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Karst research in Romania: Geological and hydrogeologic setting of Bihor Mountains

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ABSTRACT

About 1.4 % of the landsurface of Romania consist of karst. This low percentage is due to Pliocene and Quaternary deposits which overlie the limestone and dolomite, the predominant karst forming rocks.

More than 12,000 caves are known, a part of these are well decorated with speleothemes.

One of the most important karst region of Romania, is situated in the Bihor Mountains, which form the central part of the Western Carphatians (Apuseni Mountains). Details concerning karst, geology, tectonics, and hydrogeology about this karst area, situated in the western part of Transylvania are presented in this paper.

1. GENERAL DATA

Romania is situated in the Eastern part of Europe, with an area of 237,500 km^2 (91,671 sq. miles) and consists of four regions: Walachia, Moldavia, Transylvania, and Dobrogea (Fig. 1).

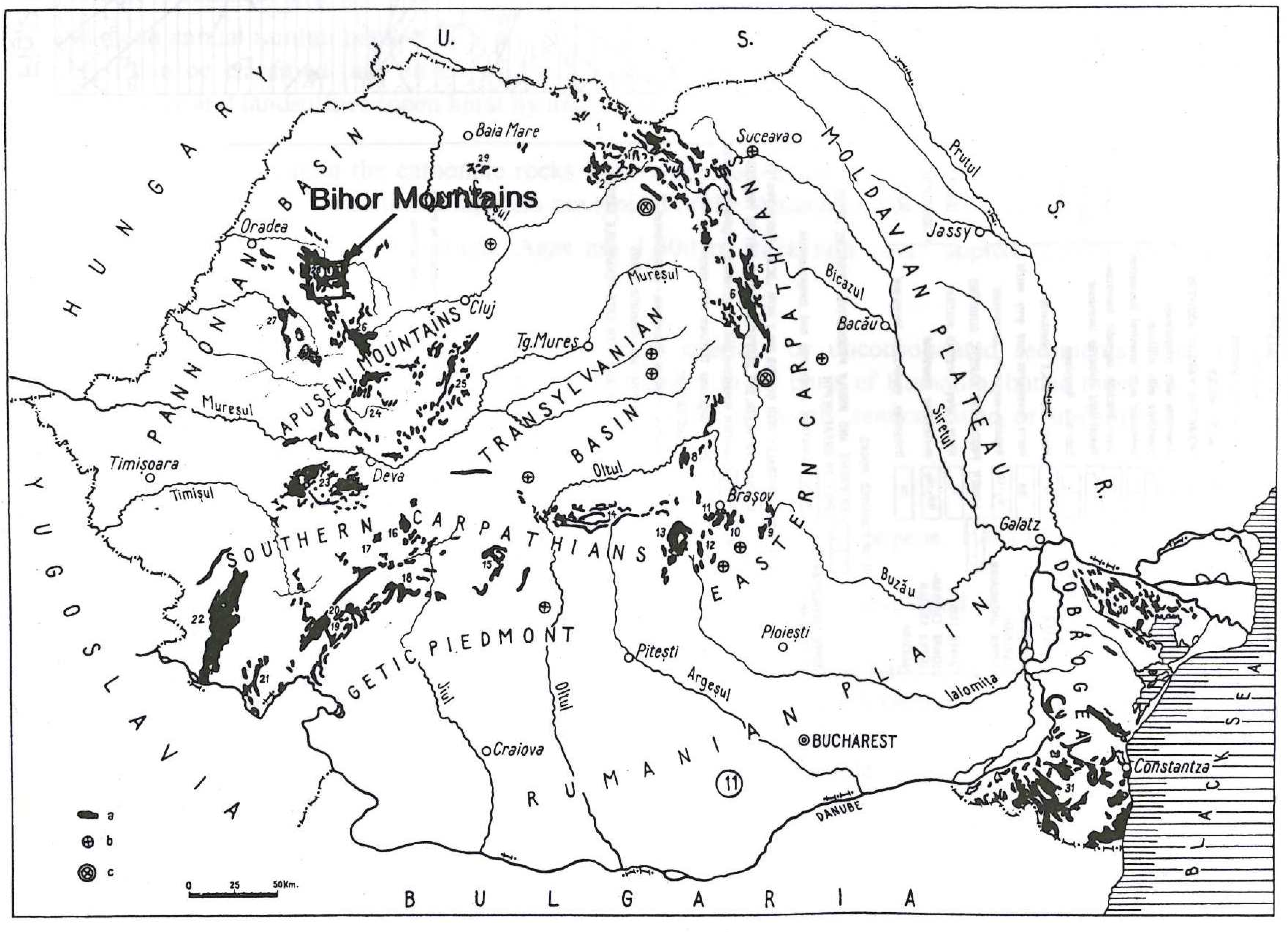


Fig. 1 Distribution of karst forming rocks in Romania (After M. Bleahu, 1964)
a = Limestones and Dolomites; b = karst developed on salt and gypsum

