



## Hydrodynamic zones of fissure-karst waters of Zemo Imereti Plateau in the Republic of Georgia

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### Abstract

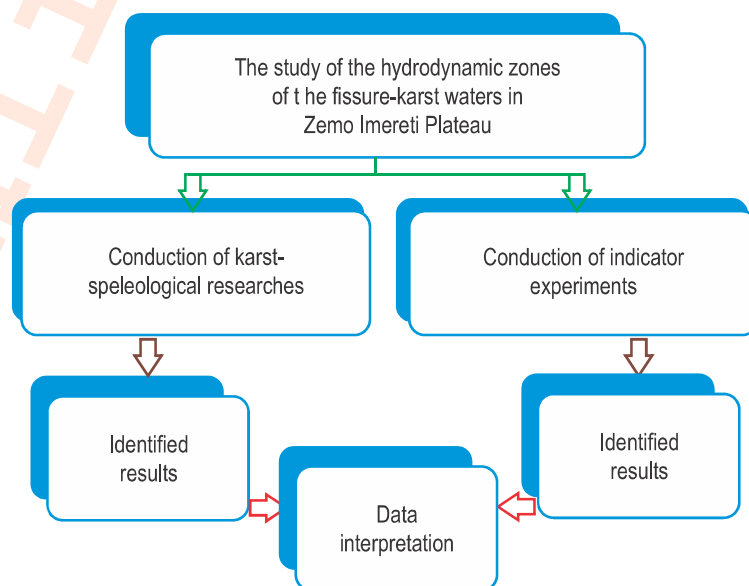
**Aim:** The aim of this research was to study the hydrodynamic zones of fissure-karst waters of Zemo Imereti Plateau. Zemo Imereti Plateau comprises the eastern most part of the karst strip of western Georgia and represents the only region of platform karst in the Caucasus, which sharply differs from other massifs of the karst strip of Georgia in structural-geological and relief terms.

**Methodology:** Based on karst-speleological researches, indicator experiments were carried out in the region. The common level of underground karst waters was identified. The existence of isolated streams of fissure-karst waters was also observed during the study that are mainly related to disjunctive dislocations. In most cases, underground streams flow under the bed of surface streams and come out on the surface as karst sources.

**Results:** Studies have revealed that formation of a common water-containing horizon in the Zemo Imereti Plateau is greatly contributed by its platform feature, particularly by the horizontal layout of relatively weakly dislocated and low-capacity karstified rocks, the structural features of the impermeable horizons and the water discharging conditions from the underground basin. In addition, the tendency towards the formation of common level of karst waters can be observed at early stages of karst development.

**Interpretation:** Based on previous studies undertaken, we drew a scheme of hydrodynamic zones of karst waters within the Zemo Imereti Plateau, where we distinguished the aeration levels seasonal fluctuation, complete saturation and depth circulation hydrodynamic zones. Within the aeration zone we distinguished the surface circulation, circulation of hanging waters, downward vertical circulation and sub-horizontal circulation sub-zones. The conditions for the formation of water circulation and karst caves in hydrodynamic zones were studied at length. Apparently, the hydrodynamic zones undergo a constant change in the background of ascending tectonic movements.

**Keywords:** Evolution, Karst, Speleology, Tectonics, Underground stream



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## Introduction

Several studies (Tintilozov, 1976, Maruashvili, 1973, Lezhava, 2015, Lezhava *et al.*, 2015) and previous experience indicate that the scale of cave origination is determined not only by the capacity of karstified rocks and by openness or density of fissures developed in them, but by the peculiarities of accumulation and discharging underground waters in the karst massifs. It is now confirmed that even in the massifs with the structure of karstified rocks that are fragmented by dense network of fissures, karst caves (empty areas) cannot be formed without long-term corrosion-erosion impacts of significant water streams.

