VISITS AND EXCURSIONS IN SICILY OF THE INSTITUT NATIONAL POLYTECHNIQUE DE LORRAINE, FRANCE

SCIENTIFIC AND TECHNICAL REPORTS

University of Palermo

Department of Physics

Visits and excursions in Sicily of the Institut National Polytechnique de Lorraine, France

Scientific and technical reports

Technical reports and proceedings of the "Meeting on Sciences and Technologies for the Environment: Environmental problems in Sicily and Lorraine regions: case studies and solution proposals", held on the 2nd of March, 2010 at the Maggio Lecture Hall of the Faculty of Mathematical, Physical and Natural Sciences of the Palermo University

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FOREWORD

This volume collects the technical and scientific contributions presented in the occasion of the "*Meeting on Sciences and Technologies for the Environment: Environmental problems in Sicily and Lorraine regions: case studies and solution proposals*", held on the 2nd of March, 2010 at the Maggio Lecture Hall of the Faculty of Mathematical, Physical and Natural Sciences of the Palermo University. The meeting, organized by the same Faculty and supported by AMAP, has represented the ideal conclusion of an intense program of visits and excursions performed in Sicily by a numerous group of teachers, researchers and students belonging to the "Institut National Polytechnique de Lorraine (INPL)" of Nancy, France. Their program included, among others, technical trips to the Bellolampo landfill, the Rosamarina dam, the Scillato springs and the Acqua dei Corsari water depuration plant. Therefore, these notes summarize the excursion outcomes as well as a group of scientific contributions relevant to recent researches carried out in the respective regions of Sicily and Lorraine.

So, it seems clear the intent to pose the bases of an auspicial cooperation between the involving institutions, i.e. the Palermo University and this French public University of Technology of Nancy. This represents also a further knowledge opportunity for the students of both countries along their study and formation curricula. Indeed, it is opportune to remember that cultural exchanges among prestigious university and scientific organizations constitute the fundaments of all the European educational and research strategies, to which the Palermo University itself acknowledges the highest importance.

A felt appreciation is addressed to the Faculty of Mathematical, Physical and Natural Sciences of the Palermo University, namely its vice-President prof. Benedetto Abate, for hosting the meeting and divulgating its significance near the Palermo University students. A particular greeting and gratitude is addressed to the whole staff of AMAP in the visited plants, which has created, with elevated competence and availability, an ideal, warm welcome atmosphere for the French guests. Finally, special thanks are addressed to the Department of Physics of Palermo University, namely its Director prof. Maria Brai, which has supported this publication.

Therefore, the presentation of this volume is pregnant of satisfaction, with the final auspices that it could tangibly represent the premise of future meeting occasions between the involved institutions.

Antonio Cimino, editor
(Department of Physics, University of Palermo)

INDEX

ENVIRONMENTAL MANAGEMENT IN SICILY AND LORRAINE REGIONS: COMPARATIVE CASE STUDIES

Team of engineering students and teachers in Sciences and Technologies for the Environment (STE) -National Polytechnic Institute of Lorraine (INPL); Nancy, France.

SUMMARY

INTRODUCTION

Every year, the students from the Sciences and Technologies for the Environment (STE), specialty of the National Polytechnic Institute of Lorraine (INPL), go on study tour to compare the environmental management among the visited countries and the study area in France, the Lorraine region.

The organization of visits and the logistics of this trip are ensured by the students to practice their ability to project management. Indeed, following this field study, students will go for their final professional internship 6 months to end of study, which marks the final step before graduating as an engineer.

This year the destination was Sicily and the schedule of visits was as follows (25th of February to the 6th of March 2010):

	Friday 26/02	Saturday 27/02	Sunday 28/02	Monday 01/03	Tuesday 02/03	Wednes.03/03
8h-9h						
9h-10h	Capo Rama					
10h-11h	WWF	Castellammare	Monreale	Saline di	Palermo Dam	Acqua dei Corsari depuration plant
11h-12h				Trapani		
12h-13h				WWF	Scillato springs	
13h-14h						
14h-15h	*Rifiuti Zero*	Zingaro Natural	Segesta	Marsala		
15h-16h	*Palermo*	Reserve		plant	Meeting in	City tour in
16-17h	Overview of		Erice		Palermo	Palermo
17h-18h	the landfill &				University	
18h-19h	meeting					

	Tuesday 04/03	Friday 05/03
8h-9h		
9h-10h	Meeting with	
10h-11h	Paolo Guarnaccia	Cefalù/
11h-12h	*Rifiuti Zero*	Madonie Park
12h-13h	*Palermo*	
13h-14h		
14h-15h		
15h-16h	Etna	Cefalù/
16-17h		Madonie Park
17h-18h		
18h-19h		

Legend

- Tourism
- Natural and artificial environment
- Water management
- Resources and economy
- Waste management
- Sustainable development topics

The main topics of studies are the ones indicated on the legend of the previous schedule.

The aim of this approach is to have an overview of the environmental management of the studied areas.

I/ NATURAL AND ARTIFICIAL ENVIRONMENT

WWF
World Wide Fund For Natu

Regarding the natural resources of Sicily, we observed a rich fauna and flora with several protected endemic species. This related to the diversity of landscapes and geological structures involved. We have in this regard had the opportunity to visit several natural reserves including two managed by WWF: “Capo Rama” (Fig. 1) and “Saline di Trapani e Paceco” (Fig. 2).

We also visited the Regional Park of the Madonie, the Natural Reserve of Zingaro and the Etna Regional Park.

Fig. 1. Capo Rama.

Fig. 2. Trapani and Paceco saltworks

We noted that reserves managed by the WWF were very well kept and seemed effectively protected (we have not noticed trash on sites, for example).

Comparison with France in general:

Nevertheless, the quoted parks appear to have less strict regulations than in France. Indeed, we do not have access to this regulation; however, we noticed the houses in them: this is not possible inside French national parks and plastics wastes and others mostly left by tourists were clearly visible.

II/ WASTE MANAGEMENT

Regarding waste management in Sicily, we met a civic association that aims to inform the public about the problems related to waste. The name of this association is *Rifiuti Zero*. In fact, very little information is made about the management of waste and people do not know what happens to their garbage.

We have observed the discharge of Palermo located in an area normally protected in the hills above the city! This struck us by the complete absence of sorting (Fig. 3) and the accumulation of “percolate” seeping into the underlying karst geologic structure (Fig. 4)!

Fig. 3. Household wastes.

Fig. 4. Landfill of Palermo.

Bruxelles, le 19 mars 2009:

The European Commission is sending Italy, pursuant to Article 228, a first written warning for failing to comply with a ruling of the Court of European Justice Communities issued in April 2008 on the incorrect transposition in Italian law of the EU directive concerning waste discharge.

Several articles of this Directive have not been included in relevant national legislation and the transitional compliance existing landfill was incompatible with the Directive.

The Directive on the landfill of waste sets a series of measures relating to the location, construction and management of sites to prevent or minimize water pollution, soil and air caused by landfill sites. It was adopted in 1999 and should be implemented in national law July 16, 2001 at the latest. Italy has still not completely implemented certain provisions of this Directive, including those relating the criteria for acceptance of waste at landfills.

The fact that the European Commission pursues legal action against Italy over infringements of Community legislation in the environmental field, particularly regarding the land filling of waste, shows that there is indeed room for improvement in this area.

Comparison with Lorraine region:

Waste management in France is much more selective in the sense that the waste is sorted and - depending on their characteristics - differently treated.

Treatments used for industrial wastes depend on their characteristics: physic and chemical treatment, incineration, co-incineration, biological treatment, storage of final waste or deep burial. We can also speak about recovery of green waste and sludge from wastewater treatment plants in agriculture, collection and recycling of glass, paper and some plastics as regards household waste, etc...

III/ WATER MANAGEMENT

Fig.5. Hydrological cover of Sicily.

The area of this island is 25 684 km². The climate is Mediterranean semi-arid with a rainfall average of 650 mm/year.

Hydrological cover:

There are 39 rivers (Fig. 5), whose Simeto (catchment area of 4200 km^2), 3 natural lakes but also 31 artificial ones. Concerning groundwater resources, there are 14 hydrogeological basins and related aquifers (partially unfit for consumption because of excessively high salinity).

AMAP S.p.A.
RISORSE IN AZIONE PER IL BENE COMUNE

We were fortunate to be joined by Antonio Cimino who is an hydrogeologist at the University of Palermo. It allowed us to meet the actors of AMAP (Municipal Agency of Water Management in Palermo) and go with them to visit a dam that supplies water to Palermo (Fig. 6), Scillato springs (Fig. 7) and the depuration plant of Palermo (Acqua dei Corsari depuration plant).

Fig. 6. Dam supplying Palermo.

Fig. 7. Scillato water springs.

The dam that we visited is only a collector of water and nearly 50% of the water which meets during the winter period is lost by evaporation at the arrival of summer.

We may also note that a significant percentage of water is generally diverted from aquifers by individuals or organized groups for private purposes.

We have observed another striking issue concerned the quality of the pipes. Indeed the old pipes that feed the city are not rehabilitated and those who are outdoors increased losses. **This means that the water management can be re-evaluate to be more sustainable.**

We visited the depuration plant of Palermo (Figs.8 & 9), which seems quite standard in terms of its functioning (see IPPC: *Integrated Pollution Prevention and Control in EC legislation*). However, we failed to understand how it was possible to manage all wastewater from a city of more than 700 000 inhabitants with a depuration plant that has a capacity of only 440 000 equivalent inhabitants!

The expansion of plant capacity is underway but at present it cannot meet the real needs of the city. It should be noted that a project is also being studied to add an anaerobic circuit following the aerobic one and retrieve the generated biogas for energy recovery plants.

Figs.8 & 9. Acqua dei Corsari depuration plant.

The paradox of Palermo: a province excess water and yet in crisis

Water scarcity is caused by an imbalance between supply and request. The question is to determine its origin. The water crisis is not a problem of unavailable resources but a problem of their management. The trend of precipitation of course affects the amount of resources available but it cannot, alone, explain the shortage, because dams have precisely been built to protect the city from this type of situation.

We are witnessing a structural water crisis. First, because it is a long term, deep, latent and permanent water system crisis. Then, because it is caused by the failure and obsolescence of infrastructure. The inventory of infrastructures requires to distinct two geographic areas, first area is the provincial one where are the main water resources (surface water and groundwater) and infrastructure (dams, reservoirs, unit drinking, penstock, waterworks), and secondly local space across which the water supply is managed.

Sicily is among the Italian regions the one which owns the most important park of dams. An ambitious political capital has indeed been launched following the major shortages of the 1960s and 1970s, which were interpreted as the consequence of a lack of infrastructure to store and carry water. However, thirty years later, almost no dams have been approved, and many of them have never received permission to fill!

The origin of those restrictions, which lead to generally underutilized dams, is mainly due to: litigation and bankruptcy, causing the interruption and indefinite lengthening of works; the identified defects, which bring into question the safety of facilities and measuring devices failure...

The policy of water sector development, as in Sicily throughout the *Mezzogiorno*, has focused on primary infrastructure (see Becchi, 1990). Works have thus been realized as dams, treatment plants, water networks, then the penstocks while, simultaneously, the modernization and the development of urban distribution networks were neglected.

The failure of Palermo distribution is due to his age: 30% of the network has more than thirty years. A tenth is even older than fifty years. In addition, a poor overall conservation status is to be noticed. These failures are not new today: heavy losses were recorded since the late 1960s. The crisis distribution network cannot be reduced to a simple technical aspect. Indeed, aging equipment and pipelines is a natural process, part of the development of any infrastructure. **So, the engine of this crisis is political: it was processed by the absence of program maintenance and upgrading of the network.**

Comparison with Lorraine region:

Typically, in France it is mandatory that the design of wastewater treatment plants meet the size of the city where wastewater is collected.

It is also interesting to note that reservoir of rainwater are introduced to avoid overflow in case of heavy rainfall, which is not the case in the site of Palermo.

In Lorraine in many small rural villages or isolated houses, the system put in place is septic tanks. We also found in Lorraine as elsewhere in France pipelines maintenance problems but they have a lower degree than the situation in Sicily.

IV/ RESOURCES AND ECONOMY

We consider that Sicilian economy now relies mainly on large clusters as agriculture, fisheries, industries, tourism but also, let's be honest, the Mafia, which still generates an economic product extending not only on the island but also on the entire peninsula.

- Currency: Euro
- Labor force: Services (59%), industry (34%), Agriculture (7%)
- Major trading partners: Countries of the European Union, OPEC, the United States.
- GDP (Gross Domestic Product): 67 073.3 million euros
- Number of companies: 235000
- Unemployment: 20%

Agriculture and fisheries

Agriculture is mainly grown in coastal areas (20% of GNP, Gross National Product): there are crops of grapes, citrus fruits (the famous lemons from Sicily), nuts, and two centuries of olive groves, cereals and wines such liquors like Marsala (Fig. 10) or Passito of Pantelleria. Fishing is also an important role in the economy, such tiny but still spectacular the ancestral tuna fishing in the Mediterranean, colled "mattanza": this fishing is to catch tuna in the Atlantic on the path leading to their reproduction. The Japanese are very fond of tuna Sicilian and buy whole cargoes.

The Gulf of Messina, Mazara del Vallo, Sciacca and Castellammare del Golfo (Fig. 11) are the ports where fishing is active, tuna and shellfish are the prey of Sicilian fishermen.

Fig. 10 Marsala production.

Fig. 11. Fishing boats in Castellammare del Golfo.

Tourism and industries

Until the '70s, Sicily showed a demographic balance in deficit, in fact, Sicily has suffered the departure of men and women immigrants to the U.S. or Europe in search of work, so lack of investment and entrepreneur has not helped the insular economy.

The mines of the Caltanissetta region in the nineteenth century were large producers of sulfur, but declined from the 50s. Today the main industries are directed towards the exploitation of deposits of methane and oil discovered 20 years ago. Production and refining of hydrocarbons have favored the installation of large petrochemical pole (Augusta, Ragusa, Gela, Milazzo, Porto Empedocle), while Palermo and Messina performs activities related to the shipyards.

In recent years, the island's economy has benefited from the development of activities related to new technologies and telecommunications, particularly in the area of Catania, in what is called "Etna Valley".

Latest economic dream dated back more than 30 years: the achievement of a bridge over the Strait of Messina, the project is still under study. The island will possess then the longest suspension bridge in the world.

In addition, the introduction of the Euro will give, in a long term, an economic recovery to residents of southern Italy. The revival of Sicily, which is an opening on the Mediterranean countries, will help the future Europe to be more competitive with the rest of the world economy.

But economic problems do not prevent Sicily to offer Sicilians very high purchasing power, comparable to that of Rome or Milan; tourists appreciate white sand beaches and an unparalleled archaeological heritage in Europe through its very numerous medieval monuments, baroque, antique (Agrigento, Segesta, see Fig. 12, Taormina, Eraclea Minoa…) now world famous. In recent years, the tourism economy grows increasingly becoming the mainstay of the island, but it is still very far from being achieved and expressed its full potential.

Fig. 12. Greek temple in Segesta.

The Mafia

The collection of *Pizzo* (extortion) has been the basis of the Sicilian Mafia structure: it is the assertion by force and violence of a criminal authority on a district or village. The Pizzo is a source of revenue. Since the late 1960s, the capital accumulated by these mafia activities is laundered with the most modern means available in the financial system and International Monetary Fund. The strict demarcation between lawful and unlawful activity is thus becoming increasingly difficult to track. But the Mafia should not be an impediment to tourism, If it remains invisible is why today we no longer speak of Sicily as the home of the Mafia, but a wonderful island full of resources that it must operate.

Comparison with Lorraine region:

With 44 billion euros, the economy of Lorraine generates 3.4% of French GDP (Gross Domestic Product), which set the Lorraine region in 8th place of 26 French regions. Business services and logistics sectors have the strongest growth, while the situation of traditional industries (textiles and metallurgy) deteriorates.

- 80 000 business including 284 of more than 200 employees
- 570 foreign companies from 27 different nationalities, 69 000 jobs.

<u>Unemployment rate:</u>

% workforce	1995	2000	2001	2002	2003	2004	2005	2006
France	11,6 %	9,4 %	8,7 %				9,6 %	8,6 %
Lorraine			8,1 %	8,6 %	9,3 %	10 %	9,8 %	9,0 %

<u>GDP distribution by sector of activity:</u>

	Lorraine	**France**
GDP 2 000 milliards d'euros	44,3	1 383,35
Agriculture	2,5 %	2,8 %
Industrie	30,7 %	25,6 %
Service	66,8 %	71,6 %

V/ ENERGIES

In Sicily, the energy production is over the consumer demand. Indeed, this surplus of energy created in this region is exported to the Italian metropolitan territory (Fig. 13). The colored area indicates the energy surplus of the region (source: Terna–figures in GWh).

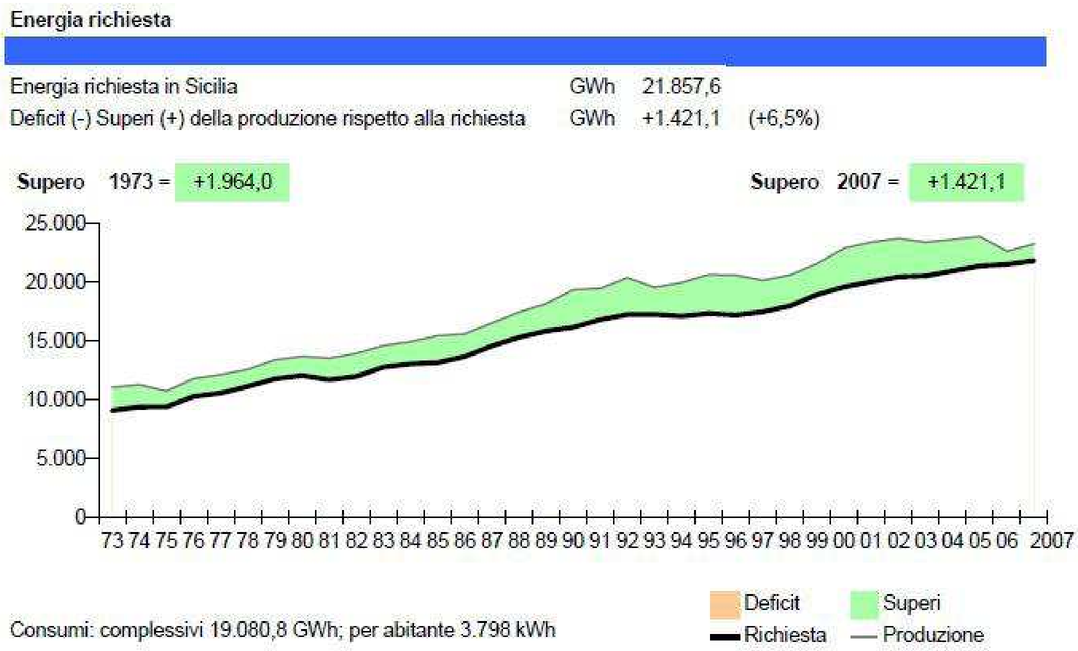

Fig. 13. Historical trend of total energy consumption (thick line) and production (thin line) in Sicily (1973 – 2007)

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Fig. 14. Power plant sites in Sicily.

