THEMATIC MAPPING ON GROUNDWATER CHEMISTRY: FIRST RESULTS PERTAINING TO SPRINGS IN THE REGGIO-EMILIA APENNINES (NORTHERN ITALY).

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FOREWORD

Italian Law 152/99 informed by European water resources management directives, appointed Regions the task of compiling an inventory of local springs. The information is organized in a data base, to be gradually implemented according with the progress of data collection. Within the Emilia-Romagna region, the Servizio Geologico has been working on the inventory since 2000, when the project for thematic maps on a "Masterplan on geo-environmental hazards" began. In 2003, these maps at the scale of 1:250,000 were issued: one map deals with aquifers in the Emilia-Romagna mountain area, a sector of the Northern Apennines, which are detailed at a regional level for the first time (Viel, De Nardo & Montaguti, 2003). This first-approximation map on mountain aquifers, the latter informally named "rocce-magazzino" ("storage-rocks"), was used as a reference for the Piano di Tutela delle Acque (regional Plan for Water Protection) adopted in 2005. Since this first data collection, the regional inventory of springs (with particular attention to tapped ones) has been implemented and carried out in the provinces (the administrative subdivisions of Italian regions) according to the distribution of Public Agencies and Companies that manage aqueducts and of Institutions committed with water-use permits.

GEOGRAPHIC AND HYDROGEOLOGIC FRAMEWORK

To the south, the Reggio Emilia Apennines are limited by the boundary between Emilia-Romagna and Tuscany; the area corresponds to the mountain sectors of the Enza and Secchia catchment basins, both these rivers being affluents of the Po. To the north the border of the study area is represented by the imaginary line drawn between the towns of Canossa and Vezzano. Canossa is renowed as the historical setting of the struggle between the Pope, his ally the Countess Matilde and the German Emperor Henry IV, in the Middle Ages. Elevations are comprised between two thousand metres (Alpe di Succiso, 2017 m, M. Cusna 2120 m) and approximately four hundred metres a.s.l. From a general point of view, the Emilia-Romagna aquifers mostly correspond to turbiditic formations, while aquitards are to be found in marly and shaly chaotic units. Aquifers that are similar to karst, carbonatic ones are located in evaporites of local importance. Springs commonly present values of mean discharge that are almost unitary; values of tens of litres per second are very rare and typical of evaporites or severely fractured areas within massive arenites. In the study area the main springs are located in the highest, local Apenninic sector, near the boundary with Tuscany ; they are to be found in the evaporites of Triassic age ("Calcare cavernoso" Auctt.), locally covered by debris accumulations of morainic origin. According to Canedoli et alii, 1994, the springs named "Polle Gabellina" and "Ponte Barone" yield 118 and 70 l/s respectively. These are the main springs feeding a 1100 kilometre long aqueduct (managed by the AGAC Company) which provides the Reggio Emilia mountain area with potable water. Other groups of springs are located in turbidites, corresponding to the Oligo-Miocene formations of Arenarie di Monte Cervarola and Macigno, according to the geological literature (e.g. Chicchi & Plesi, 1999). Moreover, sulphur springs are present in the area and exploited as healthy "thermal" (though cold) waters at the Cervarezza spa.

THE INVENTORY OF SPRINGS

In the period 1999-2002, data on springs was collected by the Servizio Tecnico di Bacino which is responsible for water-use permits in the Reggio-Emilia area. Locally (Toano and Villa Minozzo municipalities), information was gathered by means of field surveying, because of the abundance of small, private aqueducts.1. Using the GIS programme ArcView, 662 points symbolizing the documented springs were digitized on raster, 1:10.000 scale maps. Chemical and microbiological analyses was

[1] These activities were carefully done by Elisa Fava, a consultant of the Servizio Geologico.

carried out on 245 of these springs as prescribed by Italian law to assess their suitability as drinking water. These routinary chemical and physical parameters became attributes in the data-base, each analysis making a record geographically referred to a sampling point. Upon initial analysis, we realized that some of the sampling points did not coincide with springs themselves, as samples may be taken in more "convenient" but hydrogeologically less representative points, rather than from the actual source of an aqueduct e.g. houses or public drinking fountains. A first screening of available data was carried out, so that reliable (i.e. sampling points matching springs) and less reliable (sampling points other than springs) chemical analysis were split up.