The karst region of Zemo Imereti Plateau consists of easternmost part of the karst strip of western Georgia and is the only platform karst region in the Caucasus (Lezhava, 2015; Lezhava *et al.*, 2015, 2019a; 2019b; Asanidze *et al.*, 2017). The Zemo Imereti Plateau sharply differs from other massifs of karst strip of Georgia and occupies the central, relatively elevated part of intermountain plain of Georgia. Most part of the surface of plateau is located at a height of 400-800 m above sea level. It is characterized by deep river gorges and the peculiar soft relief of watershed areas. The uniform surface of plateau in itself is dissected in relatively small plateaus with plain surfaces and steep slopes by deep (100-250 m) canyon gorges of the Kvirila River and its tributaries (Jruchula, Nekrisa, Bogiristskali, Rganisghele, Katskhura, Buja, Sadzalikhevi, etc.). Important information on the geology of study area can be found in several publications (Gamkrelidze, 1933; Kuznetsov, 1927; Janelidze, 1940a, 1940b; Kakhadze, 1941, 1948; Geguchadze, 1973; Gudjabidze, 2003; Chikhelidze, 1948; Shiriashvili and Vashakidze, 1972). The boundary of the karst region of Zemo Imereti Plateau coincides with the surface contact line of the Cretaceous limestones with older formations (Bajocian porphyritic suite – in the north and east, and the Middle Paleozoic granitoids – in the south and west), which is the geological substrate of the karst (Fig. 1). Existence of a solid Hercynian platform has stipulated the layout feature of Mesozoic-Cenozoic suites on it (sub-horizontal or slightly sloped), which is represented mainly by the Valanginian-Hauterivian, Barremian and the Turonian-Danian limestones, and the Tertiary clays and sandstones. The platform structure of the plateau has played an important role in the origine and development of surface and underground karst forms and underground karst flows.

## Materials and Methods

In the course of this research, field geomorphological and karst-speleological large scale surveys were carried out. To prove the origin trend of common level (common system) of karst waters at early stages of karst development, a correlation of hypsometric levels of the entries of horizontal caves and outlets of sources was made. On the basis of field surveys, boreholes and geological section analyses, the topography of upper tectonic was restored

(Mesozoic-Cenozoic) from the layer of Zemo Imereti structural plateau, which had a significant impact on the formation of underground karst waters and their movement peculiarities.

On the basis of using dye water tracing (indicator experiment) method, the movement routes of underground karst waters and their discharging areas were identified. The common levels of karst waters and the isolated streams of fissure-karst waters were detected.

## Results and Discussion

On the basis of speleological survey and indicator experiments carried out, the common level of underground karst waters was identified. It is noteworthy that together with the common level of underground waters, the existence of isolated streams of fissure-karst waters was also observed *i.e.*, mainly related to disjunctive dislocations. In most cases, the underground streams flew under the beds of surface streams and appeared on the land surface as karst springs (Fig. 2).

The accumulation of water and formation of a common water-containing horizon within the Zemo Imereti Plateau is significantly contributed by its platform character, *i.e.*, slightly angled or horizontal layout of karstified rocks with weak dislocation and low thickness, as well as the structural features of the water impermeable horizon and the conditions for water discharge from the underground basin. It is noteworthy that the Kvirila River and its tributaries do not cross the limestone cover to its bottom – to Likhipe plain beyond the city of Chiatura. Therefore, all morphologically distinguished plateaus on both sides of the Kvirila River have a common limestone foundation, which, together with structural peculiarities and all above-mentioned conditions, creates favorable condition for the formation of common level of karst waters.

The trend of origination of common level of karst waters (or the common system) is observed at early stages of karst development, the proof of which is the location of entrances of horizontal caves and the outlets of sources at almost similar hypsometric levels (Fig. 3).

Karst caves in the Zemo Imereti Plateau are mostly the product of evolution of hydrodynamic zones. This evolution had started from Upper Pleistocene and is still active today. During this long process that has been in progress on the background of tectonic (neotectonic) movements, the hydrodynamic zones have undergone constant modification: dying-drying of upper zones and conceiving-watering of the underlying zones. Exactly, the ascending tectonic movements and alternation of delayed epochs has stipulated the storey-like layout of caves in the plateau.

