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GROUNDWATERS AS A NATURAL LANDSCAPE ELEMENT

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In the presented study the author deals with the relationship of geography of groundwaters. Groundwater as an element of nature with its occurrence and circulation relates to geographic environment and their interaction therefore is to be evaluated by methods of physical geography. The research of groundwaters must start from the macro and microstructures of the relief, rains and circulation paths of the hydrophysical environment. In evaluating the interaction relationships one has to start from the relief macrostructures in the following sequence: plains, mountain basins and plateaus.

Groundwater can be studied from various aspects, in concentrating on its various features. One of the possible aspects is the geographic one. Geography as a landscape science studies groundwater as one of the landscape-system element. It does not study groundwater as such, but the network of relationships, which connect groundwater with the other landscape elements. It studies its relationships to rocks, relief, climate, soil, surface water, vegetation, as well as to society. This, in truth, is but a very gross outline of relationships. The mentioned landscape elements affect groundwater through certain relevant properties from the groundwater standpoint. They are, for ex., permeability, sepage (total infiltration and substratum capacity to receive water). The spectrum of these relevant properties is very wide and variable. It changes in space and time.

The geographic approach to groundwater can be indicated as synthetic, because it tries to incorporate groundwater to the widest possible variable network of relationships. In this sense it differs from approaches, which can be indicated as analytical and which concentrate on one or only some relationships, penetrate into its depth and details without the intention of widening the spectrum of relationships. Predominantly thus is oriented the research of groundwaters, for ex., in hydrogeology, hydraulics, hydrochemistry, engineering hydrogeology, etc. In spite of a different approach the analytical and synthetical researches of groundwater are not contradicting, but completing. The priority of a synthetic approach is that it can study with more detail the

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groundwater space and time variability, resulting from its varied position in the landscape system (4).

In this short study the synthetic geographic approach can be applied in its entire extent. We concentrate our attention mainly to relationships between grounwater, rocks and relief.

Within the frame of a geographic approach we study groundwaters in the context with natural units (plains, basins, plateaus, mountain ranges), which modify the processes of groundwater refilling and circulation and which form in them for themselves their own circulation and accumulation regime (10). Spatially, horizontally and vertically, the modification may be often hydraulically equal or variable. Based on morphologic boundaries and vertical articulation of the area we determine the influence of precipitation on groundwater refilling, meanwhile the basic factors are the magnitude and time distribution of precipitation, the propensity of the cover to filtrate water and the rock environment capacity to receive it. The criterium within the frame of circulation paths and accumulations is the local erosion basis bounded by the highest and the lowest axis point of the main river course in the drainage area. Thus we will obtain a notion and map representation of three basic types of groundwater refilling: areas with groundwater refilling solely from precipitation, areas with groundwater refilling solely from higher situated neighbouring areas and areas with groundwater refilling from rivers, lakes and water reservoirs (13). Between them there are different varieties of seasonal and long-term groundwater refilling. The simplest refilling from precipitation is in the mountain ranges, the most complicated in the flood-plains, partly also in the basins. This entire cycle is considered as the hydrologic-hydraulic process, which takes place on the terrain surface and passes to the substratum aquiferous environment, where various quantitative and qualitative factors are added (10). Fig. 1 presents the basic diagram of structural systems. System elements and varieties at a lower level of division may be many.

Fig. 1 shows the illustration of precipitation waters basic balance distribution and their circulation-accumulation paths in the substratum conditioned in the first place by physical-geographical conditions, the relief geomorphologic structure, by its profile, cover and other factors.

We do not and cannot deal with all the shades, which we should and could study in the terrain from the hydrography standpoint, in order to know the real natural conditions in the landscape related to water interaction with it, but we will bring out only those, which in the other science disciplines are valued only marginally.