The selection of data was achieved using additional information:

- a thematic map on aquifers in the Reggio Emilia Apennines at the scale of 1:50,000, issued for the above cited "Masterplan". This allowed springs to be related to geological units
- the network of aqueducts (geometry) at a regional level, issued by the Servizio Tutela e Risanamento Risorsa Acqua of the Emilia-Romagna Region.

Matching this information it is possible to identify analytical data that is fairly representative of groundwater yielded by a specific "roccia-magazzino", which can be used for further study.

GEOSTATISTICS APPLIED TO GROUNDWATER CHEMISTRY FOR THEMATIC MAPPING

1) At full-extent

On first results, approximately 158 of the 245 available chemical analyses are reliable enough to be used for thematic mapping, i.e. they show a clear relationship between sampling point location, springs and the geological formations hosting aquifers. A good result, if we consider that it derives from the all-purpose inventory of springs; which represents the first step for any territorial analysis dealing with groundwater in mountain areas. The parameters chosen for thematic mapping are the following ones:

conductivity, at 20°C in µS/cm, the most widespread parameter in the study area is present in each analytical report

sulphate concentration in mg/l, a natural tracer for groundwater yielded by evaporites (gypsum).

Using geostatistics, contour-lines expressing distribution and values of these parameters were traced. Contouring was applied to the whole study area and the resulting thematic maps (figures 1 and 2) must be considered first-approximation ones as they do not take into account the existence of permeability boundaries, separating hydrogeologic complexes hosting aquifers from less permeable ones. Under this condition, contouring expresses the "regional" trend in the distribution of the examined parameters, rather than actual, expected values.