Based on the schemes of hydrodynamic zones presented by several workers (Sokolov, 1962, Maksimovich, 1963,

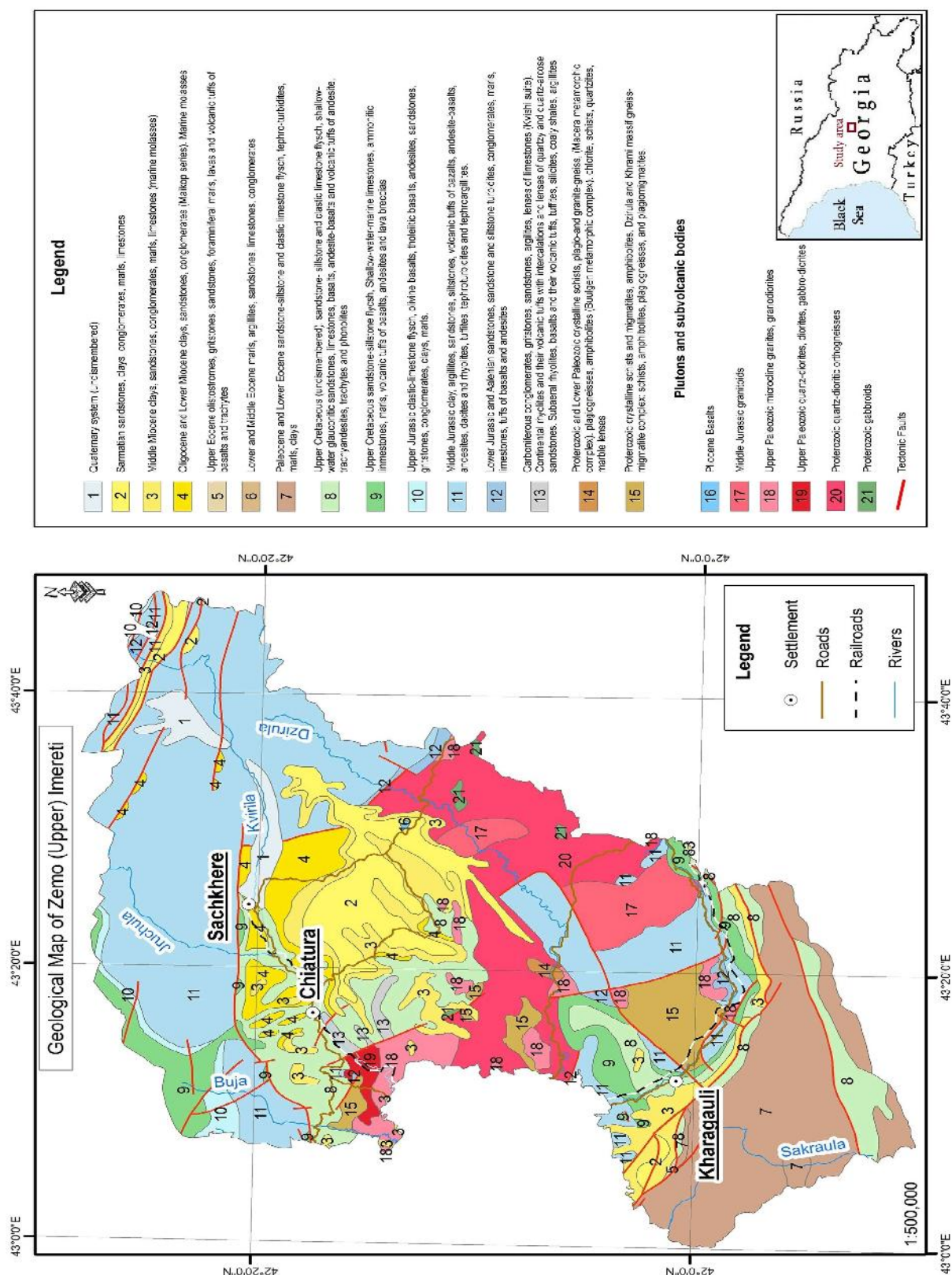


Fig. 1 : Geological map of Zemo Imereti Plateau (Gudjabidze, 2003).



Tintilozov, 1976, Dublansky, 1977, Kiknadze, 1979) together with the materials obtained by us during field and experimental surveys for last several years, we have distinguished 4 zones within the Zemo Imereti Plateau: aeration or vertical circulation zone, zone of seasonal fluctuation of levels, complete saturation zone and depth circulation hydrodynamic zone. Within the aeration zone, sub-zones were also distinguished (Fig. 4).