Plain areas are quite often divided (in the territory of Slovakian regularily) into flood-plains, flood-plain terraces and hilly countries (8). They are the biggest reserves — accumulations of groundwaters with unconfined level, bound to fluvial accumulations of gravels and sands. Below them in the underlying Neogene sediments — in layers and lenses of sands or fine-grained gravels there occur waters with confined artesian level (12). In hydraulics and in drawing diagrams of mathematical and hydraulic models the aquiferous environment is usually considered horizontally and vertically as a homogeneous environment, to which a certain thickness is attributed on the basis of investigation of a relatively small extent, hydrophysical rock parameters are calculated, as the coefficient of permeability, the coefficient of flow and active po-

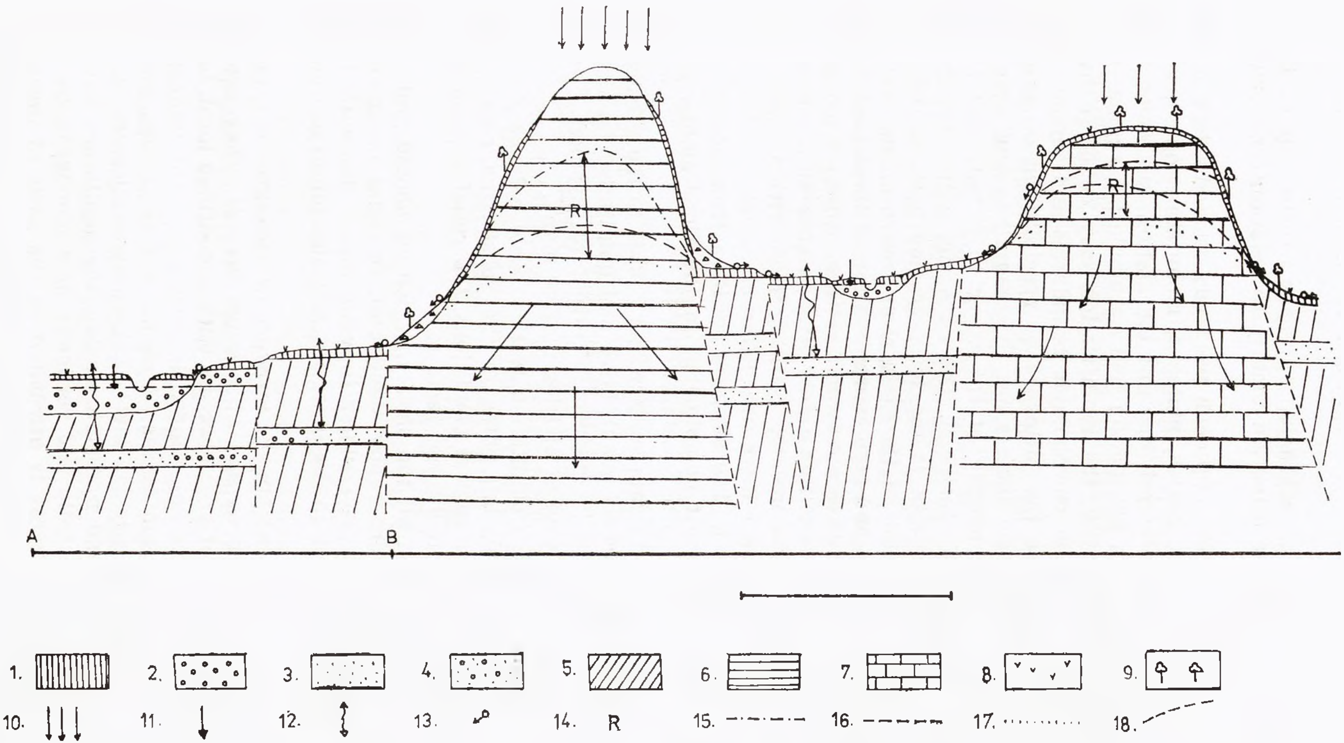

Fig. 1. Geoecological Landscape Natural Types. *A* — Intramontane lowland landscape of moderate zone, *B* — Mountainous landscape of moderate zone: *1* — covering loams, *2* — gravels, *3* — sands, *4* — gravel with sand, *5* — impermeable sediments (clays, merls), *6* — various solid rocks (sandstones, conglomerrates, granites, etc.), *7* — various solid rocks (limestones, dolomites, etc.), *8* — slope sediments and talus, *9* — forests and vegetation, *10* — infiltration of rain waters, *11* — flow and passages of groundwaters in the rock environment, *12* — horizons of artesion waters, *13* — springs, *14* — fluctuation of groundwater levels, *15* — maximum groundwater levels, *16* — medium, average groundwater levels, *17* — minimum groundwater levels, *18* — fault tectonic lines.

rosity (which has presently numerous, frequently unrealistic indications) and determined are, for ex., the reserves of groundwaters by various calculation methods. In this process it is forgotten that laboratory diagramatic modelling cannot replace even from far the dynamic reality of nature, which under multiform influences changes harmonically with the remaining components of nature — mainly with rains, flows in surface water courses and with the change of facies of the aquiferous environment through the influence of polycyclic sedimentation, in which isotropic environment alternates the anisotropic one in the vertical, as well as in the horizontal position.

Little space in the research of groundwaters in plains is left for morphologic depressions, dead channels, island area (e. g. on the Danube), interfluve areas, dunes, or winddriven sands. And it is evident that each of these morphologic forms has its specific relationships with the groundwaters. Dead channels, equally as terrain depressions can seasonally bind (or accumulate) and seasonally refil groundwaters. Their relationships with the groundwaters are given by their magnitudes, depth below the terrain, relationship with the groundwater level, with their tectonic or depression occurrence, way of refilling and drainage of their waters, etc.

