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ANALYSIS OF TIME-DEPENDENT FACTORS OF BOSSEA KARSTIC SYSTEM (MARITIME ALPS - ITALY)

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ABSTRACT

Since 1982 the Bossea Cave has been equiped for a continuous study of the flow discharge of a peculiar karstic system, where a limestone complex is supported and surrounded by basement rocks (quarzites and porphyroides). Dye tracer tests and hydrogeochemical analysis made possible to understand the behaviour of the system in different periods of the year. When no precipitations occur in the recharge area discharge is mainly supplied by the fractured quarzites aquiclude. Some chemical markers (sulphate and silica) have been identified in the system; they are related to two different recharge zones, the former made up by carbonate rocks, the latter by cristalline basement rocks. Conductivity shows a good correlation with flow-rate and the highest conductivity values mark the high-water sections of the hydrograph. Only heavy rainfall causes a relative lowering of conductivity, expecially when its effect is added to Spring snowmelt.

INTRODUCTION

The research program drawn up in order to understand and exploit the groundwater resources in Italy, has pointed out different behaviours of some karstic systems in southern Piedmont (NW Italy).

Four underground scientific gaging stations have been installed, these stations being representative of different kinds of karst whose hydrodynamic bahaviours show remarkable differences. One of these stations, located in the Bossea Cave (operative since 1982) is equiped with an hydrometrograph-aided weir, a pH-recorder, a conductivity-recorder and a six channels thermograph, while an automatic sampler provides the sampling of water at fixed intervals.

The Bossea karstic system (intake area about 5 km^2) is situated on the Maritime Alps in the Corsaglia Valley, between 1700 and 800 metres a.s.l. (fig. 1).

The carbonate aquifer forming the karst structure is made up by a limestone complex aged from Middle Triassic to Upper Cretaceous; it is oriented E-W and bounded by distinct tectonic lines which put in contact limestones and fractured quarzites of the Permian-Triassic continental suite. The hydrostructure, situated cross-wise the main axis valleys, drains the surface runoff coming from impermeable basement lithotypes. The terminal part of the well-developped hypogeus conduits network is constituted by a set of big syphons partially explored (flooded zone) and feeds a perennial emergence.

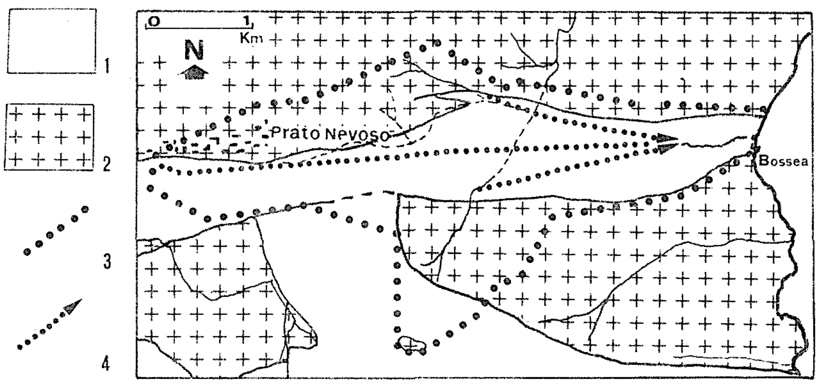

Fig. 1 - Hydrogeological sketch of Bossea karstic system. 1 = main aquifer (limestone); 2 = aquiclude (crystalline basement); 3 = hydrostructure boundary; 4 = groundwater flow directions.

A number of small lateral conduit-streams (effluent subsystems), yelding a constant physical-chemical discharge, feeded by crevice network, reach the main cave system.

ANALYSIS OF BOSSEA SYSTEM RECHARGE PROCESS

The Bossea system is a typical mountain karst influenced by weather conditions of middle latitudes. It shows a quite fast response towards input changements. During four years of observation the lowest discharge values (50 l/s) have been recorded in winter time (with "close" system and no input), or at the end of the Summer in absence of rainfall. During the period March/May the system is mainly fed by snowmelt (fig. 2) and it shows a progressive increase in the hydrograph, with a series of daily fluctuations (regular steps or little peaks of discharge in conformity with the thermic conditions in the recharge area. When snowmelt is added to rainfall (1986) or after rainfall of some lenght (1983), the hydrograph reaches the highest discharge values (about 1200 l/s, fig. 3). For most of the observd cases the end of the rainfall coincides with the highest discharge peaks (maximum delay: 1 hour).

