GROUNDWATER FLOW CIRCUITS IN THE SALENTINE KARSTIC AQUIFER (APULIA, ITALY) AS DEFINED BY THE ANALYSIS OF RADON CONCENTRATIONS

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ABSTRACT

Surveys carried out in a large portion of the coastal carbonate aquifer in the Salentine Peninsula showed that ^{222}Rn is always present in the groundwater, though with a very broad range of concentrations. The observed concentrations were found to be correlated with the presence, within the aquifer, of "terra rossa" which, as already pointed out in previous works, contains fairly large amounts of ^{226}Ra.

Groundwater circulation and storage are determined by the state of fissuring and karstification of the carbonate aquifer and by the presence of more or less important amounts of "terra rossa". Big karst conduits and large cavities that contain this kind of residual material play an important role in the process of waters enrichment with radon. The research reported in this paper has showed that radon concentrations are instrumental in providing useful information on subterranean water circuits ending up in coastal springs, as well as on the aquifer's state of karstification.

1. FOREWORD

Investigations carried out to date in the Puglia region to check for the presence of natural radioactive isotopes in groundwaters circulating inside carbonate aquifers have shown that radon, a radioactive gas, is always present, though at widely differing concentration levels. In particular, it has been found that wherever groundwater is sampled, this gas always occurs at concentrations ranging from a few pCi/l to some thousand pCi/l.

In earlier studies such presence was correlated mainly to groundwater flow velocity (Cotecchia 1977). However, it has been shown lately that the observed variability of concentrations over time is caused by different processes originating from the hydrological cycle as well as from natural phenomena (Tadolini et *al.*, 1994-a) and from water withdrawals while the "terra rossa", which is a residual product of carbonate rock weathering, actually represents the main source of ^{222}Rn; in Puglia, this kind of material is widely distributed both at the soil surface and in depth and contains significant amounts of radionuclides (Tadolini Spizzico, 1996).

It is well known that the state of fissuring and karstism in carbonate formations is often attended by the presence of "terra rossa" that may affect two important hydrogeological parameters namely, permeability and water storage.

2. INVESTIGATIONS

Radon was employed as an indicator in this study which was aimed at seeking correlations between the occurrence of "terra rossa" on the one hand and groundwater flow velocity, the carbonate aquifer's permeability and its state of fissuring and karstism, on the other hand.

Radon has a half-life of 3.8 days while the Salentine karstic groundwater has an especially long residence time owing to the fact that flow velocity is extremely low, just about a few dozen centimetres per day (Cotecchia, 1977; Cotecchia et *al.*, 1989)

The study covered groundwater circulating in a vast portion of the Salentine Peninsula coastal carbonate aquifer which is characterized by a generally high degree of fissuring and karstism though it may vary widely at sites from very high to just negligible values.

In order to simplify the interpretation of the very special hydrogeological environment discussed here, the permeability characters are expressed in terms of the specific yields observed by test pumping a large number of boreholes; higher specific yields are usually due to a higher state of rock fissuring and karstism, hence to a higher degree of permeability.