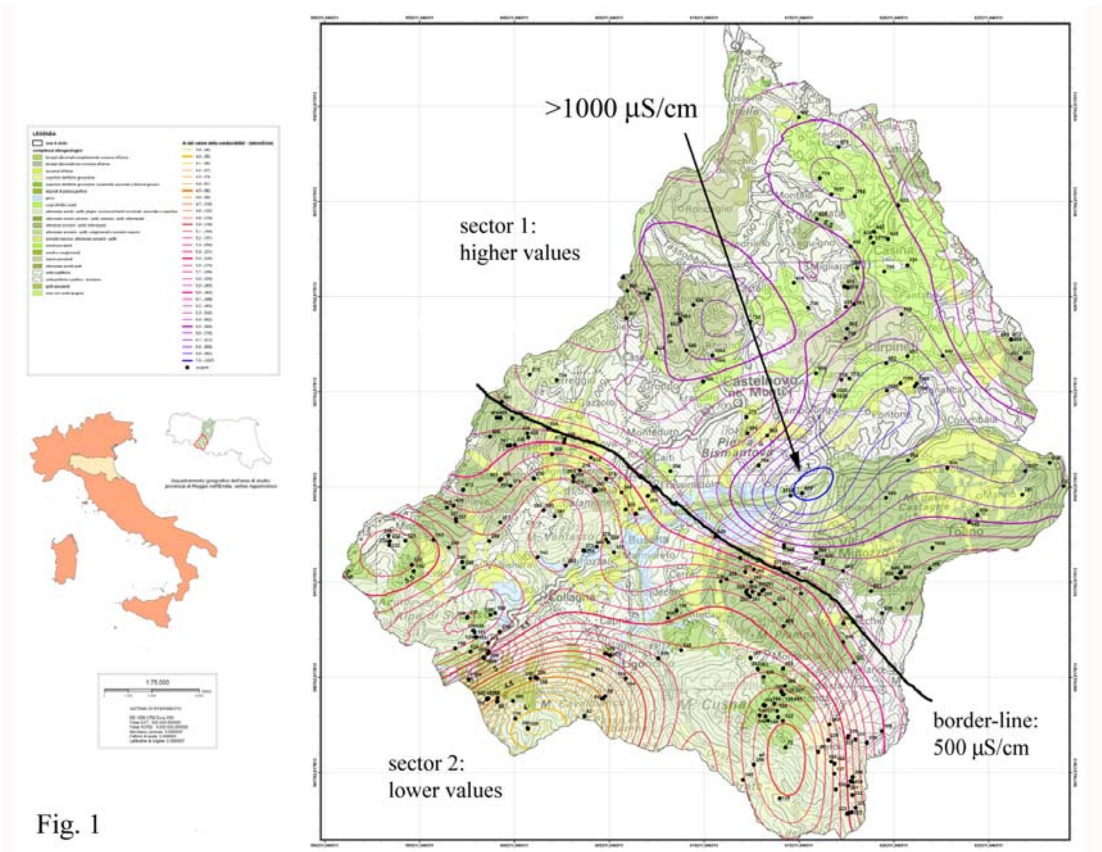


Figure 1 – Distribution of conductivity.

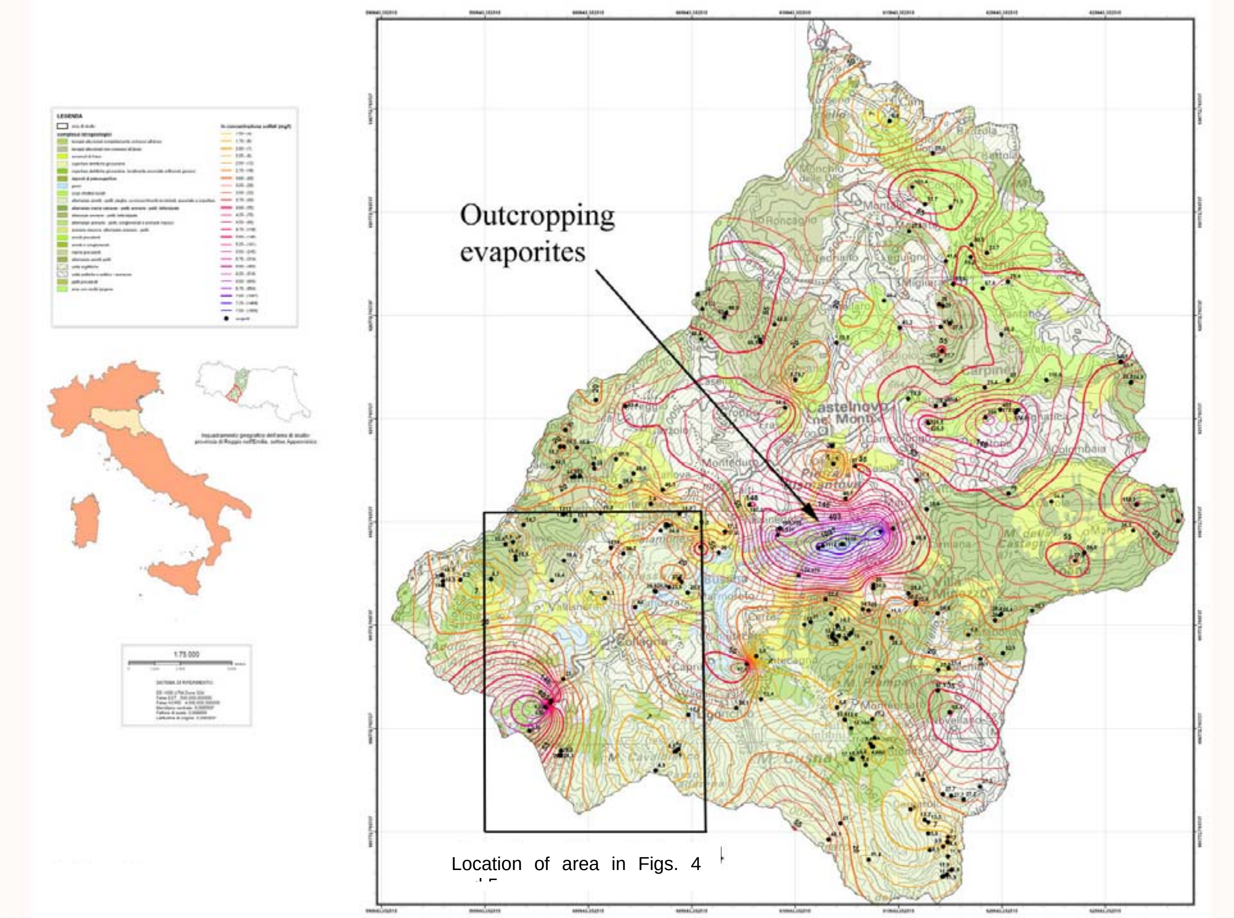


Figure 2 – Distribution of sulphate concentration.