The same applies and still in a greater measure to old dead and actual channels of rivers and brooks. We know that old dead channels, though frequently burried, levelled with the surrounding terrain, had in their past development in the bed and river bank sedimentation gravels and sands, which even now privilege parths of flow and accumulation of groundwaters. Known are cases (in the Váh river flood-plain of the Ilava and Trenčín basins), where sedimentation of gravels and sands in the beds of old channels, today invisible already, has greater thicknesses of aquiferous gravels and sands and greater groundwater reserves than have the surroundings of the recent water course (15). In the territory of Slovakia they are usually the right-sided flood-plain areas, where in the formation of the river network, rivers cut deeper their beds in the impermeable underlier. The flood-plain areas of certain rivers are directly interlaced with old beds and channels. Their occurrence and existence were given the name „derivation of river beds“. In this derivation it is necessary to study gradually all the old beds. In the research of the Danube area several generations of old beds of the main course were found on the right side, as well as on the left one according to what hydrologic activity in that or the other time had the Alpine or the Carpathian rivers under the simultaneous subsidence of the Neogene basin.

In the lowland areas a particular activity in the interaction with the groundwaters is represented by the wind-blown sands, their genesis, extent, lithology and petrographic composition, surface cover, their hydrophysical properties, etc. They occur mainly in two genetic categories — with predominance of sands to pure sands and with predominance of loamy particles above the sandy ones. They form typical morphologic formations of the terrain and their relationship with the groundwaters is variable. Sometimes they are deposited directly on loams of older terrain above the level of groundwaters, sometimes they are rooted below the level of groundwaters, they occur also below the terrain. Usually they are relatively a good infiltration environment for rain waters, which flow through them down to the level of groundwaters. When they are deposited directly on the impermeable underlier, as it is frequent in the Záhorie lowland, they form springs on their margins, or line points of issue and wet grounds. Within the frame of complexity studied are all the modifications of blown sands and their relationships with groundwaters. In this sense the hydrologic and hydrogeologic research neglects relatively blown sands and their importance in the enrichment of water reserves.