The thermoelectricity represents 93% of the energy used in Sicily.

On the Fig. 14, the red filled squares indicate conventional power plants which provide power to the grid; the red squared squares indicate power plants for self production, used by industry. Blue squares indicate the hydroelectric power plants.

Others energies:

- wind energy represents 854 GWh;
- 9 hydroelectric plants: 703 GWh;
- solar energy: 1,5 GWh.

Comparison with Lorraine region:

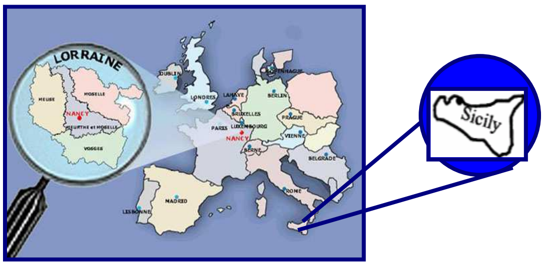
The main energy production used is nuclear with 5200 MW, fossil energies are little used, and solar energy represents 305 MW, which is less than in Sicily.

It is interesting to underline that the peak of consumption in Lorraine is during winter period and at the opposite in Sicily it is during summer time!

VI/ SHARING BETWEEN UNIVERSITIES OF PALERMO AND NANCY

We gave a lecture at the University of Palermo with several themes of environmental research, as the general program described below:

Università di Palermo, Facoltà di Scienze Matematiche, Fisiche, Naturali



Tuesday, 2nd of March, 2010, h. 15.00

Palermo, Maggio Lecture Hall, Via Archirafi 26

- Anne-Sophie Gournier *et alii* (*Opening lectures*): *Expected aims and preliminary outcomes of INPL visit in Sicily*
- Guillaume Echevaria: *Sciences and Technologies for the Environment (STE) in Lorraine by INPL multidisciplinary researches*
- J. L.Bersillon: *How to stop and eliminate glyphosate from agricultural runoff and drainage*
- P. Lerouvillois & O.Chery: *"Operation sustainable campus"*
- B. Abate: *A geological sketch of Western Sicily*
- A. Cimino & A. Oieni: *Advanced methods for pollution risk assessment in Sicily*
- R. Guarino & V. Ilardi: *Important plant areas of Sicily*

CONCLUSIONS

In conclusion, we can address the problem of political and economic approach of the environment. Indeed, without political or economic interest in the environment, it is left-handed itself in a modern world that is increasingly consumer and producer of all types of waste!

In this regard, we have noted that in general, rules in Sicily regulatory documents are well made, but in many cases the application of those rules are nonexistent.

Moreover, relations between private and public sector are different from those known in France and, especially, in the Lorraine region.

Indeed, the private sector has more power at the expense of the public, while in France the overload of our administration procedures, even if often criticized, however, can protect against abuses that prevail in profitability primarily monetary. What justifies the emergence of unsustainable environmental management, but also a gap between rich and poor, heavily marked that we observed in Sicily.

A GEOLOGICAL SKETCH OF WESTERN SICILY WITH PARTICULAR REGARD TO MADONIE MTS.

Benedetto Abate & Gaetano Ferruzza (Department of Earth and Sea Sciences, University of Palermo).

REGIONAL GEOLOGICAL FRAMEWORK

The Madonie Park is located in the middle of the Mediterranean region. This sector of the earth's crust evolves continuously and has a very complex geological history that started over 220 million years ago. This region is still undergoing a deformative phase, which is confirmed by the strong seismic nature of the Mediterranean area, see Fig. 1 (CADET & FUNICIELLO, 2004).

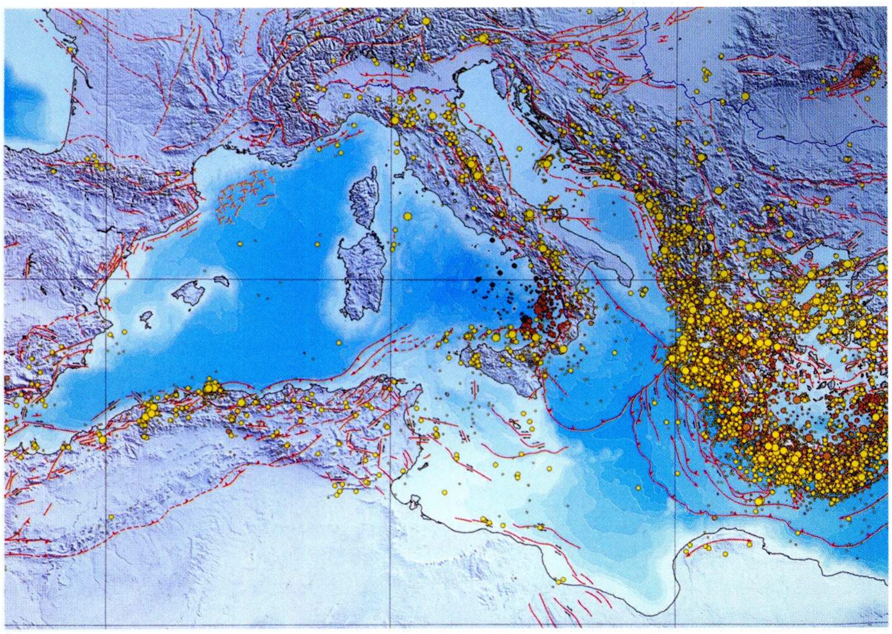


Fig. 1. Geodynamic map of the Mediterranean. The small circles represent the earthquakes epicentres (CADET & FUNICIELLO, 2004).

The structural representation shows the areas that are tectonically most active, where the earth's crust was, and still is, moving. This can be seen from the position of the seismic areas, where a greater concentration of epicentres of past earthquakes occurs. These create continuous strips that cross the entire Mediterranean and specifically the Sicilian-Apennine chain. The area of the Madonie Park is a segment of the structural formation belonging to the Sicilian portion of the Apennine mountain chain. This mountain chain extends along the entire length of the Italian peninsula, crosses the northern sector of Sicily and continues along the North African coast after crossing the Sicilian channel below sea level. The portion of the Northern Sicilian chain is formed by numerous geological masses characterized by large geometrical elements (extending from a few km up to tens of km), albeit not very thick. They form a group of imbricated units made up of Mesozoic carbonatic and siliceous rocks, see Fig. 2 (CADET & FUNICIELLO, 2004, *quoted paper*).

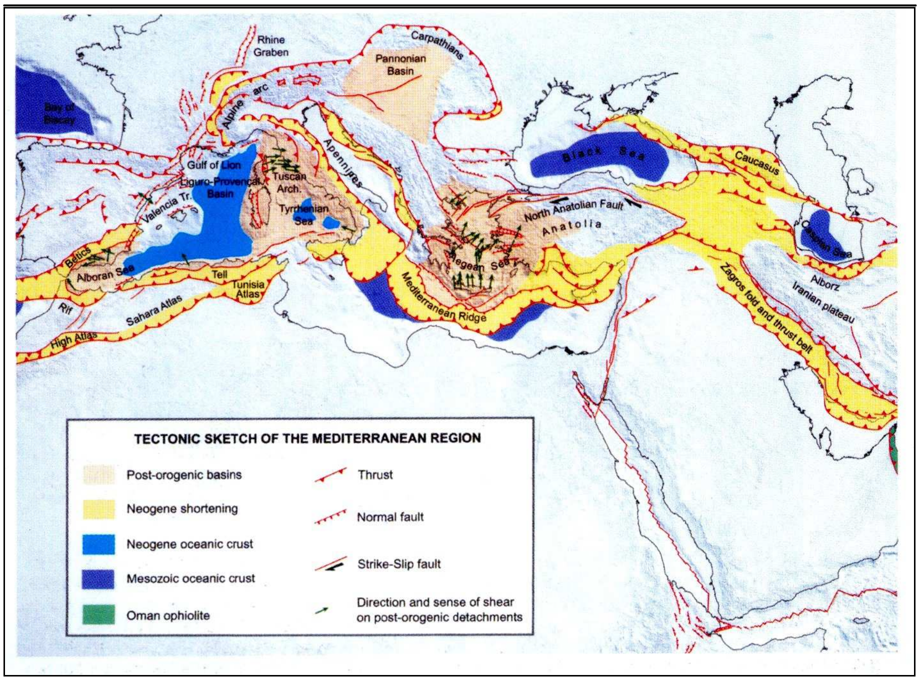


Fig. 2. Tectonic sketch of the Mediterranean region. (CADET & FUNICIELLO, 2004).

The rocks that currently form the structural body of the Madonie result from a series of deformations that have affected sea, and also ocean, areas whose positions were different from where they are found today. Geological studies have made it possible to identify different palaeogeographic domains in Sicily that gave rise to the formation of platform and field rocks and of volcanic rocks metamorphic rocks. These different palaeogeographic domains were subsequently deformed during orogenetic phases and are known as follows: Sicilides, Numidian Basin, Panormide, Imerese, Trapanese and Sicano domains. These included alternating pericontinental regions, carbonatic platforms and pelagic basins that followed strips that went from the closest domain to the continental area (Sicilides) towards the open sea domains (Panormide, Imerese, Trapanese and Sicano). One can find deformed syntectonic terrigenous deposits from the Mio-Pliocene period on these terrains (Fig. 3).

The Sicilian chain is therefore characterized by an overlapping of pellicular structures deriving from the deformation of original Meso-Cenozoic basins (Imerese and Sicano) and the Neogene covers over a prism, at least 10 km thick, formed by carbonatic units deriving from the deformation of the original carbonatic platform (locally known as Hyblaean, Trapanese, Saccense, Panormide). The tectonic wedge in turn lies on the non-deformed foreland outcropping in the Hyblaean Plateau and continues into the Sicilian Channel (Hyblaean-Pelagian). The retro-deformation of stacked bodies initially suggests that the original sedimentary multi-stratum was shortened by at least 50%.

The orogenesis that caused the creation of the chain probably started towards the end of the Oligocene period (about 24 million years ago), with the deformation and internal imbrication of the Calabrian crystalline structures and of their terrigenous covers.

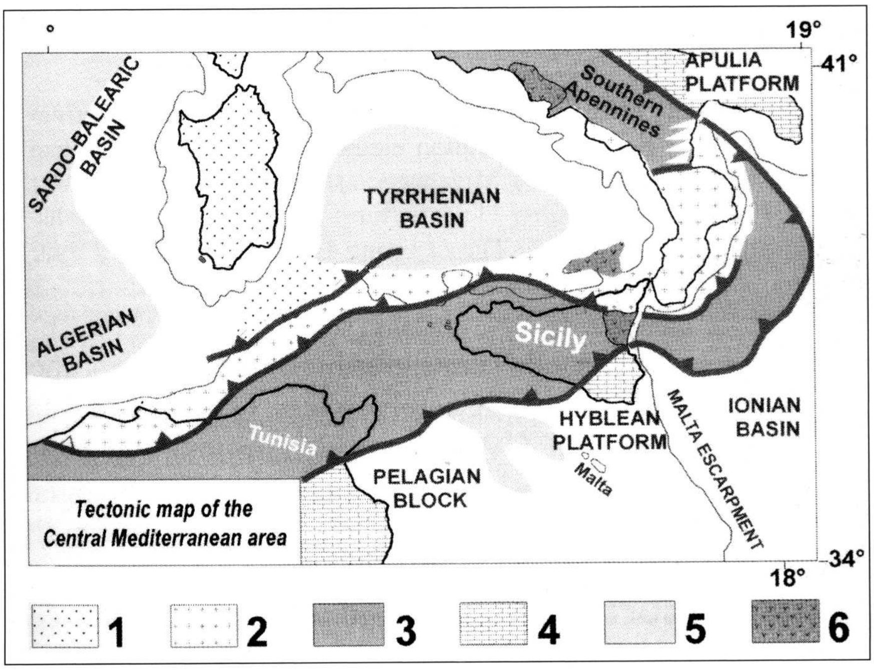


Fig. 3. Tectonic map of the Central Mediterranean area (CATALANO *et al*., 2002). 1) Corsica-Sardinia; 2) Calabrian Arc, Kabylians and “Internal” Flysch sequence ophiolites; 3) Maghrebide-Sicilian-Southern Apennine nappes and deformed foreland; 4) foreland and mildly folded foreland (Tunisia, Hyblaean plateau, Apulia); 5) areas with superimposed extension; 6) Pliocene-Quaternary volcanoes.

It lasted until the Middle Miocene (Burdigalian-Lower Langhian interval, 20,3-15 My), during which the overstep on the internal units was completed (Sicilides). The foredeep basins, broadly speaking, progressively migrated towards the South-East. They were characterized by Flysch deposits from the Upper Oligocene-Lower Miocene (Capo d'Orlando Formation, Reitano Formation and Numidian Flysch plots). The deformation of the sedimentary covers of the African continental margin was the first to reach the basin domains, which were inside the carbonatic platform domains and probably located on a thinned continental crust. This deformative phase brought about the highest structural units that are present in the chain today.

The deformation of the basin carbonatic units and their overlapping on the foreland of the time occurred mainly during the Tortonian period. Initially it was started by *intrastrata décollement* (duplex geometries). After detaching from the bedrock, the sedimentary bodies rotated 70-100° clockwise and later, and/or at the same time underwent internal imbrication.

This deformative phase also affected carbonatic platform areas of the foreland, causing a bland deformation during the same period. The overlapping of the basin units and of the corresponding covers over the foreland occurred during the Upper Serravallian-Lower Tortonian periods. Parts of the Numidian Flysch were inserted into the tectonic pile probably before the Upper Serravallian, and after detaching themselves from the Imerese substratum and undergoing deformation (at the same time or before the deformation of the Imerese substratum) (CATALANO *et al.,* 1996).

Starting from the end of the Tortonian period, the deformation reached the Iower 1ev-els. lt progressively affected the body of the carbonatic platform that deformed following large antiforms in an east-west axial direction. Later, during the Upper Pliocene, these structures were dislocated by tensions that had NE-SW plicative directions (OLDOW *et al*., 1990).

TECTONIC EVOLUTION OF THE MADONIE BELT

Tectonics studies the deformations affecting the earth's crust due to movements of the plates forming the globe's surface, as they come closer or move further away from each other. The Madonie range is a relatively recent mountain chain. It reached their current state after the Middle Pliocene following tectonic phenomena that affected the northern sector of Sicily.

The shortening of the earth's crust, due fo the African and European plates coming closer, created the Apennine-Maghrebide chain. Therefore, all the rocks in the Madonie area, before the deformation, lay at the bottom of an ocean whose area extended much further than it currently does. Some of the structures that emerged during these tectonic phases are quite visible in various areas of the Madonie. Below a description is given of the various tectonic phases that occurred during this region's geological history.

The oldest rocks in the Madonie are from the Middle-Upper Trias period (about 230 - 220 My). This is when continents started separating and the appropriate marine conditions occurred, within a fracture of the earth's crust (depression), which led to deposits of sedimentary rocks that derived their source of nourishment from the nearby continent. This area evolved in the period between the Upper Trias and the Oligocene (220-23.5 My). During this period marine areas expanded and a distensive tectonic area was created. The direct fault linked to the latter area caused certain sectors to lower, leading to the formation of deep marine basins in certain areas. At the same time, however, the sea remained relatively shallower in other sectors. This led to the creation of carbonatic platform areas, similar fo the ones that can be found today in oceanic coral reefs in the Red Sea and the Caribbean.

Between the Lower Miocene and the Middle Tortonian (23.5 -10 My), the compressing deformation affected rocks that had previously formed. This ed fo the creation of a tectonic pile whose elements were progressively laid one on top of the other according fo a North/South movement. Thus, complex mountain ranges were formed. These are rich in tectonic structures, such as faults, folds, and tectonic doublings, and can easily be seen in various places within the Park (Fig. 4). Later, between the Upper Miocene and the Lower Pliocene (10-3.4 My), there were more deformations that lifted the mountain chain in the northern areas and led to the formation of a sedimentary basin in the southern sectors. During the Lower Pliocene, specific rocks, locally known as *Trubi*, were deposited in certain areas. Their lithological characteristics (mails and marly limestones), as well as the presence of fossils that are typical of a pelagic and basin environment (e.g. planktonic foraminifera including *Globigerina* and specific *Orbulina*), indicate this is a deposition environment of a sea basin, between 500 and 800 m deep.

Outcrops of Trubi are visible in various areas of the Park (North of Polizzi and on the eastern incline of Monte Ferro). They indicate recent tectonic phenomena that have dislocated the Madonie mountain chain over the last 3-4 million years. On Monte Ferro, the Trubi outcrop at around 1,600 m. Therefore, we can assume that certain portions of the Madonie recently increased their height by at least 2,200 m.

The area continued to increase in elevation during the Upper Pleistocene (the last 0.7 My). From this period different sectors underwent different increases in elevation, as can be seen from the direct faults corresponding to the vertical rock walls that have North-West/South-East and north-east/south-west directions. Also, there are flat terraced areas (quaternary marine terraces), which are parallel to the coast in the northern area of the park. This is further proof that these areas were elevated recently.

These flat surfaces are at different elevations. The lowest terrace is between the current sea level and 25 m; the second is between 100 and 150 m, the third is between 170 and 250 m.

