HYDROGEOLOGY OF GALESE SPRING. MAR PICCOLO OF TARANTO (SOUTH ITALY)

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Abstract

The basin of the Mar Piccolo represents one of the areas of greatest hydrogeological interest in the region of Apulia. Situated between two large hydrogeological units (Murge and Salento), the basin is characterized by the presence of numerous submarine and subaerial springs (locally known as "citri").

This paper first outlines the structural features of the area examined and it is pointed out that tectonic phenomena have played a major role in the hydrogeological evolution of the zone and also in conditioning the flow-paths of the underground waters into the sea.

The second part of the paper is particularly concerned with the Galese spring which, with a discharge of 500 l/s, represents the largest subaerial spring in the Mar piccolo basin.

The surveys carried out, as well as defining the hydrogeological and chemical parameters of the spring, have highlighted the hydrodynamic and hydrochemical influence exerted by the sea on the karstic groundwater and also its influence on the evolution of phenomena of marine intrusion.

Lastly, the connections that have emerged between the Galese spring and the Galese "citro" have proved to be of particular interest.
1 Introduction

The present work is part of a wider programme of research that has been carried out by our Institute over the past few years on one of the most interesting hydrogeological areas in Apulia: the basin of the Mar Piccolo of Taranto (Cotecchia 1955-56, 1977; Tadolini and Zanframundo, 1975; Tadolini et al. 1983).

Characterized by a particular geometrical shape, the basin of the Mar Piccolo represents the most southern part of the Murgian hydrogeological unit and its only outlet to the sea on the Ionian coast.

Tectonics and the presence of a thick formation of clay, involving the entire Ionian front of the hydrogeological unit, affect the flow of water seawards; this flow is found only in concentrated form through numerous subaerial and submarine springs, the latter being known locally as "ci- tri".

The enormous quantities of water, with a relatively low salt content, that flow, unused, into the sea every year have, over the years, assumed considerable economic importance because of the major advantages that the entire economy of the area would stand to gain if the water were utilized.

Apart from the acquisition of information of a general nature on the hydrogeology of the area examined, this study is also concerned with obtaining information, through research carried out on the Galese spring, on the hydrological and hydrochemical behaviour of the entire drainage complex of the Galese.

2 Geological outlines

The area examined develops in an amphitheatre shape around Taranto and covers a surface of about 1000 sq.Km. It is characterized by large outcroppings of calcareous rocks which are karstified and, in places, covered by calcarenites; there is also a modest surface hydrography constituted essentially by deep inlets.

These characteristics tend to disappear in the most western part, giving way to physical features typical of the Lucania region, because of the thick overlying clay layer.
Alluvial deposits (HOLOCENE)
Marsh silts (HOLOCENE-PLEISTOCENE)
Conglomerates and sands (PLEISTOCENE)
Calcareousites (ITYRMENIAN-CALABRIAN)
Clay (CALABRIAN)
Calcareousites (UPPER PLIOCENE)
Limestones, dolomitic limestones and dolomites (CRETACIOUS)

Figure 1. Schematic lithological map

The oldest rock formations to be found in the area (Figure 1) are represented by mesozoic carbonatic rocks made up predominantly of limestones, dolomitic limestones and dolomites. These formations, which constitute the geological foundation of the entire region of Apulia, are characterized by evident stratification and by fracturing which is visible throughout the area, and they have also been subject to widespread karst phenomena which make them particularly permeable (Martinis and Robba, 1971).

Proceeding in stratigraphic succession from bottom to top, we find Pliocene calcarenites, transgressive on limestones, then Calabrian clays which constitute an uninterrupted layer of increasing thickness from north to south.

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On top of the Calabrian clays which, in the coastal areas, come into direct contact with the calcareous substratum, we find, on the eastern side, coarse calcarenite while, on the western side, there are conglomerates and marine sands. Both these units are Pleistocene (Martinis and Robba, 1971; Ricchetti 1967).