An important morphologic element in lowlands and basins are terraces and alluvial cones, which are significant systems elements of the hydrographic research with an independent refill in groundwaters, an independent regime and quality. Terraces and their treads can be determined with a relative ease by morphologic methods. More exacting for research are the alluvial cones, whose heads reach deeper down in the lowlands and may merge with the fluvial plain by sedimentation. The study of groundwaters and their genesis in terrace and alluvial cones is relatively more complicated as it would seem. Here often of help is the different water chemism, which nearly always differs from itself in certain components. In the hydrogeographic study of terraces it is necessary to pay attention to spring issues below their edges in the passage to flood-plain areas, eventually line passages of groundwaters to wet grounds, or directly to flood-plain groundwaters. In alluvial cones the occurrence of springs is single, because the groundwater level in them merges continually with the water level of flood-plain sedimentations. Lower and higher terraces, same as the alluvial cones form frequently together with the flood-plain even a continual area between neighbouring morphologic units and groundwaters. Alluvial cones, as well as terraces drain slope and débris springs quite frequently by hidden water passages.

Of a great importance in the study of groundwaters in lowlands are the interfluve areas and the density of river network. The density of river network proves also the existence of small or big basins of groundwaters, which are interconnected with surface waters in the river beds. The interfluve areas are particular horizontal water-divides between individual water courses. Their shape and size varies seasonally or periodically, according to the hydrologic activity of respective water courses. Groundwaters of the interfluve areas form their own hydrologic characteristics, which reflects more frequently the influences of the water course more active hydrologically. In the territory of Slovakia these relationships can be studied in the Danubian lowland between the Váh, Čierna voda and the Danube and in the Eastern Slovakian lowland between the Topľa and the Ondava, as well as between the Ondava and the Laborec. The hiatus of the river network or its little density form the dry steppe land.

The influence of physical-geographical factors on the infiltration of rain waters to groundwaters and their accumulation in the geographic environment manifests itself very markingly in mountain ranges. One can assert that most shown in the mountain ranges are the primary interaction relationships between water and the morphologic structure of mountain ranges. One can also affirm that without the study and knowledge of physical-geographical phenomena and morphologic surface forms, it is impossible to know the laws of interaction of the main hydrologic balance components as are precipitation, evapotranspiration, infiltration, discharge and total losses. The present discrepancies and „deficiencies" in hydrologic balances of mountain ranges are due to quite accustomed methods of research, which reposes mainly on the evaluation of discharges in water courses and on the yield of springs measured ununiformly, as well on the precipitation of uniform planar distribution. The area surface is taken in km^2 without regard to the contrasting morphology, shape of the mountain ranges is not considered, deep forks and valleys, slope dip, character of ridges, summits, peaks and saddle-backs, height and thickness of moraines, troughs, glaciers, etc. What regard mountain plateaus, except karst areas, not considered are their size, discordance of geological deposition conditions, exposed rock environments, forest cover, precision of hydrologic waterdivides, relationships between individual valleys, etc. Within the frame of mountain range hydrologic balances still many hydrofactors are to be studied and confronted, in order to make the total balance as near as possible to real values. It is to be noted that the best known in practice is the hydrogeologic balance of karst areas, which after the Quaternary fluvial deposits are the second greatest water yield reserve of drinking waters and therefore a greater attention was paid to their study.