Fig. 4. Panoramic view of the Madonie Mountains. From West to East: Monte dei Cervi, Cozzo Piombino, Pizzo Carbonara, Monte Mufara, Monte Quacella and Monte San Salvatore. The Panormide Tectonic Unit (*right side of the picture*) overlays the Imerese Tectonic Unit (*left side of the picture*).

These marine terraces can easily be seen along the coast from the mouth of the Imera River to the town of Cefalù. They can also be observed from the panoramic viewpoint of Campofelice di Roccella, where a straight coastline can be seen with large beaches and a few marine terraces that become lower towards the North. A second fault system (whose direction is between N-S and NNW-SSE) is indirectly confirmed by the varying elevations of different terraces of the same order. Furthermore, the main rivers generally follow the direction of this system (Fig. 5).

STRATIGRAPHY

Stratigraphy is one of the disciplines that study sedimentary rocks.

Its aim is to order events in correct chronological succession and reconstruct the geographic and environmental configurations of the past. Stratigraphic methods include tools from biology, palaeontology, sedimentology, palaeogeography, geochemistry, and geophysics. However, it is based on the study and use of fossils and on their evolution. People have been interested in fossils since ancient times but their importance was only understood from the 18th century. This is when it was discovered that the study of fossils was key to developing a relative chronology of geological events, despite the impossibility of dating them precisely.

From the '50s, radioactive isotopes first made it possible to establish absolute dates. Over the last decades, dating has become more accurate, though it is still developing. However, it enables us to have well-defined time reference points on a global or regional level. These tools, together with others employed by stratigraphy, allow us to study space-time location of sites and related events. Thanks to them we can reconstruct the organization and history of the outside layers of the earth, using lithological "documents" that are available on the surface of the earth's crust.

With their lithological, sedimentary, and palaeontological characteristics, rocks provide evidence of most of the dynamic, biological, physical, and chemical events they have undergone. By solving this geological "puzzle", we can therefore understand what has happened on earth over the last millions of years and, furthermore, this can also allow us to develop plausible forecasting models. For these reasons we have decided to describe in detail the rocks and sedimentary layers outcropping in the Madonie Park, since they can provide us with an interpretative key for the evolution of the central part of the Mediterranean.

CONCLUSIVE CONSIDERATIONS

Aim of this paper was to provide a useful tool not only for those who are new to these topics but also for those who wish to deepen their knowledge of certain geological aspects of Sicily (ABATE & FERRUZZA, 2004). With this aim, we regionally described above the main outcrops (see again Fig. 5), starting from quaternary deposits and also illustrating the post- and syntectonic terrigenous deposits, which cover with disconformity the various tectonic units in the area.

The perspective is now to carefully analyse all these units by a geometric viewpoint, from the highest up to the lowest. The various formations or units comprising them are elsewhere depicted, from bottom to top, according to their stratigraphic order (ABATE & FERRUZZA, 2004).

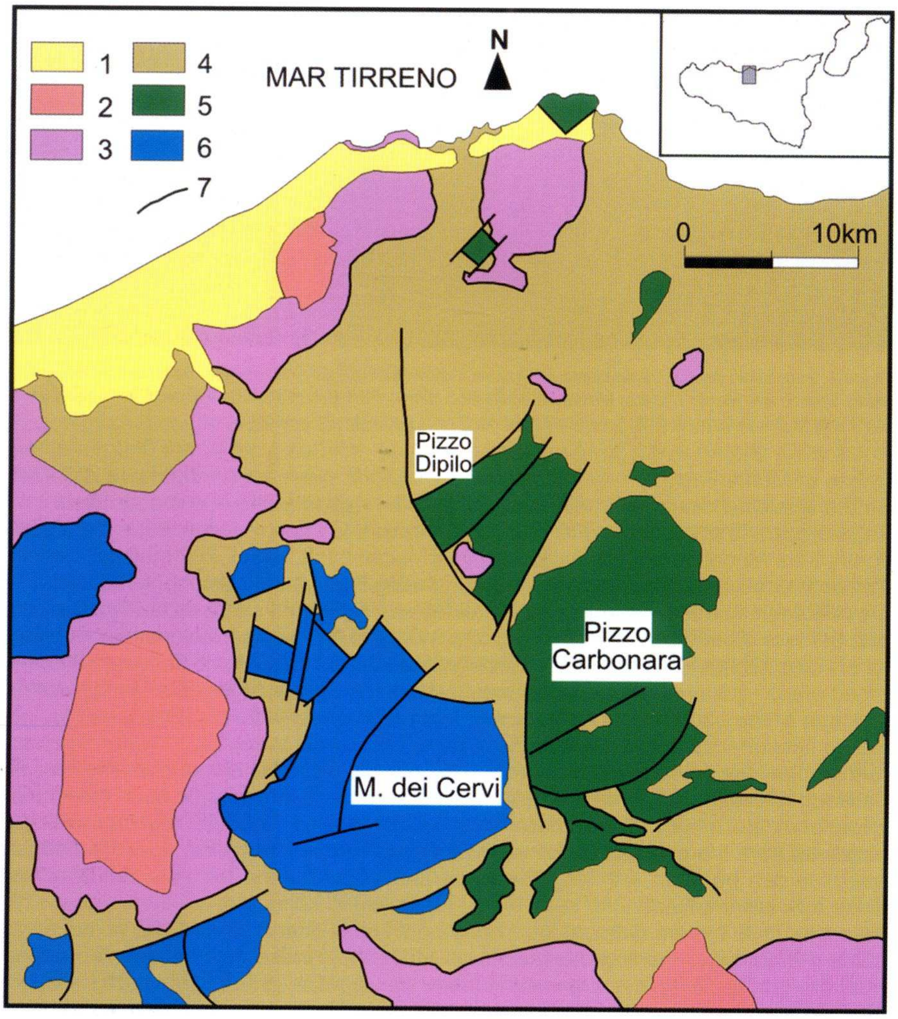


Fig. 5. Structural-geological sketch of Madonie Mts. (Grasso *et al.* 1978, Abate et *al.* 1982, Abate *et al.* 1988, modified). Legend: 1) Quaternary deposits; 2) Post and syntectonic Upper Tortonian to Lower Pliocene terrigenous, evaporitic and carbonatic rocks; 3) "Sicilidi" Tectonic Units derived from more Northern domains and characterized by variegated clays and tufitic marly limestones (Cretaceous-Oligocene); 4) Numidian Flysch Units constituted by Lower Miocene foredeep clastic deposits (mostly quartzarenites), unconformably overlying the Mesozoic - Cenozoic Panormide and Imerese domains; 5) Panormide Tectonic Units derived by the deformation of the Mesozoic - Cenozoic rock successions ascribed to carbonate platform facies; 6) Imerese Tectonic Units derived by the deformation of the Mesozoic - Cenozoic rock successions ascribed to basin environment; 7) Faults and thrusts.

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THE MITIGATION OF GROUNDWATER CONTAMINATION RISK IN ANTHROPIZED SECTORS OF SICILY

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INTRODUCTION

Sicily region comprises coastal and mountainous sectors with important environmental and geological features, accurately reported in a number of specific papers. These scientific contributions were aimed to furnish various contributions to the hydrogeological knowledge of mountainous as well as alluvial aquifers, opportunely outlining the relations between pervious and impervious formations. In this frame, since sixties, the carried out hydrogeochemical and geophysical surveys have delineated quality and vulnerability characteristics of water complexes, also depicting groundwater recharge phenomena from inland mountains to coastal sectors.

This note summarizes some well-focussed aquifers, as the ones located in Northern Sicily: Author mentions as excellent test-sites the coastal Acquedolci and S. Agata di Militello belt. Author also reviews recent risk assessments, performed by SINTACS and GALDIT systems, offering the most recent outcomes of contamination risk implementation relevant to groundwater and proposing a better zoning and classification of sectors characterized by more or less pollution susceptibility.

GROUNDWATER NEEDS AND AVAILABILITIES IN THE ANTHROPIZED SICILY

Sicily knows, in spite of relatively drought conditions, a good availability of waters. In fact, many geological units present a generally fair water potentiality, manifested by notable aquifers and spring that, along with a diffuse distribution of artificial basins, create a sufficiently productive aqueduct network (CIMINO, 1988 and 1989, *also for the following*). This has allowed growing of urban and industrial poles in morphologically favourable zones, as the coastal belts, at the same time depopulating the inland areas and unbalancing water reserve needs/availabilities ratios.

Nevertheless, the economical development of these areas, closely connected to the accessibility of resources and services, has caused a significant crisis for the excessive concentration of requirements. The consequent lack of equilibrium between water needs and resource availability, in the different areas of Sicily, has led to an irrational use of them. Anthropic activities, often including the agricultural ones, have enlarged the areas characterized by contaminations and resources impoverishments, creating the conditions of a progressive worsening of the life quality. In such a situation, groundwaters become the most vulnerable resources, as frequently acknowledged in urban areas (NOURY & MALMASI, 2005).), so imposing - since eighteens –serious and urgent proposals of remediation strategies and interventions.

As a consequence of the above statements, the high hydrogeological risk of many areas of Sicily is likely due to the difficult management of water resources, relatively diffuse in many Mediterranean areas (HAMDY & TRISORIO-LIUZZI, 1994). The main cause is the diffusion of several private and public bodies treating water problems. Among the results of this situation it has to be mentioned the irrational distribution of surface as well as groundwater sources for the different purposes, as dramatically the Palermo metropolitan area knows (CIMINO, 1986): the sole efficient outcomes of colossal works, yet uncompleted, have been the extremely high costs and a definitive territory upsetting. At the same time, it has to be mentioned the lack of systematic controls of the hydrogeological parameters, leaving the groundwater resources without any planning. Unavoidably, the main peopled areas suffer the degradation of the relevant aquifers, so imposing different strategies of remediation.

HYDROGEOLOGICAL SETTINGS AND VULNERABILITY ASSESSMENT IN COMPLEX AREAS OF SICILY

It is often difficult to clearly and unequivocally express, in such complex areas as the above depicted, all the information relevant to vulnerability of an aquifer. At this proposal, the Author of this note remembers the works performed in Sicily on hydrogeology and contamination risk (Fig. 1).

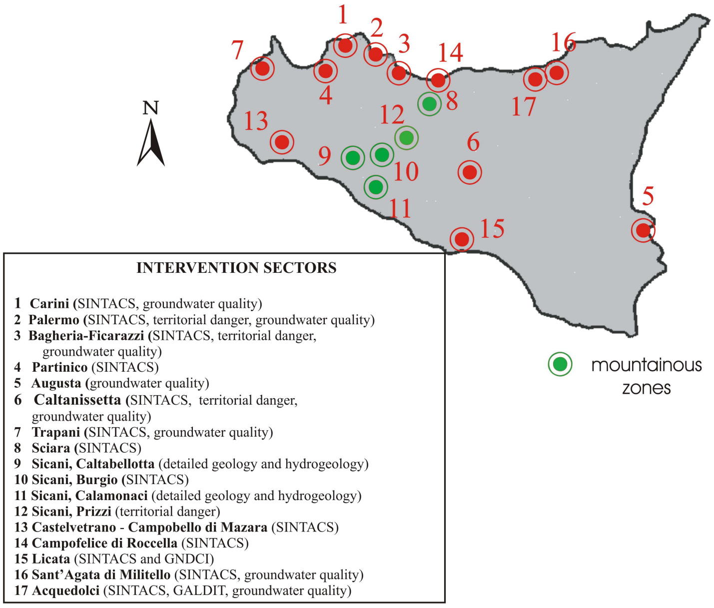

Fig. 1. Contamination risk mapping performed in coastal and mountainous areas of Sicily

In order to correctly depict aquifer features, it was necessary to collect numerous pieces of information, ranging from the geometry of hydrogeological units, to the hydrodynamic regime and the groundwater geochemistry. The interactions aquifer-water-pollutants, these last ones coming from different contamination sources can be localized in well-delimited sectors or, at the contrary, diffuse in large territories. So, a suitable tool for suitably identify the groundwater exploitability in a certain area can be offered by regional maps presenting a summarized behaviour of aquifers (BUDETTA *et al.*, 1994), or by local, thematic maps and/or sections showing only the most important hydrogeological elements (POŹNIAK, 1980). Valid examples are given by vulnerability and risk cartographies relevant to more or less complicated aquifers, considered as true water complex systems, absolutely changing the way of thinking and the aquifer management policy itself. The quoted Fig. 1 explicates the efforts to face this problem in Sicily.

In particular, the Northern Sicily littoral belt has been interested by a number of works regarding quality and vulnerability of water systems. This problem has reached heavy levels in drought conditions, where coastal territories see a depauperation of water resources. Proposals of the quoted projects are essentially directed to mitigate the pollution risk and to preserve the environmental conditions (Fig. 2). This figure shows, besides the territory zoning, the littoral areas of Acquedolci and S. Agata di Militello and, also, the inland karst areas up to Traura Mt. - Rocche del Crasto range, belonging to the *Longi-Taormina Unit*

(GIUNTA & NIGRO, 1997) the hydrogeological importance of which has already been adequately valorised in the past (CIMINO *et al.*, 1998).

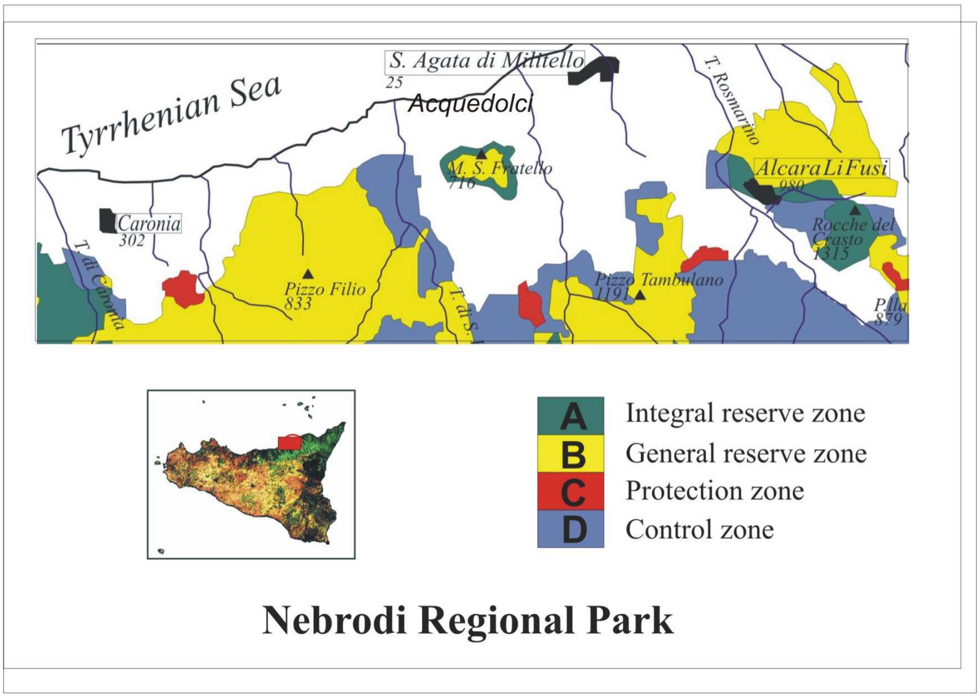

Fig. 2. Test site locations of contamination risk works carried out in North-East coastal belt of Sicily.

In spite of their apparent lithological homogeneity, the quoted coastal aquifers have generally to be recognized also as complex groundwater systems (CIMINO *et al.*, 2007a): essentially due to the non-uniform granulometry of littoral deposits and their consequent permeability anisotropy, and the extremely irregular relationships among flysch and/or karst units, complicated by the diffuse occurrence of metamorphic edges too. In these conditions, the availability of advanced models of aquifers is strongly felt. As a matter of fact, among the copious risk investigations carried out in Sicily by the Author of this note in these last years (CIMINO *et al.*, 2000a and 2000b), enhanced cartography has been already produced in selected Sicily sectors, introducing statistical procedures (CIMINO *et al.*, 2009). In these recent contributions, mapping procedures have represented new synthesis tools thanks to computer implementations in archive and overlay data processing. The interest has been mainly directed to develop parameters close to the pollution risk concept, as *intrinsic vulnerability*, *groundwater base quality* and *danger exposition* to the pollution risk, this last one strictly linked to the territorial occurrence of contamination sources (ANDOLINA *et al.*, 2001, 2003). In detail, the risk against the sea encroachment, spreaded in most of Italian coastal regions (CAPELLI *et al.*, 2007), will be carefully considered.

a) The Acquedolci test-site

The Acquedolci plain lies in the Northern coastal belt of Sicily, being bordered by Tyrrhenian Sea on the north, by steep mountains (Pizzo Castellaro and San Fratello Mt.) on the South and by Inganno and Furiano Torrents at its Eastern and western boundaries respectively (Fig. 3). Referring to this hydrostructural scheme, permeability degrees of the geological formations can be related to seven hydrostructural complexes characterized by various permeability features (CIMINO *et al.*, 2008a).

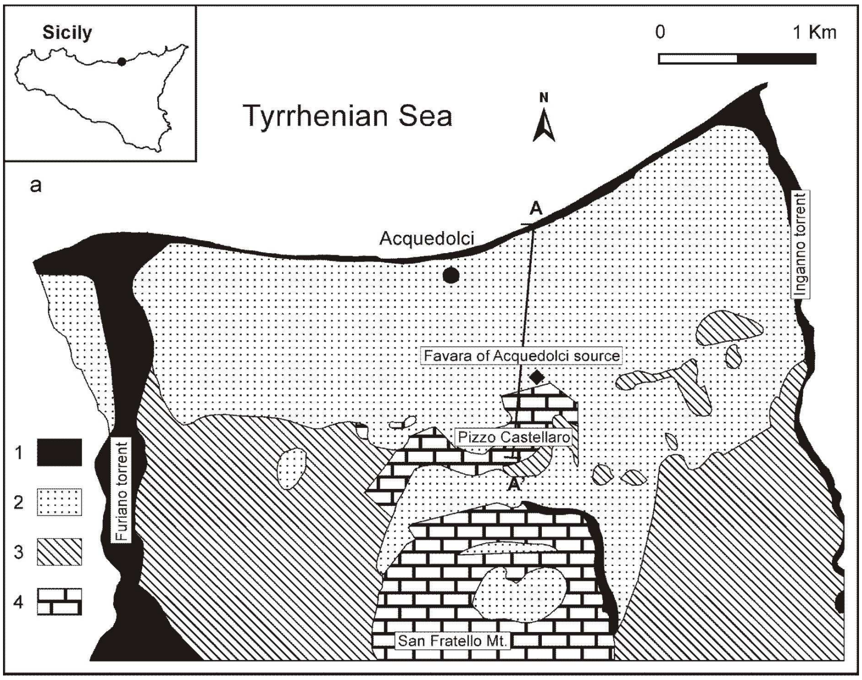

Fig. 3.- Hydro-structural scheme of the Acquedolci coastal plain. 1) Sandy-gravelly-arenaceous complex; 2) sandy-arenaceous Quaternary complex; 3) clayey-marly-arenaceous complex; 4) Mesozoic calcareous-dolomitic complex (From Cimino et al., 2008a, modified).

