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WORLD INVENTORY OF KARST RESEARCHERS: PRELIMINARY REPORT

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ABSTRACT

G.K.W.: Karst research, IGU Study Group.

A brief preliminary report on a world inventory of karst researchers is presented. About 100 scientists from 26 Countries sent the proposed form.

The first results outline a number of 25 fields of study. A new form is proposed to create a permanent data base of all scientists involved in karst research. The list will be published in a further paper to promote the future international cooperation in karst research and the acquaintance among scientists.

INTRODUCTION

This world inventory was at first proposed by the corresponding member Catherine Coxon from Dublin. This suggestion was reported in a Circular of the Study Group and encouraged the Japanese group, under the guide of Kazuko Urushibara-Yoshino, to send a propositional form for the inventory.

Ugo Sauro, present chairman of the IGU Study Group "Environmental changes in karst areas (S.88.6)", by the occasion of the International Conference on Environmental Changes in Karst Areas which took place in Italy in September 1991, sent a more complete form to all the members of the group. This is the first known attempt to make such an inventory of karst researchers.

By the end of October 1991, only 93 scientists answered. It is evident that this number is not enough to point out the characteristics of the whole group (which is composed by 300 corresponding members). Moreover the analysis is affected by the presence of some large groups of the same country as the Japanese one.

RESULTS

Considerations on the age of karst researchers

As it can be seen in the chart in Fig. 1, the modal class of researchers is 41-45 years old; few researchers are less than 25 years old.

The number of scientists from 20 to 25 years old is equal to that from 71 to 75. The diagram in Fig. 1 shows a sounding asymmetry with a tail towards the ranges of older age, as demonstrated by the difference between the mean age (44) and the median age (42).

Fig. 1 Number of researchers per ranges of age

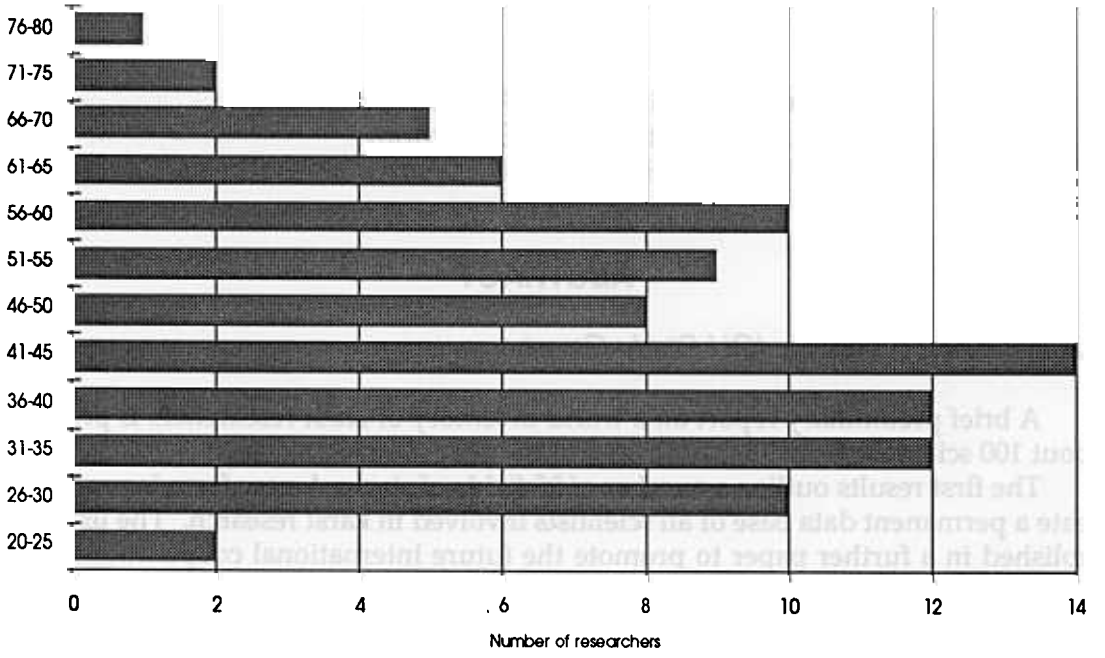


Fig. 2 Researchers per country

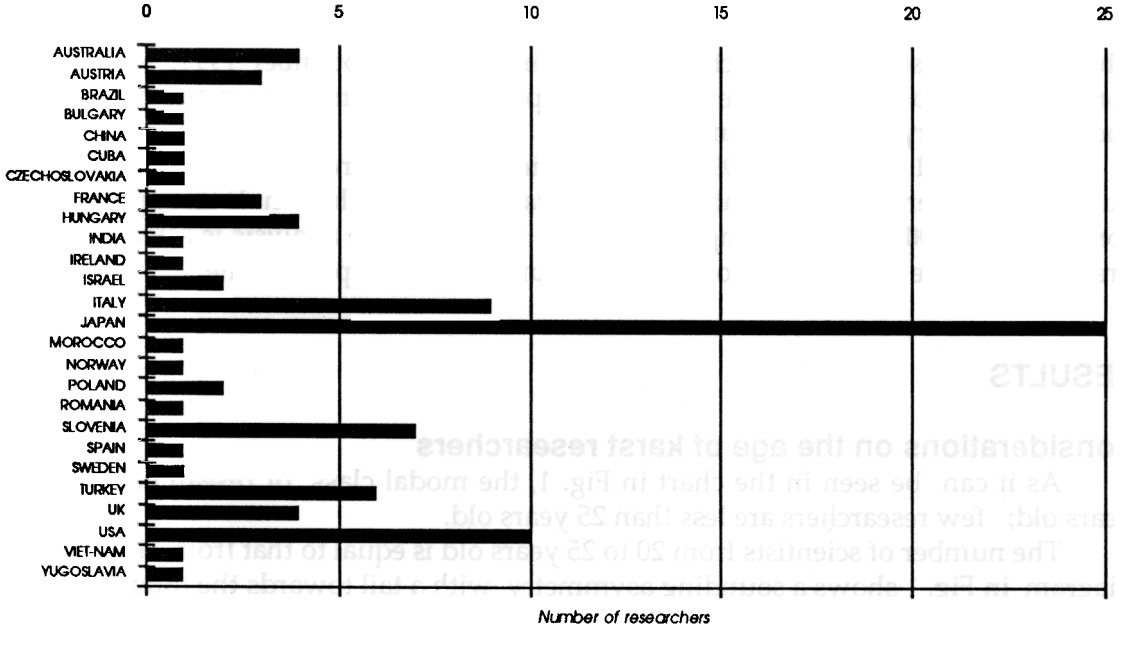


Table 1- Domestic or foreign areas of research.

Age	Working only in own country	Working only in foreign countries	Working in own and foreign countries
Percentage of < 35 years old	79%	8%	13%
Percentage of 35-50 years old	47%	0%	53%
Percentage of >50 years old	76%	6%	18%
Percentage of the whole group	**71%**	**4 %**	**25%**

We believe that this distribution is to be considered linked with the increase in the number of researchers noted in last decades, due to the growth of university population.

Nationality of karst researchers

In Fig. 2 and in the maps of Fig. 5 it is shown how some continents are not well represented. For instance, in Africa and in South America we have just one researcher (from Morocco and Brazil); in Asia a lot of Japanese researchers answered (27% of the total), but only three Countries are present (India, China, Japan).

The majority of scientist come from Europe, nevertheless some countries are missing here too.

Geographic areas of research

Most of researchers works in their own country, but we observed a large number (25 percent) studying also in foreign countries (See Table 1). Only a few use to work exclusively abroad.

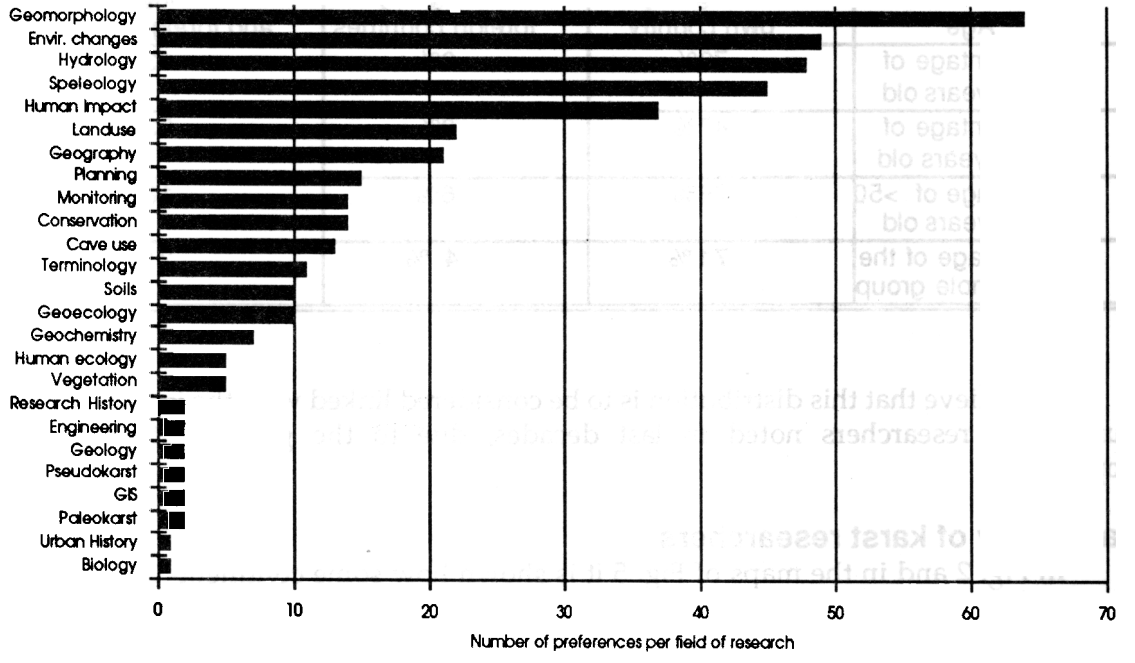
Researchers belonging to the 35-50 range use to work abroad more than the others; probably this is due to the availability of funds and the propensity to travel. On the other hand, younger and older people work more in their own country, the former ones because of lack of funds, the latter ones because they avoid tiring journeys.

Foreign countries chosen as area of study are spread all around the world, but

Table 2 - Number of researchers and mean number of preferences given to fields of study related to three ranges of age.

Age	N° of researchers	Percentage of researchers of the entire group	Mean number of preferences given to fields of study
< 35 years old	22	24 %	4,4
35-50 years old	36	40 %	3,8
>50 years old	32	36%	4,7

Fig. 3 Number of preferences per fields of research



China and secondarily Italy and Yugoslavia are preferred.

Studies are carried out in 41 countries. But we didn't receive the inventory form by domestic researcher from 15 (36%) of them; those countries are: Bahams, Belize, Greece, Guatemala, Iceland, India, Jamaica, Korea, Malaysia, Papua-New Guinea, Philippines, Somalia, Syria, Switzerland, Thailand.

Countries studied, not only by domestic researchers, but also by foreign scientists are 24. The 15 countries listed before represent the 62% of the foreign studied countries

Number of prefences per fields of research

In the first inventory form sent by the Japanese group there were 9 disciplines. Later, the Study Group modified the form and increased the subjects to 17 with the possibility to add some other items. From the forms we received, we got 8 subject more (25 in total). In Fig. 3, all the choices given by researchers to the 25 matters are represented. Researchers gave their options to more than one subject (see Table 2, fourth column).

In the chart of Fig. 3, three distinct groups are recognaisable.

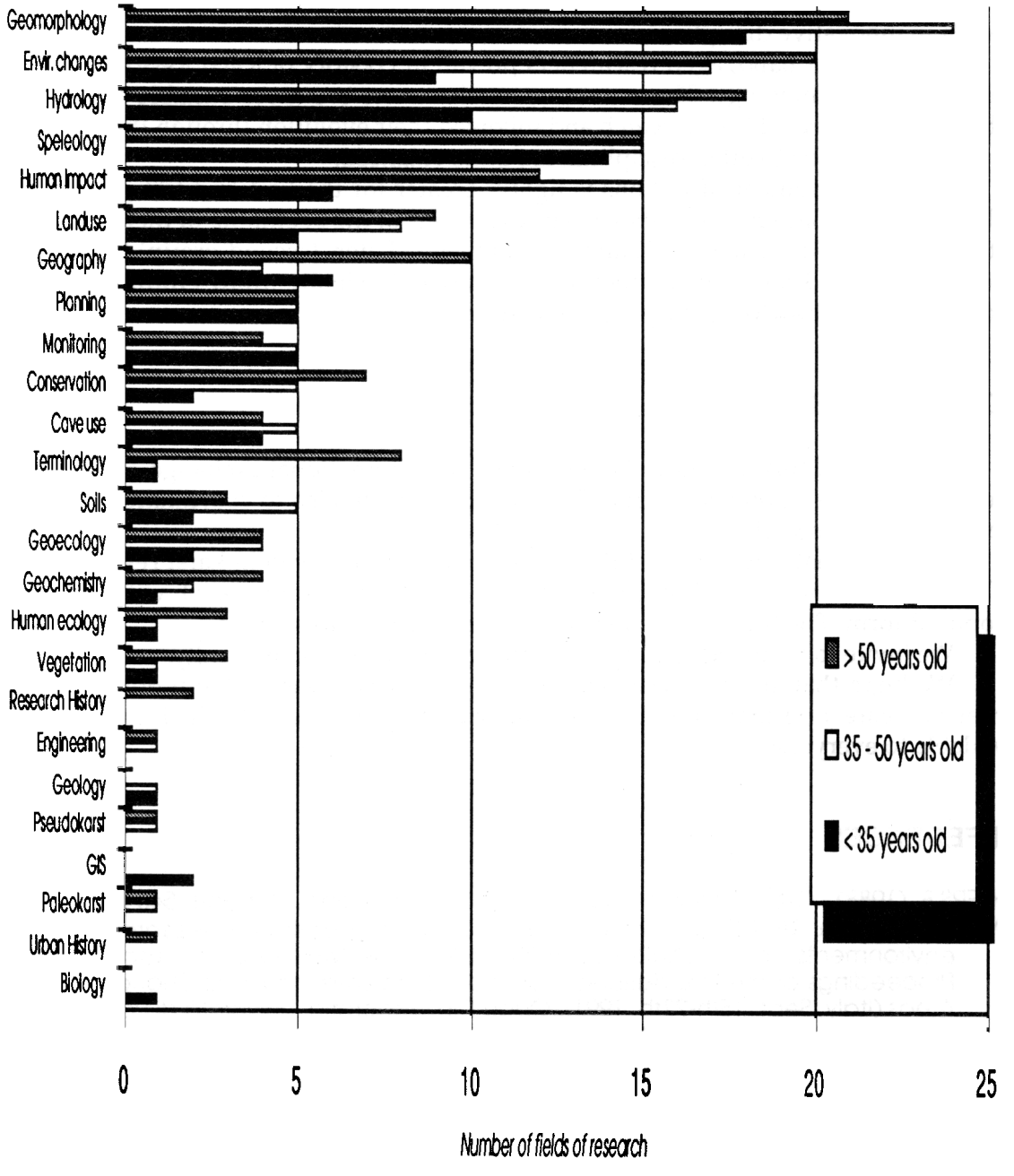
In the first group, composed by the most chosen subjects, the main discipline is Geomorphology with 64 options. Environmental Changes, Hydrology, Speleology and Human Impact got more than 36 preferences.