In figure 1, conductivity achieves maximum values (more than 1000 µS/cm) in almost the same area where maximum sulphate concentration occurs (more than 1500 mg/l) in figure 2: there, aquifers are to be found in karstified gypsum, yielding mineralized and sulphate-rich groundwater. The boundary of 500 µS/cm in figure 1 divides two areas: upside groundwater is more mineralized than down the black contour. To draw contour lines, geostatistics were applied as follows. Examining the frequency of values of sulphate concentration, the distribution of data values becomes Gaussian (normal) when the logarithms of values are plotted: it is thus of lognormal type. The best model approximating the variogram curve (describing the spatial continuity of the examined data) is spherical (figure 3). A lognormal distribution is observed for conductivity as well; the variogram is of linear type, with no negligible “nugget effect” .

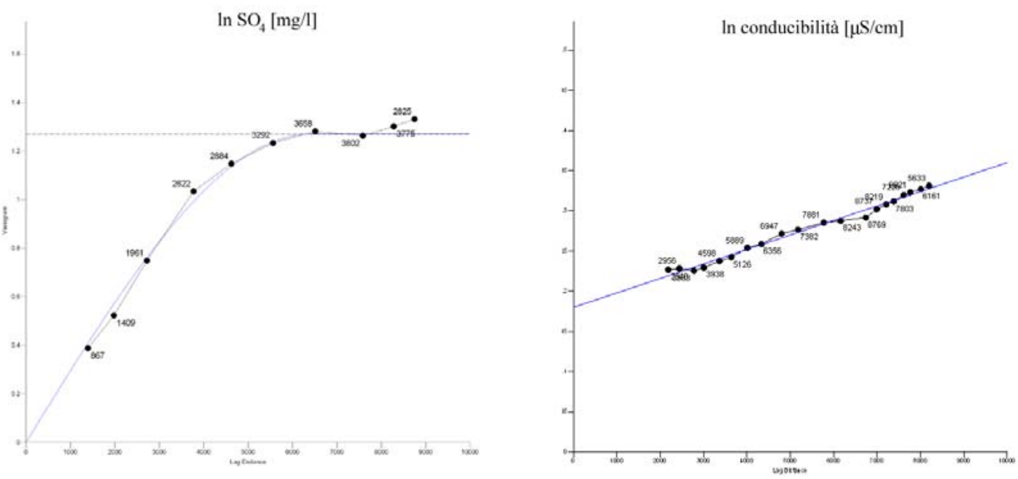
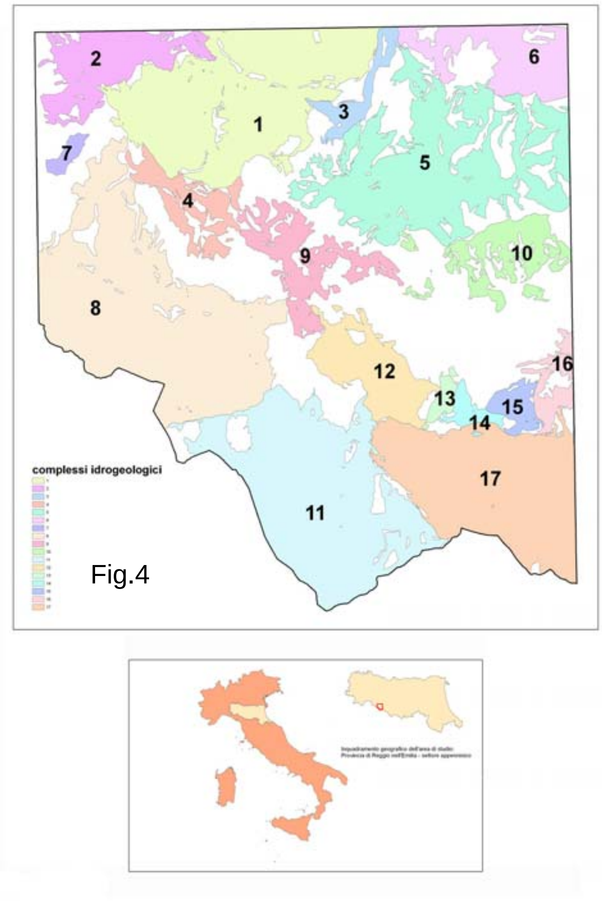