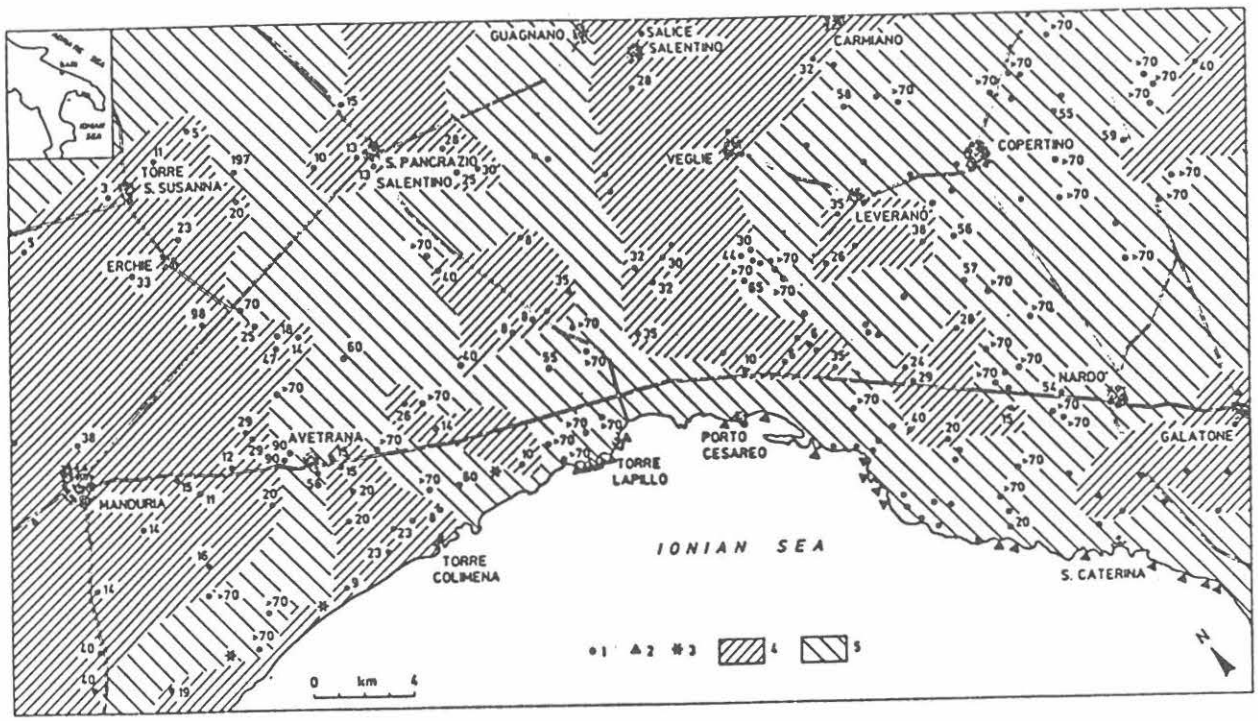

Fig. 1- Specific discharge (Qsp) values distribution (1: well; 2 coastal spring; 3: suaberial outflow; 4: Qsp < 50 l/s • m; 5: Qsp > l/s • m).

The map in figure n. 1 highlights areas with distributions of specific yields below and above 50 l/s.m. , respectively. Noteworthy, these distributions correlate well with the area's typical tectonic-stratigraphic features (Tadolini et *al.*, 1995).

As shown in figure n. 1, the most outstanding permeability factors along the coastline are revealed by the presence of a large number of springs.

The study area presents a variety of karst forms, sinkholes and dolinas, which, thanks to natural and/or man-induced leaching, contribute to making the "terra rossa" penetrate from the land surface, where it occurs in varying amounts over more or less widespread areas, down to different depths. Surface distribution of "terra rossa" can also depend on local farming practices: this residual carbonate rock material is collected, transported, handled and distributed on the soil, then used by peasants to grow some particular crops.

Two different types of symbols in figure n. 2 denote two fields, for different distributions of ^{222}Rn concentration values, below or above 270 pCi/l respectively, as measured in groundwater samples taken dynamically. Still other symbols denote water points at which radon values are higher than 600 pCi/l, with peaks of up to 3400 pCi/l.

The aquifer can be characterized by correlating the observed variety in radon concentrations, to its different states of fissuring and karstification.

Radon concentrations in waters sampled from coastal springs were found to be well correlated with those measured in boreholes drilled just inland from the coastline, despite the obvious fact that they are diluted in seawater (Tadolini et *al.*, 1994-b).

This was confirmed by the observed relationship of salt contents and corresponding radon cncentrations between boreholes and springs supplied by the same water like, for example, the spring at Torre Castiglione (^{222}Rn=960 pCi/l; T.D.S. 8.5 g/l) and the corresponding inland borehole (^{222}Rn=1610 pCi/l; T.D.S. 4.91 g/l), or in other similar circumstances.