In the second group there are the disciplines between 22 and 5 options.

In the third group, Biology, Hurban History, Paleokarst, Geographical Information Systems (GIS), Pseudokarst, Geology, Engeneering and History of Karst Research obtained only one or two preferences. The reason is to be found in the

Fig. 4

Fields of research chosen by different age researchers



marginal interest of those subjects in respect of the main themes studied by the Study Group, or because they are specific or new.

Subjects in respect of the researchers' age.

In Fig.4 the diagram shows the options given to the subjects related to the ranges of age.

Only young people are involved in Biology and Geographical Information Systems. For the latter subjects this is perhaps due to the interest and skillness of young people in innovative disciplines.

On the other hand, aged researchers prevail in Hystory of Karst Research, Urban History and Terminology. Those more general matters are more suitable to scientist who faced various fields of research and followed their evolution through the time.

Choices given to other disciplines are quite balanced.

The mean number of options is lightly greater for the first and last group (see Table 2, fourth column). We believe that researchers at the beginning of their career are interested of various aspects of karst environments. Later (second group) they gain a specialization and they narrow their field of research. Finally (third group), with the growth of their knowledge, they widen their targets.

CONCLUSIONS

The aims of this inventory is to facilitate the international exchange of data and the acquaintance among scientists. This will be helpfull also to coordinate the future trends of karst research.

We think that it will be usefull if all the scientists involved in karst research (also belonging to other Scientific Organizations, Working Groups, etc.) will send the proposed form. The final form is reproduced at the end of this paper.

We invite to fill it and to diffuse it among the scientific community.

We hope that all the researchers involved in karst areas will join our project in order to create a permanent data base. The inventory will be published and always available to everyone.

REFERENCES

EHLERS E. (1988) - Orbis Geographicus 1988/92. Steiner Werlag, Stuttgart, 546 pp.

FINLAYSON B. & SAURO U. (1991) - International co-operation in research on karst environments. In : SAURO U., BONDESAN A. & MENEGHEL M. (eds) (1991) - Proceedings of the International Conference on Environmental Changes in Karst Areas (Italy, Sept. 15th-27th, 1991). Quad.Dip.Geografia, Università di Padova, 13.

XINHONG L. (ed) (1991) - IGCP 299 Newsletter. Institute of Karst Geology, Guilin, China, 139 pp.

INTERNATIONAL GEOGRAPHICAL UNION

Study Group: Environmental Changes

in Karst Areas (S. 88 6)

WORLD INVENTORY OF KARST RESEARCHERS

Family Name _____

First Name _____

Birth Date _____

Present Position _____

Title _____

Institution _____

_____

✉ Adress of Istitution _____

✉ Postal Code _____ City_____

Country _____

☎ Telephone number _____

✆ Fax number _____

Affiliations

- ❒ IGU - International Geographical Union
- ❒ UIS - Union International de Spéléologie
- ❒ IAH - International Association of Hydrogeologists
- ❒ IGCP - International Geological Correlation Program
- ❒ IAG - International Association of Geomorphologists
- ❒
- ❒

Studied Areas:

Region	*Country*
1_____	_____
2_____	_____
3_____	_____
4_____	_____

Fields of Study

- ❒ a) Geomorphology of karst regions
- ❒ b) Environmental changes in karst areas
- ❒ c) Hydrology in karst areas
- ❒ d) Speleology
- ❒ e) Human impact in karst areas
- ❒ f) Land use in karst areas
- ❒ g) Geography of karst regions
- ❒ h) Planning of karst regions
- ❒ i) Monitoring tecniques
- ❒ j) Conservation of landscapes, natural monuments and resources of karst areas
- ❒ k) Cave use and management
- ❒ l) Terminology of karst
- ❒ m) Soils in karst areas
- ❒ m) Soils in karst areas
- ❒ n) Geoecology in karst areas
- ❒ o) Geochemistry in karst areas
- ❒ p) Human ecology in karst areas
- ❒ q) Vegetation in karst areas
- ❒ r) History of research in karst
- ❒ s) Engineering in karst areas
- ❒ t) Geology in karst areas
- ❒ u) Pseudokarst and parakarst
- ❒ v) GIS applications in karst areas
- ❒ w) Paleokarst
- ❒ x) Hurban history in karst areas
- ❒ y) Biology in karst areas

Make a photocopy of this form for you and your colleagues, fill it and send to:

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THE SPRINGS OF MONTORIO AND THE KARST AQUIFER OF THE CENTRAL- WESTERN LESSINI MOUNTAINS (VERONA - VENETIAN PRE-ALPS)

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ABSTRACT

G.K.W.: karst hydrology, human impact, water quality

Geogr. K.W.: Italy, Venetian Prealps, Monti Lessini

The research carried out during the last three years on the Montorio springs and the karst aquifer of Monti Lessini has allowed to evidence that:

- the Montorio springs are fed by a karst type of aquifer from a large hydroigeological basin in the Monti Lessini;
- the average overall discharge of the springs is very high: 4.5 m^3/s;
- the hydrogeological basin is wider than the hydrographic basin of the valley of Squaranto;
- the quality of the bottom karst waters is on the whole good and seems to be only partly affected by impact forms in the mountain basin.

In the basin different forms of human impact are present and locally strong as it is evidenced in a detailed map.

INTRODUCTION

The Montorio springs, situated 2km to the NE of the town of Verona, have been famous since at least the time of the Romans for their remarkable average discharge of about 4.5 m^3/sec.

In actual fact knowledge of this important group of springs from the geological and hydrogeological point of view has been limited to a brief mention by NICOLIS (1898) and to some partial contributions (SORBINI,1987; MENEGHEL et al, 1986).

This research, which developed out of a proposal put forward to various Public

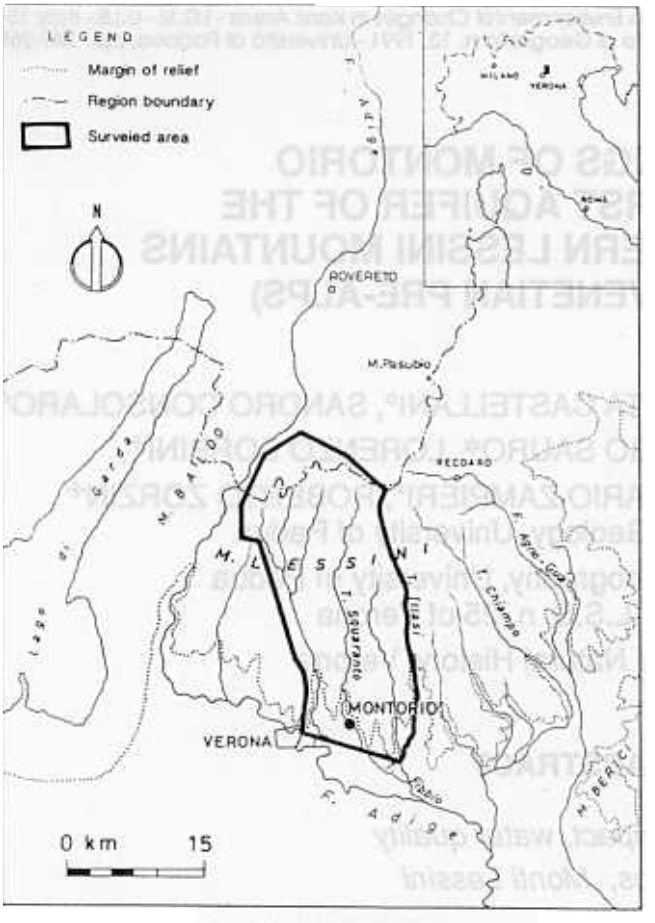


Fig. 1 - MAP OF STUDIED AREA

Fig 1

MAP OF
STUDIED AREA

Bodies, is aimed at deepening our knowledge of the feed basin of the springs. These in fact comprise one of the main features of karst hydrodynamics in the Lessini mountains, as well as in relation to phenomena of human impact (SORBINI, 1987).

Research has been co-ordinated by L. Sorbini.

GEOLOGICAL FRAMEWORK

The Lessini mountains, at the feet of which are to be found the Montorio springs, are situated at the southern edge of the Southern Alps and are bordered to the South by the flood plain of the Po (fig.1). They are formed by a succession of covering rocks the large majority of which are mesozoic and to a lesser extent tertiary. On a basement of Dolomia Principale (upper Triassic) which crops out on the steep slopes of the Valley of the Adige to the West, the Valley of the Ronchi to the North and the Valley of the Illasi to the East, the frame of this group of mountains is made up of shallow water carbonates named Calcari Grigi. During the Lias the area was a structural high(Trento Platform) on which a carbonate platform developed (CASTELLARIN, 1972).

The rapid drowning of the platform below the photic zone, set off by the extensional movement which lead to the development of the Jurassic Thetis (WINTERER & BOSELLINI, 1981), it subsequently produced the sedimentation of

pelagic deposits of an age between Middle Jurassic and Upper Cretaceous which go by the name of Rosso Ammonitico Veneto, Biancone, Scaglia Rossa.

In the Tertiary the closure of the Thetis ocean, as a result of compression, recreated conditions of sedimentation of shallow water on the Trento Plateau with the deposition of Eocene limestones and Priabonian Marls, on which Miocene sandstones and biocalcarenites lie disconformably; deposits of the Oligocene age are missing on almost all of the Veronese Lessini mountains, probably because of the emersion of the area caused by tectonic movement, along with a pronounced eustatic fall. In the Palaeogene the area was affected by basic volcanism above all in the eastern sector of the Lessini, in the Alpone-Agno semigraben (BARBIERI, DE ZANCHE and SEDEA, 1990).

In the Veronese Lessini basaltic types of volcanites are to be found, generally in places of discordant bodies, such as vents and dykes, as well as pyroclastites and epiclastites intercalated among sediments.

The main tectonic events which have determined the present structural framework of the Lessini mountains are palaeogenic extension, which fragmented the area in network of fractures in a submeridian trend, and neogenic compression, which produced the roughly E-W overthrust of the Corno d'Aquilio-Corno Mozzo- ridge of Mount Scriccio (ZAMPIERI, 1990). On the western edge of the mountains a compressional structure is to be found in a Giudicarie trend (Mt.Pastelletto Fault, NNE-SSW).

In the Neogene erosion processes predominated on the Lessini mountains, with the removal of a large part of the tertiary formations, progressive karstification (a process which had already begun in previous epochs) of the tertiary and mesozoic rocks and the deepening of valley troughs even when considerably below the actual sea level.

In the Quaternary the predominant activity in the southern parts of the main valleys has been the depositing of alluvial material resulting from erosion in the mountain area.

From a morphotectonic point of view the Lessini consist in a tableland which merges towards the plain formed of sedimentary rocks of brittle behaviour, displaced by faults mostly of a normal type in a series of tectonic blocks stretching out in a North-South direction and slighly tilted towards the West. The main valleys have formed in the depressions between the various blocks.

THE KARST SPRINGS OF MONTORIO

The Montorio springs are situated in the lower Squaranto Valley at heights between 62 and 56 metres, inside the built-up area of Montorio, part of the Commune of Verona.

They consist of four springs: Fiumicello (Squarà), Tondello, Madonnina, Fontanon situated at the foot of the left-hand side of the Squaranto Valley, not far from the passage between the local alluvium and those of the Veronese plain (Fig.2).

The river-bed of the Squaranto is generally dry and clearly suspended in relation to the flood plain. Further south the bottom of the Squaranto Valley is in the shape of a plain about 1km wide with the two slopes as its boundaries, the left slope less steep and extending to about 2km, the right sslope narrower and steeper.