Fig. 4 reports a groundwater quality picture of Acquedolci plain, with sectors more or less influenced by contamination (CIMINO *et al.*, 2007b); in particular, sea intrusion appears to be the major risk factor). The seawater ingression phenomenon, along coastlines, is typical of this littoral Sicily area, occurring in many sectors of the Acquedolci plain, where groundwater overdraft frequently causes the advancing of salty waters through the marine intrusion wedge (CIMINO *et al.*, 2008a, *quoted paper*). The Italian laws specify, on the basis of physical-chemical parameters, the quality requisites for waters assigned to human needs, in accordance with the law decrees 2 February 2001 n. 31, successively modified by the law decree 2 February 2002, n. 27. This has allowed elaborating the quality base map for the Acquedolci plain (CIMINO *et al*., 2007c), exhibiting a wholly bed groundwater quality in large portions of this area (Fig. 4).

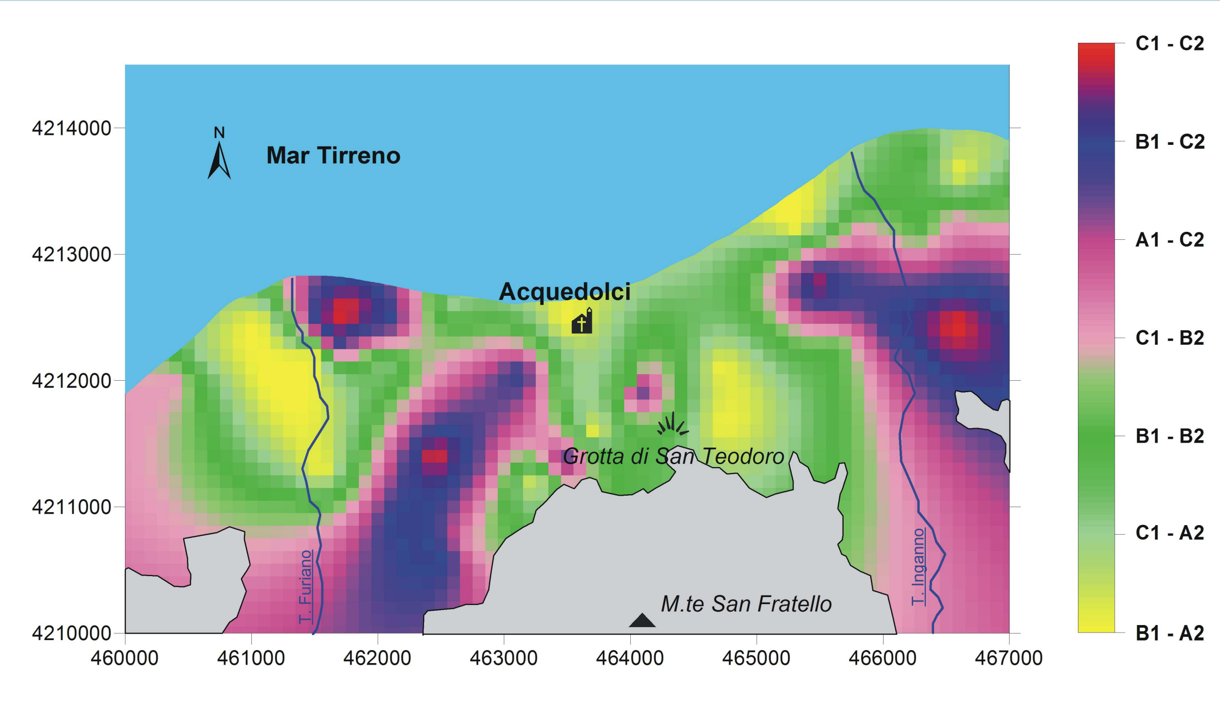

Fig. 4. Groundwater quality map of Acquedolci plain according to the classification proposed by CIVITA *et al.*, 1993, and successively modified by Italian law decrees n. 31/2001 and n. 27/2002 (CIMINO *et al.* 2007c). Quality worsens from B1-A2 to C1-C2 classes.

Fig. 5 shows the intrinsic vulnerability map of Acquedolci plain (CIMINO *et al.* 2008b). performed by SINTACS method (CIVITA & DE MAIO, 2000). Vulnerability of Acquedolci units is generally medium to elevated, mainly in the arenaceous and lapideous rocks.

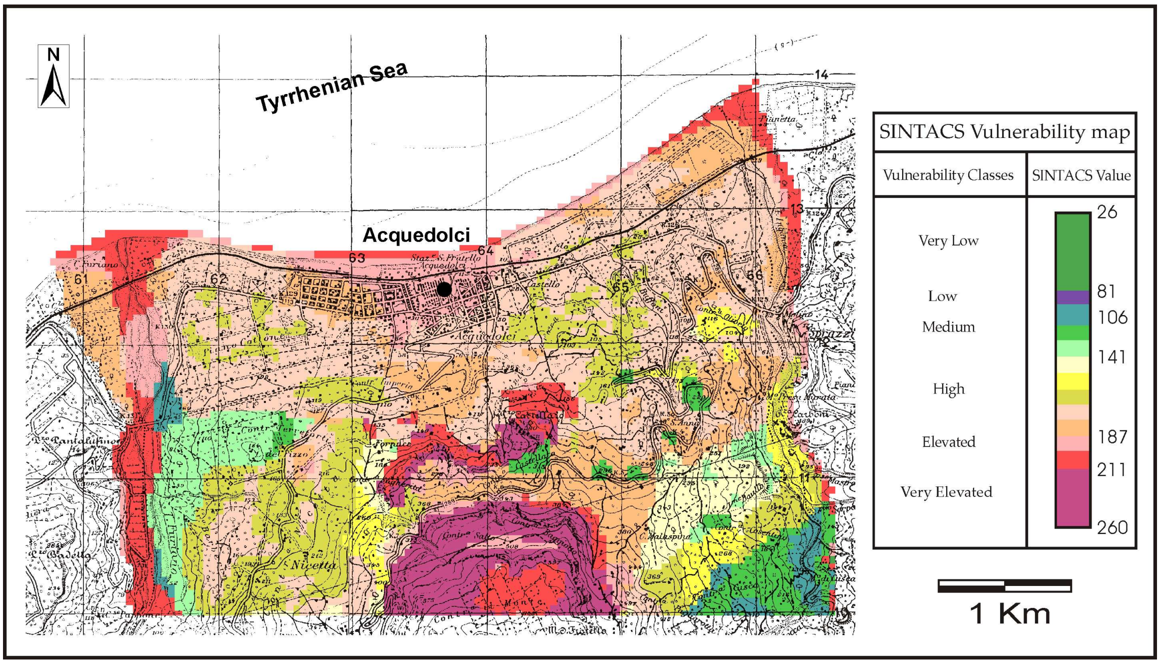

Fig. 5. Intrinsic vulnerability map of Acquedolci plain performed by SINTACS method (CIMINO *et al.* 2008b).

This plain, in details and synthetically, has been for ages intensely studied in its hydrogeological characteristics, with particular regard to their aquifers, springs and vulnerability to pollution. Fig. 6 exhibits a mapping result of the application of a further vulnerability assessment system (CIMINO *et al.*, 2008c), called GALDIT according to the six involved parameters (CHACHADI & LOBO FERRIERA, 2001).

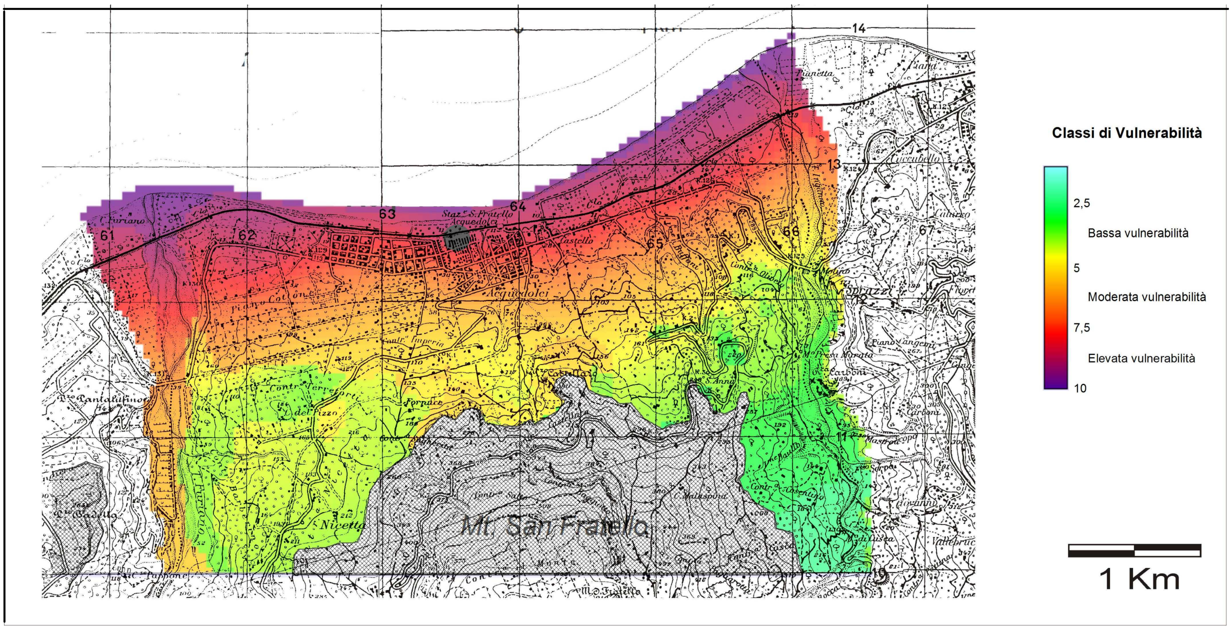

Fig. 6. Galdit vulnerabilitry map of Acquedolci plain (CIMINO *et al.* 2008c).

GALDIT mapping could represent a valid application example in region in which it was important to detect the role played by karst units (S. Fratello Mt. and Pizzo Castellaro), as regard to the groundwater circulation and the recharge of the coastal aquifers, in order to mitigate the contamination risk (ABBATE *et al.*, 2003). Similar role can be played by metamorphic edges too, especially at the Eastern margin of Acquedolci (S. Agata di Militello), where a similar SINTACS map was performed (see the following).

b) The S. Agata di Militello test-site

The S. Agata di Militello plain is widely interested by touristic and agricultural activities. Their progressive expansion is accelerated by the good availability of services and resources, among which we mention the water ones: as a matter of fact, good quality groundwater is certainly retained as a tool of economic and social launch for those sectors characterized by disordered growth. This contribution outlines here the possible advantages of this project for the social and economical development of this part of Sicily. As an example, driving roles towards the expansion of areas characterized by elevated environmental risk should be proposed, mainly in oversaturation conditions and also in relation with cost/benefit ratios in groundwater draft. This apparent criticism is clearly shown through the increasing contamination of aquifers, which even present study difficulties due to the non-homogeneity and anisotropy of groundwater systems. At this proposal, as nucleus of this project, the contamination of shallow aquifers for seawater intrusion has to be primarily and carefully depicted. This natural phenomenon is rapidly worsened and amplified by the reduced groundwater volumes as well as by the lacking of adequate recharge. This problem should be carefully token into account, for the complicated interactions between soil and water environments (aquifers and sea).

Numerous surveys have been carried out in S. Agata di Militello littoral territory. Here, researcher teams of Sicilian Universities have performed interdisciplinary investigations, with the creation of updatable databases. Since eighties, researchers belonging to various disciplines (Geology, Geochemistry, Geophysics, Statistics) formed an interdisciplinary team working in several parts of Sicily in the field of Complex Water Systems. These multidisciplinary surveys have - as main goal - the characterization and modelling of aquifers hosted in coastal and inland Sicily territories, with the objective to monitor water resources, contaminated and uncontaminated as well, implementing aquifer pollution risk mappings. Very numerous field and laboratory records have been collected and organized, archived and processed in GIS environment (TALAMO, 2004).

Most of the already produced and *in progress* studies are referred to the informal project named CIRIPA (acronyms of *Cartografia Informatizzata di Rischio Idrogeologico per gli Acquiferi dell'Area Metropolitana di Palermo*, that is *Computerized Mapping of Hydrogeological Risk for Aquifers of the Metropolitan Area of Palermo*). The Palermo region is partially addressed towards a full maturity phase for the population growth and for the numerous touristic, industrial, urban and agricultural settlings. S. Agata di Militello sector, together with adjacent plains, is strategically in a transitional phase, in which hydrogeological problems are worsened by needs of good quality waters in an economically growing region. This is the reason of the continuous efforts to improve risk awareness knowledge through advanced plans of parametric and synthesis mappings of aquifer pollution risk, which have led to new vulnerability assessments (CIMINO & OIENI, 2010). This has allowed to increase the value of the classical representations as well as to experiment innovative techniques and methodologies (CIMINO *et al.,* 2009, *quoted paper*). Hydrogeological units have been differentiated according to type and decreasing grades of permeability (OIENI *et al.*, 2010), described indicating the most diffuse lithology for every class (Fig. 7).

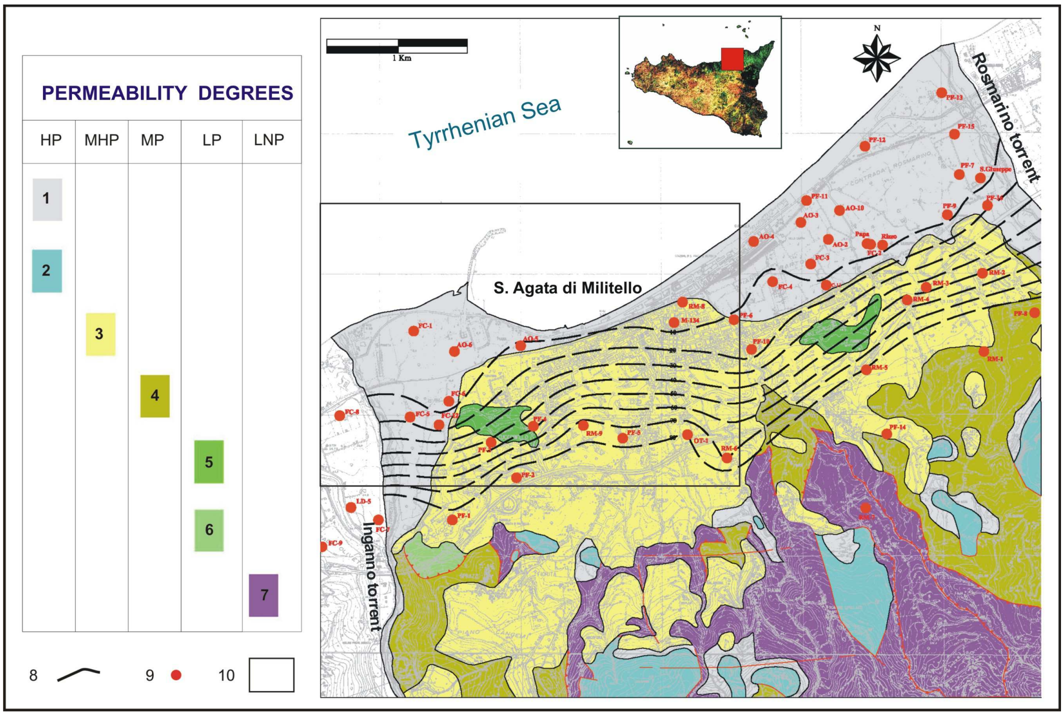

Fig. 7. Hydrogeological sketch of S. Agata di Militello plain. Legend is exposed in the text (OIENI *et al.,* 2010).

1) 2) High permeability (HP) for primary and secondary porosity. 3) Medium - high permeability (MHP) for primary porosity. 4) Medium permeability (MP) for primary and secondary porosity. 5) 6) Low permeability (LP) for primary and secondary porosity. 7) Very low or null permeability (LNP).

Figure also exhibits contour lines (*m a.s.l.*) (8) and well spots (9).

In accordance with Fig. 7, the S. Agata di Militello plain is mainly interested by two main kinds of aquifers: the coastal ones, utilized by hundreds of wells and hosted in the alluvial Quaternary formations, with piezometric levels ranging from few meters up to 80 m far from the coastline; the inland ones, represented by karst and fractured limestones and dolomitic limestones belonging to the Longi-Taormina Unit. Fig. 4 shows a broad portrait of the S. Agata di Militello area, with the Inganno (*left*) and Rosmarino (*right*) torrents. Karst sectors have here exposed in the right corner, where a recent pit along the Rosmarino torrent (*red arrow*) clearly reveals the occurrence of Longi-Taormina Unit limestones (see also picture in Fig. 5). Karst limestones, widely outcropping in the inland part of S. Agata di Militello area, essentially play the role of cover to the metamorphic tectonic units and to the whole Longi-Taormina Unit (CARBONE *et al.*, 1998; LENTINI *et al.*, 2000; GIORGIANNI *et al.*, 2007).

ADVANCED TOOLS FOR THE S. AGATA DI MILITELLO PLAIN STUDY: GROUNDWATER CHEMISTRY AND STATISTICAL ANALYSES

The S. Agata di Militello groundwater has been interested by hydrochemical prospecting, performing a statistical procedure by Principal Component Analysis (PCA) in order to evaluate possible correlations among variables, also evaluating possible matching between well locations and measured ion concentrations (WEBSTER, 2001). So, groundwater with similar geochemical behaviour was associated.