In the aeration zone (I), there is a downward movement of karst waters, fed by infiltration and influation of meteorological and surface waters. The absorption of surface waters is mainly related to tectonically weakened areas, as well as karst forms (sinkholes, ponors and caves). The karst processes in this zone are entirely dependent on the above-mentioned precipitation,

therefore, their intensive course coincides with the periods of abundant atmospheric precipitation and snow melting. The intensity of karst processes in the aeration zone is characterized by seasonal rhythmicity, which is also reflected on the sources related to this zone. The lower boundary of the above mentioned zone conditionally coincides with the surface, which underground waters reach during the period of maximum high water levels. Wells, shafts and abysses are formed in the aeration zone. The width aeration zone is mainly 150-200 m within the study area.

Surface circulation sub-zone (Ia) allocated by us in the aeration zone is directly supplied with atmospheric waters. The evaporation of part of atmospheric precipitations occurs in this sub-zone, and it produces surface flows, especially on the

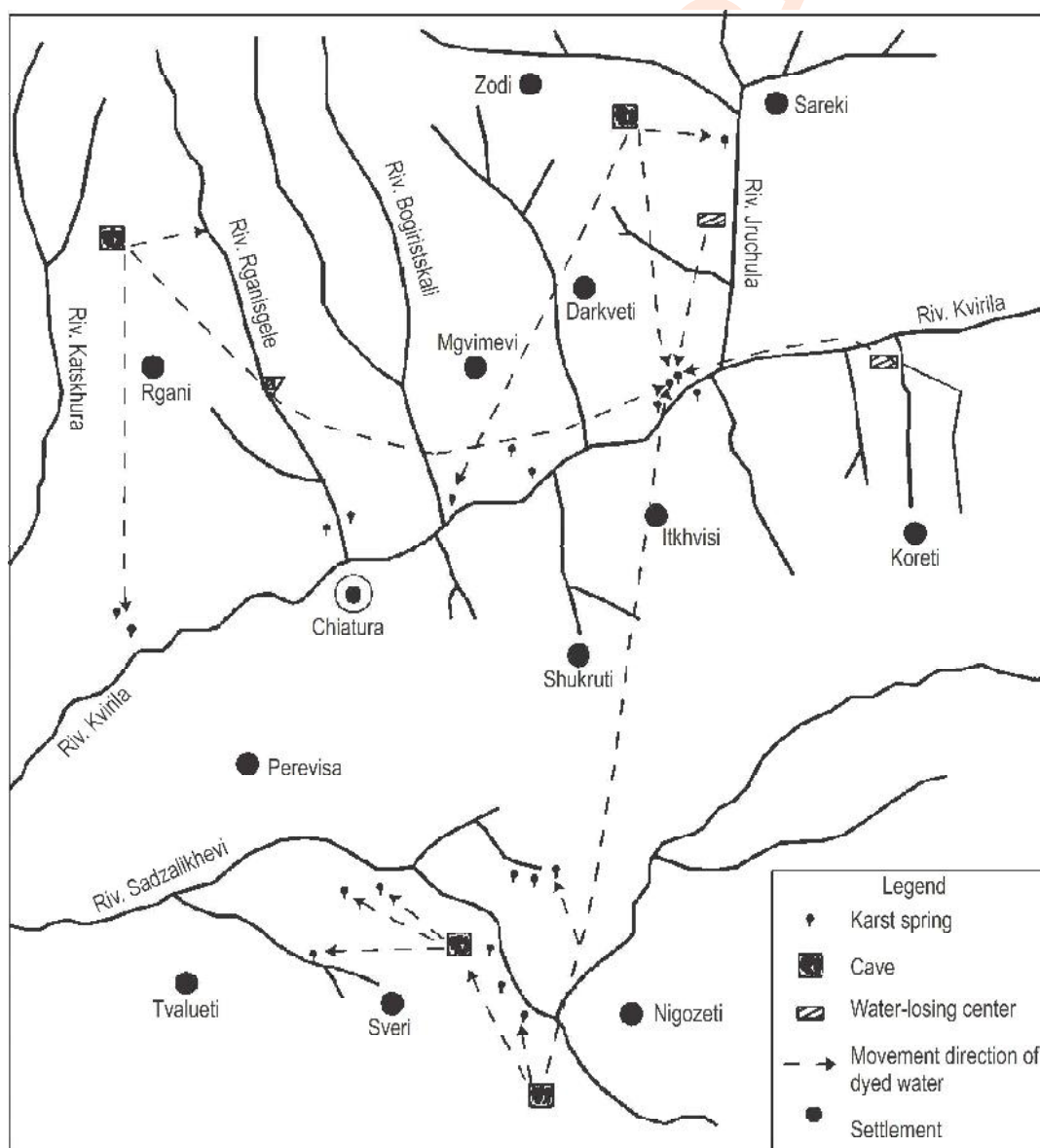
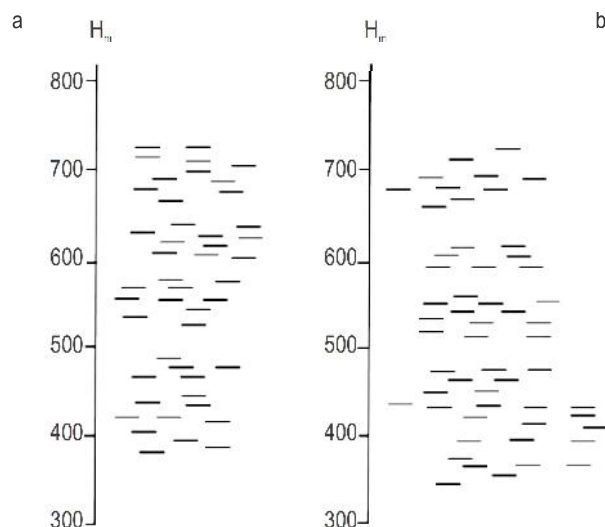