In setting up the balance of underground discharges it is necessary to study first the terrain, its morphologic structure and start from the vertical control map, in order to grasp that a km^2 of an area is not a km^2. A completely different balance value have mountain plateaus and wide ranges from ridges, cliffs and peaks. It was proved hydrologically and hydrographically that extensive plateaus and wide ranges with grassy growth, grassy soils and bushes of bilberries are capable to bind substantially more rain water and distribute it more longly into groundwaters than mountain ridges or peaks. This real transformation process of rain waters to ground waters balances their quantities in longer periods, eventually even permanently. The rain water fallen on ridges, respectively on peaks and cliffs is accumulated and transformed in major part to groundwaters only in lower positions in moraines, troughs, where it may form a system of springs, meanwhile it is frequently the same water. The most recent researches prove that areas of mountain plateaus even on flysch rocks or crystalline rocks by the size of the underground discharge and favourable precipitation conditions may near even mountain ranges with carbonate rocks. In mountain ranges with solid rock morphologic and petrographic different conditions it is necessary to study mainly the rock jointing and the zone of weathering, its disintegration and depth, as well as the discordance of deposition conditions. Discordance of aquifers may change directions for groundwater flow from one side of the hydrologic river basin to another and known are also such cases of piracy of groundwaters, in which water from brooks of one valley down the favourable dip of aquifers flows to the neighouring valley and forms there springs or refills the discharges in a lower situated brook. The indicated facts existing really in natural environment overvalue the discharges of brook of one mountain valley without autochthonous precipitation at the detriment of another valley, where the rains fell.

An interesting relationship, which must also be studied closer within the frame of hydrography, is that between storm waters of mountain ranges transformed to surface discharge by brooks flowing in basins and lowlands, where by infiltration they enrich the reserves of groundwaters in their balanced or low levels, mainly in dry periods. It is a current phenomenon in our territory and it has not yet been balance solved — by how many m^3 of water are thus enriched the reserves of groundwaters, of lowlands by surface and groundwaters from mountain ranges.

An idependent research problem are the hydraulic relationships of mountain range groundwater passage to deep flow, where the waters are metamorphosed to mineral and thermal waters. Even these waters belong to the total balance flow, but there are few reliable methods to detect their paths, as well as to determine quantitatively their volume (12).

The intent in this work was to point to the tasks of hydrogeography within the frame of physical geography and to the necessity of systems approach to the research of interaction relationships between precipitation and their transformation mainly to groundwaters in various morphologic and morphogeologic units. Pointed was solely to the most basic problems. Meanwhile we drew attention to the importance and theoretical justification of systems study of all phenomena and relationships, which affect or induce interaction relationships mainly of groundwater with the natural environment.

REFERENCES

1. ANUČIN, V. A.: Teoretičeskije problemy geografii. Geografiz., Moskva 1960. — 2. DEMEK, J.: Teoretická geografia: princípy a problémy. Studia Geographica, *46,* Brno 1974. — 3. DRDOŠ, J. a kol.: Geosystémy a ich úžitkové systémy. Záverečná správa Geografického ústavu SAV, Bratislava 1980. — 4. DRDOŠ, J., URBÁNEK, J., MAZÚR, E.: Landscape Synthesis and their Role in Solving the Problems of Environment. Geogr. Čas., *32,* 2—3, 1980. — 5. HUBA, M.: Stabilita (dynamická rovnováha) krajinného systému, Geogr. Čas., *36,* 3, 1984. — 6. LUKNIŠ, M. a kol.: Slovensko II — Príroda, Obzor, Bratislava 1972. — 7. MAZÚR, E.: Geografia — krajina — životné prostredie. Životné prostredie, *11,* 1977. — 8. MAZÚR, E., LUKNIŠ, M.: Geomorfologické jednotky, mapa 1:500 000, Atlas SSR, Bratislava 1980. — 9. MAZÚR, E., DRDOŠ, J., URBÁNEK, J.: Krajinné syntézy a ich význam pri tvorbe priestorových štruktúr životného prostredia. Životné prostredie, *14,* 2, 1980. — 10. MAZÚR, E., KRIPPEL, E., PORUBSKÝ, A., TARÁBEK, K.: Geoekologické (prírodné krajinné) typy, mapa 1:500 000, Atlas SSR, Bratislava 1980.