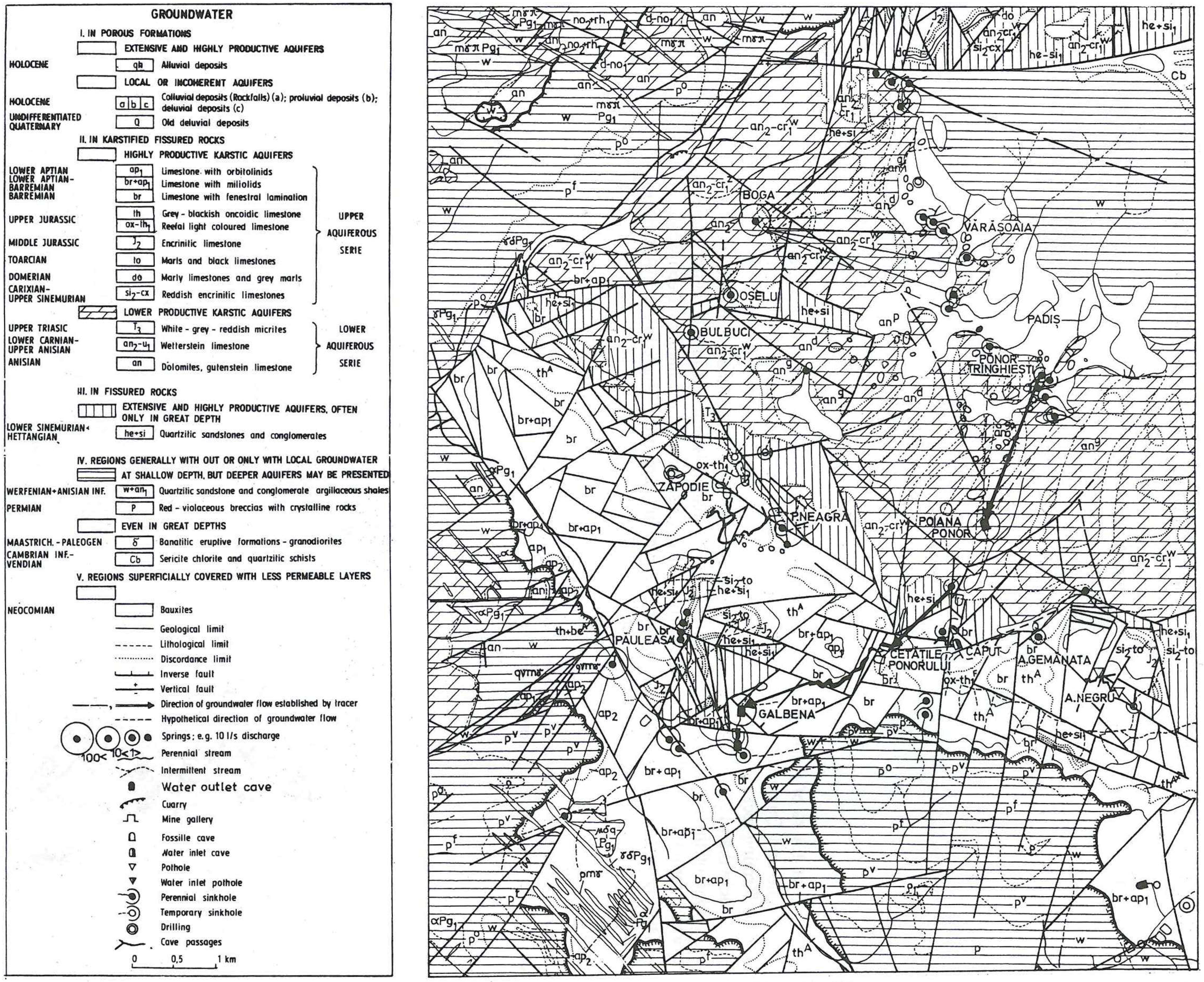


Fig.2 Bihor Mountains – Padis Karstic Plateau

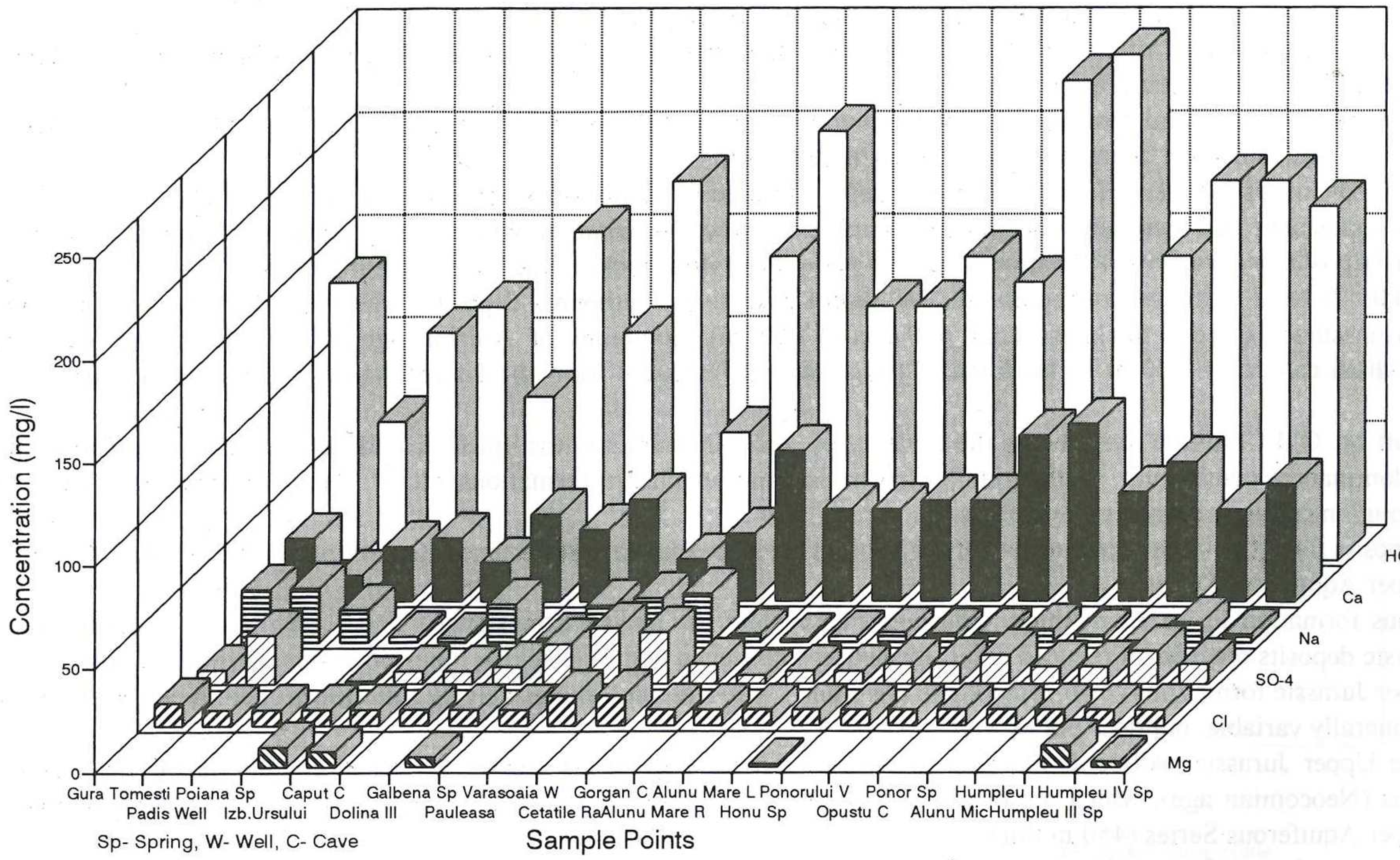


Fig.3 Water Quality Data Bihor Mountains

Romania's climate is characteristic of the moderate temperate-continental zone, with an average annual temperature ranging from $4^{o}C$ to $10^{o}C$ and mean annual rainfall between 400 mm to 1200 mm.