Fig. 2 : Movement scheme of underground waters obtained as a result of indicator tests in the Zemo Imereti Plateau.



**Fig. 3 :** The scale of distribution of hypsometric levels of horizontal caves entrances and (a) karst sources outlets (b) in the Zemo Imereti Plateau.

substrate built by Tertiary sediments. In the areas, where the latter is washed away and the Upper Cretaceous limestone layers are outcropped on the surface, the waters produced from the atmospheric precipitations, except the loss due to evaporation, completely leak into the fissures developed in the limestone layers of the same age and disappear into the depth through underground channels.

On limestone surface in the surface circulation sub-zone, these waters generate surface karst forms – corries, sinkholes and transitional to depth forms – karst wells that are so widely presented here. In the aerial zone, the circulation sub-zone of hanging waters (Ib) is significantly distinguished conditioning the outlets of small-scale sources in the plateaus and canyon slopes of the study area. In addition, there are also permanent and periodically active hanging waters. Latter are especially represented during heavy rains or spring snow melting period. The hanging sources are mainly related to the outcrops of the relatively hardly soluble rocks.

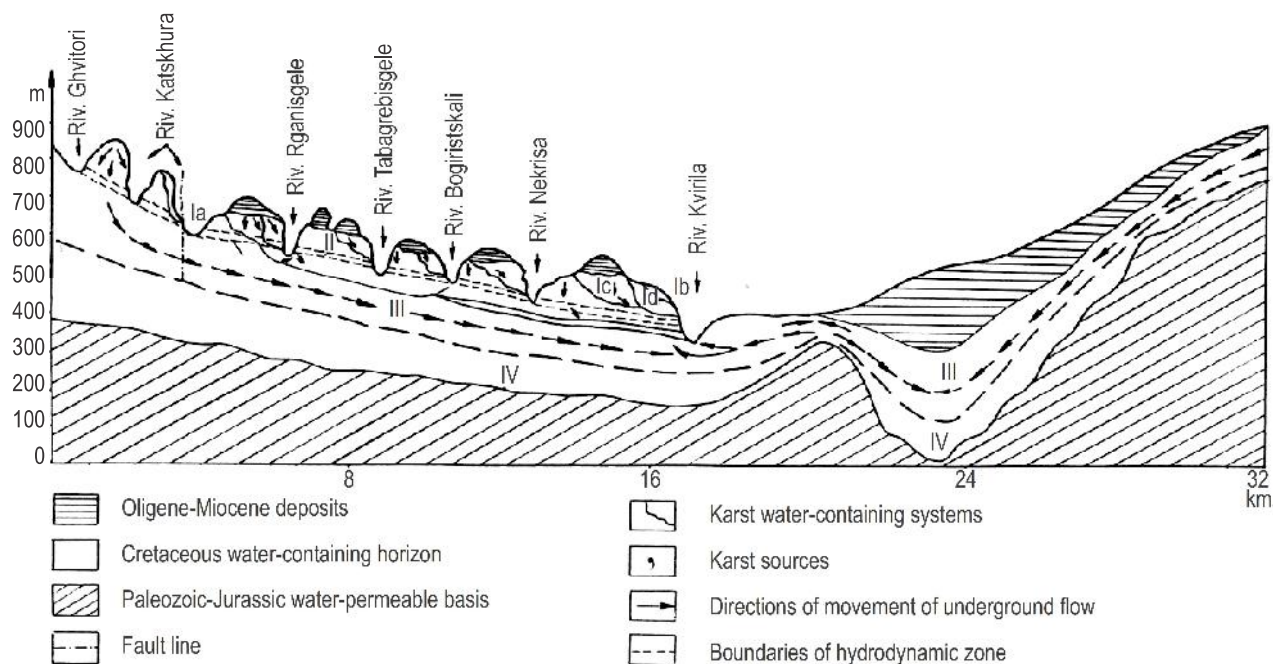
In aeration zone, the downward vertical circulation sub-zone of underground waters is distinguished with its wide distribution. We consider that the opinion of Tintilozov (1976) and Kinknadze (1979) on the existence of sub-horizontal movement sections (especially in the conditions of platform karst) of underground streams within the aeration zone (especially in its lower level) is quite right. Within the study area, at lower level of the aeration zone, there is also an evidence of sub-horizontal circulation sub-zone (Id) of underground waters, which occasionally stipulates a significant decrease in their speed. For example, the caves – Namdzvleviklde, Shvilobisa and others are entirely generated in the aeration zone and represented by the sections of vertical and sub-horizontal circulation. Most of the relic