The left slope is made up of Jurassic, Cretaceous and Eocenic rocks which are

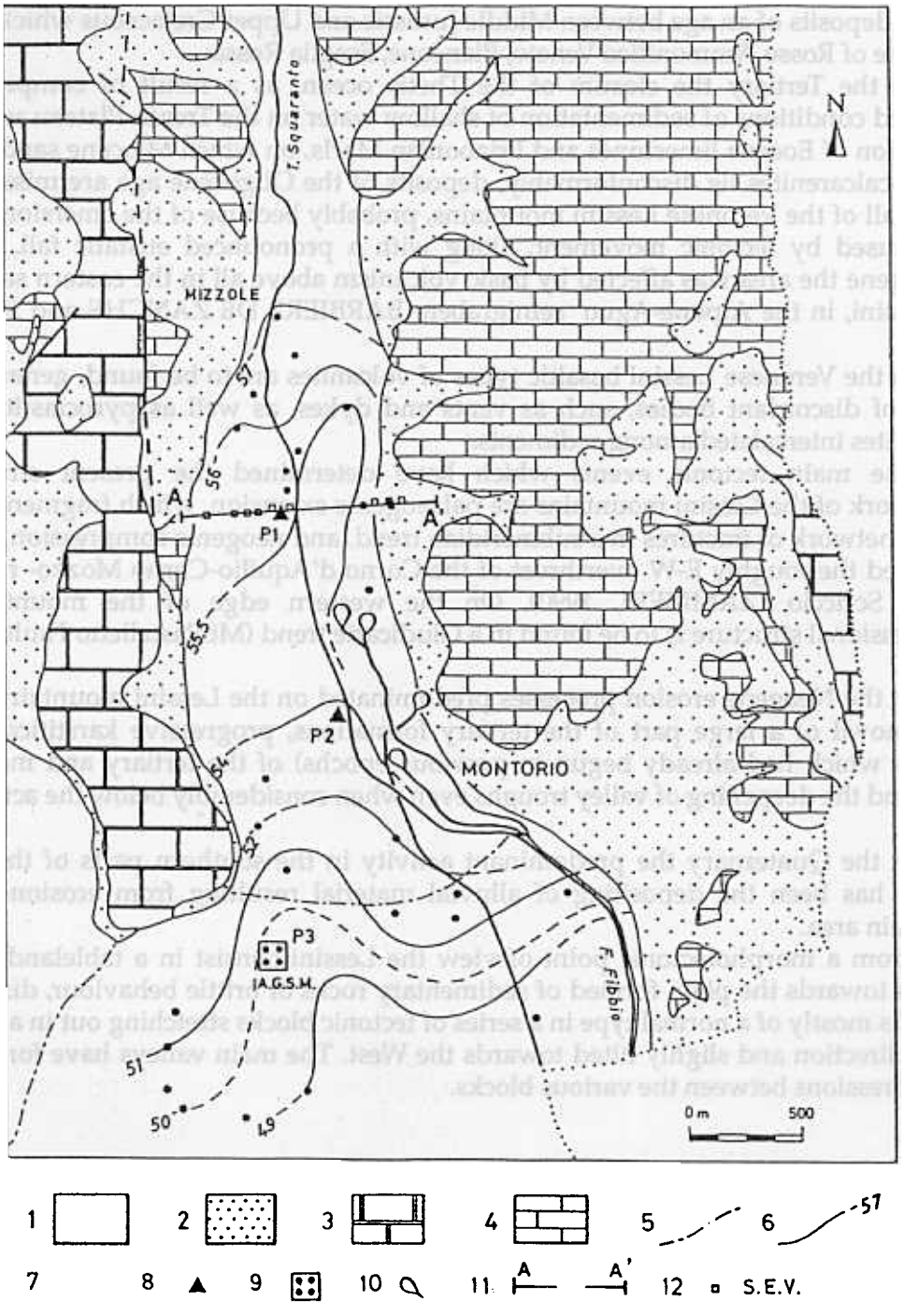


FIG.2: AREA OF HYDROGEOLOGICAL AND GEOPHYSICAL RESEARCHES OF MONTORIO NEIGHBOURINGS.

1) alluvial covers, 2) debris, 3) Eocene limestones, 4) Biancone fm., Scaglia Rossa fm., (Cretaceous), Rosso Ammonitico fm., Calcari Grigi fm. (Jurassic), 5) boundary between local alluvial deposits and those of Adige, 6) water-level contour, 7) well, 8) observation well, 9) aqueduct plant,10) spring, 11) electrical profile, 12) electrical sounding.

highly tectonized, locally affected by structures characterised by accumulations of "ancient massive landslides" (DE ZANCHE, SORBINI, SPAGNA, 1977); at its foot a broad colluvial covering stretches out which gradually links it to the alluvial plain of the river Adige.

The right side, however, is made up predominantly of Eocene rocks.

The springs studied appear as small lakes where the water gushes from the gravel and clay on the bottom.

Their geographical position, size and flow rate and the chemical characteristics of the water show them to be karst springs fed by a buried hydrogeological structure (NICOLIS, 1898, MENEGHEL et al., 1986; SORBINI, 1987).

The considerable overall discharge of the springs proves their value as a source of water. However, even if the springs were tapped to supply the Verona aqueduct in Roman times, no such provisions exist today to supply drinking water and only part of the water is used for irrigation.

The confluence of the hydrographic system which drains the area of the springs gives rise to the river Fibbio on the SSE side, and to the Fiumicello and the Fossa Cozza on the W side (Fig.2).

GEOPHYSICAL STUDIES

The lower Val Squaranto and the area of the Montorio springs have been thoroughly investigated with geophysical methods, with the aim of establishing the lithological-structural characteristics of the deposits on the valley bottom and to determine the depth and nature of the substratum on which they rest. For this purpose Schlumberger Electrical Resistivity Soundings, seismic refraction profiles and geognostic soundings were made, one of which was driven until it met bed rock (Fig.3).

The general geological and morphological features of the whole of the alluvium and of the substratum of the valley have been reconstructed on the basis of an interpretative Electrical Section positioned to the N of the built-up area of Montorio and calibrated by means of geognostic soundings, some of which were made specifically for this purpose (Fig.2 and Fig.4).

The alluvial cover consists of two main superimposed horizons. The upper one corresponds to recent and current alluvial gravel from the creek Squaranto, with a thickness of 50m in the central valley area; the lower one, 20-30 thick, can be attributed to silt-clay deposits.

The substratum, which is always more electrically resistive than the overlying silts, has been attributed to Calcari Grigi (lower Jurassic) on the left side of the valley, and to the marly limestone of the Biancone (lower Cretaceous) on the right side. As far as the middle part of the valley bottom is concerned its lithological attribution is less certain. Nevertheless it is highly probable that in the area between the P1 sounding and the Battistella well, where Calcari Grigi were found at a depth of 53 m, the rock in situ has been subject to marked lateral discontinuity, of tectonic origin, which has brought the cretaceous limestones into contact with the liassic ones .

In the more urban area, immediately around the Montorio springs, the geophysical data indicate, under the left side, the presence of a structure "in steps" buried under not very thick layers of alluvium, at a maximum width of 150-200 m. Towards mid-valley the "terrace" is delimited by a steep escarpment.

This result finds confirmation in the very considerable thicknesses of the

FIG.3:
MONTORIO MAP AND HYDROGRAPHIC FLOW NET.
legend:
1) gauging station with record,
2) gauging station,
3) canals;
4) S.E.V.,
5) seismic line,
6) observations and stratigraphic well.

alluvium (over 70 m) situated at a few dozen metres to the W of the area of the springs, and the P2 geognostic sounding where the bedrock (Calcari Grigi) was reached at a depth of almost 130 m from the ground level. As far as the depth of the hydrostructure which feed the Montorio springs is concerned, taking into account the variations in thickness of the covering layer both to the W and to the E of the inhabited area, it may be assumed to be in the order of about thirty metres.

THE HYDROGRAPHIC BASIN OF THE SQUARANTO AND THE HYDROGEOLOGICAL BASIN OF THE SPRINGS

Given the karst nature of the springs an analysis was made both of the surface hydrographic basin, situated upstream, and of a possible karst feed basin.

The hydrographic basin upstream is that of the Val Squaranto, a valley which ranges from a height of 1850 m to 50 m a.s.l. for a planimetric length of about 30 km, a width of about 3-4 km, and an area of about 100 km^2 . This basin consists of the valley in the strict sense of the word which is narrow and deep and in a system of lateral "plateaus" which are generally less sloping.

The possible karst basin may extend to other valleys of the Lessini, situated both to the West and to the East of the Val Squaranto, such as the Valpantena, the Valle di Mezzane and the Val d'Illasi. In this connection it should be remembered that the systematic use of tracers could make a valid contribution in solving this problem; however, for the time being this technique has been impracticable both because of the size and complexity of the mountain basin and because of current legislation.

The Lessini, where these valleys are to be found, although consisting to a great extent of limestone rocks, have a well developed hydrographic network, even though the various valley segments are in general without watercourses. Only in segments of a fifth hydrographic order or higher may ephemeral watercourses form, on the occasion of heavy rainfall. The pattern of the hydrographic network consists of principal axes, with a predominant N-S direction, at times converging at a low angle, in which well-hierarchized lateral systems are connected, roughly in an E-W direction. The main axes consist in canyon- type valleys, formed along morphotectonic structures of a "fault angle depression" and /or "tilted graben depression"sort (SAURO, 1978); the lateral branches, however, are systems of dry valleys in a setting of wide ridges of a plateau nature, and suspended on the slopes of the canyon-type valleys.

In areas of limited expanse fields of doline may also be found. The geomorphological style of this part of the Lessini may therefore be defined both as fluvialkarst, and tectokarst (SAURO, 1973).

The Montorio springs lie in a postion towards which several lines seem to converge determined by important morphostructures such as the upper Valpantena and its related tributary branches, the Val della Marciora, the Val dei Falconi and the Val di Squaranto. These morphostructures are controlled by fault systems predominantly in a NW-SE, NNE-SSW and N-S direction,which affect the whole Lessini plateau.

In an ideal outline representative of the large majority of the basin two principal morphological elements may be identified (Fig.5):

- plateau type ridges;
- steep valley sides as in canyons.

Amongst the plateau type ridges can be distinguished:

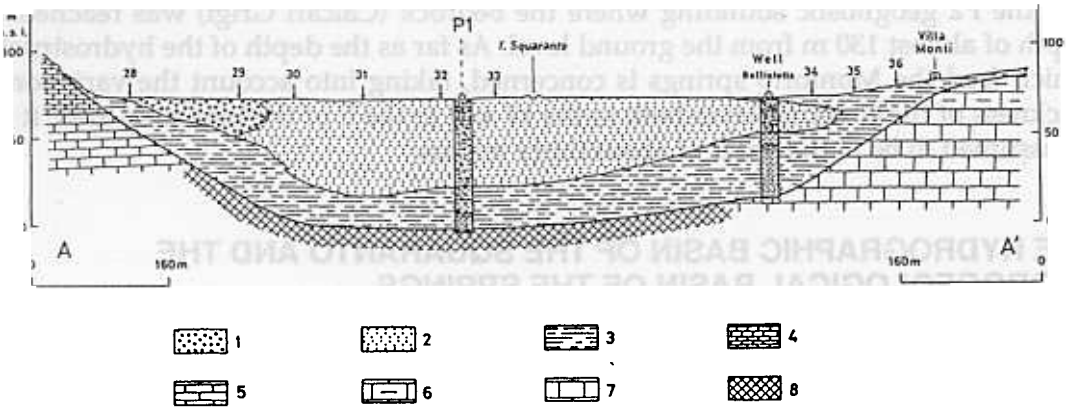


FIG.4: GEOELECTRICAL SECTION IN THE LOVER PART OF THE SQUARANTO VALLEY (north of Montorio)

- ridges with rounded summits in eocenic rocks (also to be found in the hilly region of Verona);
- structural benches or mesa-like surfaces in Scaglia Rossa;
- convex slopes with softened shapes or rounded ridges in Biancone, at times with dome-shaped summits;
- benches and structural surfaces (mesa-like summits at times) in Rosso Ammonitico;
- level slopes in Calcari Oolitici and in Calcari Grigi.

Amongst the steep slopes of the canyon-shaped valleys the following are recognisable:

- benches of Rosso Ammonitico;
- the walls underneath the benches in Oolitic limestone;
- escarpments and stepped slopes in Oolitic limestone and in Calcari Grigi.

In relation to these lithological and morphological types "suspended aquifers" are to be found at various levels where a flow of lateral percolation predominates (Eocene limestone and subordinately Scaglia Rossa), and real karst aquifers where a flow of vertical pecolation is predominant.

THE PRINCIPAL HYDREOGEOLOGICAL STRUCTURES AND THEIR RELATIONSHIPS

The alluvial and debris complex of the valley bottom.

The alluvial soils of the valley of the creek Squaranto which hide the productive hydrogeological structure, reach a considerable depth (100 m) immediately to the S of Montorio, where it interconnects with the alluvial fan of the river Adige.

The numerous electrical soundings and geognostic perforations carried out for this purpose, have confirmed not only the rapid thickening of the cover in the final stretch of the valley, but also that it is one of the sections with most gravel (Adige

floods), whereas further N there is a widespread abundance of muddy-clayey material (Lessini floods)(Fig.2).

A phreatic type of aquifer is present in all the alluvial subsoil where the depth of the watertable varies from 30 m in the northernmost area to 1 m in the southernmost area. Nevertheless a further deepening of the average water level up to 10-12 m is to be found corresponding to the passage to the Adige floods, the limit of which is shown by the dotted line in Fig.2; the originally Lessini aquifer joins up with the aquifer system of the upper Veronese plain.

On the basis of the data collected so far the aquifer of the mid-valley of the Squaranto can be divided into two sectors; the one to the N of Montorio seems to be closely conditioned by the overall dispersal of the modest flow of the creek Squaranto which occurs at the apex of the alluvial fan. For the time being it is considered that a significant contribution by the rock formations of the substratum may be excluded. Corresponding to the springs and immediately to their S a perceptible evolution in the hydro- geological nature of the alluvial complex is to be seen:

- the dimensions of the aquifer structure increase, both in lateral extension and in depth;
- the wells are more numerous and are distributed more uniformly; - the hydraulic characteristics of the aquifer improve decisively from N to S;
- the pattern of the equipotential lines stratum mark very clearly the variation in the hydrodynamic structure in the porous medium corresponding to the built-up area of Montorio, where the flow lines diverge from a pole in alimentation (Fig.2).