Fig. 8 summarizes the location of wells and the results of geochemical prospecting relevant to the mostly characterizing ions and identifies at least three sectors of well clustering, according to the groundwater chemical compositions (OIENI *et al.*, 2010, *quoted paper*).

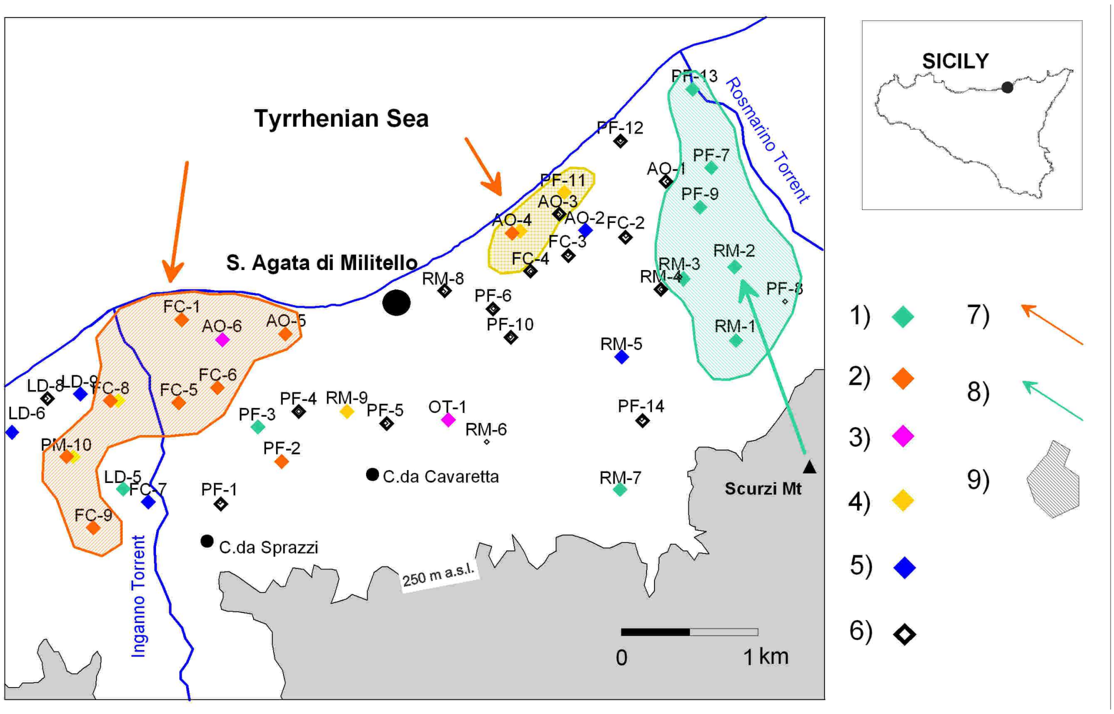

Fig. 8. Hydrochemical clustering of well groundwater in S. Agata di Militello area. 1) Wells characterized by high pH values and prevalence in Ca2+ concentrations; 2) wells characterized by high Cl- concentrations; 3) wells characterized by high K+ concentrations; 4) wells characterized by high NO3- concentrations; 5) wells characterized by low NO3-, CO32-and Ca2+ concentrations; 6) non classified wells; 7) main sea encroachment pathways; 8) schematized aquifer recharge pathway from karst units; 9) sectors characterized by homogeneous geochemical behaviour (clustering procedure, see text). (OIENI *et al.*, 2010).

The Eastern sector, left to Rosmarino Torrent, evidences - besides elevated pH values - a notable prevalence in Ca^{2+}, testifying the groundwater recharge to the plain from karst rocks. western and Eastern-Central sectors reveal pollution by sea encroachments (Cl^- and Na^+) and high nitrate content respectively: here recharge is only for precipitations, generally overcome by excessive groundwater drafts (FETTER, 2001). Other sectors of the plain expose different groundwater concentrations, in particular in form of increasing of Na, Mg and Cl ions, which may characterize the seawater intrusion effects (CIMINO *et al.*, 2008b, *quoted paper*). This appears evident in the Central and western sectors, particularly in the Inganno torrent fan, where the lack of fresh water recharges, along with the coarse granulometry of alluvions (chiefly gravelly), favour the salty water ingression and the well contamination. The clustering in more sectors demonstrates that groundwater of S. Agata di Militello plain belongs to different hydrological deep as well as shallow pathways. Nitrate concentrations are presumably connected to a great agricultural practice with heavy use of fertilisers and/or to a contamination for seepage civil spreading in the soil. Lastly, waters of the western sector are characterized by temperatures higher than the southern one due to sea-intrusion: indeed, this can be described by the higher temperatures in littoral wells of the S. Agata di Militello area, together with the chlorine contamination.

CONCLUSIVE CONSIDERATIONS

The cases and examples, above shown, have demonstrated the various hydrogeological conditions of certain areas of Sicily. In order to describe certain different cases, the possibility to set new perspectives of management is here discussed, also considering the potential and effective groundwater risk. The summarized experiences suggest the following conclusive elements: a) the proposed methodologies can present good resolutions in most of the observed Sicilian areas, especially integrating and elaborating different data; b) the geochemical surveys can solve geophysical interpretation ambiguities; c) the integrations of methodologies and elaborations has to be encouraged.

The importance of metamorphic rocks should be acknowledged in hydrogeology and proposed as essential element in water resources planning in zones with low productivity (Peloritan area), where different permeability values are usefully connected with the relevant contrasts of apparent resistivity; maps of *groundwater probability and pollution vulnerability,* mentioned and presented for certain risk sectors of Sicily, can represent a first quick tool for users: these maps can continuously be updated - adding further parameters - monitoring the quality of groundwater and suggesting their different utilizations for different purposes.

Fundamental elements of this research are represented by the suggested methodological, innovative aspects. In the same way, it is essential that aquifers are recognized as complex water systems, with anisotropy effects and lacks of homogeneity in the vectorial quantities (i. e. *hydraulic conductivity*). Exchanges of expertises and applicative experiences are project milestones: equipments and laboratories of different expertises are jointly working to reach objectives through the development of new procedures, involving young researchers too. Therefore, S. Agata di Militello experience constitutes the aggregation nucleus of a pilot wider programme, overcoming the present initial stage and becoming an elsewhere replicable model in similar aquifer criticisms.

Furthermore, geoelectrical prospecting as a tool for the salt contamination estimation is strongly recommendable, in spite of possible ambiguities caused by the occurrence of interbedding clayey strata in the surveyed aquifers. As a matter of fact, similar outcomes in resistivity responses often can to drive towards incorrect modelling of aquifers. In the considered areas, resistivity values offer similar value ranges in occurrence of salinity or clays. Nevertheless, interpretation ambiguities can be solved by comparing geophysical results with geochemical data of wells and/or stratigraphic known sequences, thanks to close wells. Also in these cases, complimentary statistical elaborations of chemical constituents of water wells can furnish good results, adopting - for example - the PCA procedure (Principal Component Analysis).

Lastly, the Author of this note emphasises expected final outcomes of this project as useful tool for spin-off possibilities in scientific and social-economical ambits, in order to encourage young researchers' activity and development.

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GREEN LANDSCAPES OF SICILY

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THE PHYSICAL SETTING

Sicily is the largest Mediterranean island, with an extension of nearly 26,000 km^2. The Sicilian territory is predominantly hilly or mountainous: one fourth of the island is at more than 700 m a.s.l.; two thirds range between 300 and 700; one sixth below 300 m a.s.l. The geographical position of Sicily, its complex geological history and the high topographic diversity make the island one of the most heterogeneous Mediterranean territories, under the geo-morphologic, edaphic and climatic viewpoint (Fig. 1).

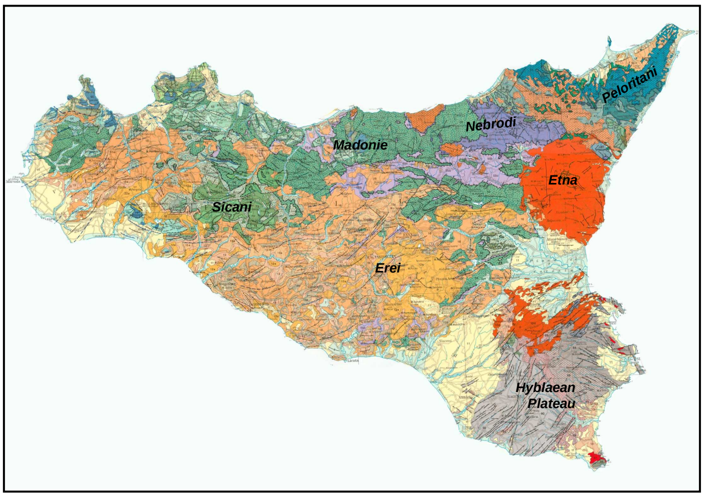

Fig. 1. Geologic map of Sicily (after (after DEL FRATI *et al.*, 2000, modified), with the indication of the main mountain districts: Peloritani (siliceous metamorphites), Nebrodi (flysch, some schists and limestones), Madonie (alkaline rocks, quartzitic sandstones, clays), Etna (volcanic rocks), Sicani (sandstones, limestones, gypsum), Hyblaean Plateau (limestones), Erei (sandstones, marls, gypsum, clays).

The single most relevant landmark of the island is Mt. Etna (currently standing 3329 m), the biggest volcano of the Mediterranean region. It dominates the Eastern side of Sicily, with multiple layers of erupted materials that cover an area of 1190 km^2, with a basal circumference of 140 km. Apart from Etna, the main elevations of Sicily (ranging from 1400 to 1979 m) are aligned along the so-called Sicilian Apennine, ranging along the NE-coast from the Strait of Messina up to the valley of the Torto River. Three sectors can be recognized, from east to west: Peloritani, Nebrodi and Madonie Mountains. Peloritani are constituted by the oldest outcrops of Sicily: a complex of different metamorphic rocks (gneiss, schistose and phyllitic alternations) partially covered by sedimentary sandstones and limestones. Nebrodi are mostly consisting of quartzose sandstones rocks, clayey and silty depositions belonging to the Numidian Flysch. Madonie are formed by carbonatic, dolomitic and quartzitic outcrops, frequently interrupted by outcroppings of salty clay and layers of halite. Carbonatic and dolomitic rocks are forming, as well, relieves in the western part of Sicily, overlapping a basal complex constituted by carbonate sands and clays.

The central and southern parts of Sicily are characterized by the hilly complex of "normal" and "chaotic" depositions belonging to the Messinian evaporitic series (the "Gessoso-Solfifera" Formation), mixed with whitish marls of the late Pliocene and by yellowish Plio-Pleistocene calcareous sandstones.

The south-Eastern corner of Sicily is formed by the carbonate platform named "Hyblaean Plateau", a succession of horizontal layers of Mesozoic limestones frequently interrupted by a radial system of deep canyons departing from the highest elevation (Mt. Lauro, 970 m a.s.l.) formed by alkaline basaltic flows and calcareous tuff that covered the northern portion of the plateau during the Pliocene. The Hyblaean and the Etnean region are divided by the largest alluvial plain of Sicily, the so-called "Piana di Catania", created by the depositions of the main Sicilian river: the Simeto, collecting water from the southern side of Mt. Soro (*i.e.* the main elevation of Nebrodi Mts.) and all along the western flank of Mt. Etna. The plain of Catania is the most important agricultural area in the region, consisting of 108,097 ha of arable land and 102,350 ha of permanent crops.

Simeto is the only river of Sicily whose flow is reaching the average of 18 m^3/s, followed by the Alcantara- (8.8 m^3/s) and the Platani River (6.9 m^3/s). Most of the Sicilian rivers are modest (less than 1 m^3/s), with a pronounced seasonal gap during the summer months, due to the lack of rainfall, the short persistence of snow and the relatively small extension of the catchment basins.

CLIMATE AND BIOCLIMATES

The average annual temperatures recorded by the weather stations of Sicily are ranging between 17-18 °C at the sea level and 7-5 °C around 1800 m a.s.l. Trends of temperatures are greatly influenced not only by the elevations, but also by the distance from the sea and by the exposure: daily and seasonal temperature ranges are the lowest along the northern coast of the island (ZAMPINO *et al.* 1997). The highest temperatures are recorded in July in the inner districts, with frequent peaks well above 40 °C. In the same areas, minimum temperatures go frequently below 0°C during the winter months. The coldest month is January, with average min. temperatures of 9-10 °C in the lowlands and 1-0 °C around 1800 m a.s.l.

According to the Rivas-Martínez's bioclimatic classification (BRULLO *et al.*, 1996), the following thermotypes and ombrotypes are occurring in Sicily (abbreviations: T = Average year temperature, It = Index of thermicity):

- <u>Inframediterranean</u> (T = 18-20 °C, It = 500-450) upper semiarid (Lampedusa) and upper dry (Linosa and Pantelleria).
- <u>Lower Thermomediterranean</u> (T = 16-18 °C, It = 449-400) lower dry (coastal districts from Licata to Pachino), upper dry (Egadi Islands, coastal districts from St. Vito Lo Capo to Licata and from Pachino to Augusta), lower subhumid (coastal districts from St. Vito Lo Capo to Capo Gallo, Cefalù, from Augusta to Acireale, NE-Hyblaei, Aeolian Islands), upper subhumid (coastal districts from Cefalù to Messina).
- <u>Upper Thermomediterranean</u> (T = 16-18 °C, It = 399-350) lower dry (Piana di Catania), upper dry (hills of southern and SE-Sicily), subhumid (inlands of Trapani and Agrigento, hilly and coastal districts from Giardini to Messina), lower humid (Mts. surrounding Palermo, foothills of northern Peloritani and eastern flanks of Etna, from Acireale to Giardini).
- <u>Mesomediterranean</u> (T = 13-16 °C, It = 349-210) upper dry and lower subhumid (Mts. of western and central Sicily, southern flanks on Madonie and Nebrodi, southern Hyblaei), lower humid (northern flanks of Nebrodi and Peloritani, top of the Hyblaean plateau), upper humid (eastern flanks of Etna and Peloritani).
- <u>Supramediterranean</u> (T = 8-13 °C, It = 209-70) subhumid /lower humid (top of Madonie, Sicani, Nebrodi and western slopes of Etna), upper humid (top of Peloritani and eastern slopes of Etna).

- <u>Oromediterranean</u> (T = 4-8 °C, It = 69- -10) humid (Etna, between 2000 and 2800 m a.s.l.).
- <u>Cryo-oromediterranean</u> (T = 2-4 °C, It = -11- -100) upper humid (Etna, above 2800 m a.s.l.).

Distribution maps of the thermotypes and ombrotypes of Sicily are reported in Figs. 2 and 3.

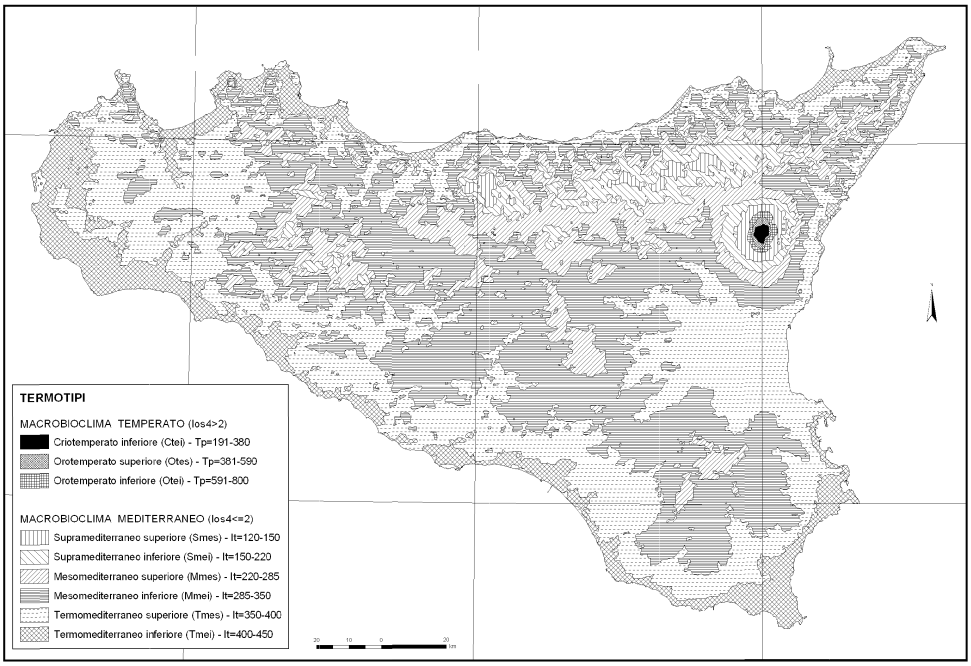

Fig. 2: Distribution map of the thermotypes of Sicily (after BAZAN *et al.*, 2006).

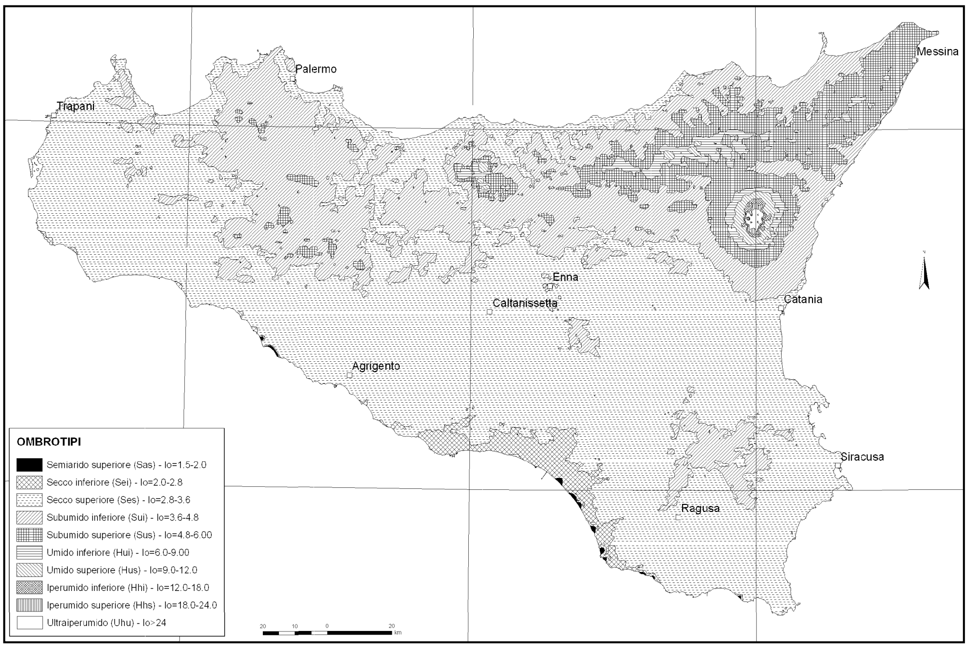

Fig. 3: Distribution map of the ombrotypes of Sicily (after BAZAN *et al.*, 2006).