caves are located within the aeration zone of the region. Rganisklde, Tsilto III, Gvarjilasklde, Nakhiznebi, Sachinkia, Nigozeti, Bnelaklde, etc. where following the waters are no longer.

There is a zone of seasonal fluctuation (II) located on the border of aeration zone and complete saturation zone within the Zemo Imereti Plateau, which is distinguished by seasonal variability of karst water levels. Sokolov (1962) points out that this zone is of transitional nature regarding neighboring hydrodynamic zones and with the dependence on the underground water levels (the latter depends on climate conditions), sometimes it joins with aeration zone, and sometimes – with complete saturation zone. Therefore, as mentioned above hydrodynamic zones of underground waters are in close relation with each other. For example, the aeration zone waters can get in the complete saturation zone from the seasonal fluctuation basin and take part in feeding of deep circulation zone sources itself.

In the study area, high activity of karst as well as, in general, the full spectrum of karstification and some of the karst sources; active periodically or permanently; are related to seasonal fluctuation zone. The increase or decrease of debit of these sources last for several weeks, according to duration of humid or dry periods. The capacity of level's seasonal fluctuation within the structural plateau would be measured by 2-3 tens of meters, the evidence of which is a significant seasonal fluctuation of levels on almost all major karst sources (Ghrudo, Monastery, Lezhubani, Tiri, etc.). In addition, during high water period, as per field surveys, head of some sources temporarily shifted up by several tens of meters. This fact indicates that there are cavities of significant capacity in the border of aeration and complete saturation zones, where water levels significantly vary in relation to the abundance of atmospheric precipitations. The main reason for the rise of underground river levels in karst cavities is not only the poor pass-through ability of fissure, but also the colmatage of canals.