That being said and if a hydrogeological model such as one of "buried karst resurgence" is accepted, it would seem plausible to consider that such a system is partly a tributary of the alluvial aquifer system.

The carbonatic systems of the mountain basin.

The upper carbonatic system (Eocene) plays an entirely secondary rôle in the process of water capture and transmission to the more continuous and deeper fracture system. The reasons are connected to the very reduced extension of the outcrops (4% of the whole surface of outcropping lithotypes in a basin considered to be about 220 km^2) and to their módest thickness (Fig.5).

The lower carbonatic system has been divided into two sub- systems: moreorless marly limestones of the Cretaceous (Biancone and Scaglia Rossa) and pure limestones of the Jurassic (Calcari Grigi and Gruppo di S.Vigilio); the latter play a determining and distinct hydrogeological rôle.

The marly limestones, which account for 51% of the outcropping rocks, are characterised by an elevated capture capacity of meteoric and stream waters. This system, therefore, has basically the function of storing a large quantity of water and conveying it deep down through the filtration movement of a diffuse nature with a prevalent vertical movement.

The jurassic limestones represent about 45% of the outcropping rocks. Such a group has a considerable thickness 400-500 m and is subject to recharge with rain and snowfall of an indirect type as well, thanks to the active drainage of the cretaceous formations above. In the partly dolimitised jurassic limestones a fairly evolved Karst is particularly developed with few or no springs.

A result of a predominantly vertical karst drainage in the central and western Lessini mountains is both the scarcity of springs, more marked in the high and medium Lessini where the average outflow of the springs at altitude is probably less

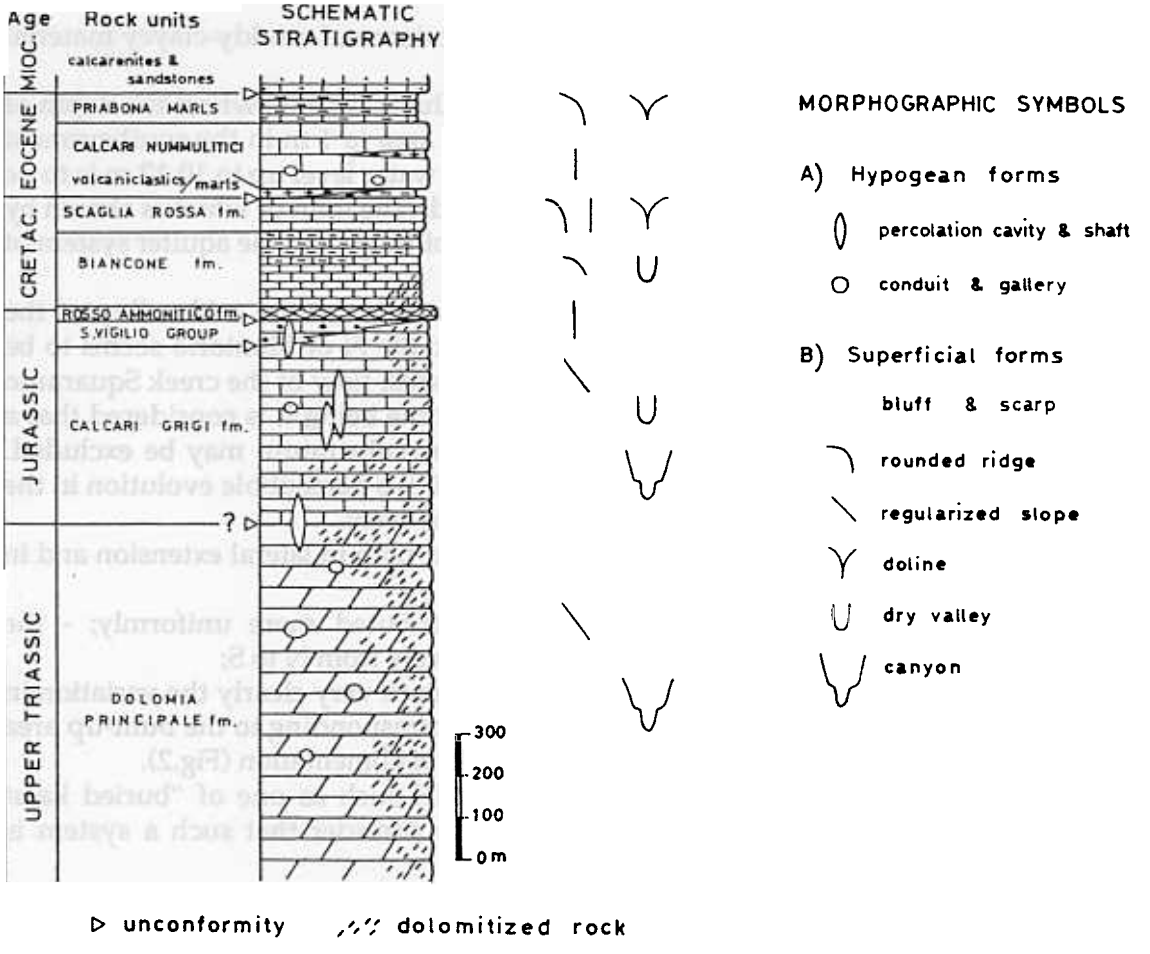


FIG.5: SCHEMATIC STRATIGRAPHY OF THE STUDIED AREA

than 1 litre per km^2 (SORBINI, 1980), and the great frequency of vertical cavities explored.

From this brief general background, if it would seem clear that it is permissible to talk about a deep karst aquifer, though at the moment there are no unambiguous elements to definitely confirm this though it must be situated in the Dolomitic limestone base system.

THE HYDROGRAPHIC SYSTEM OF THE MONTORIO SPRINGS AND THE CONTROL NETWORK

In the hydrographic system of Montorio two principal areas of emergence are distinguishable (Fig.3).

The first includes the Fiumicello (Squarà) and Tondello springs (62 and 61 m altitude), the second includes the Fontanon spring and the Madonnina spring (57 and 58 m altitude).

In order to obtain a continuous and differentiated check on the flow of the two

spring areas, 4 gauge-stations were set up on the Fiumicello-Tondello system (A;B;C;D) and 5 on the Fontanon-Madonnina (E;F;G;H;I). Almost all of the stations were regularised with articles manufactured out of sheet metal and platforms for measurements using a calibrated flow-meter (Tab. 1).

In addition level detectors by immersion were installed with transmitters for automatic recordings. The same type of equipment was installed in the two piezometers on the valley bottom, P1 and P2.

Because of the considerable difficulties encountered in setting up the complex system of data collection, the time series at present available cover a maximum time span of 20-22 months.

On the hydrographic basin of the Squaranto valley (100 km^2), 4 pluviometric stations were installed whose utilizable data, which in this case cover a period of not more than 12 months, were integrated with those of several long term observation stations (Tab.2-3).

With reference to the historic series 1921-1950, precipitations within the basin are between 800 and 2000 mm/year, show spring and autumn maxima and are strongly affected by altitude. In the Roveré station the annual average of 1087 mm for the thirty-year period can be considered the pluviometric average for the basin. It should however be emphasised that the climate of the Lessini is extremely variable in nature so that it is difficult to establish a "regime" on the basis of a series of a few years (FLIRI, 1975).

SOME CONSIDERATIONS ON THE HYDROMETRIC, PIEZOMETRIC AND PLUVIOMETRIC DATA

In Fig.6 some hydrograms are set out of the karst aquifer unit (a), of the alluvial aquifer unit of the valley bottom (b), and the pluviometric data of the Roveré station (c). Even though the observations cover as yet a modest time span, some considerations are possible.

To begin with the karst nature of the springs has been confirmed. In fact, hydrometric variations close to a metre were measured in a space of a few hours, with maximum variations in global discharge of 10 m^3/s. Again on the basis of the data available at present it would seem to be completely justified to consider the Montorio springs as belonging to the same hydrostructure. The minimum discharge, equal to 1.4 m^3/s, measured at the Fontanon system in relation to a period of pluviometric deficit of an exceptional nature, can be attributed to "base flow" of the "reservoir". The volume of this reservoir, definitely of remarkable proportions, can be estimated using the method of an "Emptying Curve" when a reliable"flow scale"is available for all the measurement sections.

The springs regime is closely conditioned by the precipitation on the mountain basin. It seems possible to distinguish the contribution of the mantle of snow by comparison of the hydrometric state in 1989 to that of 1990, again at the Fiumicello spring. From March to the first ten days of Septèmber 1989 a relatively persistent flood phase was recorded; this was followed by a prolonged phase of emptying of the "reservoir" related to the dry period already referred to.

The hydrometric behaviour of the spring in 1990 was completely different. The flood phases were briefer and less long-lasting, the average "base flow" of the spring drastically reduced. Therefore since no substantial difference in contribution emerges

Tab. 1

FLOW RATES AT THE VARIOUS GAUGING STATIONS IN MONTORIO

	Squarà system									Fontanon system											
	A		B		C		D		Partial Total	E		F		G		H		I		Partial Total	TOTAL
Date	Q	h	Q	h	Q	h	Q	h	Q	Q	h	Q	h	Q	h	Q	h	Q	h	Q	Q
30.06.88	2,08	*	0,4	*	1,14	60,54	0,61	60,54	*4,23*	*	*	0,3	54,22	0,12	*	1,49	54,98	1,9	52,15	*3,81*	**8,04**
12.11.88	0	60,67	0,07	*	0,18	60,11	0,1	60,07	*0,35*	0,04	*	0,19	54,16	0,16	*	0,64	55	1,24	52,12	*2,27*	**2,62**
12.01.89	0	60,32	0,07	59,27	0	59,98	0	60,02	*0,07*	0	*	0,18	53,98	0,15	*	0,74	54,96	1,18	52,07	*2,25*	**2,32**
22.02.89	0	60,23	0	59,18	0	59,98	0	59,98	*0*	0	*	0,18	54	0,14	*	0,85	54,98	0,62	52,03	*1,79*	**1,79**
28.04.89	3,56	62,1	0,52	59,47	1,24	60,45	0,84	60,27	*6,16*	0,08	*	0,33	54,36	0,1	*	2,46	54,97	2,36	52,25	*5,33*	**11,49**
22.06.89	0,9	61,49	*	*	0,79	60,33	0,38	60,29	*2,07*	0,02	*	0,32	54,06	*	*	*	*	*	*	*0,34*	**2,41**
04.08.89	1,56	61,92	0,47	59,46	1,28	60,4	0,61	60,3	*3,92*	0,03	*	0,38	54,13	0,08	*	1,2	55,19	2,19	52,18	*3,88*	**7,8**
15.09.89	1,88	61,95	0,41	59,47	1,17	60,4	0,66	60,24	*4,12*	0,03	*	0,29	54,33	0,07	*	0,64	55,01	2,88	52,31	*3,91*	**8,03**
15.12.89	0	60,23	0,02	59,34	0,16	60,11	0,1	60,06	*0,28*	0,01	*	0,17	54,11	0,11	*	0,65	55,01	0,99	52,12	*1,93*	**2,21**
06.02.90	0,63	61,37	0,14	59,36	0,62	60,27	0,32	60,15	*1,71*	0,01	*	0,27	53,98	0,12	*	1,19	55,04	1,1	52,12	*2,69*	**4,4**
02.10.90	0	60,23	0	59,18	0	59,98	0	59,98	*0*	0,03	*	0,16	53,95	0,05	*	0,22	55,22	0,97	52,18	*1,43*	**1,43**
29.11.90	2,55	62,09	0,26	59,38	1,19	60,47	0,82	60,46	*4,82*	*	*	0,36	54,07	0,17	*	2,14	54,94	1,59	52,17	*4,21*	**9,03**
15.03.91	1,79	62	0,29	59,39	0,99	60,38	0,66	60,35	*3,73*	*	*	0,3	54,34	0,18	*	1,81	54,79	1,43	52,16	*3,72*	**7,45**

Q = rate in mc/s

h = hydrometric altitude in m

* = not surveied value

from the balance of annual rainfall (1989 - 1990) on the basin, it must be assumed that substantial contributions are made to the Montorio springs by snowfalls, perhaps even from mountain areas which have not yet been taken into consideration. Such falls were fairly abundant in the 1988 - 1989 season and almost totally absent in the 1989 - 1990 season.

One final interesting observation emerges from the analysis of the piezometers taken in the two wells P1 and P2; not only can the perfect correspondence with the phases of the spring water system be seen, but also the surprising contemporaneity between the beginning of piezometric peaks in the porous medium and hydrometric ones at the spring.

HYDROGEOCHEMICAL ASPECTS OF THE KARST WATERS

A comparative study of the hydrochemical data of the Montorio springs and of some of the springs in the Lessini mountains has made the evaluation of some of the environmental parameters possible. Among these, altitude is of particular importance in comparing the solute content of the waters. In fact it can be seen how the Montorio springs move away from the average line of regression in so far as the feed basin is very extensive and the average relative altitude lies in a range between 550 and 700 m a.s.l.(Fig.7).

The "annual hydrochemical regime" of the solute content, detectable both from

Tab. 2

Stations	Altitude(m)	Heigth of rain h_{pi} (mm) 1990	Area of polygons a_i (km^2)	$h_{pi} \times a_i$
Ca' Pigno	475	636	59	37.524
Roverè	847	1065	75	79.875
Zambelli	824	928	123	114.144
Revolto	1336	1390	---	---
S.Giorgio	1500	1039	126	165.564
Totals			383	397.107

Mean precipitation over the considered basin : $h_{pm} = \frac{397.107}{383} = 1037$ mm

the residue at 180 °C and from the total hardness and conductivity seem to show the opposite tendency to that of the discharge, even in connection with the melting of snow in spring.

Finally, the close analogy between the karst waters of the mountain springs and those of Montorio should be pointed out, (Tab.4) whilst the phreatic waters in the alluvium of the valley bottom show a consistently higher solute content.