FLORA AND VEGETATION

The vascular flora of Sicily and surrounding islets is currently estimated in around 3,000 species (GIARDINA *et al.*, 2007): floristically, the Sicilian territory turns out to be one of the richest in the Mediterranean. The high diversity of species is primarily related to the previously mentioned high topographic and bioclimatic diversity of the island. Moreover, for its geographical position, Sicily can be defined the crossroad of the Mediterranean flora, as many species are reaching here the northern- (*Reaumuria vermiculata*, *Zyzyphus lotus, Rhus tripartita*, etc.), southern- (*Fagus sylvatica*, *Ferulago campestris*, *Allium ursinum* etc.), eastern- (*Chamaerops humilis, Ambrosina bassii, Cistus crispus* etc.), western- (*Fritillaria messanensis*, *Salvia fruticosa*, *Jasminum fruticans* etc.) limit of their distribution range. These occurrences testify ancient biogeographical connections with the mainland (starting from the Messinian Age), as well as the plant migrations driven by the Plio-Pleistocene climate swings. Climate changes may locally lead to the severe reduction and splitting of plant populations. This is the case, for instance, of the disjoint Sicilian populations of *Heteropogon contortus*, *Artemisia alba*, *Sesleria nitida* ssp. *sicula*, *Koeleria splendens*, *Helictotrichon convolutum* that probably reached the island in the Pleistocene, during the dry interglacial periods (GUARINO, 2006).

At the same time, the insularity and the geographical segregation of refuge areas (coastal capes and high mountain districts) promoted the survival of many biogeographical relics and the differentiation of a rich endemic flora, currently estimated in 338 species, among which the genera *Allium*, *Limonium*, *Astragalus*, *Anthemis*, *Erysimum*, *Centaurea*, *Brassica*, *Viola*, *Hieracium* display remarkable examples of schizo-endemics resulted from the splitting of ancient distribution ranges, combined with the efficient occupation of particular ecological niches. In addition to the schizo-endemics, many Tertiary relics survived in Sicily, some of which are currently known as palaeo-endemics. This is the case, for example, of *Abies nebrodensis*, *Cytisus aeolicus, Erica sicula ssp. sicula*, *Petagnaea gussonei*, *Pseudoscabiosa limonifolia*, *Rhamnus lojaconoi*, *Zelkova sicula.*

As a whole, approximately 1/4 of the whole Sicilian flora (about 750 *taxa*) has got a remarkable biogeographical and systematic interest (BRULLO *et al.* 1995). Many of these elements are currently threatened by the human activities, although the Sicilian flora is better preserved than the Sicilian vegetation. Most natural communities have been degraded or permanently altered throughout Sicily and surrounding islets. The natural vegetation is threatened by continuing conversion to agriculture, pasture, and urban areas. Frequent fires, logging of remaining native woodlands, exotic species, intensive grazing are also common threats, as well as the touristic exploitation of the coastal districts. As Sicily has been a central crossroads of human activity for thousands of years, it offers a major perspective on all the problems and challenges of accommodating humans and nature in the much trampled Mediterranean basin.

The vegetation of the island shows almost everywhere the traces of a long-lasting exploitation of the land. The only well preserved patches of natural vegetation are limited to the most inaccessible places (cliffs, screes, rocky ledges, very steep slopes and windy ridges, plus the Etnean heights). In total, they cover a surface of about 7300 ha, i.e. 0.29% of the island (BAZAN *et al.*, 2009).

With reference to the phytosociological classification of plant communities (BRAUN-BLANQUET, 1964; BRULLO *et al.* 2002), the most well preserved natural plant communities of Sicily are those belonging to the following *syntaxa*: *Rumici-Astragaletea siculi* (orohopilous chamaephytic vegetation), *Scrophulario-Helichrysetea* (hemicryptophitic and chamaephytic vegetation of screes, talus slopes and riverbeds) *Saxifragion australis* (chasmophytic vegetation on alkaline rocks), *Dianthion rupicolae* (chasmophytic vegetation on acidic rocks) and, in part, *Crithmo-Limonietea* (halo-chasmophytic vegetation of rocky coasts).

The Sicilian woodlands can be also included in the relatively well preserved natural vegetation, although most of them are disturbed by husbandry and periodical coppicing. The following phytosociological units are represented (BRULLO *et al.*, 2008): *Quercetalia ilicis* (holm-oak woods, cork-oak woods, plus a large number of different wood-types dominated by the turkey-oak and/or by the stone-oak: a species-complex counting several different species in Sicily); *Querco-Fagetea* (beech-woods, riverside woods). In total, Sicilian woods are covering approx. 72,000 ha, i.e. 2.9 % of the island.

The rest of the island is colonized by secondary and synanthropic vegetation. The secondary vegetation includes chestnut-woods and reforestations, scrublands (*Quercetalia calliprini*, *Prunetalia spinosi*), garigues (*Cisto-Micromerietea*, *Cisto-Lavanduletea*), perennial semi-natural grasslands (*Molinio-Arrhenateretea*, *Lygeo-Stipetea*), covering in total 23.12%

of the island. The synanthropic vegetation (*Onopordetea acanthii*, *Secalietea*, *Stellarietea mediae,* etc.) is widely distributed on 1,245,000 ha, i.e. nearly 50% of the island, wherever an extensive agriculture is performed (BRULLO & GUARINO, 2007; BRULLO *et al.* 2007). Most of the Sicilian territory is occupied hard-wheat fields, but other dry-land farming, like olive groves and plantations of almond, pistachio, ash-tree, still characterizes a relevant part of the Sicilian rural landscape (Fig. 4).

Fig. 4. Olives, carob-trees, stone-walls are featuring a traditional landscape in the Hyblaean region, not far from the town of Ragusa (SE-Sicily).

Intensive agriculture covers around 25% of the island. Citrus groves, orchards, greenhouses and vineyard are included here. The impact of intensive agriculture is progressively increasing, together with the popularity of the Sicilian wines and early-fruits. Mechanized agricultural practices, chemical fertilizers and pesticides are drastically selecting the weedy plants, penalizing the Mediterranean plants and enhancing the chances of non-native weeds. Modern technology, like everywhere in the world, underpin the modern trend "from local to global". It is hard to believe that ubiquitous plants, like *Oxalis pes-caprae* or *Pennisetum setaceum*, arrived in Sicily such a short time ago. They belong to a process of "banalisation" of the landscape that is one of the newest forms of global impact.

TRENDS AT LANDSCAPE SCALE, PROTECTED AREAS AND MANAGEMENT PROBLEMS

As we have seen, the main feature of the Mediterranean region is a remarkable diversity of habitats, with hilly or mountainous inland and few alluvial plains in coastal sites. There is a tight coexistence of semi-natural and synanthropic ecosystems, with a great topographic and biological diversity, driven by ecological gradients of different intensity, highly influenced by the distance from the sea and by the orientation and altitude of the mountains. The natural patchiness of the Sicilian landscapes has been often increased up to critical levels by the human activities. Land use and human demography have significantly changed during the last six decades, as a consequence of the mechanization of agriculture, the decline of the extensive land use and traditional agriculture, particularly on terraced fields (BARBERA *et al.*, 2009). The development of new economic sectors, like services and infrastructures functional to the tourism, promoted the concentration of people within few miles from the coastline, with an ever increasing impact on coastal habitats. On the other hand, many lands used by agriculture or husbandry until recent times are currently abandoned, particularly in the mountain districts (Fig. 5).

Fig. 5. Hilly landscape with abandoned terrace-fields above Taormina and Castelmola (NE-Sicily).

One of the newest issues in the policy of the Sicilian administration is the protection of natural and cultural landscapes. The first three protected areas have been created in the year 1981 (regional law nr. 98), all three in coastal districts: Stagnone di Marsala, Vendicari, Zingaro. In 1988, with the regional law nr. 14 1988, followed by the Regional Plan for wildlife preserves, issued in 1991, to the first three protected area, 79 new ones have been added. In addition to these protected areas, four regional parks were established: Etna in 1987, Madonie in 1989, Nebrodi in 1993 and Alcantara in 2001.

In more recent times, following the “Birds Directive” (79/409/EEC) and the “Habitats Directive” (92/43/EEC), the "Natura 2000 network" of Sicily includes 214 SCIs (*Sites of Community Importance*) and 47 SPZ (*Special Protection Zone*), many of which overlapping the previously mentioned regional parks and reserves. When the management plans of SCIs and SPZs will become operative, 8% of the Sicilian territory will be protected (GUARINO, 2008). Two main kinds of protected areas can be found in Sicily: those occurring on mountains are on average quite extended, the coastal ones, instead, are on average six times smaller. Many of them are just little spots that have been set to save the saveable, i.e. the few coastal traits escaped from the massive urbanization that took place in those districts in recent times. The conservation and management of the Sicilian coastal sites, exposed to the pressure of strong economical interests, is quite problematic and poses a number of specific themes (GUARINO & GUGLIELMO, 2010).

Aim of the every protected area in the world is to promote conservation strategies *in situ* for threatened habitats and species. This should be done by the set up of a network of stakeholders, administrators and scientific experts which will support capacity building, management and policy actions. Unfortunately, these intentions are inevitably constrained by the lack of scientific knowledge on the ecosystem functioning and by the reality of limited economical resources. Conservation must therefore be based on the establishment of priorities, in order to determine how these limited resources could be best allocated (GUARINO *et al*. in press).

People’s perception on protected areas is, in most of the cases, limited to the recreational or aesthetical function of biotopes and biodiversity: a kind of “playground for ecologists” that can be used for outdoor activities and experiential marketing. This limited view should be widened through the use of protected areas as living labs for the environmental education, to raise the public awareness on the function of ecosystems, but unfortunately managers and planners seem to be much more sensible to the marketing and promotion of typical products and to the construction of infrastructures in order to improve accessibility and usability of these areas. This is not necessarily a negative aspect, but it can be so if it becomes the priority target for the development of protected areas. Environmental education is also education to a smart parsimony, to the reduction of waste, to the awareness of gestures. It is also education to the motion, to walk on natural terrains by adapting to the roughness of the pathways. Too many habitats and natural sceneries have been irreparably spoiled by senseless interventions to “improve” accessibility and usability. This is the case, for example, of the renowned Etnean “Rifugio Sapienza" and surrounding areas, where thousands of absent-mindedly tourists are brought on Mt. Etna "to walk on the lava", with best regards to the superficiality that already characterizes the average way of living of the urban people.

The only way to contrast these dangerous shortcuts is to look at the *Natura 2000 network* and, more in general, to every protected area, as a system with strong interactions with the non protected areas, i.e. part of the productive system at the basis of the economical development of the human societies. To preserve biodiversity on the long term, it would be probably more effective to reduce the energetic inputs around the protected areas, rather than to build infrastructures and to implement management plans and actions within them.

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HEAVY METAL CONCENTRATIONS IN MARINE COASTAL ENVIRONMENTS:

A TOOL FOR POLLUTION MONITORING

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INTRODUCTION

In this paper a review of the most recent studies on pollution of Sicilian coastal sites is reported, with particular reference to heavy metal concentration in marine environments. Monitoring of contaminants, especially those of anthropic origin, has been planned and carried out in order to assess the pollution status of the areas. We report on heavy metals in marine coastal sediments and biotas (namely *Posidonia oceanica*, effectively considered as a true biological indicator). This study is in the frame of a more general assessment of environmental conditions in the Palermo urban area aimed at its protection against contaminants of many kinds and levels. Careful attention will be given to the most recent methodologies of analysis referred to the main inorganic pollutants, together with the settlement of the progressive environmental risk in this critical sector of Sicily.

CHEMICAL STUDIES OF THE "*POSIDONIA OCEANICA*" IN WESTERN SICILY

Posidonia oceanica sea grasses present thick infralittoral communities, called *meadow ecosystems*, which are widely spread throughout almost all Mediterranean Sea coastal regions. They furnish the most important contribution to coastal primary production, and they are the habitat of many species. Due to its bathymetric range (from 0 to -40 m), this ecosystem is directly exposed to a number of anthropogenic impacts, like industrial and urban contaminants. In particular, heavy metals, along with natural and anthropogenic radionuclides, are responsible for a strong contamination of the *Posidonia oceanica* meadows. Causes can be represented by both terrigenous and atmospheric contributions (SANCHEZ-CABEZA & MOLERO, 2000). In fact, it should be taken into account also that serious levels of heavy metals could affect similar ecosystems.

The pollution grade in the Mediterranean region is generally inhomogeneous, no impact study having isolated a particular marine organism as a direct biomonitor of the contamination processes. *Posidonia oceanica* has by now been suggested as a bioindicator to report environmental modifications (PERGENT *et alii*., 1995). Geological characteristics of the meadow sites should also be carefully considered to differentiate pollution and natural contributions from chemical element rates. Relationships among trace metals concentrations in plant fractions and sediments also play a real role (NICOLAIDOU & NOTT, 1998). Extrapolation of concentration values from one site to another may be confounded by many factors such as the physiological status of the organisms, the environmental variability and the geochemical characteristics of the habitat.

As part of a more general project launched over ten years ago (CIPE-MIUR, *Metodologie Integrate di indagine in aree di pregio ambientale mirate alla valorizzazione e gestione delle Risorse* Project, now expired), making use of various methodologies directed to environmental protection, preliminary investigations of metal and radionuclide contaminations in *Posidonia oceanica* and sediments in four sites of the Northwestern coast of Sicily has been carried out (Fig. 1).

Fig 1. Locations of samplings in the investigated sites of the area (Western Sicily).

Sampling locations have been selected to be very similar for geochemical and lithological characters, but different for proximal pollution situations. Four heavy metals (Cu, Cd, Pb and Zn), four natural radionuclides (^{40}K, ^{210}Pb, ^{228}Ac and ^{214}Bi) and one artificial radionuclide (^{137}Cs) were selected for the analyses. Records were compared with the major, minor and trace elements measured in specimens collected in the same sediment sites.

The association among the values of heavy metal concentrations in *Posidonia oceanica* and sediments could provide some hints to finding remedial actions with respect to the pollution of anthropogenic origin. Moreover, a rough assessment of the state of the marine environment near the Northwestern coast of Sicily can be obtained from the survey.

The chemical and mineralogical composition of sediments, trace-metal concentrations and radionuclide specific activities in sediments and *Posidonia oceanica* samples from meadows in Northwestern coast of Sicily (Italy) have been determined. X-ray fluorescence and diffractometry, atomic absorption spectrophotometry and high-resolution gamma spectrometry have been used. Table 1 shows some records relevant to the XRD laboratory examinations, specifically for the Egadi stations (TRANCHINA *et alii*, 2004).

	Quartz SiO_2	*Calcite* $CaCO_3$	*Magnesian calcite* $Ca(1-x)Mg(x)CO_3$	*Aragonite* $CaCO_3$	*Dolomite* $CaMg(CO_3)_2$	*Feldspar* $(K,Na)Si_3O_8$
Egadi						
Station 1	8 (1–15)	21 (17–22)	23 (2–42)	16 (1–27)	32 (2–72)	0
Station 2	3 (1–7)	22 (14–35)	37 (5–63)	17 (4–27)	21 (2–55)	0
Station 3	5 (0–16)	22 (6–38)	35 (14–63)	22 (9–31)	16 (9–39)	0

Table 1. XRD mineralogical analyses on the Egadi sites (see Fig. 1). Results are shown as mass percentage of sediments: mean values over three samples from different transects in the same site, collected at the same depth (ranges in parentheses). Subset from TRANCHINA *et alii*, 2004.

Standard statistical techniques have allowed detailed comparisons among values from different sites and/or different types of samples. This work has confirmed that *Posidonia oceanica* is a fair biomonitor of heavy-metal pollution in the investigated areas of Sicily

No correlation of trace-metal concentrations in sediments and plant has been detected in this preliminary study. However, a correlation between Cd concentration in plant and seawater was already reported as well as an analogous behaviour assumed for Pb (SANCHIZ *et alii*, 2000). Consequently, metal concentrations in *Posidonia oceanica* might indirectly be a measure of bioavailable metal concentrations in the environment rather than total concentrations. The plant/sediment ratio of concentrations is particularly large for Zn. This also applies to Cd, since it was always under the detection limits in sediments. This indicates that bio-enhancement takes place in *Posidonia oceanica*.

The potassium concentrations (proportional to ^{40}K activity determined by gamma spectrometry), with values in rhizomes higher than in scales, is in wide-ranging conformity with the known significant function of this element in plant expansion.

POSIDONIA OCEANICA AS A SIGNIFICANT BIOLOGICAL INDICATOR TO MONITOR ANTHROPOGENIC LEAD CONCENTRATION IN MARINE ENVIRONMENT

Posidonia oceanica, as known, is capable to reliably watch the changeability of environmental metals, principally lead (Pb). Lead concentration analyses, measured in the scales and rhizomes of *Posidonia oceanica*, where collected in seven sites in selected coastal belts of Sicily (Fig. 2).

