracks), tectonic joints, cracks of relaxation of tension in the slopes of erosive valleys.

The most often karst forms meet in fracture zones "the northwest – southeast" orientations in the range of azimuths $120\text{-}130^0$ – $300\text{-}310^0$. The same direction is characteristic and for orientation of the majority wadi (fig. 4).

Distribution of joints in the massif, width of their disclosure and extent of filling variously. The coefficient of linear density of joints varies from 1,43 to 8,33. Its average value for massif 4,09. Width of joints changes from 0,04 to 0,60m. Width of cracks for the massif in general averages 0,20m. The cracks which are completely filled (extent of filling of 100%), but within some intervals, regardless of their geomorphological accessory are most often fixed, extent of filling of joints fluctuates from 30 to 100%. As filler of joints most often there is diluvial dense loam. Single joints fragmentary (to 70%) are filled with secondary gypsum, as a rule, its fibrous difference – selenit.

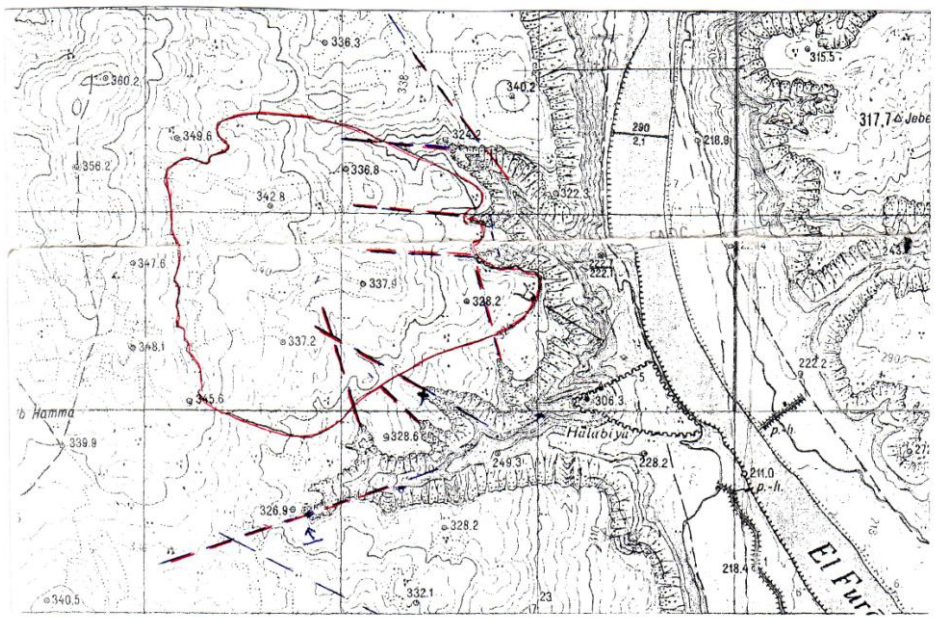

Figure 3. Fragment of block structure of the karst massif. Shaped lines – estimated axes of the faults limiting tectonic blocks

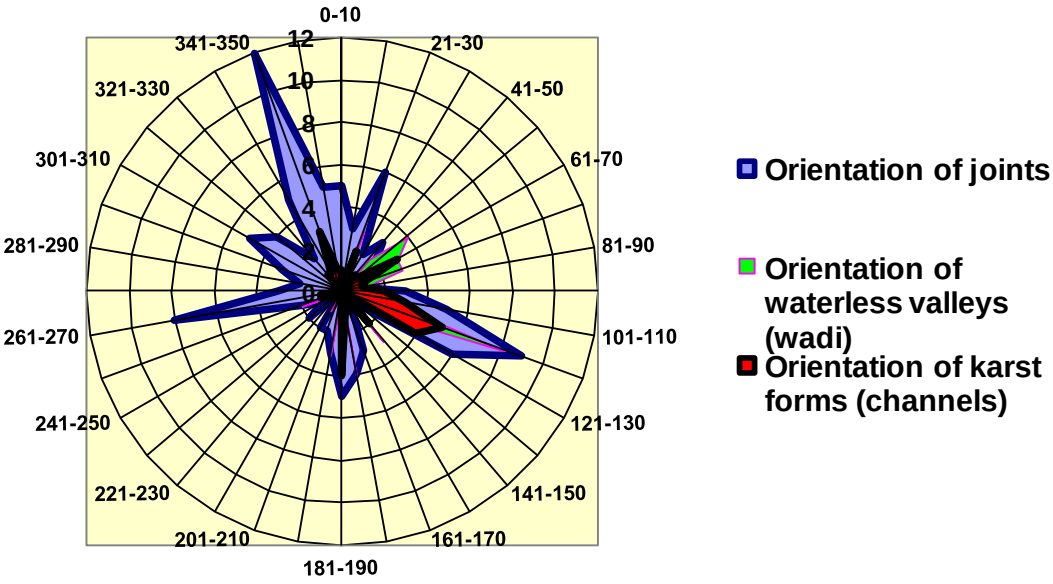

Figure 4. The cumulative diagram of frequency of occurrence of tectonic joints gypsum-marl thicknesses, azimuths of strike of waterless valleys (wadi) and karst forms

Degree of fracture dissociation of sulphate-marl thicknesses is various depending on the provision of the site opened with these or those elements of erosive cuttings concerning a slope of the valley of the Euphrates River (slope, near-slope zone, water separate plateau) and is correlated at the local level with elements of waterless valleys. So maximum values of coefficient of linear density are recorded in the rocks of the top parts of wadi (to 8,33). High values of coefficient are characteristic for mouths of branches of wadi, on average 5,09. The coefficient 4,10 (on average 2,2) is characteristic for mouths of extended wadi.