Chemical erosion in the area of the karst basin of the Montorio springs has been estimated to be in the order of 35 - 40 $m^3/km^2/year$, equivalent to an average thickness of rock of 3.5 - 4 cm per 1000 years (MENEGHEL et al, 1986).

ASPECTS OF HUMAN IMPACT IN LESSINIA

In the course of research some of the most significant aspects have been surveyed and mapped of the natural landscape modified by man, of the elements of karst hydrology and of the degree of anthropization of the central-western Lessini (on the scale of 1:20,000: "Human impact in the karst environment of Lessinia"; not included in this volume)(AA.VV., 1991-92).

In the map key a distinction has been made between five different categories relating to : 1) land use, 2) karst forms, 3) hydrology, 4) productive settlements, 5) quarries.

The category "land use " provides indications not only as to land use, but on the actual landscapes of the Lessini mountains. A distinction has been made between five situations, three of which relate to natural or semi-natural aspects (thick and sparse wood; pasture land, orchards and cultivated land; areas with predominantly rocky outcrops, mostly Rosso Ammonitico) and two relating to artificial aspects.

The karst form category includes dolines and both horizontally and vertically distinct caves.

In the "hydrology" category only springs and temporary swallow holes have been shown.

In the "productive settlements" category a distinction has been made between chicken farms, pig farms, food factories and factories of other types. Cattle farms have not been indicated as they are distributed in a relatively homogeneous way in the altitude range 600 - 1200 m and situated, in general, in relation to the approximately 400 populated centres known as "contrade" clearly shown on the map. Part of the cattle

Tab. 3

Stations	Altitude (m)	Mean heigth of rain 1921-1950 (mm)	Area of polygons a_i (km^2)	$h_{pi} \times a_i$
Grezzana	166	964	41	39.524
Fosse	954	1.232	49	60.368
Cerro	729	986	50	49.300
Roverè	847	1.087	52	56.524
Giazza	758	1.485	53	78.705
Erbezzo	1.118	1.197	95	113.715
Tregnago	371	1.083	57	61.731
Totals			397	459.867

Mean precipitation over the considered basin $hpm = \frac{457.867}{397} = 1158$ mm

herds of the Lessini mountains are taken to alpine pasture in the more than 100 "malghe" of the high Lessinis during the summer season.

The "quarry" category differentiates between two main types of quarry: open or in tunnel distinguished in active and inactive. The hundreds of small quarries dispersed over the territory have not, however, been indicated, opened in the past by the inhabitants of the small settlements for local needs.

The quarrying industry, which is still important in Lessinia, consititutes on the one hand an important economic resource, on the other an easily perceptiblee form of land occupation and impact.

From an overall reading it can be seen that the most important aspects of human impact on the territory can be distinguished in five groups:

- intense urbanization with a high concentration of artisan and factory building on the plains of the valley bottom and in particular in Valpantena;
- intense urbanization, predominantly related to the phenomenen of second houses, on some mountain ridges and in particular on the Cerro-Corbiolo-Bosco Chiesanuova ridge;
- elevated concentration of chicken farms in the hills up to about 600 m a.s.l.;
- presence of large concentrations of pig farms near the valley slopes;
- presence of numerous active and inactive quarries both open and tunnelled, situated predominantly in the Valpantena and on the ridge of Sant'Anna di Alfaedo.

THE QUALITY OF THE WATERS

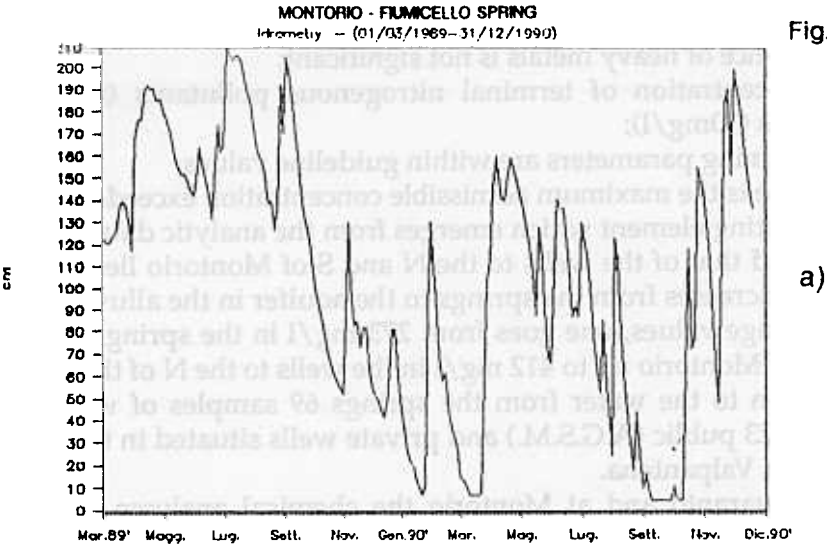
In the Environmental Chemical Section of the P.M.P. of the U.L.S.S. 25 (Verona) a total of 223 water samples were analysed from the Fiumicello (Squarà), Tondello, Fontanon and Madonnina springs over a time span running from the month of February 1988 to the month of October 1990.

From this analysis it emerges that the water can be classified as slightly mineral water (Dir.CEE 80/777). In the saline group calcium bicarbonate predominates.

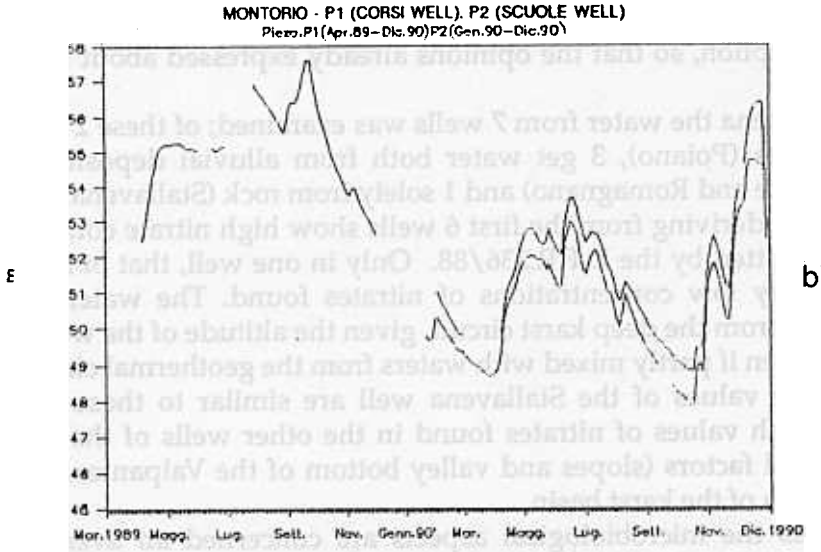
The water of the four Montorio springs have shown good chemical qualities in as much as:

- they are almost free of organic microcontaminants and from primary

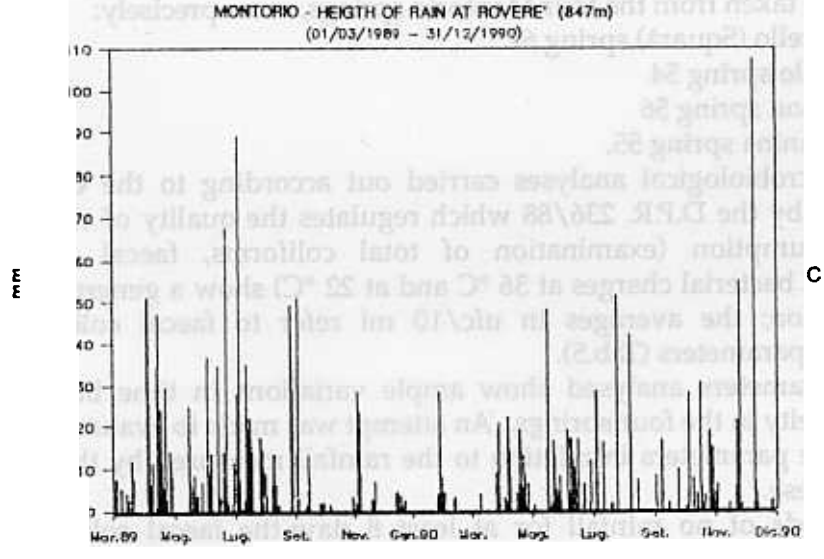
Fig. 6


MONTORIO - FIUMICELLO SPRING
Idrometry – (01/03/1989–31/12/1990)
cm
Mar.89' Magg. Lug. Sett. Nov. Gen.90' Mar. Mag. Lug. Sett. Nov. Dic.90'

a)


MONTORIO - P1 (CORSI WELL). P2 (SCUOLE WELL)
Piezo.P1(Apr.89–Dic.90)P2(Gen.90–Dic.90)
m
Mar.1989 Magg. Lug. Sett. Nov. Genn.90' Mar. Magg. Lug. Sett. Nov. Dic.1990

b)


MONTORIO - HEIGTH OF RAIN AT ROVERE' (847m)
(01/03/1989 – 31/12/1990)
mm
Mar.89 Mag. Lug. Set. Nov. Gen.90 Mar. Mag. Lug. Set. Nov. Dic.90

c)

nitrogenous pollutants;

- the presence of heavy metals is not significant;
- the concentration of terminal nitrogenous pollutants (nitrates) is close to guideline values (10mg/l);
- the remaining parameters are within guideline values;
- in no case is the maximum admissible concentration exceeded.

An interesting element which emerges from the analytic data of the waters of the four springs and that of the wells to the N and S of Montorio lies in the fact that the saline residue increases from the springs to the aquifer in the alluvial deposits. In fact, taking the average values, one goes from 273 mg/l in the springs to 359 mg/l in the wells to the S of Montorio up to 412 mg/l in the wells to the N of the built-up area.

In addition to the water from the springs 69 samples of water were analysed taken from the 23 public (A.G.S.M.) and private wells situated in the Val Squaranto, at Montorio and in Valpantena.

In Val Squaranto and at Montorio the chemical analyses, although revealing different situations, within chosen pararmeters the resulting values did not exceed the maximum concentrations permitted by current legislation for water intended for human consumption, so that the opinions already expressed about the spring waters are validated.

In Valpantena the water from 7 wells was examined; of these 2 come solely from alluvial deposits (Poiano), 3 get water both from alluvial deposits and solid rock (Quinto, Nesente and Romagnano) and 1 solely from rock (Stallavena).

The water deriving from the first 6 wells show high nitrate contents, above even the limits permitted by the D.P.R.236/88. Only in one well, that of Stallavena, 292 m deep, were very low concentrations of nitrates found. The waters from this well probably come from the deep karst circuit, given the altitude of the well-bottom and its stratigraphy, even if partly mixed with waters from the geothermal circuit. Considering that the nitrate values of the Stallavena well are similar to those of the Montorio springs, the high values of nitrates found in the other wells of the Valpantena may depend on local factors (slopes and valley bottom of the Valpantena) rather than on overall pollution of the karst basin.

As far as the microbiological aspects are concerned an average of about 56 samples were taken from the four Montorio springs, more precisely:

- Fiumicello (Squarà) spring 61
- Tondello spring 54
- Fontanon spring 56
- Madonnina spring 55.

The microbiological analyses carried out according to the C3 control model provided for by the D.P.R. 236/88 which regulates the quality of water destined for human consumption (examination of total coliforms, faecal coliforms, faecal streptococchi, bacterial charges at 36 °C and at 22 °C) show a generalized situation of faecal pollution; the averages in ufc/10 ml refer to faecal coliform and faecal streptococchi parameters (Tab.5).

The parameters analysed show ample variations in time but with a certain contemporaneity in the four springs. An attempt was made to evaluate the tendency of some of these parameters in relation to the rainfall measured by the pluviometer of Roveré Veronese.