Finally, lagoon and marshy silts are to be found, predominantly in the eastern sector, along with current and recent alluvial deposits. The area examined does not present any special structural complexity and is characterized by a strict correspondence between morphology and tectonics, so that the highest reliefs coincide with the structural highs constituted by Mesozoic limestones.

The salient features of the tectonics of the area are constituted by the Mottola-Lizzano syncline, the Statte anticline, and the constant lowering

![Tectonic map with depth to top of calcareous bedrock](image)

Figure 2. Tectonic map with depth to top of calcareous bedrock
in a NE-SW direction of the Mesozoic limestones, caused partly by their cracking in this direction and partly by the numerous faults that can generally not be seen on the surface (Martinis and Robba, 1971; Zorzi and Reina, 1962).

Because of the considerable importance of this latter aspect for the hydrogeology of the area, an attempt has been made, by studying the various layers of rock to define the probable dislocation of the main submerged faults.

This study (Figure 2) has shown the presence of a complex network of faults, all normal and with a non-estimable throw, running predominantly in two directions — the main one being in the Apennine direction, almost parallel to the axes of the folds, the other being normal with respect to the former.

3 Hydrogeological outlines

Unlike the surface hydrography, characterized by deep inlets which, in the rainy periods, carry rapidly into the sea the meteoric water that does not infiltrate the subsoil, the underground hydrography is particularly rich in water resources.

These generate two separate systems of circulation: one is constituted by the waters flowing in the Pleistocene soils overlying the Pliocene clays and is generally known as the "surface groundwater", while the other is constituted by the waters flowing in the permeable layers as a result of fracturing or of karstification of the Mesozoic limestones and is known in literature as the "deep groundwater" (Cotecchia, 1955-56, 1977).

Since the fresh waters of the deep aquifer lack an impermeable bed, they are balanced on top of the marine waters of continental invasion and have sea level as their base flow level.

Field studies, carried out basically in order to study the deep groundwater, have brought to light in particular the close connection between the hydrogeology and the tectonics of the area (Figure 3).

Tectonic movements that have occurred in time have in fact contributed to the creation along the coastal strip of a thick and wide impermeable barrier constituted by Calabrian clays which conditions both the cir-
Permeable rocks through fissuring and karstification
Permeable rocks through porosity
Practically impermeable rocks

Figure 3. Schematic hydrogeological map

culation and the way in which the groundwaters flow into the sea.
In fact, because the groundwaters are forced to circulate under pressure and are not allowed to flow naturally, in a diffused way, into the sea, "safety valves" have been formed in the clayey layer, constituted by subaerial and submarine springs, through which the waters pour into the sea at a rate of about 10 mc/sec (Tadolini and Zanframundo, 1975; Tadolini et al. 1983).

Of course the presence of these springs is especially concentrated when structural conditions are more favourable, as is the case in the area corresponding to the Mar Piccolo of Taranto, where a complex network of faults and reduced thicknesses in the clayey layer have helped to form as many as 8 springs and 32 "citri", all grouped together within a range
of 10 Kms (Cerruti 1938).

In fact, from the study carried out it would appear that the simultaneous presence (Figure 4) of the clayey layer, which helps to preserve high hydraulic heads, and of a submerged fault, which constitutes a preferential drainage route, may have produced, locally, the start of piping phenomena giving rise to the creation of springs.

Similar considerations may also be drawn by examining the hydrogeological map (Figure 3) in which both the isohalines, obtained in dynamic conditions, and the isopiezometric lines show clearly the influence of tectonics on their distribution.

Moreover, the role of tectonics is a particularly active one in relation to marine intrusion phenomena if one considers that while, on the one hand, faults constitute preferential flow routes for groundwaters, on the other they facilitate the entry of marine waters.

Figure 4. Schematic hydrogeological cross-section
The complex of springs (Figure 5) of the Galese is constituted by two geographically distinct groups of spring waters - one being submarine, known as "Citro Galeso", the other subaerial, called "spring Galese".