Romania's karst can be classified into three categories, characterized by the depth to the karst aquifers and the relationship between the karst aquifer and landsurface (open karst hydrogeological system or confined) .

1.1. *Deep Karst* type features occur in the carbonate rocks underlying non-soluble bedrock and overlain by aquicludes or aquitard deposits (consolidated deposits). These confined aquifers are typical of the Walachian Platform (geological name used for Romanian Plain). The carbonate deposits of Malm-Barremian Ages are 1,500 m thick and cover approx. 25,000 km^2 of the Walachian Platform.

1.2. *Shallow Karst* type features are formed in carbonate rocks overlain by unconsolidated sediments. The thickness of the overburden ranges between 10 m to 50 m. This type of karst is found in all parts of Romania, but is most common in Dobrogea, where the overburden is mainly loess. The shallow type karst aquifer is mostly semiconfined or unconfined. The average area covered by shallow karst type is approx. 3,500 km^2.

1.3. *Bare karst* occupies about 4,400 km^2 (Bleahu, 1965) of the Romanian territory (approx. 1.4% of Romania's landsurface) and is formed in Paleozoic, Mesozoic, and Neogene deposits.

The bare karst type take into account the rocks on which the karst proper is developed as limestones, dolomites, crystalline limestones, salt and gypsum.

The Paleozoic deposits are recrystallized and represent about 16% of the total bare karst area.

The Mesozoic deposits belong to two sedimentary cycles (Triassic- 17.8% and Jurassic - Cretaceous 47.3%) and the Neogene deposits to a third cycle (Eocene, Tortonian and Sarmatian - 16.8%) (Bleahu, 1965).

The most karstified deposits belong to the Jurassic- Cretaceous sedimentary cycle, as a result of their lithological , structural , chemical, and hydrogeological characteristics.

2. GEOLOGICAL AND HYDROGEOLOGICAL SETTING OF BIHOR MOUNTAINS

Situated in the central part of the Western Carphatians, the Bihor Mountains present large karstifiable surfaces. The most representative is the Padis Karstic Plateau (Fig.2).

In the area, the Bihor unit and posttectonic cover formations consist of Paleozoic, Mesozoic, Tertiary and Quaternary sedimentary formations, which are underlain by metamorphic rocks (Mantea 1985).

In the Mesozoic deposits several Triassic, Jurassic, and Cretaceous formations have been identified.

Quartzitic sandstones and a sequence of shale, of Werfenian- Lower Anisian, or Werfenian age (about 70 m thick), associated with Permian deposits or crystalline formations form the main impervious rocks at the base of the limestones.

The Middle Triassic Deposits are represented by almost exclusively carbonate deposits, which appeared as a succession of Gutenstein Limestones (whose thickness does not exceed 150 m), dolomites of Anisian age (60 m thick) and Weterstein limestones, which can reach 300 m in thickness. These carbonate deposits form the Lower Aquiferous Series (approx. 500 m thick).

As a result of Old Chimeric movements the territory of Bihor Mountains was uplifted, and new sources of clastic sediments appear, predominantly continental. Hettangian - Lower Sinemurian clastic formations attain 160 m in thickness and include quartzitics conglomerates, sandstones, and shale.

These deposits form the impervious strata between the Triassic and Jurassic limestones, separating the Lower Aquiferous Series from the Upper Aquiferous Series.

Calcareous formation up to 45 m thick, considered equivalent to Gresten Limestones (Upper Sinemurian-Carixian age) and Middle Jurassic deposits outcrop on reduced areas, formed as a sequence of grey-blackish limestones and encrinitic limestones.

The Upper Jurassic formations cover remarkable areas and are represented exclusively by limestones. The thickness of the Upper Jurassic is generally variable, but does not exceed 300 m.

When the Upper Jurassic sedimentation ended, the New Kimmerian phase creates favorable conditions for the bauxite ore emplacements (Neocomian age), which are overlain by the Eo-Cretaceous limestones. The Jurassic and Cretaceouses limestones form the Upper Aquiferous Series (450 m thick).