HYDROGEOLOGICAL CONDITIONS

Combination in a geological section of the jointed, water containing layers of gypsum and rather waterproof marl, lying subhorizontal, don't provide formation of the water-bearing horizon, uniform for all thickness. Results of drilling show that the waters collecting on various elevation marks of rather local water emphasis though have hydraulic communication, but are actually separated in a vertical section. The formed pressures have local character and are connected with degree fracture permeability of this or that layer of gypsum during the periods of year abounding in water. The jointing in the thickness of gypsum provides its permeability in the range of coefficient of filtration of 0,006-0,43 m/days. The coefficient increases in constantly washed out part of the massif – lower than a surface of the III-IV terraces on 30-60m where reaches 16,5m/days. Rather weak degree of karst manifestations of near-slope zone is explained by that in the studied territory in the top part of the karst massif during periods of year rather abounding in water the surface runoff prevails over groundwater runoff (average value of surface runoff of 5,4 l/sec./sq.km), and during the dry periods the groundwater runoff in this part of a section is practically absent.

Underground waters in the conditions of slow movement to the valley Euphrates or to valleys wadi quickly are sated sulfate-ion and lose ability to dissolution. The high mineralization characterizes waters of gypsum-marl thickness: from 3,5 to 27 g/dm^3. A mineralization on average across the territory – 6 g/dm^3. In gypsum with permeability from 15m/days and above the mineralization decreases to 3-4 g/dm^3. Underground waters get a pressure and decrease in a mineralization up to 2,6-3,7 g/dm^3 closer to the central part of a bottom of valley of the river.

Considering that fresh waters are characteristic only for stream of Euphrates (0,4 g/dm^3) and a narrow strip within deposits of flood plain (to 1 g/dm^3), the effect of "dilution" of waters of gypsum-marl thickness and increase of their aggression to gypsum is observed only on sites where stream of the river approaches most close to the gypsum-marl rocks of bed of the valley. On other, not "washed out" sites, waters in an alluvium deposits can be sated with salts to 30-35 g/dm^3 even within a high flood plain.

KARST FORMS AND FEATURES OF THEIR DEVELOPMENT

Karst in near-surface part of the gypsum-marl rocks thickness. The open or naked type of karst is developed within slopes of the valley of the Euphrates River and within slopes of large (main) valleys of wadi in their average and top parts, free from slope deposits.

Feature of development of processes of dissolution in these conditions is that fact that here the speed of developing of gypsum eluvial is much lower than the speed of erosive processing on surface of gypsum. Here everywhere there are fragments of shapeless subvertical and subhorizontal channels. The configuration of walls of the channels and small originally spherical and hemispherical small cavities underwent gravitational change. Gypsum layers contain a set of caverns.

Eluvial thickness of gypsum in hydrogeological and geological-karstological relation carries out functions of the top part of an epikarst zone – absorption of surface runoff , its transfer to groundwater runoff and redistributions between the water carrying out joints [5]. The shielding thickness function is not less important. Underlying gypsum are closed from intensive influence of agents of physical weathering. Also the dissolving impact of atmospheric waters and the absorbed waters of surface runoff on underlying gypsum weakens.

On contact of weathered gypsum with the high density of joints of weathering with notweathered gypsum density of joints sharply decreases and the subvertical drain of water changes the direction on subhorizontal, directed towards valleys of the river and wadi. As a result in the lower part of weathered gypsum thickness the channels of subhorizontal orientation are formed. Channels are formed on crossing of joints of weathering and of a bedding plane. Channels in cross section have a form of the semicircle lying the basis on the bedding crack plane. The cross

sizes of channels change from 30 to 50sm. Both cracks of bedding and channels are often filled by loam. Extent of filling to 100%.

The morphological range of the superficial karst forms of an epikarst zone is very limited. The largest polygenetic forms are presented by a karst and erosive log waterless valleys (wadi). These wadi are independent elements of a landscape, and their spatial development is controlled by elements of tectonic structure of the massif. To valleys of wadi the majority of actually karst forms – niches, grottoes, fragments of channels of pressure head (freatic) and a free-flow (vadose) subhorizontal and subvertical overflow of the underground waters, joints expanded by dissolution, microkarrens is dated (fig. 5,6).