11. PORUBSKÝ, A.: Prehľad o vodnom bohatstve Slovenska. Geogr. Čas., *2,* 1969. — 12. PORUBSKÝ, A.: Vznik minerálnych vôd a zvláštnosti ich tvorby na Slovensku (in Rebro A. a kol.: Vody osviežujúce a uzdravujúce), Osveta, Martin 1979. — 13. PORUBSKÝ, A.: Hydrogeológia, mapa 1:500 000, Atlas SSR, Bratislava 1980. — 14. PORUBSKÝ, A.: Podzemné vody Slovenskej socialistickej republiky. Geogr. Čas., *2,* 1981. — 15. PORUBSKÝ, A.: Typy podzemných vôd, mapa 1:750 000 Atlas SSR, Bratislava 1980. — 16. TARÁBEK, K.: Klimaticko-geografické typy, mapa 1:1 000 000, Atlas SSR, Bratislava 1980.

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PODZEMNÉ VODY AKO PRVOK PRÍRODNEJ KRAJINY

Jedným z významných hľadísk štúdia podzemných vôd je aj geografické hľadisko. Geografia ako veda o krajine študuje podzemnú vodu ako jeden z prvkov krajiny — systému. Skúma jej vzťah k horninám, reliéfu, klíme, pôde, vegetácii, povrchovej vode a konečne aj k spoločnosti.

Geografický prístup k pozemnej vode možno označiť ako syntetický, lebo sa snaží začleniť pozemnú vodu do čo najširšej variabilnej siete vzťahov. V štúdii je sústredená pozornosť najmä na vzťahy medzi podzemnou vodou, reliéfom a substrátovými horninami, ktoré sú jej obehovými a akumulačnými faktormi. Pri tomto štúdiu vychádzame zo základných makroštruktúr reliéfu v následnej postupnosti: nížiny, kotliny, pohoria a horské plošiny. Uvedená schéma je znázornená na obr. 1, kde názorne vidieť základné bilančné a distribučné prvky zrážkových vôd a ich obehovo-akumulačné cesty v substráte.

Každá morfologická štruktúra má vlastný obehový a akumulačný režim podzemných vôd, ktorý sa môže medzi štruktúrami prejavovať kontinuitne alebo diskontinuitne, trvale alebo sezónne. Hranice medzi nimi môžu byť geologicko-tektonické, ale aj erózno-morfologické.

Základné formy reliéfu (nížiny, kotliny, pohoria, plošiny) modifikujú procesy tvorby, obehu a akumulácie podzemných vôd tak vo vertikálnom, ako aj v horizontálnom smere. Základné formy reliéfu členíme ešte na formy nižšieho radu, napr. pri nížinách sú to terasy, pahorkatiny, kužele, priehlbne, staré ramená, pieskové duny a pod. Každá z týchto foriem má svoj zvláštny vzťah k podzemným vodám. Podobne je to pri pohoriach, kde morfológia vytvára hrebene, sedlá, chrbty, štíty, morény, trógy a hlboké doliny. Aj tu vidíme veľmi diferencovaný vzťah podzemných vôd k morfologickej stavbe. Na rozsiahlych plošinách, najmä na krasových, môžeme zasa študovať celkom iné hydrografické javy a obehy podzemných vôd.

Všeobecne treba povedať, že podzemnými vodami ako prvkom prírodnej krajiny sa musí zaoberať aj geografia v rámci komplexnosti svojich disciplín, ale aj pre vodu samu, ako nenahraditeľnú zložku prírodného a životného prostredia.