The Hettangian- Lower Sinemurian sandstone deposits are impermeable rocks intercalated between these two aquiferous series, and are known as an aquifuge or aquiclude. Between two relatively impervious rocks, the Lower Aquiferous Series is a confined aquifer. Groundwater flow in these rocks is restricted to fracture zones, which allow an intercommunication between the two aquifers, with flow preferentially directed from the Triassic to the Jurassic and Cretaceous deposits.

Due to this fact, in general the yields of springs situated in the Upper Aquiferious Series are higher, being separated as Highly Productive Karstic Aquifers, while the Lower Aquiferous Series are Lower or Medium Productive Karstic Aquifers.

The waters of the Bihor Mountains karst aquifers are dominated by calcium bicarbonates and the TDS varies with source. Cave stream and karst spring waters are mostly saturated with respect to calcite. Well waters (installed in non-carbonate deposits) and surface waters (disappearing streams) have higher concentrations of sodium chloride and sulfates (Fig.3).

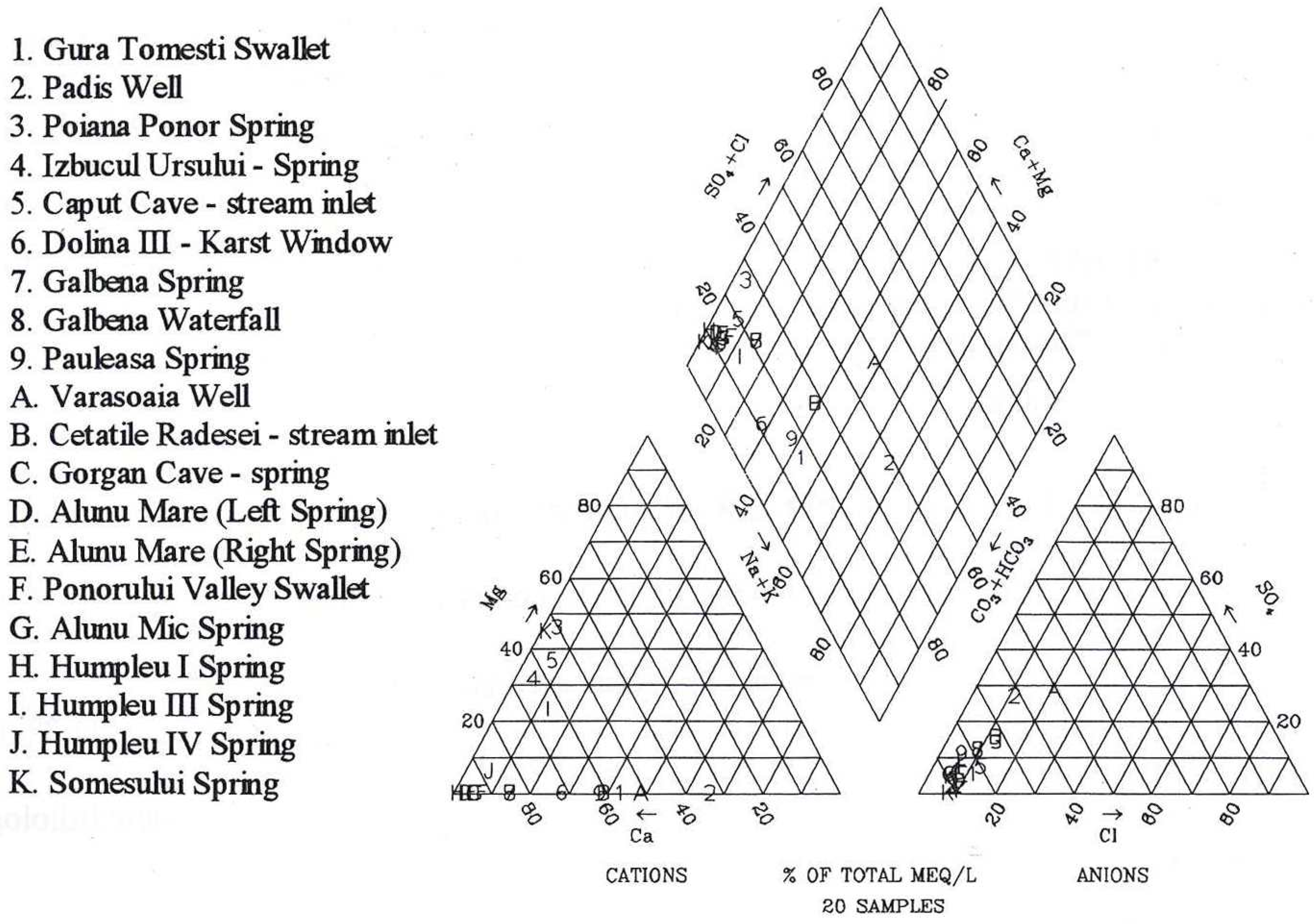
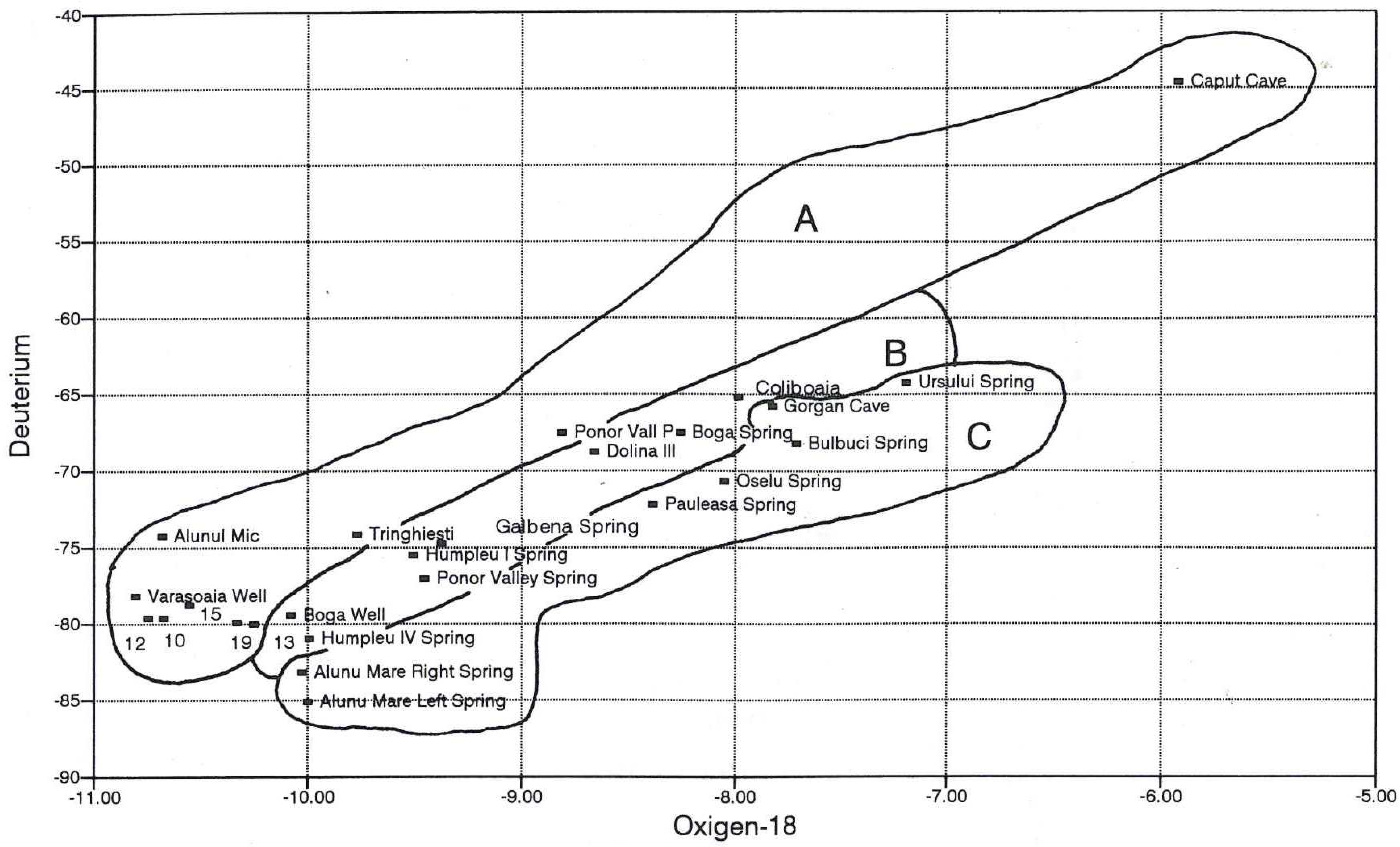


Fig.4 Piper Diagram - Bihor Mountains



10 - Honu Spring; 12 - Padis Well; 13 - Poiana Ponor Spring; 15 - Galbena Waterfall; 19 - Cetatile Radesei Cave (outlet).