Figure 5. The right bank of the Euphrates River, the valley wadi Halabiya. Microkarrens of selective dissolution

Figure 6. The right bank of the Euphrates River, the valley wadi Halabiya. Mouth of the erosive-corrosion channel of overrflow of the joint-karst waters along a board of valley wadi

Karst in weak weathered gypsum-marl rocks thickness. Thickness is opened fragmentary in steep slopes and on the bottoms of valleys wadi. Exposures on the front often have the step character which is built up by erosive and corrosion terraces on a roof of the layers covered by diluvial loam. Sometimes thickness is opened in the form of steep exposures which height fluctuates from 4 to 8m and in the form of a miniplateau (the leveled surfaces of a roof of layers) at the bottom of valleys wadi which surface is free from slope deposits.

The studied part of the massif doesn't contain large karst forms. The recorded karst forms are fragments of rather ancient cavities and are located in middle or top parts of steep banks of the valley of the Euphrates River. The largest forms are presented by grottoes and niches. Their average height is 1,3 m, and average extent 1,9m. Underground karst cavities are in the thickness opened when drilling and have the vertical sizes from 0,4 to 4,6m. Cavities concerning their high-rise situation (in absolute marks) are divided into two groups: cavities in a high-rise interval 184,0-211,0m (from a sole of erosive cutting of the valley to Euphrates River level) and cavities in an interval 211,0-234,0m (from Euphrates River level above). All cavities are revealed when drilling in near-slope part and in a sole of slopes of the valley of the Euphrates River.

The first group of the cavities is recorded on failures of the boring equipment. The vertical sizes of cavities change from 0,3 to 4,6m. Cavities, as a rule, without filler. In the hydrodynamic relation it is cavities of a zone of subvalley (under the bed of the river) circulation of underground waters. Cavities are focused in the direction of the valley, the bed of the river and formed along cracks of ground on the sites put by soluble rocks, forming in them channels. The most probable age of cavities – the Holocene.

Cavities of the second group are filled with loam with inclusion of the fragments of gypsum, dense clay, and in certain cases gravel and pebble material. These cavities were formed also, as well as cavities of the first group, in zone of subvalley circulation of underground waters, but in the course of deepening of the valley of the river were brought out of the sphere of hydrodynamic activity and filled with autochthonic and allokhtonny material. The vertical sizes of cavities change from 0,4 to 2,7m. The most probable age of cavities – Pleistocene.

It should be noted that degree of deep karstification decreases from water separate plateau to the slopes of valley. According to drilling the maximum degree of karstification of gypsum-marl rocks thickness observed in the slopes of the valley of the right and left banks (coefficient of deep karstification from 9,5 to 12,0%). The minimum of karstification (coefficient from 5,5 to 3,1%) is observed in the depth of near- slope zone on removal 0,4-1,2km respectively from a slope brow.

CONCLUSION

Spatial localization of the karst forms, their morphological set, morphometric parameters, lack of typical karst forms (sinks) and forms caused by rather long period of development of karst process (floor, difficult in a planned projection) testify to some features of karst development.

The structural and geological structure of gypsum-marl massif and its hydrogeology are limited the possibilities of realization of karst process in the form of large cavities or difficult karst systems (caves).

On development time the karst forms share on two groups. Forms of the first group, allegedly Eo- Neopleistocene age, are dated for the top and middle parts of the slopes of large wadi, to a middle part of banks on contact of the gypsum layers and alluvial deposits in the valley of the Euphrates River are lower of seasonal fluctuation of levels of underground waters zone.

The second group of the karst forms – Holocene (modern). Forms of this group are dated for the lower part of slopes and at bottom of valley wadi with the developed longitudinal profile of rather regional basis of erosion. These forms are characteristic and for drive, whose longitudinal profile is formed now (suspended mouths in the middle parts of slopes of the valley of Euphrates). The forms (as a rule, the channels) providing the subvertical descending and subhorizontal overflow of underground waters in the near-slopes zones also belong to this group. In group of the modern also the cavities which are formed in the banks of the valley of the Euphrates River within a modern zone of seasonal fluctuation of level of underground waters and in bottom of the valley are carried.

Surface karst forms are presented by karst-erosion waterless valleys (wadi), erosion and karst niches, corrosion grottoes, microkarrens.

Underground forms of epifreatic and hypogene zones are most often presented by vadose and freatic channels. Everywhere the joints expanded with dissolution meet.

Under the terms of structure of karstified thickness and on nature of the cavering deposits are allocated:
– an armored karst on sites of development of basalt cover;
– it is covered-blocked karst on sites of lack of basalt cover where gypsum-marl rocks thickness is covered with deposits of Pliocene or alluvial-diluvial cover of an Early Pleistocene;
– an open (naked) karst on sites of water separate plateau and in bank where sulphatic layers come to a surface or are fragmentary blocked by a thin cover eluvial-diluvial deposits by thickness to 1m;
– covered karst, within development of alluvial thickness – the suballuvial karst in gypsum-marl rocks thickness in the bed of valleys of the Euphrates River.

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