In periods of no rainfall for at least 8 days,the faecal coliforms and faecal streptococchi were equal at 6.4 ufc/100 ml and 2.3 ufc/100 ml respectively (number of

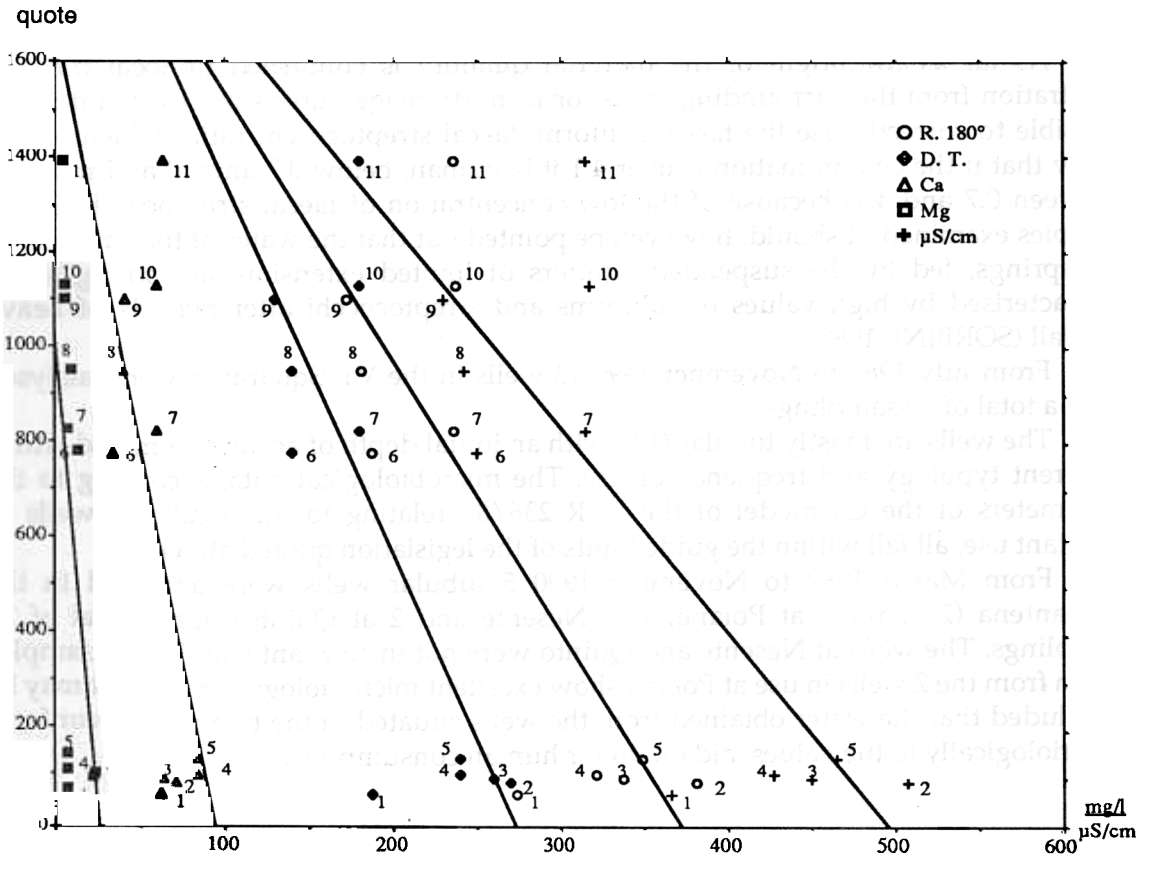


FIG. 7 - Linear regression altitude versus salinity and conductivity of some springs and karst waters of Lessini Mountains

N°	Springs	Elevat. (m)	pH	R.180°	NO_3 mg/l	Cl mg/l	Alc. mg/l	T.H. mg/l	Ca mg/l	Mg mg/l	Cond µS/cm	SO_4 mg/l	P_2O_5 mg/l	Na mg/l	K mg/l
1	Fiumicello (Squarò)	65	7,6	274	10	6	168	187	62	7,8	366	12	,24	2,4	1,6
2	Montecchia di Crosara	90	7,5	381	15	11	240	270	71,6	22,1	508	33	,26	13,8	1,4
3	Cazzano di Tramigna	100	7,4	337	14	3	241	260	64	24,3	450	16	,06	2	1,3
4	Avesa	110	7,4	321	10	3	229	240	84	7,3	428	17		2,7	,5
5	Mezzane di sotto	140	7,3	349	12	4	240	240	84	7,3	465	•	•	2,3	1,6
6	Giazza	780	8	187	4	•	120	140	33,6	13,6	250	10	•	,4	,3
7	Cantero	825	7,6	236	5	1	180	180	60,4	7	315	12	,1	2,5	,9
8	Fontani	950	7,8	181	3	•	120	140	40	9,7	242	8	•	,9	,2
9	Scandole	1100	8,1	172	6	•	107	130	40,8	6,8	230	12	•	,5	,2
10	Spluga della Preta	1130	7,5	238	13	5	166	180	60	6,3	318	11	1,06	1	1,2
11	Fittanze	1390	7,9	236	4	•	171	180	64	4,9	315	12	•	,4	,4

samples = 13). Vice versa analyses repeated at a brief interval of time and carried out immediately after rain and a rise in the hydrometric level gave the results in Table 6.

From the table increases of a certain magnitude can be seen in the parameters analysed in the periods a),b),c) to which overall height of rain values are greater than 80 mm. In the periods d),e),f),h), with total rainfall below 80 mm, modest or no increases at all were recorded in relation to the basic situation.

The g) period in which considerable height of rain does not correspond to an average increase in the faecal coliform quantity, is difficult to interpret.

As far as the origin of the bacterial quantity is concerned (if local through infiltration from the surrounding areas) or from drainage liquids in Lessinia it is not possible to correctly use the faecal coliform/faecal streptococchi ratio (which would show that if the contamination is over 4.1 it is human, below 0.7 animal and mixed if between 0.7 and 4.1) because of the low concentration of faecal streptococchi in the samples examined. It should, however, be pointed out that the water of the small high-up springs, fed by the suspended aquifers of limited extension and strength, are characterised by high values of coliforms and streptococchi after periods of heavy rainfall (SORBINI, 1980).

From July 1988 to November 1990 13 wells in the Val Squaranto were analysed with a total of 19 samplings.

The wells are mostly tubular (12), with an initial depth of around 15 m and with a different typology and frequency of use. The microbiological data, according to the parameters of the C3 model of the DPR 236/88 relating to the 9 tubular wells in constant use, all fall within the guide limits of the legislation quoted above.

From March 1989 to November 1990 5 tubular wells were analysed in the Valpantena (2 of them at Poiano, 1 at Nesente and 2 at Quinto), for a total of 20 samplings. The wells at Nesente and Quinto were not in constant use. The 11 samples taken from the 2 wells in use at Poiano show excellent microbiological results. It may be concluded that the water obtained from the wells situated in the two valleys conform bateriologically to the values laid down for human consumption.

CONCLUSIONS

From what has been shown above it may be deduced that:

- the Montorio springs are fed by a karst type of aquifer;
- they represent only part of the overall outflow which also occurs within the alluvium of the valley bottom;
- the average overall discharge of the springs is very high: 4.5 m^3/s, at least on the basis of the measurements carried out so far with an absolute minimum of 1.4 m^3/s and a maximum of almost 12 m^3/s; as a result it must be presumed to have a wider feed basin than the hydrographic basin of the creek Squaranto;
- organic-type pollution seems to be accentuated in periods of particularly high rainfall;
- the quality of the bottom karst waters is on the whole good and seems to be only partly affected by impact forms in the mountain basin.

However it must be pointed out that the water in high altitude springs fed by small aquifers of limited size and thickness, have a high streptococcus and coli content, especially after periods of rainfall (SORBINI, 1980-87). Consequently, even though the mountain basin as a whole does not seem to present a high vulnerability level, particularly localized impact phenomena are quite evident.

ACKNOWLEDGEMENTS AND REMARKS

This research has been backed from 1988 onwards by the Municipal Administration of Verona, in particular by the Office for Ecology through the Museum

Tab. 5.

Spring	Faec. colif.	Faec. strepto.
Fiumicello	30,4	24,7
Tondello	66,8	16,7
Fontanon	41,6	25,6
Madonnina	83,8	45,0.

Tab. 6.

Period	N° of samples	Height of rain	Faec. Col.	Faec. Str.
a) 20-21/5/88	2	104,6	67	34,0
b) 7-8/06/88	2	89,1	93,5	35,5
c) 24/02-1/03/89	4	82,0	56,3	2,8
d) 30/01-1/02/90	2	47,2	14	0,5
e) 29-30/03/90	2	58,4	1	0,0
f) 9-11/04/90	3	63,4	10,3	5,3
g) 26-27/11/90	2	93,2	25,0	29,0
h) 11-15/03/91	3	49,4	26,3	17,0
dry periods	13	0,0	6,4	2,3

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BIBLIOGRAFIA

AA. VV. (1989) - Il Fiume Adige: stato delle conoscenze e problematiche gestionali. Comune di Verona. Arsenale Editrice; 341pp.

AA. VV. (1991-92) - Studio delle principali strutture acquifere carsiche ed alluvionali del territorio veronese. (con due carte alla scala 1:35.000: a) Carta Geologica dei Lessini tra la Valpantena e la Val d'Illasi; b) Carta dell'impatto umano nell'ambiente carsico dei Monti Lessini tra la Valpantena e la Val d'Illasi). Mem. Museo Civ. St. Nat. Verona, II serie , sezione Scienze della Terra, n. 4 (in print).

CAPELLO C.F., NANGERONI G., PASA A., LIPPI BONCAMPI C., ANTONELLI C. & MALESANI E. (1954) - Les phénomènes karstiques et l'hydrologie souterraine dans certaines régions de l'Italie. Ass. Intern. Hydrol., 37/2, 408-437.

CASTELLARIN A. (1972) - Evoluzione paleotettonica sinsedimentaria del limite tra "Piattaforma veneta" e "Bacino lombardo" a nord di Riva del Garda. Giorn.Geol., 38, 11-212.

DONA' F. (1955) - Elementi per una climatologia di alcune zone pascolive del Trentino. Ist. Geod. Geofisica Università Padova, 21, 109-148.

FLIRI F. (1975) - Das Klima der Alpen im Raume von Tirol. Innsbruck-München-Wagner; Monographien zur Landeskunde Tirols, Folge 1, 454 pp (vedi anche le carte climatiche dello stesso Autore in "Tirol Atlas", sezione D).

MEGNIEN C. (1964) - Observations hydrogéologiques dans le Sud-Est du Bassin de Paris. Mém. B.R.G.M., 25, 288pp.

MENEGHEL M., SAURO U., BACIGA M.L., FILECCIA A., FRIGO G., TONIELLO V. e ZAMPIERI D. (1986) - Sorgenti carsiche ed erosione chimica nelle Prealpi Venete . Studi Trentini di Scienze Nat., 62, A.G., 145-172.

MIETTO P. & SAURO U. (1989) - Grotte del Veneto: paesaggi carsici e grotte del Veneto. Regione del Veneto e La Grafica Editrice (Vago di Lavagno-VR), 415 pp.

NICOLIS E. (1898) - Circolazione interna e scaturigini delle acque nel rilievo sedimentario-vulcanico della regione veronese e della finitima. Accademia di Verona, v. 54, s. 3, f. 1, 209 pp.

NICOLIS E. (1901) - Geologia ed idrologia della regione veronese. In "La Provincia di Verona" a cura di Sormani-Moretti, vol. 1°, 60pp.

PASA A. (1954) - Carsismo ed idrografia carsica del Gruppo del Monte Baldo e dei Lessini Veronesi. C.N.R., Centro Studi Geogr. Fis. , Ricerche sulla morf. idrogr. cars., 5: 150 pp

PASA A., DURANTE PASA M. V. & RUFFO S. (1960) - L'ambiente fisico e biologico Veronese. In "Verona ed il suo territorio" I°, Istituto Studi Storici Veronesi, 5-36 Verona.

SAURO U. (1973) - Il Paesaggio degli Alti Lessini. Studio geomorfologico. Museo Civ. di St. Nat. di Verona, Mem. f.s., 6, 161 pp.

SAURO U. (1974) - Aspetti dell'evoluzione carsica legata a particolari condizioni litologiche e tettoniche negli Alti Lessini. Boll. Soc. Geol. It. , 93, 945-969.

SAURO U. (1977a) - Aspects de la morphogenèse anthropique dans le milieu karstique Alti Lessini. Norois 95 (bis), 149-163.

SAURO U. (1978) - Forme strutturali e neotettoniche nei Monti Lessini. Gruppo Studio Quatern. Padano, 4, 31-60.

SAURO U. (1987) - The impact of man in the karstic environments of the Venetian Prealps. Karst and Man, University of Ljubljana. Study Group on Man's impact in Karst. Proc. Int. Symposium on human influence on Karst, Postojna , Yugoslavia , 1987, 241-254.

SORBINI L. (1980) - Primi risultati di una ricerca d'acqua in Lessinia. La Lessinia- ieri oggi domani 1980, 127-136.

SORBINI L. (1987) - Le «risorgive» di Montorio fonti di informazioni sullo stato di salute delle acque sotterranee di una parte della Lessinia. La Lessinia- ieri oggi domani 1987, 7-12.

SORBINI L. (1989) - Paleoidrografia della pianura circostante il Fiume Adige. in AA. VV. (1989) - Il Fiume Adige. Comune di Verona. Arsenale Editrice; 105-122.

SORBINI L., ACCORSI C.A., BANDINI MAZZANTI M., FORLANI L., GANDINI F., MENEGHEL M., RIGONI A., SOMMARUGA M. (1984) - Geologia e geomorfologia di una porzione della pianura a sud-est di Verona. Mem. Museo Civ. St. Nat. Verona, II serie , sezione Scienze della Terra, n. 2.

WINTERER L. & BOSELLINI A. (1981) - Subsidence and sedimentation on Jurassic passive continental margin, Southern Alps, Italy. A.A.P.G. Bull., 65, 394-421.

Proceedings of the International Conference on Environmental Changes in Karst Areas - I.G.U.- U.I.S.- Italy 15-27 Sept. 1991 ; Quaderni del Dipartimento di Geografia n. 13, 1991 - Università di Padova, pp. 269-277

KARST ENVIRONNMENT AND HUMAN IMPACT ON THE SETTE COMUNI PLATEAU (PREALPI VENETE)

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ABSTRACT

G.K.W.: human impact, geography of karst regions, impact of war
Geogr. K.W.: Sette Comuni Plateau, Venetian Prealps, Italy

The Sette Comuni prealpine group is a large plateau extending on an area of about 600 km^2, and with a range of elevations between 600 and 2300 m. It consists mainly of carbonate rocks of mesozoic age and is characterized by a relief strongly controlled by tectonic structure and with fluviokarstic landforms in its southern and central part, with glaciokarstic landforms in its northern part.

The karstic aquifer inside the massif feeds 3 large karst springs on the east side, in the Brenta Valley, which have an average discharge of about 15 m^3/sec.

This prealpine group is the more antropized plateau in the belt of Venetian Prealps. The main villages are inside the central basin, called "conca di Asiago" from the name of the small town of Asiago.

The first human impact took place during medieval age when deforestation of large areas occurred both to produce charcoal and to enlarge grazing areas.

The impact of I World War was impressive in the plateau when for about 3 years strong battles took place. The numbers of soldiers oscillated between 200.000 and 400.000, hundreds of kilometres of roads, trenches and tunnels were built and millions of projectiles were exploded. Most of the villages were totally destroyed. At the end of the war the plateau was a stony desert.

After the World War II a development of mass tourism took place, with the building of holiday-home areas, hotels, ski facilities, etc., and thus the urbanization of the mountain areas began.