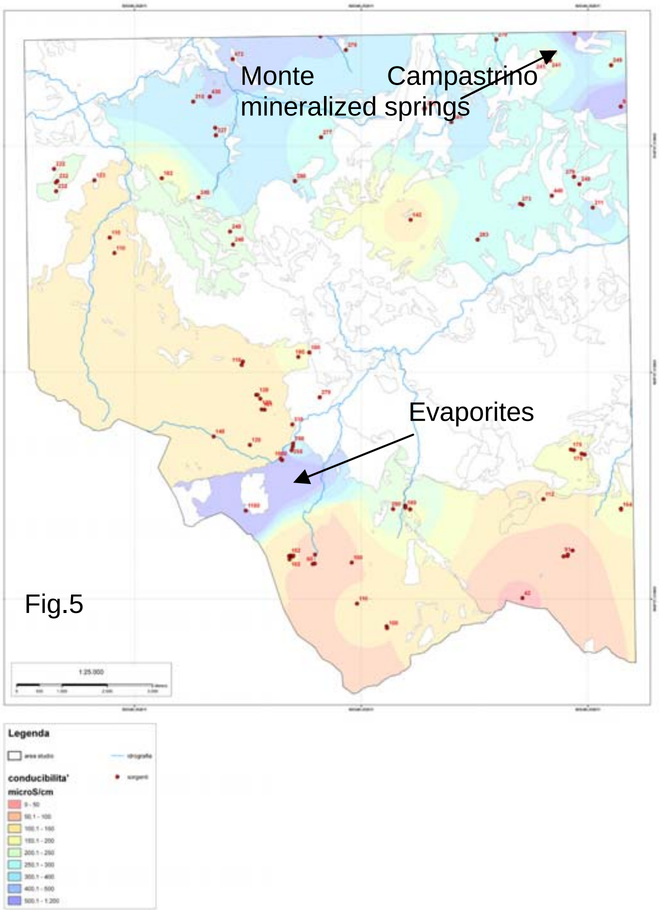
Figure 3 – Variograms of examined data

2) Detailed maps

To overcome first approximation maps, a sector of the study area (figure 2) was chosen for more detailed contouring at the scale of 1:10,000; in this second approximation, correlations were applied only to data located in the same group of hydrogeologic complexes. Groups were obtained matching springs with geological units, to obtain 17 hydrogeologic settings, depicted in figure 4; contouring was separately applied to 9 of these areas, provided with groundwater chemistry data.

As the number of sampling points is always less than 20 in each hydrogeologic setting, the Inverse Distance Weighting (IDW), a deterministic and non-statistical interpolating method has been used. Figure 5 shows one of the detailed maps obtained by correlating data within each hydrogeologic setting, dealing with conductivity (87 sampling points): orange to yellow colours correspond to classes of values from 0 to 200 µS/cm, blue from 250 to 400 µS/cm, violet to more than 500 µS/cm.





Figures 4 and 5, explanation in the text.

The correspondence with geology is outstanding: the distribution of the highest values of conductivity evidences both minor outcrops of evaporites and mineralized, “thermal” sulphur springs of the Monte Campastrino area. The same was done with the 49 sampling points corresponding to sulphate concentration values. The new contours based on hydrogeologic settings, though more reliable than the full-extent ones, will require local adaptation and reshape with respect to the boundaries between hydrogeologic complexes

CONCLUSIONS

In this experimentation, chemical analytical data was derived from a general, all-purpose data base on springs, compiled in accordance with Italian law. Geostatitistics were experimentally applied to the study of groundwater chemistry in mountain aquifers, correlating selected data values both at full-extent and within each hydrogeologic setting, the latter method being more coherent with geology. The degree of approximation of the resulting maps has been discussed. Thematic mapping provides a good tool for studying groundwater chemistry, besides “classical” classification diagrams that are more commonly utilized.

ACKNOWLEDGEMENTS

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