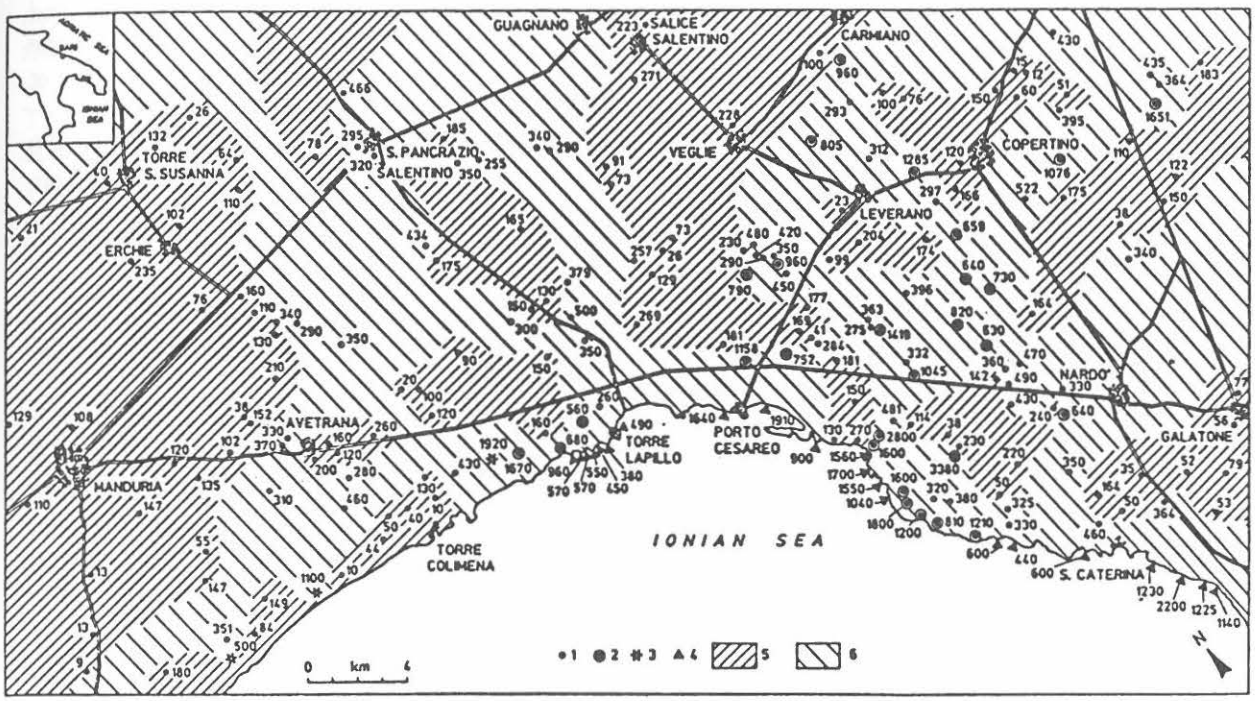

Fig. 2 - ^{222}Rn values concentration (1: well; 2: well with ^{222}Rn concentration > 600 pCi/l; 3: subaerial outflow; 4: coastal spring; 5: ^{222}Rn < 270 pCi/l; 6: ^{222}Rn > 270 pCi/l).

3. RESULTS

Areal distributions of radon concentration values can be correlated with the aquifer's hydrodynamic characteristics, as expressed in terms of specific yelds; such features derive not only from the rock's state of fissuring and degree of karstification, but also from the more or less conspicuous, yet widespread, presence of "terra rossa".

The data collected and processed for the purpose of this work show that, in the area just off Avetrana, radon concentrations are comparatively high while specific yelds are rather low. In the light of the information given above, this may be due to a significant presence of "terra rossa" that obstructs the cracks and fills the cavities so that permeability in that portion of the aquifer is markedly reduced.

Permeability is fairly high (Qsp>100 l/s.m) in the vicinity of Torre S. Susanna whereas radon concentration (<70pCi/l) is rather low: this means that in those parts of the aquifer where the state of fissuring and karstification is more developed, "terra rossa" is present in correspondingly lower amounts.

In the coastal strip west of Torre Columena, seaward outflows of karstic groundwater are strongly conditioned by the last patches of Calabrian clays presented all over the Tarantine Ionian Arc. Such stratigraphic conditions cause ground waters to flow along lines running practically parallel to the coast, then out into the sea at sites where the described impervious formation is no longer present.

It is worth noting that where the water heads are comparatively high and the thickness of the impervious clay layer is rather small, springs may develop because the impervious roof of a particular portion of the aquifer has been burst open. Examples of this kind are the Chidro and the Boraco springs located several dozen meters seaward from the coast (Cotecchia et *al.*, 1973).

In the inland area between Torre Columena and Torre Lapillo, where groundwater flows under moderately confined conditions and seawater ingression is rather strong, both specific yelds and radon concentrations are low (Tadolini et *al.*, 1995).

Conversely, specific yelds are low and radon concentrations are high between Torre Santa Susanna and San Pancrazio Salentino where the rock is heavily fissured and karstified and there are remarkably rich "terra rossa" deposits.

Lastly, groundwater is heavily drained by coastal springs scattered between Torre Lapillo and Porto Cesareo: this is revealed by observing the pattern of the piezometric surface as well as by the presence of many significant groups of springs some of which yield rather heavy discharges (Tadolini et *al.*, 1995; Tadolini et *al.*, 1996).

Radon concentrations in the grouped outflows in the vicinity of Torre Lapillo are between 500 and 600 pCi/l; instead, the submarine springs along the coastal stretch from Porto Cesareo to Santa Caterina show values ranging between 1200 and 1600 pCi/l. Inland, at the water points covered by this study, the corresponding values were as follows: 600 to 700 pCi/l and 1300 to 2800 pCi/l.

Along the coast east of S. Caterina, radon concentrations in submarine springs are remarkably high (2200 pCi/l); but could not be compared with those of the coastal belt due to lack of suitable water points. However, at about 2 km off the coast, where the aquifer's permeability is low, radon concentration is also low.

Given the environmental setting described above, a particular hydroisotopic cycle can be briefly defined as follows: as rainwater flows away over soils that contain "terra rossa", it becomes enriched in radon. As soon as it turns into "supply water" for groundwater replenishment, it conveys both radon and, under favourable geoenvironmental conditions, any existing "terra rossa"; groundwater inside the aquifer becomes increasingly enriched in radon as it flows out through subterranean cracks and cavities often containing varying amounts of "terra rossa"

As a consequence, although radon half-life is brief and flow velocity is rather slow, groundwater is quite rich in radon precisely because circulating waters are in more or less continuous contact with such "terra rossa" as may be present inside the aquifer. In the light of the above discussion, precisely the latter circumstance suggests that the various radon concentrations observed in this study basically depend on the existence of the karstic phenomenon, hence on the occurrence of "terra rossa" that is more or less copiously and variously distributed inside the aquifer.

With a higher degree of karstification, hence in the presence of big karst conduits and extended cavities with "terra rossa" deposits, very large water volumes are often directly in contact with the "terra rossa".

Lastly, radon concentrations measured in flowing coastal springwaters reveal another peculiar feature of the study area: inland sea water intrusions penetrate from below, not laterally, except in a few rather well-defined portions of the aquifer, generally without seaward outflows.

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