Fig.5 Environmental Isotopes Ratio Bihor Mountains

The Piper diagram in Fig. 4 indicates that most springs (except a few main karstic springs) in the Bihor Mountains are calcium rich with little magnesium.

The diagram reveals for the anionic proportions an exceptional grouping of waters in the bicarbonate type field. Also a grouping can be observed in the diamond-shaped cation-anion graph, reflecting that the Bihor Mountains have calcium (magnesium) bicarbonate waters with low TDS.

The environmental isotopic analyses for Bihor Mountains waters shown in Fig.5 indicates that the waters from the various resources presented above can be arranged in three distinct groups (Table 1):

Group A: Waters in which the relative Deuterium and O-18 content are between 11.12%o and 1.95%o. This group includes surface waters, wells (wells installed in non-carbonate deposits) and spring waters with small recharge areas, over 50% of the discharge supplied by disappearing streams and precipitation.

Group B: Waters in which the relative Deuterium and O-18 content range between 1.95%o and -1.44%o. This group includes Deep karst aquifers, where more than 20% of the yield comes from surface streams and less than 80% from percolation and endokarstic condensation.

Group C: Waters in which the relative Deuterium and O-18 content are between -1.44%o and -6.74%o. This group includes Deep karst aquifers, where less then 20% of the yield comes from surface streams and more than 80% from percolation and endokarstic condensation.

The Padis - Cetatile Ponorului karstic plateau

The Padis - Cetatile Ponorului karstic plateau, with a 54 km^2 of limestone outcrop, is formed by 23.5 km^2 Triassic limestones and 30.5 km^2 Jurassic and Cretaceous carbonates (Fig.2).

In this area 26 disappearing streams and 18 karstic springs have been identified.

Most of the disappearing streams are situated on Triassic limestones. Tracing experiments (Oraseanu, 1985) indicate that the preferential flow directions are toward the west and south in the central part of the plateau.