Two analysis of the recession curve have been performed by MANGIN methodology (1970) for the years 1983 and 1985 hydrographs. In the first case (1983), the curve has been purified from parasite floods of great importance; in 1985 the exhaustion

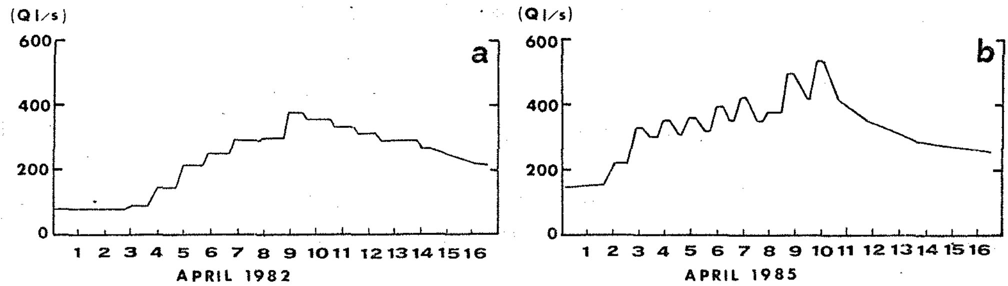

Fig. 2 - Snowmelt in the Bossea karstic system: a) continuous melt (overcast sky, 1982); b) pulsating melt (cloudless sky, 1985).

curve has been disturbed only by some flood events scarcely visible on the hydrograph. On table 1 data referring to the analysis of the curves are reported. The exhaustion coefficient (α) shows a quite low value and the great importance of the fracture network feeding the system. This seems to be confirmed from the low infiltration rate coefficient (η_i) and from the quite long infiltration nough-time (q_0). The outflow heterogenicity coefficient (ϵ) indicates a complex behaviour of the system and feeding from areas with peculiar geological and hydrodynamic features.

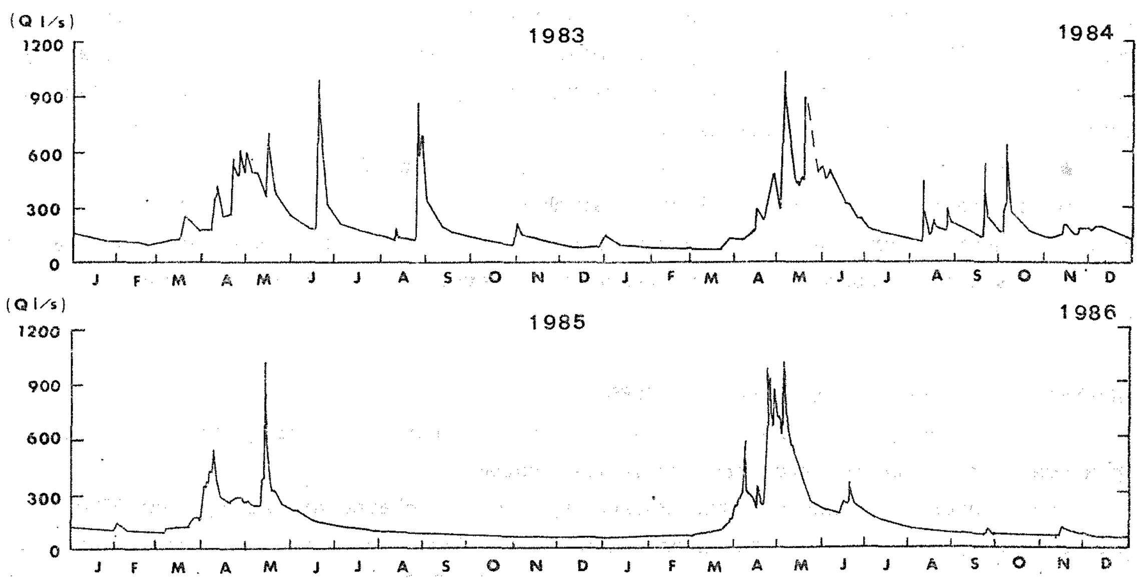

Fig. 3 - Discharges (1983-1986) of Bossea karstic system.

Table 1 - Recession curve parameters of Bossea karstic system.