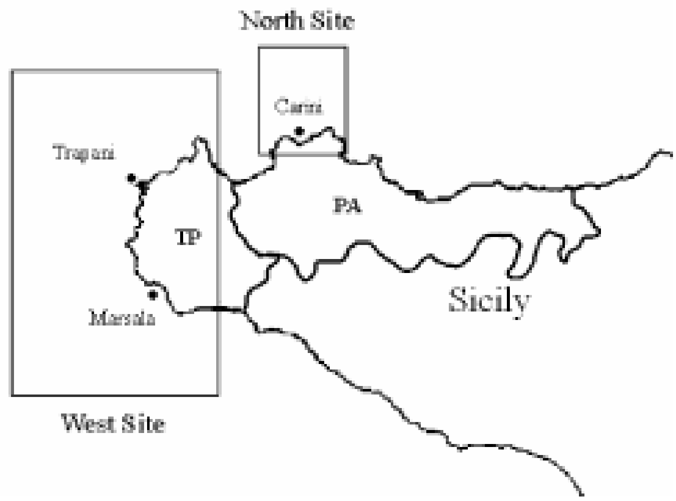

Fig. 2. Detail of the investigated sites located along the of North and West Sicily coasts (provinces of Trapani and Palermo).

These have consequently been fractioned according to lepidochronological investigations. So, lead concentration tissues in *Posidonia oceanica* were measured by using the flame atomic absorption spectrophotometry technique. The measured lead concentration were compared with the estimated lead emission in air for the gasoline sold and used for combustion in mobile vehicles engines in Sicily. By computation of the Pearson cross-correlation coefficient, it was shown that lead concentration, which is measured in the scales of *Posidonia oceanica*, is statistically correlated to lead emission in air, so reflecting the rate of lead pollution in littoral marine settings (TRANCHINA *et alii*, 2005).

Posidonia oceanica (L.) Delile is a sea plant largely diffused all over the Mediterranean region. Many factors make this marine phanerogam an excellent candidate to monitor the coastal environmental conditions. First, its relative longevity (even more than 50 years of average life); second, the fact that its growth remains over different seasonal cycles; last, its property to collect different kinds of contaminants, as metals, organochlorines and radionuclides. It is also known that *Posidonia oceanica* grows in dense meadows that live close to the coasts and spread down to depths of 30-40 m and over, depending upon water characteristics such as turbidity, temperature and salinity. Therefore, *Posidonia oceanica* interacts with marine coastal biocenoses. In *Posidonia oceanica* organism, it is possible to distinguish three different kinds of tissues: leaves with an annual cycle of life, rhizomes that maintain the leaves and have orthotropic trends, and scales at the bottom of the leaves. When the leaves of *Posidonia oceanica* expire, their blades detach from the bases, while the bases themselves stay on the rhizomes forming a scale. The dating of fragments of rhizomes and scales is usually performed by fractioning *Posidonia oceanica* according to its life cycle. In fact, the cyclical modification of the scale thickness of the rest on the rhizome allows defining the beginning and the conclusion of an annual life sequence. This methodology is called the lepidochronological method (CALMET *et alii*, 1988).

The evidence that this marine plant is capable to evidence the littoral concentration of pollutants has been recently shown. Several authors (see, for instance, PERGENT-MARTINI & PERGENT, 2000) pointed out that *Posidonia oceanica* is capable to “take record” of the yearly concentration of mercury (Hg) in different tissues of the sea plant. In particular, they observed that the Hg concentration of *Posidonia oceanica* was well related to the change of environmental Hg concentration. Yearly concentration of metals can be measured after having chosen the fragments of scales and rhizomes linked with the considered life year of *Posidonia oceanica*, according to the lepidochronological method above mentioned. Further, this technique allowed some researchers to prove that rates of ^{137}Cs found in the scales of *Posidonia oceanica* were fairly related with ^{137}Cs fallout.

The purpose of this research is to illustrate that *Posidonia oceanica* is also capable to consistently watch the variability of ecological lead (Pb) as well as mercury and radio-cesium.

To this aim, Pb concentration measured in the scales of *Posidonia oceanica*, which have been collected in seven different locations along the littoral belts of Sicily and subsequently fractioned according to the lepidochronological method, is related to records of gasoline consumption. So, lepidochronological lead content in the scales of *Posidonia oceanica* is shown to be statistically linked to the chronological model of the Pb emission in air, which is connected with the burning of the gasoline sold and used in the Island.

For the four studied macrosites, the correlation coefficients between Pb concentration in the scales and Pb emissions in air are shown in Table 2.

site	lithology	SiO_2[a]	CaO[a]	Pb[b] sediment	Pb[b,c] scales	Pb[b,c] rhizomes
Carini	calcite	5.0	45	8.4 ± 0.9	10.3 ± 1.3	9.3 ± 1.0
Trapani	calcite	5.0	47	7.3 ± 0.8	7.8 ± 0.8	4.2 ± 0.6
Marsala	calcite	9.3	45	8.3 ± 0.9	6.5 ± 0.7	4.8 ± 0.6

Table 2. Concentration of lead in shallow sediments, scales, and rhizomes (last lepidochronological year) of Posidonia oceanica and concentration of oxides of Si and Ca by XRF analysis in samples of shallow sediments simultaneous collected as *Posidonia oceanica*. SiO_2 and CaO are expressed as a mass percentage in the hydrated samples. [b]Pb concentration is expressed in $\mu g\ g^{-1}$. [c]Pb concentration for the last lepidochronological year. From TRANCHINA *et alii*, 2005, modified.

Almost all the macrosites show statistically important rates of correlation. The North and West macrosites (see again Fig. 2) show very high correlation rates, probably explained with the strong population of the area, with grave traffic situation and relatively elevated levels of industrialization. The SE2 macrosite (East Sicily) exhibits elevated grade of correlation, due to the extremely contaminated spot of Ognina Bay and the Cape Negro location, characterized by inferior anthropogenic contributions. The existence of these two levels of pollution in SE2 involves that in the sequential considered time (1988 - 2001) the level of correlation is smaller than the one found for Ognina Bay only. The SE1 macrosite (also located in East Sicily) shows not statistically significant levels of correlation, due to the low levels of urbanization and of automotive traffic conditions characterized by this macrosite.

In summary, differently from the accumulation of Hg in *Posidonia oceanica* (PERGENT-MARTINI, 1988), we find that in each site Pb accumulates in scales rather than rhizomes. Such action is autonomous as respect the levels of pollution of the sites. Furthermore, the Pb concentration in the rhizomes of *Posidonia oceanica* are approximately steady in the whole considered lepidochronological time and no time dependence on the pollution level of the site can be estimated. Reversely, Pb concentration in scales follows the contamination of the studied spots. Indeed, in all the locations where the procedure of phasing out of lead from gasoline was expected to be effective, as in sites near industrial and urban zones, the Pb concentration in the scales demonstrates noticeable chronological trends linked with lead discharge in the air.

All these findings and the endemic dispersion of *Posidonia oceanica* in Mediterranean basin indicate the scales of this marine phanerogam to be a fair biological monitoring tool for the investigation of Pb contamination in Mediterranean coastal marine environment. The fact that Pb concentrations are retained in the scales for long time, up to 20 years at least, makes it promising to evaluate the variations in Pb concentration over long time period with only one sampling.

SPREADING OF HEAVY METALS IN MARINE COASTAL SEDIMENTS IN PALERMO GULF

Metals in sea environments have both natural and anthropogenic sources. Since metals are not subject to bacterial degradation, they are a fundamentally stable accumulation in the sea and, consequently, they get gathered in the marine deposits (CLARK, 2001).

Defining of the metal sources in the environment as a result of human activity is relatively complex due to the very large rate of natural inputs (*i.e.* erosion of ore-bearing rocks, wind-blown dust, and volcanic activity and forest fires). Issues influencing metal concentration in the sediments are linked to: (1) mineralogical and granulometric composition; (2) red-ox state of the metal; (3) pH and Eh of environment; (4) adsorption and surface precipitation processes (SADIQ, 1992).

Since metals contribute in various biogeochemical means, they have good mobility and can be bio-accumulated by sea organisms as planktonic or benthic foraminifera algae, and plants and so bio-enhanced up the food chain with the top predators unloading the largest dose of conservative substances (CLARK, 2001, *quoted paper*), sometimes with damage effects for humans beings (see, as an example, in SINDERMANN, 2006).

Manufacturing and human activities are more and more located near the littoral regions and, as a result, metal concentrations in coastal marine environment have increased in the latest years. A stable monitoring of contaminant concentrations (together with metals) in deposits is required to assess the sea coastal environment circumstance. Many papers have lately focused their consideration on sediments from industrialized coastal areas discovering that metal levels in sediments are severely influenced by human works and that a study of metal grade in sediments can be a good tool to define the level of environmental sea pollution (DI LEONARDO *et alii*, 2006).

Data of Cr, Cu, Hg, Pb and Zn concentrations are measured in the sludge portion of 30 deposit samples relevant to the Palermo Gulf (Fig. 3, TRANCHINA *et alii*, 2008), for which area no other methodical revise is obtainable in scientific literature (see Table 3).

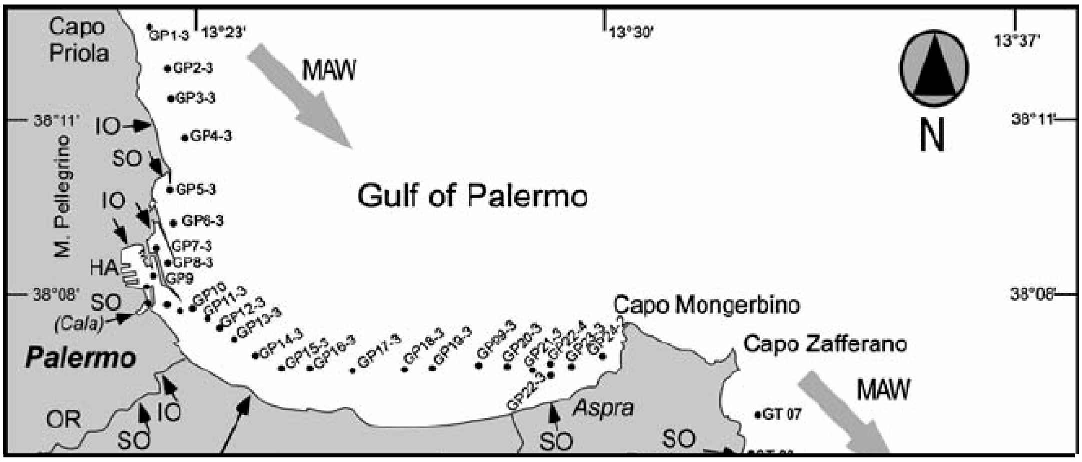

Fig. 3. Location of sampling sites in the Palermo Gulf. From TRANCHINA *et alii*, 2008, modified.

This bay represents, in fact, an area where both low and high impact human activities (such as a harbour area with dockyards) are present. Enrichment factors for the fine sediment fraction have been estimated for each metal to assess whether the metal concentrations can be considered as part of natural background or not. Extensive statistical analysis using ratio matching technique, hierarchical clustering, minimum spanning tree and principal component analysis have been performed on analytical data to perform the geographical distribution study of pollutants and their relationships (GUILLEN *et alii*, 2004).

The described wide investigation of metal (Cr, Cu, Hg, Pb and Zn) concentrations in surface soft bottom deposits in the Palermo Bay have been carried out showing the occurrence of accumulation areas.

These areas are reliable as respect to the location of contamination sources. As a matter of fact, the prospected spots in proximity of the harbour and those near the Oreto River mouth are largely the most contaminated ("OR" in Fig. 3).

Area	Station	Zn	Cr	Cu	Pb	Hg
North-West (NW)	GP01.3	67.1	13.3	10.5	13.5	0.12
	GP02.3	47.2	20.0	16.7	15.4	0.11
	GP03.3	55.2	17.1	16.6	18.5	0.10
	GP04.3	58.6	19.8	21.6	29.7	0.19
	GP05.3	66.9	22.5	32.8	33.0	0.34
	GP06.3	91.6	36.6	28.7	29.3	0.25
Harbor area (HA)	GP07.3	187	33.2	90.7	41.4	0.52
	GP08.3	269	46.3	196	57.4	0.95
	GP09.1	752	69.9	698	220	2.7
	GP09.2	224	48.6	178	58.0	1.5
	GP09.3	282	69.0	335	65.7	2.0
	GP10.1	332	44.9	120	50.3	1.0
	GP10.2	287	56.8	94.6	56.8	0.97
	GP10.3	216	51.2	72.2	45.9	0.91

Table 3. Metal concentrations, in $\mu g\ g^{-1}$, measured in the <63 μm sediment fraction, in samples relevant to the Northern as well as the harbour sectors of Palermo Gulf. From TRANCHINA *et alii*, 2008, modified.

For every measured metal constituents, enrichment factors have been calculated from the average values measured in deposits picked up in sectors relatively far from contamination sources (Gulf of Termini, West of Palermo Bay) and considered as *background values* (see again TRANCHINA *et alii*, 2008). They testify the occurrence of contamination gradients in the Palermo Bay. Statistical methodologies, specifically PCA (*Principal Component Analysis*) and *cluster analysis*, executed on similarity matrix obtained by ratio matching techniques, provided additional insight into the sampling area description in terms of both geographical and pollution distribution, particularly through the correspondences in metal ratio concentrations.

LEAD POLLUTION CHRONOLOGY BY DATING OF A MARINE SEDIMENT CORE IN THE PALERMO GULF (WESTERN SICILY): THE $^{210}PB_{EX}$ METHOD

Heavy metal concentration analysis in marine deposits seems to be a reliable tool to assess the pollution of marine coastal environments. Sediments actually behave as reservoir capable to replace metals with marine water and neighbouring biota (see, for example, SADIQ, 1992, *quoted paper*).

A broad research carried out in the last years in Palermo deposits allowed to evaluate the general pollution of the area. Particulars on the environmental and geological properties of this investigated sector of Sicily can be also found in previous papers (*i.e.*, TRANCHINA *et alii*, 2008, *quoted paper).* In this paper, we focus our attention on lead concentrations in segments of a sediment core relevant to a particular contaminated spot of Palermo Bay (Fig. 4). Core has been dated using the well-known $^{210}Pb_{ex}$ method, within a steady sedimentation rate model (CARROLL & LERCHE, 2003). Specific activity of ^{137}Cs has also been estimated as an independent test of the validity of the resulting time scale.

Radiometric dating allows absolute measurements of the deposit age, as demonstrated by the literature in many research papers (see, as an example, VAALGAMAA & KORHOLA, 2004). The method of the $^{210}Pb_{ex}$ (or unsupported ^{210}Pb) has been here used (Fig. 5). In particular, the ^{210}Pb activity in the sediment has two diverse sources, detailed in the following.

Some of the ^{210}Pb results from the radioactive decay of ^{226}Ra previously occurring in the marine deposits (supported ^{210}Pb). The other part of $^{210}Pb_{ex}$ is due to the sedimentation of the ^{222}Ra daughters. The action of the supported ^{210}Pb can be known from the activity of ^{226}Ra. This last activity can be recognized by means of the activity of its daughter ^{214}Pb, provided the samples have been kept sealed in their containers long enough to attain the secular equilibrium situation. The $^{210}Pb_{ex}$ activity (i.e., not derived from the 226Ra radioactive decay) can then be estimated as the difference between ^{210}Pb total and ^{226}Ra activities. The $^{210}Pb_{ex}$ decays with its own half-life time, equivalent to 22.3 years, so being very appropriate to the purpose of dating the sediment core we were interested (BOER *et alii*, 2006).

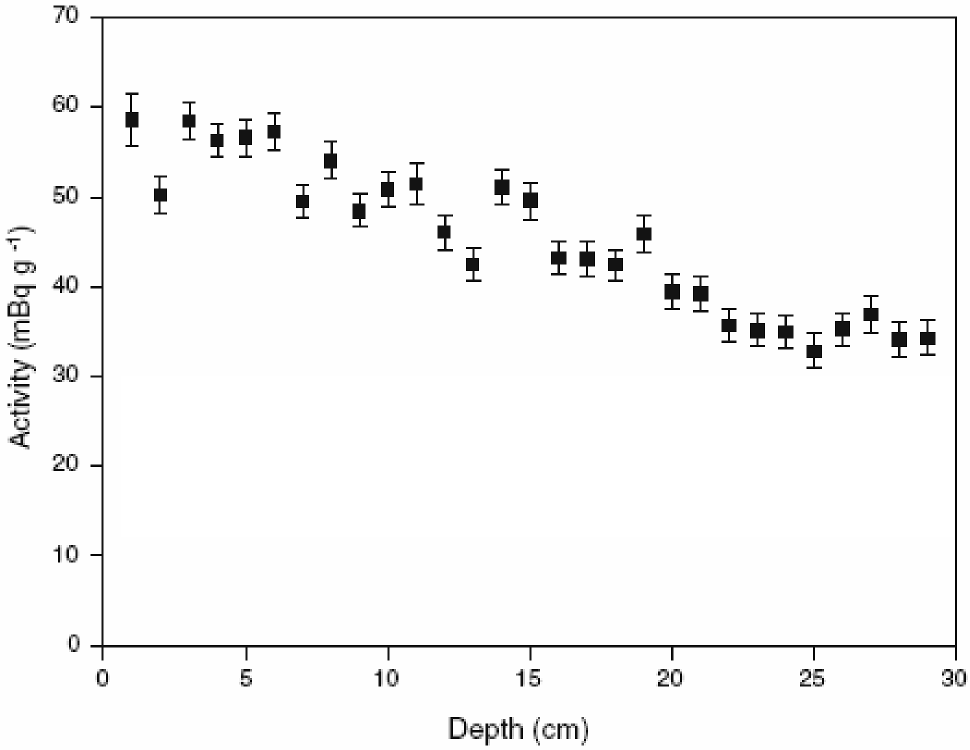

Fig. 4. Diagram shows the activity of the 210Pb$_{ex}$ is in a sediment core of Palermo Bay (see Fig. 4). Total ^{210}Pb activities is a function of the core section depth. Error bars refer to ±2σ uncertainties. From RIZZO *et alii*, 2009, *modified.*

Anthropogenic Pb production in this situation in recent decades is strongly related to Pb contents in gasoline (NEEDLEMAN, 2000). Other sources of Pb are linked to manufacturing applications. However, the main anthropogenic contribution to the environment is the combustion of gasoline with lead alkyls content as antiknock additives. For instance, the n. 31 report of the GKSS (*Forschungszentrum Geesthacht GmbH Institut für Küstenforschung*) calculates that the fraction of lead emanation in air due to the carrying causes in Europe was 76.1% in 1985, 72.1% in 1990 and 68.7% in 1995 as referring to the total lead emission in air. At this proposal, see also the EU-Project ESPREME reports, (E. S. P. R. E. M. E. 2004–2006). The United States Environmental Protection Agency (USEPA) showed (*Environmental Criteria and Assessment Office,* 1986) the existence of positive correlation between Pb levels in consumed gasoline and Pb concentration in air. Furthermore, in other papers, it is outlined that atmosphere stands for the largest cause of calculated Pb de-position in lakes (GALLAGHER *et alii*, 2004) as well as in marine environments, particularly in closed basins.