In the study area, complete saturation zone (III) extends at the level of Kvirila River bed, or below it. In this zone, the karst waters moved in the horizontal direction. Its lower boundary was mainly determined by the location of local erosion basis or the existence of water impermeable sublayers. Horizontal caves developed in this zone. Permanently active and abundant-debit sources (Ghrudo, Monastery, beyond Kvirila water gryphon etc.) are also associated with it, on the expense of which the city of Chiatura and its surrounding are supplied with water. Waters that are formed in the complete saturation zone are discharged in the form of vacluses sources at the main river level, or flow below this level and flow out in the ground surface in the form of sources as proved by the results of indicator tests (Lezhava et al., 1989, 1991).



**Fig. 4:** The scheme of karst-hydrogeological basins and hydrodynamic zones of karst waters in the Zemo Imereti Plateau; Hydrodynamic zones: I–Aeration zone; II – Levels' seasonal fluctuation zone; III–Complete saturation zone; IV– Depth circulation zone; Sub-zones: Ia – Surface circulation sub-zone; Ib – Hanging waters sub-zone; Ic – Downward vertical circulation sub-zone; Id – Sub-horizontal circulation sub-zone.

The above-mentioned pressured water outlets (water gryphons) are mainly related to the locked karst systems and distribution areas of Barremian lime stones. Latter are good collectors of underground water. The pressured water outlets in the Katskura, Rganisgehele and Jruchula river gorges were reported by us, where there is an anticipation of existence of extensive basins of underground waters with complicated water-exchange (Lezhava, 2015).

The mentioned basins are supposed to represent prospective areas of obtaining drinking waters. The formation of flows in the complete saturation zone is supported by significant altitudinal difference (about 600-700 m) among the absorption and discharging areas of atmospheric waters, resulting in hydrostatic pressure in the fissures; in addition, common sinking of karstified rocks from the peripheries of structural plateau to the center, which mainly defines the directions of underground karst water movement within the structural plateau. The extent of limestones at a significant depth (160-200 m) below the local erosion basis (Kvirila River) within the Zemo Imereti Plateau and the common limestone basis indicate the existence of a depth circulation (IV) zone.

This is also confirmed by the results of drilling works. For example, according to Kuchukhidze (1986) and others, in the borehole of Sachkhere (the absolute height of the borehole 450 m) at a depth of 362-382 m from the surface (absolute height 70 m), in the Upper Cretaceous limestones, 20 m thick water-

containing horizons have been identified, where the water flow debit was  $3.1 \text{ l sec}^{-1}$ . In the Merjevi borehole, at 385-415 m from the surface (at an absolute height of 113 m) was identified with a 30 m thick water-containing horizon, a debit of  $65 \text{ l sec}^{-1}$ .

The unpublished data of Mamulia and Gambashidze are also interesting. These authors have detected water-containing horizons at significant depths during drilling carried out in the Jruchula and Kvirilariver beds. Pumping of water from these horizons did not affect the Ghrudo and other important vaucuse sources, and the debit remained unchanged. Thus, the regime observation has established the existence of not only the depth circulation, but also the fact that the vaucuse sources connected to the Ghrudo complete saturation zone have no direct hydraulic connection with the depth circulation zone.

On the basis of field, experimental and laboratory surveys within the Zemo Imereti Plateau, the unified karst-hydrogeological system (unified level) with sufficient resources of dynamic water were identified. In addition to the above mentioned system, isolated fissure-karst water systems were observed with different hypsometric location and orientation. Accumulation of water and formation of a common water-containing horizon in the Zemo Imereti Plateau is greatly facilitated by its platform character as well as structural peculiarities of water impermeable horizon and the conditions of discharging waters from the underground basin. Disjunctive dislocation seem to have a significant effect on forming isolated flows. Features of substrate



shaping formations of study area, as well as geomorphological conditions and tectonic peculiarities, lead the character of existence and distribution of hydrodynamic zones of karst waters.

The evolution of karst cavities of Zemo Imereti Plateau is closely related to the fissure-karst waters of hydrodynamic zones (aeration, seasonal fluctuation of levels, complete saturation, depth circulation).

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