YEAR	Q_0 m^3/s	Q_{R_0} m^3/s	Q'_0 m^3/s	q_0 m^3/s	t days	t_i days	α	η_1	ϵ	W_0 Mm^3	W'_0 Mm^3	V Mcm^3
1983	.869	.141	.122	.728	189	52	.002990	.019231	.330842	4.1	3.5	.35
1985	1.120	.110	.080	1.010	287	75	.004285	.013333	.302324	2.2	1.6	.61

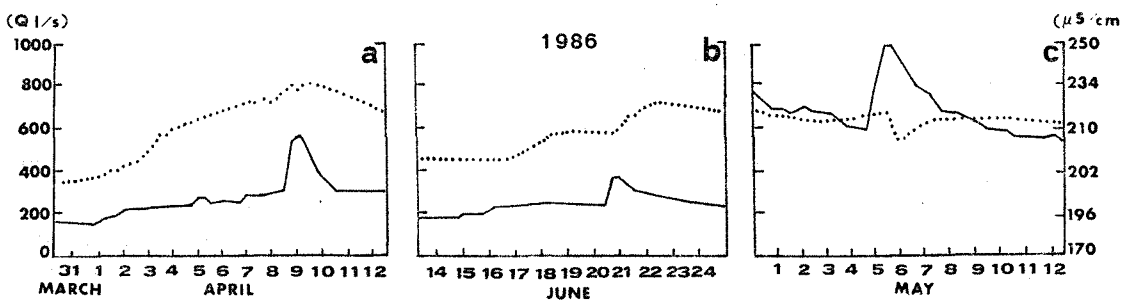

Fig. 4 - Conductivity/discharge relationships of Bossea karstic system (1986).

The dye restitution curve at Bossea spring indicates for the whole system a different behaviour during the year (variations of hydraulic head). The dye (Na-fluoresceine put into the system from a karstic loss absorbing a certain quantity of a perennial stream water), has been brought back after 300 hours in low-water conditions. The maximum velocity has been estimated in 6 m/h with very low dye concentration. Three months after the test, during the Spring high water discharge, traces of dye have been found again in the water.

A test carried out in the same karstic loss during flood conditions, has shown a shorter transit time and a velocity valuable in 83 m/h. The dye restitution lasted over 240 hours. For these reasons and according to other data (see next paragraph) it is possible to suppose the existence of a developed saturated zone and a strike flow during high-water time.

ANALYSIS OF BOSSEA SYSTEM RECHARGE PROCESS

Using time-dependent physical and chemical features, it is possible to built up a scenario of the recharge process in the system.

Groundwaters flowing out the Bossea system are characterized by low TDS; the TDS generally increases with high discharges. The continuous recording of the conductivity points out a progressive increase in TDS as a result of an increasing in discharge, when snowmelt occurs (fig. 4a) or during rainfall events (fig. 4b).