It is therefore important to consider the potential correlation between historical grades of Pb emission in air and lead concentration in sediment cores, as already exhibited for dated fractions of *Posidonia oceanica*, whose recently carried out studies were reported above in this paper (TRANCHINA *et alii*, 2005, *quoted paper*).

Gasoline burning has been, in these last years, the major cause of Pb pollution in the environmental area of our interest, due to the deficiency in major industrial plants or emissions due to coal combustion. Data on lead concentrations in shallow deposits of Palermo Gulf, together with background values, can be found in pertinent papers (i.e., TRANCHINA *et alii,* 2008, *quoted paper*). Furthermore, in the last decades, scientists and ecology researchers indicated lead as one of the major sources of environmental contamination, likely considered harmful to human health (SINDERMANN, 2005). Removing of lead from gasoline was then suggested as a possible solution for this heavy metal pollution. As a matter of fact, accessibility of only *unleaded* gasoline is nowadays mandatory in most of countries.

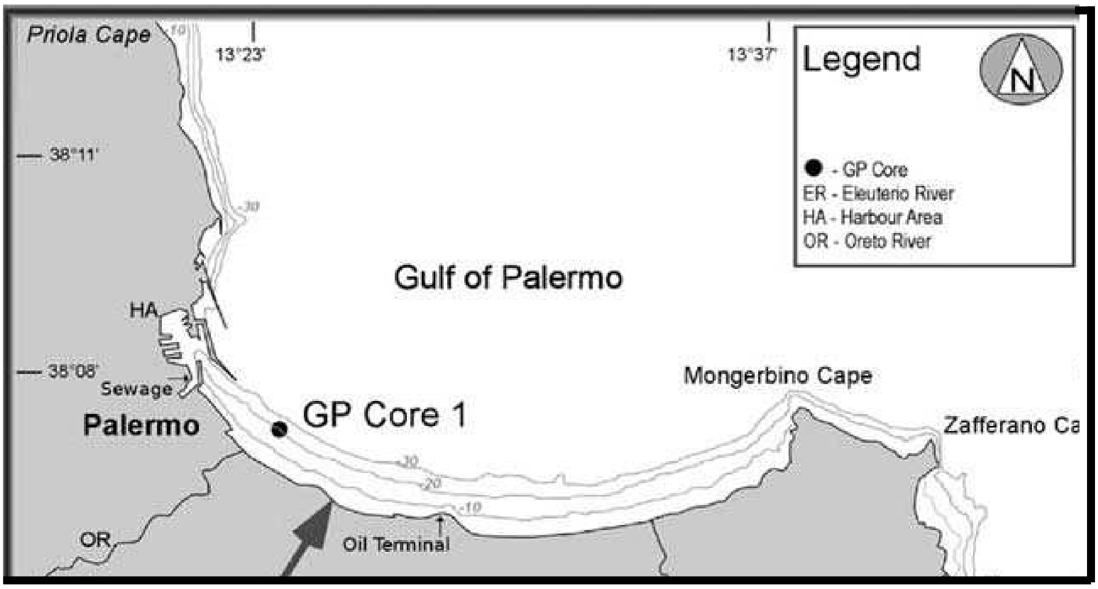

Fig. 5. The Gulf of Palermo and the location of the simple site (GP core 1). From RIZZO *et alii*, 2009, *modified*.

As a notable consideration on the $^{210}Pb_{ex}$ adopted method, through gamma spectrometry of a sediment core sampled in the Palermo Gulf, the Authors of this note emphasize its consideration as an appropriate dating tool (RIZZO *et alii*, 2009). The sedimentation rate has been evaluated to be about 6 mm year^{-1}. The resulting time scale, of the order of fifty years, also tested by measuring ^{137}Cs specific activity, has allowed us to assign temporal tags to lead concentrations measured by atomic absorption spectrophotometry. A reliable statistical correlation has been established between the two time series of lead concentrations in core sections and estimated (through available statistical information) lead emissions in air (see Fig. 6). Data also illustrate a noticeable decrease in lead concentrations (along with corresponding lead emissions) since the phasing out of lead from gasoline, a procedure progressively enforced in Italy since 1982 and at the present completed, at least in most of world countries.

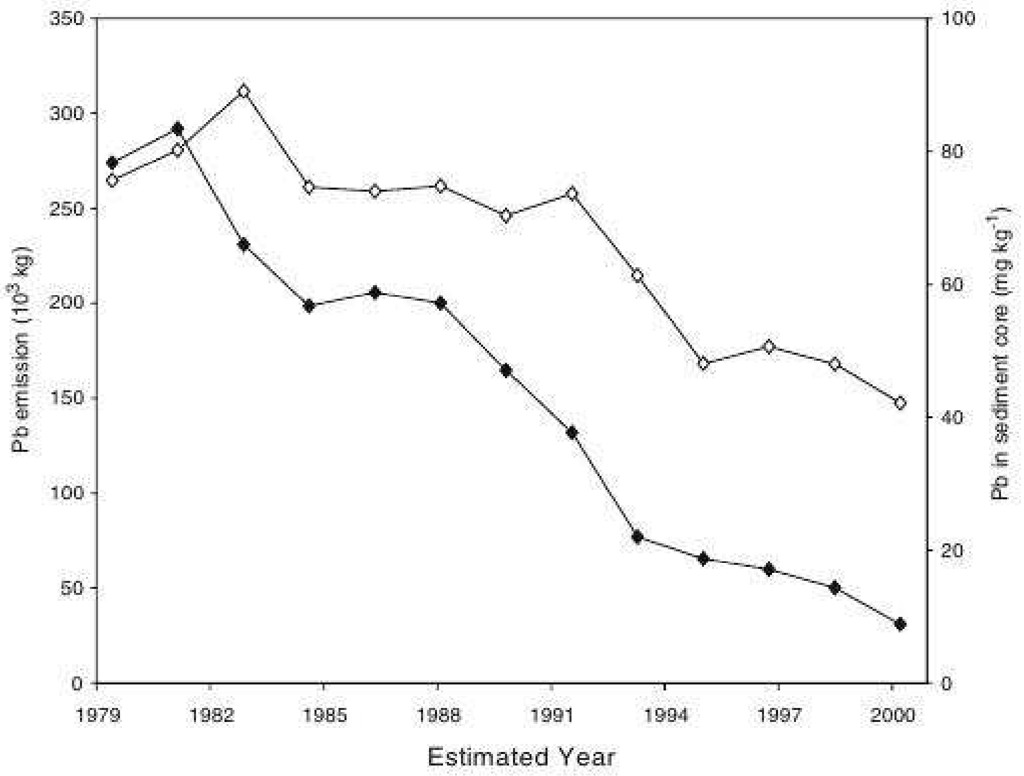

Fig. 6. Measured total Pb concentrations in the dated core sections (right axis, empty symbols) and corresponding estimated Pb air emissions in the Palermo area (left axis, filled symbols). From RIZZO *et alii*, 2009.

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THE ACTIVITY OF THE WASTEWATER LABORATORY OF THE "ACQUA DEI CORSARI" PLANT, AMAP S.P.A., PALERMO

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"Acqua dei Corsari" depuration plant, wastewater laboratory: Dr. Antonella Cicala, Dr. Giuseppina Gullo, Dr. Maria Grazia Cucchiara

THE AMAP S.P.A. COMPANY

The AMAP S.p.A. is the Company that manages the public service of the integral cycle of waters of the City of Palermo.

As of the date of its incorporation, in the early '50ies, the Company, bearing in mind the complex nature of the service activity carried out, had - as objective - that to be equipped with its own laboratories of chemical and microbiological analyses.

The objective originated from the need to implement a systematic structure of preventive control and verification of the quality of the cycle of the water whilst enabling the Company to benefit of a suitable structure of support to the service, able to provide prompt answers and guidance, in critical emergency situations.

The laboratories are certified with the International Standard UNI EN ISO 9001:2000 and organized with modern and rational criteria. They are equipped with *state of the art* instruments and equipments operated by a highly professional technical staff to guarantee the performances carried out.

The use of adequate data processing systems allows an effective management of the analytical data and their correct interpretation under a statistical point of view.

From the organizational point of view, it is worth mentioning that the Laboratory of Wastewater, located in the plant of *Acqua dei Corsari*, represents one of the specialized sections of the laboratory units of the Company. The laboratory of wastewater takes care, from the institutional point of view, of the analysis and verification of all the phases of the integrated system of the cycle of waters.

THE WASTEWATER LABORATORY OF *ACQUA DEI CORSARI*

The wastewater laboratory of *Acqua dei Corsari* (Figs.1 and 2) carries out control surveys as to wastewater treatments, sewerage pipes, characterization of the wastes deriving from the manufacturing processes, analysis of liquid wastes (leachate of the landfill, the sewage suction trucks and agricultural and food wastes) as well as studies on the processes of treatment of waters. Said activities are carried out the, in compliance with the relevant EU, national and regional provisions which provide for a system of controls, based upon pre-determined microbiological, chemical and chemical-physical parameters and the compliance with certain quality requirements.

Fig. 1. The wastewater laboratory of *Acqua dei Corsari,* AMAP S.p.A. Company.

Fig. 2. The wastewater laboratory of *Acqua dei Corsari*, AMAP S.p.A. Company.

The control planning is established on the basis of a program of analysis, agreed with the manager responsible for the processes, and it takes in account some characteristic features of the complex management of the service and the respect of provisions of law: Legislative Decree 152/06 and Regional Law 27/86, where applicable. The analyses include:

I) physical parameters: pH temperature, colour, smell (Fig.3);

Fig.3. Equipment for analyses of physical parameters.

II) chemical parameters: COD, BOD5 (Fig.4) ammonia, nitrites, nitrates, chlorides, sulfates, phosphorus, surface-active agents , etc…;

Fig.4. Equipment for analyses of chemical parameters.

III) biological parameters (microscopic analysis of the mud) (fig. 5).

Fig.5. Equipment for analyses of biological parameters.

This last one, in particular, constitutes a valid method to obtain indications on biological quality of the wastewater treatment. The microscopic observation of the sludge floc (form and dimensions) and of its constituting elements such as the filamentous microorganisms (Fig. 6) and of the microfauna (*Protozoa*) (Fig. 7) is an instrument that concurs to control, and to manage the sewage depurative process.

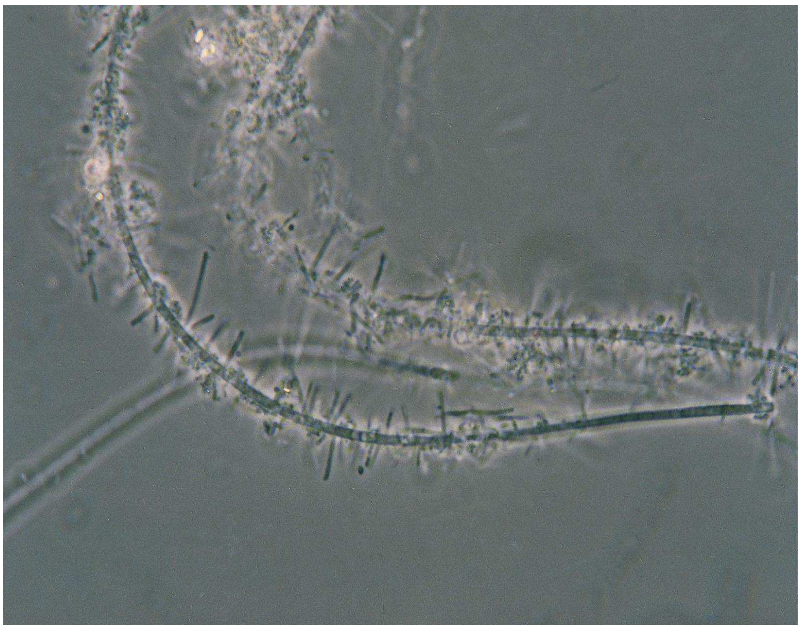

Fig. 6. Microscopic observation of filamentous microorganisms in the sludge floc.

Fig. 7. Microscopic observation of microfauna (*Protozoa*) in the sludge floc.

An effective removal of the organic substance is strictly related to the structure of the microfauna that colonizes the mud.

SAMPLING PROCEDURES AND ANALYSIS METHODS

The analysis procedure starts with the taking of samples. The sampling methods are different according to the kind of samples to capture. In fact we have:

a) instantaneous samplings (fig. 8);

Fig. 8. Instantaneous sampling.

b) medium-composites samplings (fig.9).


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Fig. 9. Medium-composites sampling.

The instantaneous sampling is characterized by only one sample captured in a single action in a determined point and within a short period of time. The instantaneous sample is to be considered representative only on regard to the conditions present at the moment in which the sampling occurs.

The medium composite sampling are realized by mixing more instantaneous samples taken over a given period of time (e.g. 3, 6, 12, 24 hours).

The sampling constitutes the first phase of every procedure of analysis and as such it is extremely complex and delicate, as if not correctly performed it can compromise and condition the result of all the subsequent steps of the process. Once collected, the samples are carried to the laboratory within the shortest possible delay and immediately analyzed in compliance with the official methods set by the laws.

It is worth mentioning however that there are different methods to delay the alteration of the samples, such as the refrigeration at 4°C, the chemical conditioning, the use of particular materials for the sampling (bottles of glass or polyethylene). The samples must however be analyzed within and no later than 24 h.

The methods are those provided for by the *Istituto di Ricerca sulle Acque* (IRSA) and by the *Consiglio Nazionale delle Ricerche* (CNR).

In case the analysis parameters are not in line with the values provided by the law, it is promptly given written notice thereof to the Head of Unit (by issuing an outside norm parameter certificate). The Head of Unit shall inform, as soon as possible, the Competent Authorities.

The alterations of the wastewater treatment, caused - for example - by a sewage entering the system having characteristics not conforming with that of an urban sewage, can materially compromise the course of the same process, causing therefore an alteration of the parameters in the final effluent.

It has to be mentioned that the failure to comply with the parameters indicated by the law implies penalty sanctions as administrative ones.

ESSENTIAL REFERENCES

ANALYTICAL METHODS FOR WATERS

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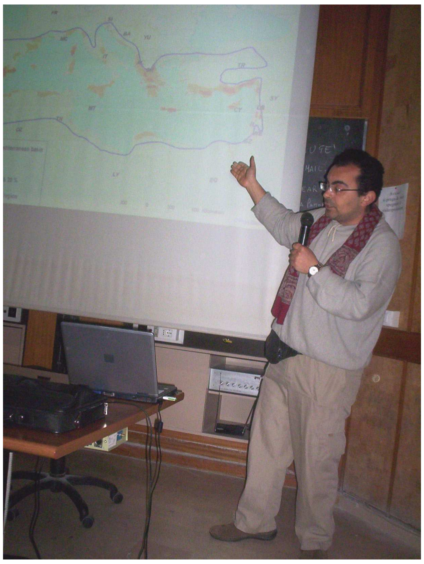
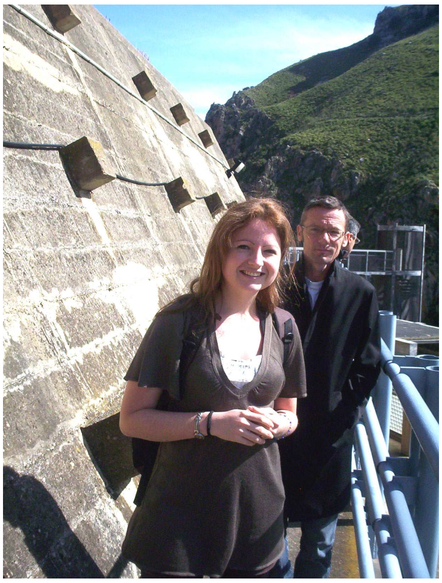
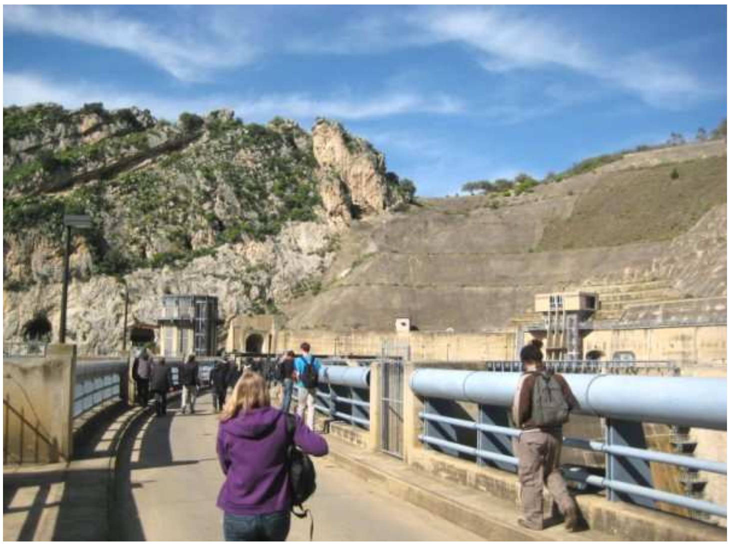
MEETING AND TECHNICAL TRIPS: SOME PICTURES



Meeting at the Faculty of Science, 2 March, 2010, talks of Anne-Sophie Gournier (INPL), Benedetto Abate and Riccardo Guarino (Palermo University)





Excursion to Rosamarina dam, 2 March, 2010

Excursion to Scillato Springs, 2 march 2010

Visit to the Acqua dei Corsari depuration plant, 3 March, 2010

Visit to the Acqua dei Corsari depuration plant, 3 March, 2010