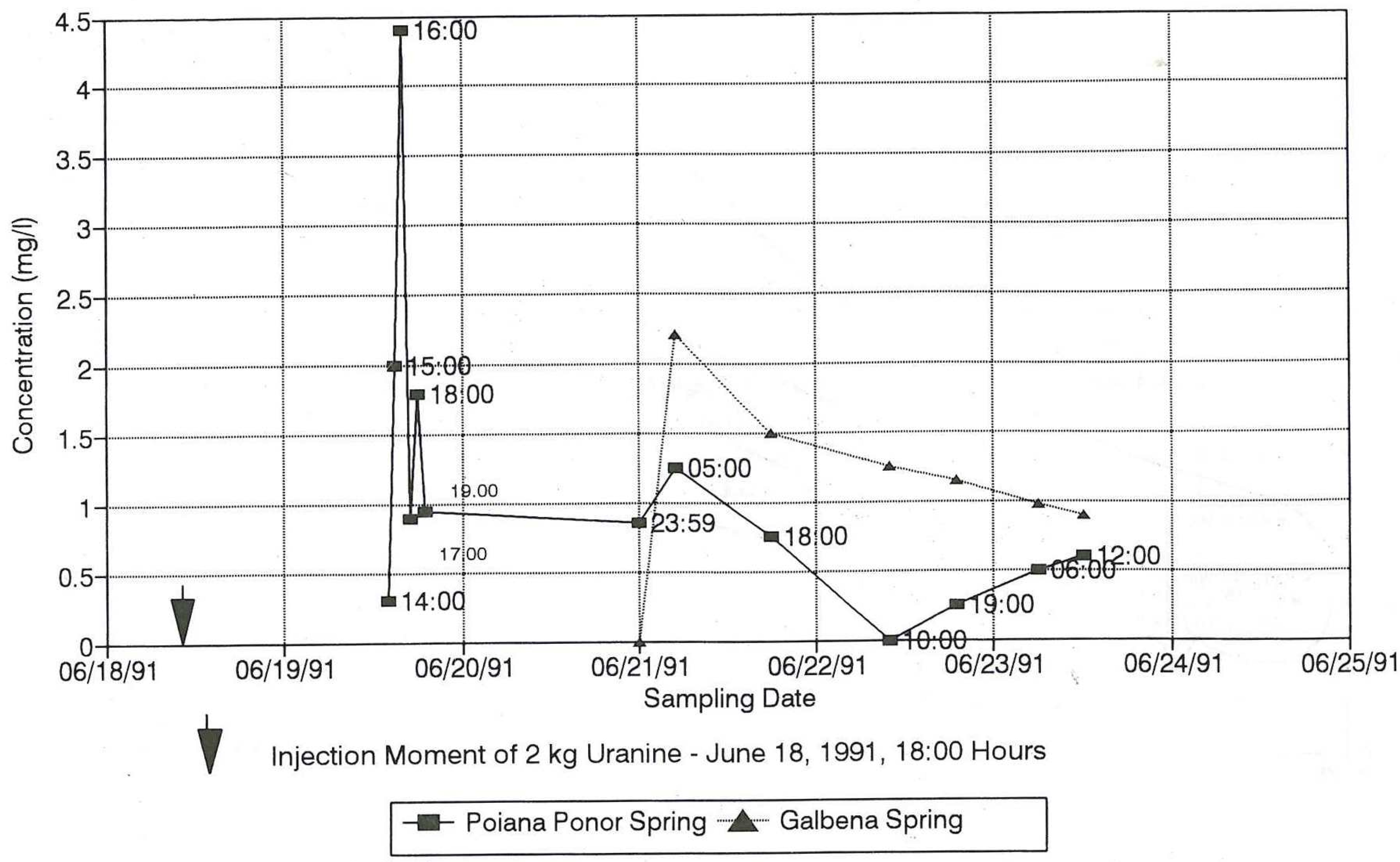


Fig.6 Tringhiesti-Poiana Ponor-Galbena Dye-Tracing Experiment, Bihor Mountains

Table 2

Stream Sink	Alt. m	Q l/s	Spring Name	Alt. m	Q l/s	Distance m	Difference level (m)	Mean Transit Time(h)	Flow Velocity
Tringhiesti	1260	15	Poiana Ponor	1100	134	1980	160	96	20.62
			Galbena	800	228	5350	460	102	71.33

The existence of the watershed in that place is controlled by the outcrop of the Hettangian- Sinemurian deposits situated at the east side of the Oselu spring and continues under the Quaternary deposits. The flow path reveals the strong dependence on the tectonic structures.

In the Padis-Tringhiesti area a disappearing stream of 50 l/s, was tested with a dye tracing experiment. The tracer appeared in the Poiana Ponor Spring. This stream after 1 km of subaerial course sinks again, to be found in the cave of Cetatile Ponorului (karst window) like a subterranean stream, which after two km of passages ends in a sump, the waters re-surfacing finally through the Galbena Spring. The Poiana Ponor disappearing stream is located in a fracture zone controlled by a fault along which the Triassic and Jurassic limestones are in contact, and serving as a connection between the Lower and Upper Aquiferous Series.

In June 18, 1991, 2 kg of Uranine was injected in to the Tringhiesti disappearing stream. The appearance of the tracer in the Poiana Ponor spring occurred after 14 hours (Table 2), the graph indicates 3 pulses of different amplitudes, and that the storage of the limestone massif is low (Fig.6).

The appearance of the tracer in the Galbena Spring occurred after 40 hours, the graph being flatter, indicates that the storage is higher downgradient.

The flood hydrograph of the Poiana Ponor and Galbena Spring is indicative of a vadose cave stream and tends to be peaked and similar to a surface river (rapid response of large channels and enlargements). The storage is strongly influenced by the proportion of the rainfall input that runs off. The lag between the input event and the output response is very short.

The water-quality data shows a relatively-low mineralized water of the aquifer reservoir during normal and increasing flow-rates. Once the flood peak passes, the newly-infiltrated water reaches the spring through karstic fissures and mineralization increases. Once the main pulse passed, the decreasing yield is followed by the dilution of mineralization (TDS).

The TDS of the spring waters ranges between 223 mg/l and 285 mg/l, which is very close to the TDS (219 mg/l) of the disappearing stream, confirming once again the high speed flow of the underground stream through the limestones.

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