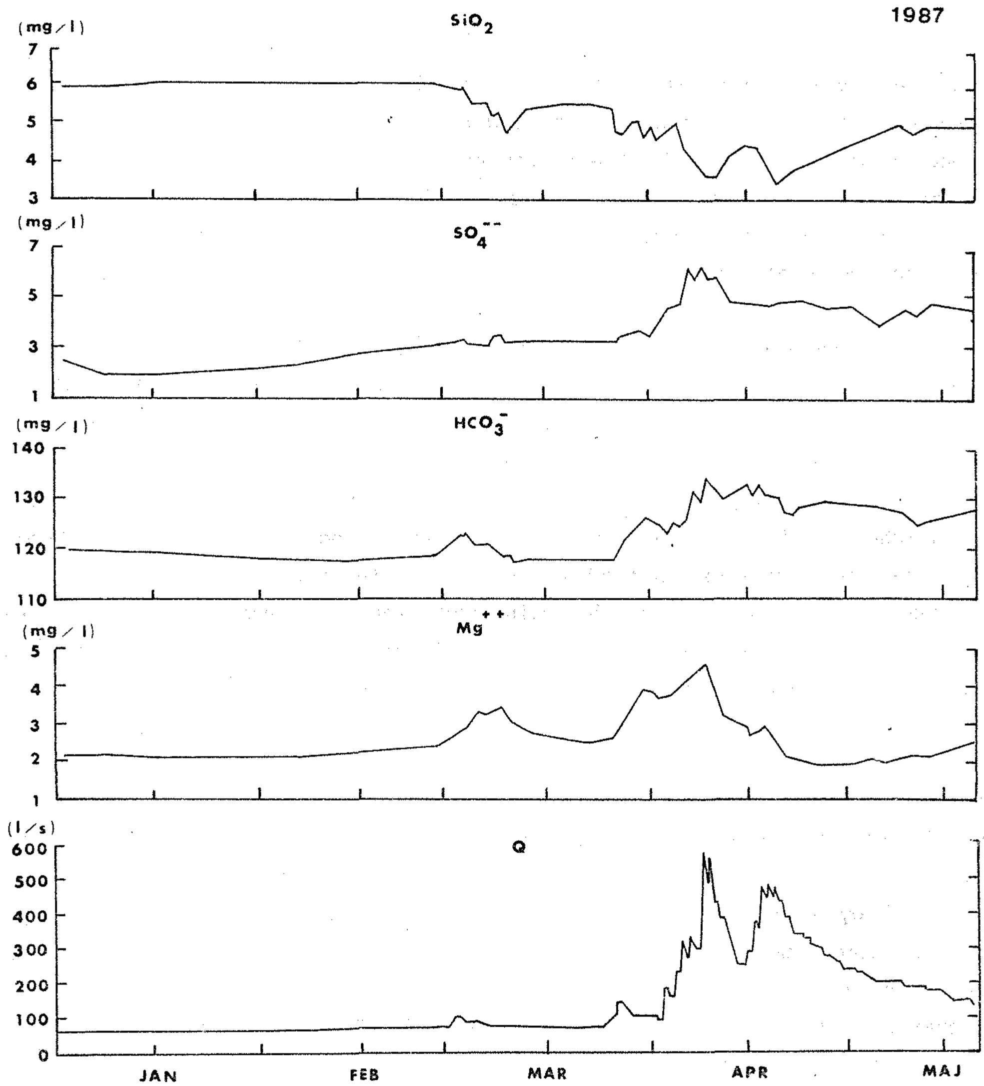

Fig. 5 - Recharge time-dependent factors of Bossea karstic system (1987). Only significant hydrogeochemical markers are plotted in the isochronous diagrams.

The delay between the discharge peak and the conductivity peak ranges from a few hours to several days, according to the saturation of the fractures network. Heavy floods cause a lowering in TDS (fig. 4c) since the flow is mainly carried out by karstic conduits.

The main natural ionic markers of the system ($SO_4^{=}$, HCO_3^{-}, Mg^{++}) and the conductivity denote similar bahaviours. After a long period of low discharge little changes of the hydrograph are characterized by significant increases of the different ionic markers (fig. 5), with delays that can last several days. Heavy floods cause a quick increase in the marker concentration, whilst a flood immediately folowing another flood gives rise to a decreasing in the ionic markers values.

As the spring collects waters coming from different areas of the system (limestones and quarzites), the ratio between the two types of water is a function of the hydraulic head of the system as follows:

- a strong hydraulic charge in the fractures network brings out a quick response of the system; this is typical of heavy raifall following rains of some lenght (water saturation of soil and fractures);
- snowmelt and moderate rainfall (absence of saturation) cause delayed responses of the system.

The silica behaviour is peculiar and it is completely different from the ionic markers one. Silica reaches the lowest concentrations during the highest discharge periods; high silica concentrations are observed during low discharge periods.

The behaviour of Bossea karstic system is quite complex and reflects the great importance of the subsystems in supporting discharge. Subsystems return peculiar waters (enriched in $SO_4^{=}$ and Mg^{++}) during flood periods; the aquiclude (fractured quarzites) supplies a continuous feeding during low-water periods.

The temperature recorded in the main subterranean stream of the system, ranges from 6.9 to 7.9 °C and shows a gradual lowering during Spring flood. Small fluctuations ($\pm$ 0.1 °C) have been recorded in an effluent subsystem.

CONCLUSIONS

Waters of different origin feed Bossea karstic system in the course of a year; hydrodynamic and hydrogeochemical features of the system are mainly related to the prevailing of one of these types of water. When no direct infiltration occurs, the system is fed by a secondary aquiclude (fractured quarzites); during this period (lasting sometimes up to six months) values of 50-60 l/s are recorded with no appreciable variations.

Discharge peaks are marked by a "piston effect" of waters flowing in fractured limestones; the conductivity increases and silica value show a peculiar lowering.

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