The "citro", situated at roughly 250 m from the coast, is constituted by a main spring, with an orifice of over 2 sq. m. in size, and numerous small outlets distributed on the sides or at the centre of a large funnel-shaped hollow, the bottom of which is about 20 m below sea level. The "citro" emits a considerable quantity of water (about 750 l per sec.) with a salt content in the order of 2.5 g per litre (Stefanon and Cotecchia 1969).

The subaerial spring, situated at about 700 m from the coast, is constituted by a group of springs which feed into a natural basin from the bottom, at a height of +3 m above sea level. Its maximum depth is less than 15 m (Ministero Lavori Pubblici 1953).

Between 1983 and 1986 a series of systematic observations were carried out on this latter spring with the aim of defining the hydrological and
Figure 6. Diagram of the most significant hydrological observations carried out on the Galese spring: 1 - sea level; 2 - spring level; 3 - discharge; 4 - Cl⁻ content; 5 - air temperature; 6 - spring temperature; 7 - marine ions/continental ions ratio
The variations in the level of the spring have proved to be directly dependent on the oscillations in the sea level (high tide-low tide), with maxima and minima transferred by about 90 minutes because of the delay with which such an influence manifests itself. Moreover, at low tide, they are also affected by periodic oscillations characterized by maximum widths of 3 cm and constant periods of about 40 minutes.

The trend of the rate of discharge of the spring has also been seen to be directly dependent on the sea level; in fact the flows are greater at high tide and smaller at low tide, with a maximum difference in the order of 20%.

The data presented so far induce one to believe that the two drainage systems, the subaerial and the submarine one, must be hydraulically connected and the way they function must be directly influenced by variations in sea level.

In general, the phases of high tide and low tide determine differentiations in the hydraulic head which have, as a direct consequence, gradual variations in the submarine discharges counterbalanced, as a result of the hydraulic connection, by variations of the opposite sign of the subaerial discharges.

This interpretation finds further confirmation in the small oscillations in the level of the spring at high tide which are typical of those induced in oscillation tanks by elastic disturbances.

Hydrochemical surveys have highlighted the fact that also the salt content of the spring waters, averaging at around 3.6 g per litre, is subject to these daily oscillations. In this regard, of particular significance are the curves of the Cl⁻ content and of the marine ion-conta...
nental ion ratio which provide unequivocal indications of the variations being proportional to the oscillations of the sea. The modest ranges in Cl⁻ content, typical of groundwaters with isolated karst ducts, indicate frontal entry – during high tide – of the sea which, when it is not stopped by the impermeable barrier, forms a brackish zone several hundred meters wide along the coastal strip.

Under these conditions the karst groundwater is more heavily influenced in hydrodynamic and hydrochemical terms by the sea with the consequent raising of the diffusion zone and drainage of the saltier waters. The curve relating to the thermal ranges of the spring waters undergoes no hydrodynamic or hydrochemical influence at all. The numerous observations carried out indicate that the spring waters always gush out at the same temperature of about 18.9°C, which makes them particularly sensitive, as is made clear in the graph, to changes of temperature in the air.

The high temperature and the salt content of the spring waters indicate, moreover, that the karst duct that feeds the springs must be situated at a very low level of the aquifer, predominantly draining the waters

![Graph showing components of water]

**Figure 7.** Main components of the waters of the Galese spring (solid line) and of the "citro Galeso" (broken line)
of the diffusion zone.
Lastly, the comparison between the chemical analyses carried out over a period of time on the spring waters has proved to be particularly significant (Stefanon and Cotecchia 1969; Zorzi and Reina 1962).
The data reported in Figure 7 show, over the years, the spring waters are undergoing a slow constant process of salinity and how this process is exclusively the result of a higher number of ions of marine origin in the chemical composition of the waters themselves. The latter is an unequivocable symptom of an evolution taking place of phenomena of pollution from marine intrusion, mainly due to an irrational exploitation of the present water resources in the area.

References

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