Obr. 1. Geoekologické krajinné prírodné typy. *A* — intramontánna nížinná krajina mierneho pásma, *B* — montánna krajina mierneho pásma: *1* — pokryvné hliny, *2* — štrky, *3* — piesky, *4* — štrk s pieskom, *5* — nepriepustné sedimenty (íly, sliene), *6* — rôzne pevné horniny (pieskovce, zlepence, žuly a pod.), *7* — rôzne pevné horniny (vápence, dolomity a pod.), *8* — svahové sedimenty a osypy, *9* — lesy a vegetácia, *10* — infiltrácia zrážkových vôd, *11* — tečenie a prestupy podzemných vôd v horninovom prostredí, *12* — horizonty artézskych vôd, *13* — pramene, *14* — rozkyv hladín podzemných vôd, *15* — maximálne hladiny podzemných vôd, *16* — stredné, priemerné hladiny podzemných vôd, *17* — minimálne hladiny podzemných vôd, *18* — zlomové tektonické línie.

Антон Порубски

ПОДЗЕМНЫЕ ВОДЫ КАК ЭЛЕМЕНТ ПРИРОДНОГО ЛАНДШАФТА

Одним из важных аспектов изучения подземных вод является географический аспект. География как наука о ландшафте изучает подземные воды как один из элементов ландшафта, рассматриваемого в качестве системы. Она (география) исследует отношения подземных вод к горным породам, к рельефу, почвам, растительности, поверхностным водам и, наконец, также к обществу.

Географический подход к подземным водам можно считать синтетическим, так как он предусматривает включение подземных вод в как возможно более широкую сеть вариабельных отношений. Статья обращает внимание, главным образом, на отношения подземных вод к рельефу и к субстратным породам, являющимся их циркуляционными и аккумуляционными факторами. При этом изучении мы исходим из основных макроструктур рельефа в следующей последовательности: низменности, котловины, горы и плоскогорья. Данная схема иллюстрируется на рис. 1. Рисунок наглядно отображает основные балансовые и дистрибутивные элементы осадочных вод и их циркуляционно-аккумулятивные пути в субстрате.

У каждой морфологической структуры имеется свой собственный циркуляционный и аккумуляционный режим подземных вод, который по отношению к другим структурам может проявляться континуально или дисконтинуально, постоянно или по-сезонно. Границы между ними могут быть геолого-тектоническими, но также и эрозионно-морфологическими.

Основные формы рельефа (низменности, котловины, годы, плоскогорья) модифицируют процессы образования, циркуляции и аккумуляции подземных вод как в вертикальном, так и в горизонтальном направлении. Основные формы рельефа подразделяются еще на формы более низкого порядка, например, в пределах низменности выделяются террасы, холмогорья, конусы выноса, депрессии, старицы, перевеваемые пески и т. п. Каждая из этих форм имеет свойственные отношения к подземным водам. Равным образом это наблюдается и в горах, где встречаются хребты, седловины, гребни, пики, морены, троги и глубокие долины. Здесь тоже наблюдаются очень дифференцированные отношения подземных вод к морфологическому строению. На более размерных плоскогорьях, главным образом карстовых, в свою очередь можно изучать совершенно другие гидрографические явления и циркуляции подземных вод.

В общем необходимо отметить, что подземными водами, как элементом природного ландшафта, должна заниматься также география в рамках комплекса своих дисциплин — в интересах самых подземных вод как незаменимого компонента природной и окружающей среды.

Рис. 1. Геоэкологические ландшафтные природные типы.
A — межгорный низменный ландшафт умеренного пояса, *B* — горный ландшафт умеренного пояса: *1* — налегающие глины, *2* — гальки, *3* — пески, *4* — гальки и пески, *5* — водонепроницаемые отложения (илы, мергели), *6* — разные прочные породы, (песчаники, конгломераты, граниты и др.), *7* — разные прочные породы (известняки, доломиты и др.), *8* — подоткосные отложения и осыпи, *9* — леса и растительность, *10* — инфильтрация осадочных вод, *11* — течения и проходы подземных вод в среде горных пород, *12* — горизонты артезианских вод, *13* — источники, *14* — амплитуда уровней подземных вод, *15* — максимальные уровни подземных вод, *16* — средние уровни подземных вод, *17* — минимальные уровни подземных вод, *18* — тектонические линии разлома.