Today nearly 15-20% of the surface of the central basin is covered by villages and tourist settlements. In total there are nearly 13,500 holiday homes.

In the Asiago Plateau about 1/3 of the water supplies is pumped from a large spring in the Brenta Valley (Cogol dei Siori Spring).. This water is partly contaminated because the urban sewage systems of Asiago and Gallio flow directly in the Gelpach creek which loses most of its water in the karst system .

A map about karst environment and human impact in the Asiago Basin gives an overview of some of the main problems of impact in the more urbanized area.

INTRODUCTION

The Sette Comuni Plateau is the more central mountainous group in the belt of the Venetian Prealps and represents a transition between the Veneto Plain and the Dolomitic Alps.

With a roughly quadrangular shape and an area of about 600 km^2, it rises at an elevation ranging between 600 m and 2300 m.

The mountainous group, delimited on the west side by the deep valley of the Astico river, on the north and east sides by the Brenta river Valley and on the south side by a belt of hills, may be subdivided in the following sub-units:

1) a southern tectonic scarp extending E-W for more than 15 km, with a surface made uneven by a succession of depressions and ridges;

2) two large erosional scarps on the eastern and western sides;

3) a northern tectonic scarp towards the Valsugana (Brenta upper Valley);

4) a southern plateau, between 1100 and 1500 m a.s.l., characterized by a network of segments of relicts karstified valleys;

5) an intermediate plateau-basin approximately 1000 m a.s.l., with a low local relief consisting of rounded ridges and small valleys;

6) a northern plateau with elevations between 1500 and 2300 m, which represent the higher area, is linked with the basin by a tectonic flexure scarp, and ends on the northern edge with a system of rocky summits.

Precipitation on the plateau is quite abundant (about 1600 mm per year on average).

GEOLOGICAL ASPECTS

The plateau mainly consists of carbonatic rocks of Mesozoic age. The main rock units are:

- Dolomia principale of Upper Triassic ;
- Limestone units of Jurassic (Calcari grigi, Rosso Ammonitico);
- marly limestone units of Cretaceous (Biancone and Scaglia).

In the plateau covers of till and fluvioglacial deposits are common.

From the structural point of view the mountainous group represents the higher part of a tectonic block overthrusted to the south, with a flexure on the southern side and a graben on the northern side.

This tectonic unit behaves rigidly splitting into faults even if it is locally bent by tectonic compression.

GEOMORPHOLOGICAL STYLES AND EVOLUTION

In these large morphotectonic units a nearly perfect congruence between the geological structure and large scale surface features is recognizable.

Since the main erosional process is the karstic one it is correct to define the relief style as "tectokarstic"; but considering also the network of inactive and partially active valleys dissecting the plateau it is correct to speak also of a "fluviokarst".

In particular, the southern plateau is characterized by a system of dry valleys with

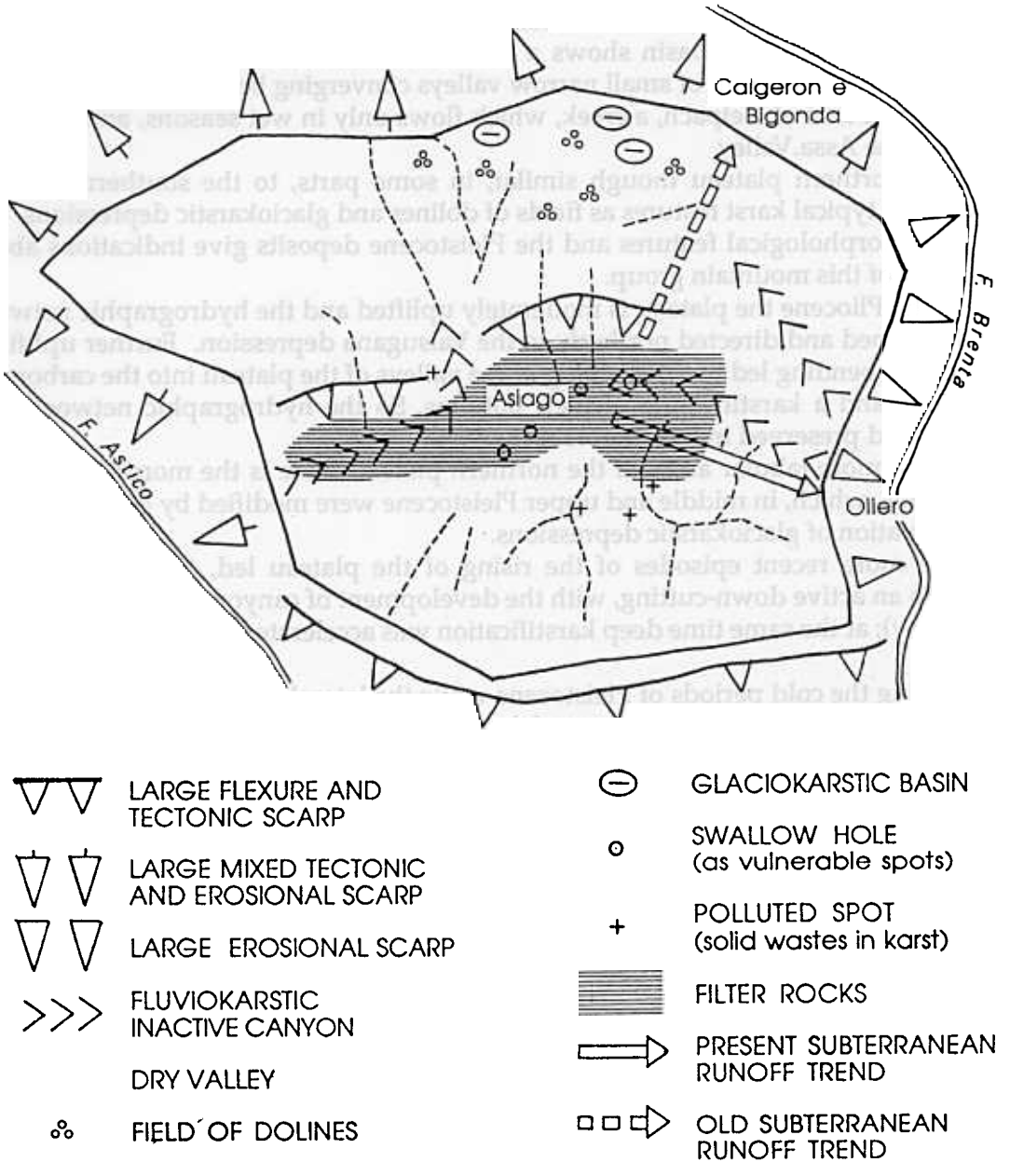

Fig. 1 - Sketch of the main geomorphological and hydrological features in the Sette Comuni Plateau

wide bottoms and depths between 50 and 300 m with regards to the interposed ridges. These ridges are rounded and with hillocky summits.

The central plateau-basin shows a low relief characterized by rounded ridges resulting by the dissection of small narrow valleys converging both towards the central hydrographic axis of Gelpach, a creek, which flows only in wet seasons, and the deep canyon of the Assa.Valley.

The northern plateau though similar, in some parts, to the southern plateau, shows more typical karst features as fields of dolines and glaciokarstic depressions.

The morphological features and the Pleistocene deposits give indications about the history of this mountain group.

In the Pliocene the plateau is moderately uplifted and the hydrographic network well developed and directed northerly to the Valsugana depression. Further uplifting and tectonic bending led to a deepening of the valleys of the plateau into the carbonatic formations and a karstification of their bottoms. So the hydrographic network was inherited and preserved in karstifiable rocks.

In the more tabular areas of the northern plateau there is the morphogenesis of doline fields, which, in middle and upper Pleistocene were modified by glacial erosion, with excavation of glaciokarstic depressions.

The more recent episodes of the rising of the plateau led, in some marginal valleys, to an active down-cutting, with the development of canyon like valleys (i.e. the Assa Valley); at the same time deep karstification was accelerated.

During the cold periods of Pleistocene while the lateral valleys were occupied by alpines glacial tongues, the upper part of the plateau was covered by a local icecap was covered with a surface area of about 220 km^2 . Glacial tongues from this icecap reached the central basin and deposited large morainic ridges. Tills and fluvioglacial deposits obstructed most of the karst shallow holes, thus favouring the surface run-off. This explains the existence of a small creek as the Gelpach. During a pre-wurmian glaciation the glacial tongues of the Assa Valley expanded laterally, occupayng also a large part of the Asiago basin.

Karstic processes led to the development of a karst underground drainage system with cavities mostly vertical in its upper part. In the plateau area more than 1300 karst cavities, one of which is about 1000 m deep, have been explored up to now.

In the lower Pleistocene the bottom aquifer, which is dammed by the tectonic flexure on the south side, flowed northerly towards the Valsugana and fed the two large spring systems of Calgeron and Bigonda caves, which have been explored for about 30 km; then the lower Brenta valley was not yet open and the river ran eastwards toward the Feltre basin. The dead valleys of Fastro and Arsié are relicts of that old course.

In the lower-middle Pleistocene, due to the opening of the lower Brenta Valley, a new karstic base level was established, and the underground waters were drained to the east. So in the Valstagna area the new karstic spring systems (Cogol dei Veci, Cogol dei Siori, Grotta di Ponte Subiolo), of valclusian type, were developed (fig. 1). These springs have a total average discharge of about 15.0 m^3/second. All the springs have been explored by speleo-divers and Cogol dei Veci spring is known for more than 2300 m.

The lithology and structure of the geological formations control the characters of karstic circulation.

In particular the marly limestones of Scaglia Rossa and of Biancone, which are closely stratified, densely fractured and contain embedded clay layers, are interested by

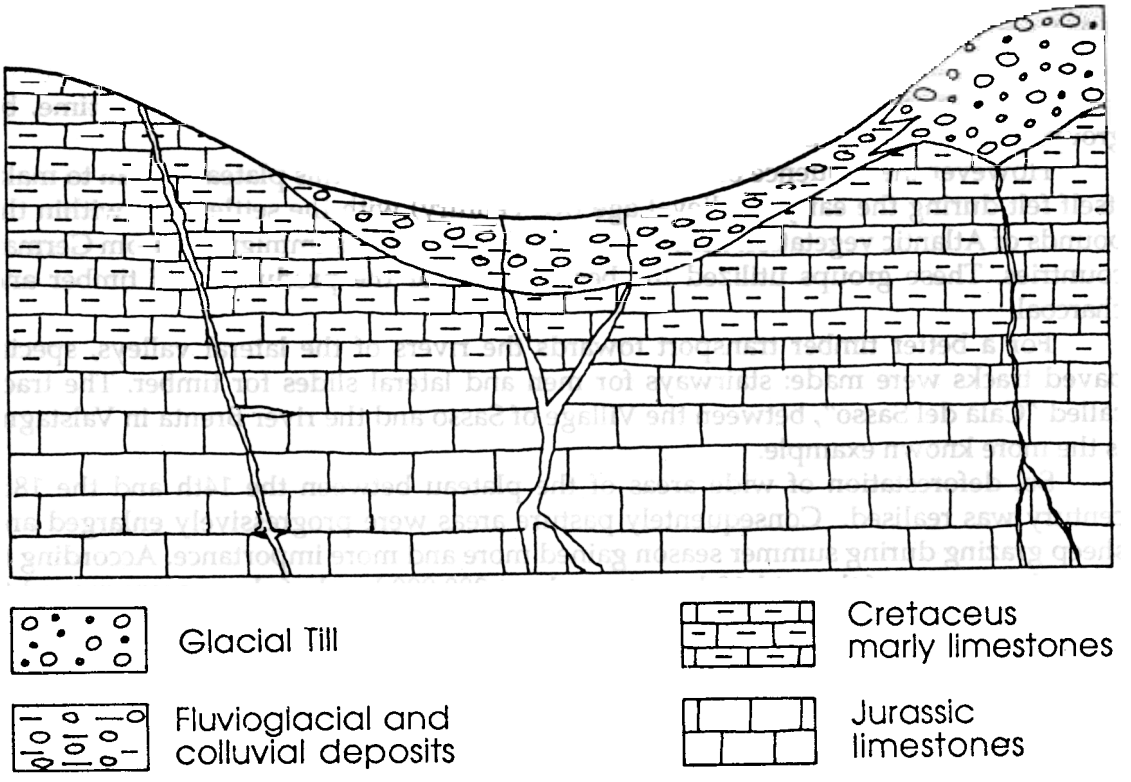

Fig. 2 - Sketch of a typical morpho-lithological section in the Asiago basin

a diffuse and slow circulation in a small lithoclastic network.

The formations of Jurassic and Upper Triassic are interested by a more rapid circulation, mostly vertical, inside the net of large fractures

As a consequence the Cretaceous formations behave both as "reservoir rocks", which lose waters slowly towards the underlying rocks, and as filter rocks.

The pleistocenic deposits show a reduced permeability and constitute also filters rocks and epikarstic reservoirs (as shown in figure 2).

An experiment with tracers outlined that the water circulation from an active sinkhole to the main springs is very fast (more than 10 planimetric km in 24 hours; GENNARI et Alii, 1989).

The comparison between the geological and geomorphological characters of the three main plateau areas outlines the reduced vulnerability of the central plateau-basin, due to the extension of Biancone and Pleistocene covers. Here, part of the surface water give origin to the slow circulation inside the more superficial rocks. On the other side, there is a concentrated circulation of water which feeds directly the deep karst reservoirs.

MAN AND THE KARST ENVIRONMENT

For its peculiar position the plateau was inhabited, since prehistoric time, by groups of paleolithic hunters.

However the influence of man on the environment of this plateau began to make itself felt during the early Medieval age (XI° century) with the settlement, within the bounds of Atlantic vegetation belt, of groups of woodlanders immigrated from German countries. These groups utilized the beech-wood for the production of timber and charcoal.

For a better timber transport towards the rivers of the lateral valleys, special paved tracks were made: stairways for men and lateral slides for timber. The track called "Calà del Sasso", between the Village of Sasso and the river Brenta in Valstagna is the more known example.

So, deforestation of wide areas of the plateau between the 14th and the 18th century was realised. Consequentely pasture areas were progressively enlarged and sheep grazing during summer season gained more and more importance. According to some documents of the mid-18th century about 200.000 head of sheep were moved to the alpine meadows of the plateau during the summer (density of more than 500 head/km^2).

Because of this over-use of the pasture, the soil was easily eroded, especially in the more fragile environment of high mountains, where rocky deserts appeared.

Cattle farming prevailed during the XIXth century. Today the number of cattle in the plateau reaches the 8600 head. During the summer a further 4700 head are transferred from the plain to these mountains.

THE VIOLENT IMPACT OF WORLD WAR

In the plateau area the impact of World War I was very violent.

During the years 1916 to 1918 between 200,000 and 400,000 soldiers have settled here; about 1,5 million crossed this area.

In the "Conca di Marcesina" about 5000 mules were counted.

Hundreds of kilometres of roads (nearly 400 km), trenches (about 200 km) and tunnels were built; large areas were under constant attack by shells and mortars: about 1500 cannons fired more than 200 tons of projectiles a day and many millions of them exploded. Most of the villages were totally destroyed.

At the end of the war the plateau was a stony desert.

After this war many of the inhabitants returned to their native lands, and after reconstructing the villages they removed and got rid of the traces of the war in the landscape. So, extensive fir forests were planted, many of the trenches and bomb craters were filled, the soil surface was cleared of many unexploded bombs and scrap metal.

From 1930 to 1960 a common occupation was to search and collect scrap metal of bombs. During World Ward II about 1500 people, called "recuperanti", have chose this work.

THE RECENT URBANISATION OF THE CENTRAL PLATEAU-BASIN AREA

After the World War II the evolution of a more integrated economic system in the urban area of the Veneto Plain was followed by the development of mass tourism, with the building of holiday-home areas, hotels, ski facilities, etc., and thus the urbanization of the mountain areas began.

The peak of the explosion of the mass tourism in the plateau occurred between the Sixties and the beginning of the Eighties. A new increase in the urbanization has taken place in the last years.

Today about 4% (20 km^2) of the total plateau surface is urbanized; in the plateau-basin nearly 15-20% of the surface is covered by villages and tourist settlements. In total there are nearly 13,500 holiday homes.

In the vacation periods beside the 21,500 inhabitants, between 40,000 and 60,000 tourists live in this prealpine area.

As a consequence of this increase in the population there are problems of water supply, liquid and solid waste production and in flow traffic.

In the Asiago Plateau most of the water supplies (about 70%) come from mountain springs fed by aquifers inside morenic and fluvioglacial deposits and about 30% is pumped from a large spring in the Brenta Valley (Cogol dei Siori Spring).

Even if there is a partial recycling of deep karstic water, this water, after its use, is allowed to flow as wastewater polluted with organic substances, chemical compounds, etc. This recycling accounts for 5-15%° of total precipitation (SAURO, 1987).

The urban sewage systems of Asiago and Gallio flow directly in the Gelpach creek which loses most of its water in the karst system feeding directly the main karst aquifer.

Till recently, solid wastes were collected and put directly in karst caves and dolines. Now the total production, about 100 tons/day in the holiday periods, is stored in the quarry situated in the till deposits of "Val di Nos".

Some chemical variations of the water of the springs in relation to different types of pollution are reported. A relatively high concentration of some metallic ions (Cu, Zn) was detected in the spring water, probably due to the many million of bomb splinters and cartridges scattered all over the ground (CELI M., PAOLETTI. ...). Organic pollution in pumped water is creating problems for water supply.

The karst water of the large springs of the plateau is utilized only for a small percentage. From the qualitative point of view, it is much better than most of the water in the conduits of the towns of the Veneto Plain which are polluted by pesticides. So it may represent a very important resource for the future development of this large urbanized region.

THE MAP "KARST ENVIRONMENT AND HUMAN IMPACT IN THE PLATEAU-BASIN OF THE ASIAGO"

During the research a thematic large scale map was prepared about "Karst environment and human impact in the plateau-basin of the Asiago" (not included in this volume. In this map some of the more significant aspects of the natural and modified landscape, of the lithological constitution, of the karst hydrology and of the degree of urbanization are outlined.

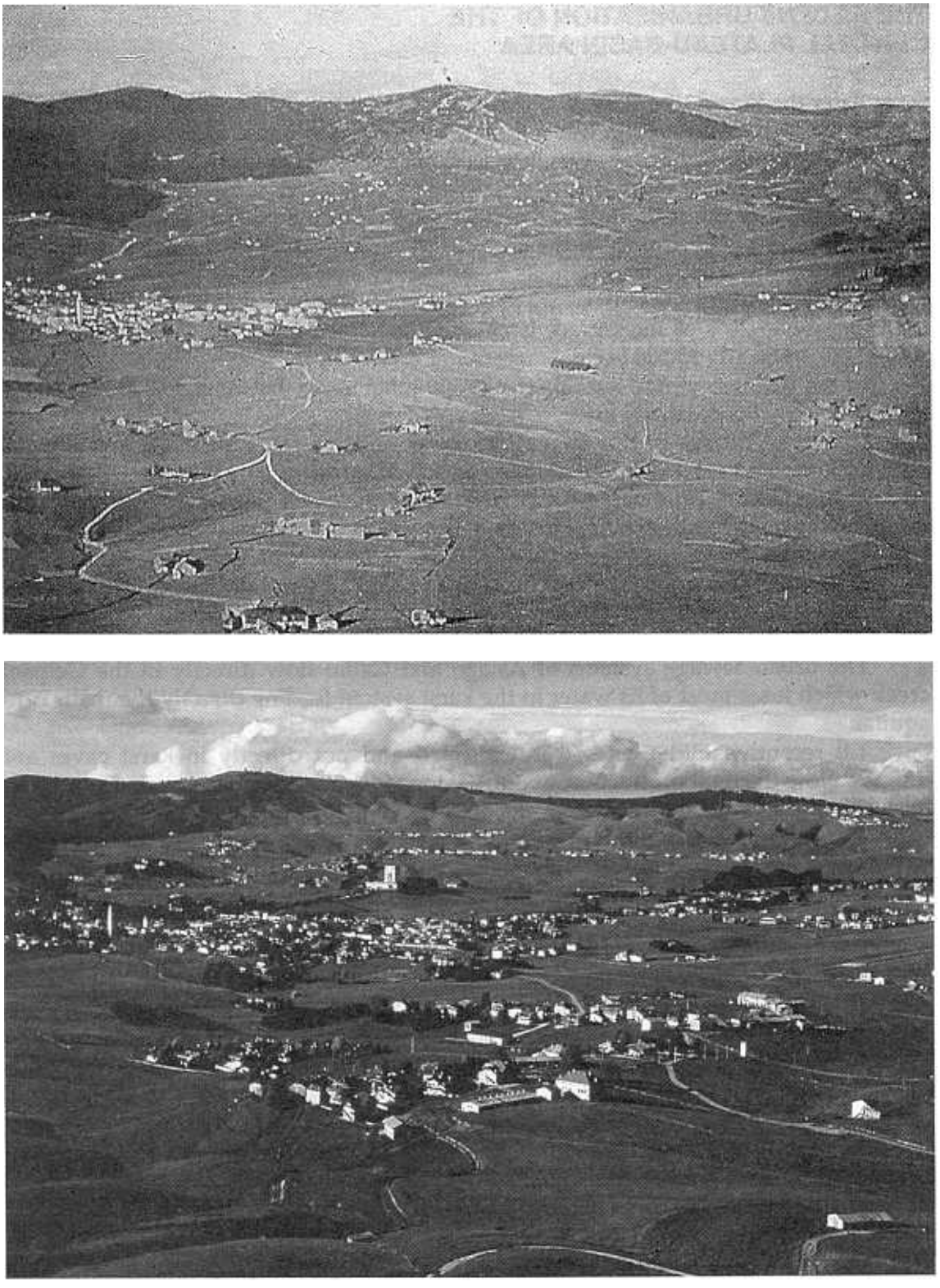

Fig. 3, 4 - Two photographs of the Asiago basin: the upper one shows the village of Asiago before of the World War I,; the lower one shows the recent urbanization of the basin

The map is meant to be an easy reading-key of the physic-geographical status of the most urbanised area of the Sette Comuni Plateau.

In the legend six different categories have been distinguished: 1) lithology, 2) soil use, 3) Karst landforms, 4) hydrology, 5) human impact, 6) World War I impact.

In the lithology category the main carbonatic formation of Mesozoic age, (after the official geological map of Italy), and the continental clastic Pleistocene deposits (on the base of a survey on the field) are mapped. In particular the main carbonatic formations are well distinguishable from the lithological and structural characters (with the exception of Calcari oolitici and Calcari grigi), and each influences the development of a peculiar morphology and surface and underground circulation network; So from the point of view of karst circulation there is a correspondence between hydrological and lithological types. The Pleistocene clastic formations and the marly limestone formation of Cretaceous behave as filter-rocks, as reservoir-rocks and locally as impermeable covers. On the contrary, the carbonatic formations of Jurassic age are deeply karstified and represent a place of rapid vertical drainage of karst waters.

As far as the "soil use" is concerned, the more common situations are the semi-natural environments of forest and spaced woodland and the grassland; a further situation is that of the urbanised areas, which represent the more impressive impact on the landscape of the basin and are clearly recognizable on the topographical base. For this reason it has not been outlined with special symbols.

In the "karst landforms" category, only a few dolines and and vertical caves, including also the karstic forms artificially obliterated by filling deposits, are mapped. In this area accessible karst cavities are totally lacking .

In the "hydrology" category, the springs, the temporary sinkholes, the artificial pounds for cattle, the temporary stream fed also by liquid wastes, and the underground main flow direction are examined.

The last categories to be considered are both aspects of the recent and actual human impact and of the World War I impact.

The most remarkable aspects of the more recent human impact is the progressive expansion of urbanised areas and the corresponding reduction of the rural areas. It is clear that in recent time the main human impact is concentrated on the "filter rocks" or nearly impermeable rocks of the central basin. So it is not difficult to plan a sewage system to remove the waste waters from the plateau area and so to reduce the pollution of karst waters. In fact the karst waters represent an important resource also for the urbanized areas of the Veneto Plain.

The representation given by the map is a document of the situation in 1991, useful both for a reflection about the perspectives of development in the next future, and for a comparison between different spatial situation and styles of impact.

(Errata corrige of the map: in the legend of the map the blue dashed line, which means temporary water course, has been omitted; in the map the small green patch on the left slope of Val d'Assa of "TAGLIATA", not far from the upper left corner of the map, must be referred to the "prewurmian deposits").

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BIBLIOGRAPHY

CASTIGLIONI G. B., MENEGHEL M. & SAURO U. (1988) - Elementi per una ricostruzione dell'evoluzione morfotettonica delle Prealpi Venete. Riv. Geografia Fis. Din. Quatern. suppl. 1 (1988), 31-44.

CASTIGLIONI G.B. (1974) - Importanza dei processi periglaciali nel Pleistocene per l'evoluzione del rilievo nelle Prealpi venete. Natura e Montagna, 21, 15-17.

CASTIGLIONI G.B., GIRARDI A., SAURO U. e TESSARI F. (1979) - Grèzes litées e falde detritiche stratificate di origine crionivale. Geogr. Fis. Dinam. Quat., 2, 64-82.

DAL PRA' A. e STEVAN L. (1969) - Ricerche idrogeologiche sulle sorgenti carsiche della zona di Valstagna, in destra Brenta, ai piedi dell'Altopiano dei Sette Comuni (Prealpi Venete). Tecnica Italiana, 34/10: 13 pp.

DE MARCHI L. (1911) - Idrografia carsica dei Sette Comuni. Ufficio Idrografico del Magistrato alle Acque , Venezia, 47 pp.

GENNARI G., LANDI M., SAURO U. (1989) - Un'esperienza con traccianti sull'altopiano dei Sette Comuni (Prealpi Venete). Atti XV Congr. Speleol. Naz. di Castellana, 1987, 369-380.

MATTANA U. (1974) - Glacialismo e fenomeni periglaciali nel territorio delle Prealpi Venete. Natura e Montagna, 21, 5-14.

MENEGHEL M. , SAURO U., BACIGA M. L., FILECCIA A., FRIGO G., TONIELLO V. & ZAMPIERI D. (1986)- Sorgenti carsiche ed erosione chimica nelle Prealpi Venete. Studi Trentini di Scienze Nat. , 62, A.G. 145-172.

MIETTO P., SAURO U. (1989) - Le Grotte del Veneto: paesaggi carsici e grotte del Veneto. Regione del Veneto - La Grafica Editrice, 415 pp.

SAURO U. (1987) - The impact of man in the karstic environments of the Venetian Prealps. Karst and Man, University of Ljubljana. Study Group on Man's impact in Karst. Proc. Int. Symposium on human influence on Karst, Postojna , Yugoslavia , 1987, 241-254.

TREVISAN L. (1939) - Il glacialismo quaternario nell'Altopiano dei Sette Comuni. Boll. Com. Glac. Ital., 19, 99-116.

TREVISAN L. (1941) - Caratteri particolari della tettonica dell'Altopiano dei Sette Comuni. Studi Trent. Sc. Nat., 22, 79-88.

ZANFERRARI A., BOLLETTINARI G., CAROBENE L., CARTON A., CARULLI G. B., CASTALDINI D., CAVALLIN A., PANIZZA M., PELLEGRINI G. B., PIANETTI F. & SAURO U. (1982) - Evoluzione neotettonica dell'Italia nord-orientale. Mem. Sc. Geol., 35, 355-376.