Zeitschrift: Eclogae Geologicae Helvetiae

Herausgeber: Schweizerische Geologische Gesellschaft

Band: 84 (1991)

Heft: 3: [Emile Argand 1879-1940]

Artikel: Seismic evidence of pre-Pliocene valley formation near Novazzano (Ticino, Switzerland)

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DOI: https://doi.org/10.5169/seals-166796

Eclogae geol. Helv. 84/3: 753–761 (1991)

0012-9402/91/030753-9 $ 1.50 + 0.20/0
Birkhäuser Verlag, Basel

Seismic evidence of pre-Pliocene valley formation near Novazzano (Ticino, Switzerland)[1]

By Markus Felber[2], Walter Frei[3] and Peter Heitzmann[4]

ABSTRACT

A 800 m long reflection seismic profile in the area of Novazzano (Ticino, Switzerland) revealed a nearly 500 m deep valley, cut into the Mesozoic-Tertiary bedrock of Campanian Flysch and Oligo-Miocene Gonfolite Lombarda. The infill of the valley consists of post-orogenic, probably clastic, late Messinian sediments which are overlain by marine Pliocene argillaceous marls and Quaternary fluvio-glacial deposits. The detrital valley infill may represent an important acquifer.

RIASSUNTO

Un profilo di sismica a riflessione lungo 800 m ha permesso di stabilire nella regione di Novazzano (Ticino, Svizzera) un canyon profondo quasi 500 m, eroso nel substrato roccioso mesozoico-terziario composto dal Flysch Campaniano e dalla Gonfolite Lombarda. Il riempimento della valle è costituito da sedimenti clastici post-orogenetici del Tardo-Messiniano cui sono sovrapposte argille marnose del Pliocene marino come pure depositi fluvio-glaciali del Quaternario. Il riempimento clastico potrebbe rappresentare un importante acquifero.

ZUSAMMENFASSUNG

In einem 800 m langen Reflexionsseismikprofil bei Novazzano (Ticino, Schweiz) konnte ein ca 500 m tiefes Tal gefunden werden, eingeschnitten in den mesozoisch-tertiären Sockel, der von Campanian-Flysch und der Gonfolite Lombarda aufgebaut wird. Die Füllung dieses Tals besteht aus post-orogenen, wahrscheinlich klastischen Sedimenten von spät-Messinian Alter, überlagert von tonigen Mergeln des marinen Pliocäns und quartären fluvio-glazialen Ablagerungen. Die Talfüllung mit klastischen Sedimenten ist vielleicht ein wichtiger Grundwasserträger.

Introduction and geological setting

During the 1988 seismic survey of NFP-20 (National research program on the deep structure of Switzerland, main lines see Fig. 1; Bernoulli et al. 1990) a short profile with only shallow penetration was recorded near Novazzano (Southern Ticino, Switzerland). The present study shall clarify the relationship between Quaternary and older post-orogenic deposits and pre-orogenic bedrock geology in the region of Novazzano. The special aim is to measure the thickness of the Quaternary cover, to test the possible presence of Pliocene sediments in the subsurface and of a hypothetical north-south oriented valley in the bedrock as proposed by Felber (1982).

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The study area lies in the central part of the Mendrisiotto (Southern Ticino) and the 800 m long profile runs SSW-NNE from the locality of Boscherina to the old farm of Motta (Figs. 1 and 2). The geological framework (Fig. 1) is marked in the Northeast by Upper Cretaceous Flysch (Longo 1968, Rutishauser 1977), in the South by the hills formed of the Oligo-Miocene Gonfolite Lombarda (Gunzenhauser 1985) overthrusted toward north over the Mesozoic formations (Bernoulli et al. 1989). The depression in between is filled with Pliocene argillaceous marls (Premoli-Silva 1965, Longo 1968, Violanti 1991) which crop out in the Valle della Motta (Fig. 2) and with overlying Quaternary deposits of lacustrine, deltaic, fluvial and glacial origin.

The lithology of the Quaternary cover in the Valle della Motta is well known from numerous shallow drill holes carried out for a waste storage site. In all these holes, some of them up to 50–60 m deep, pre-Quaternary formations were never reached. The only exception is drill hole 620.047 of the Istituto Geologico Cantonale, Bellinzona in the zone of Gallo (Swiss coordinates 719.615/078.590; Fig. 2) where sandy loams dated as Pliocene by a rich marine macro- and micro-fauna were found at a depth of 27 m (278 m above sea level).

In the borehole of Castel di Sotto (Fig. 2), the top of a continental sequence underlying, with a tectonic contact, the marine Pliocene clays was encountered at 260 m

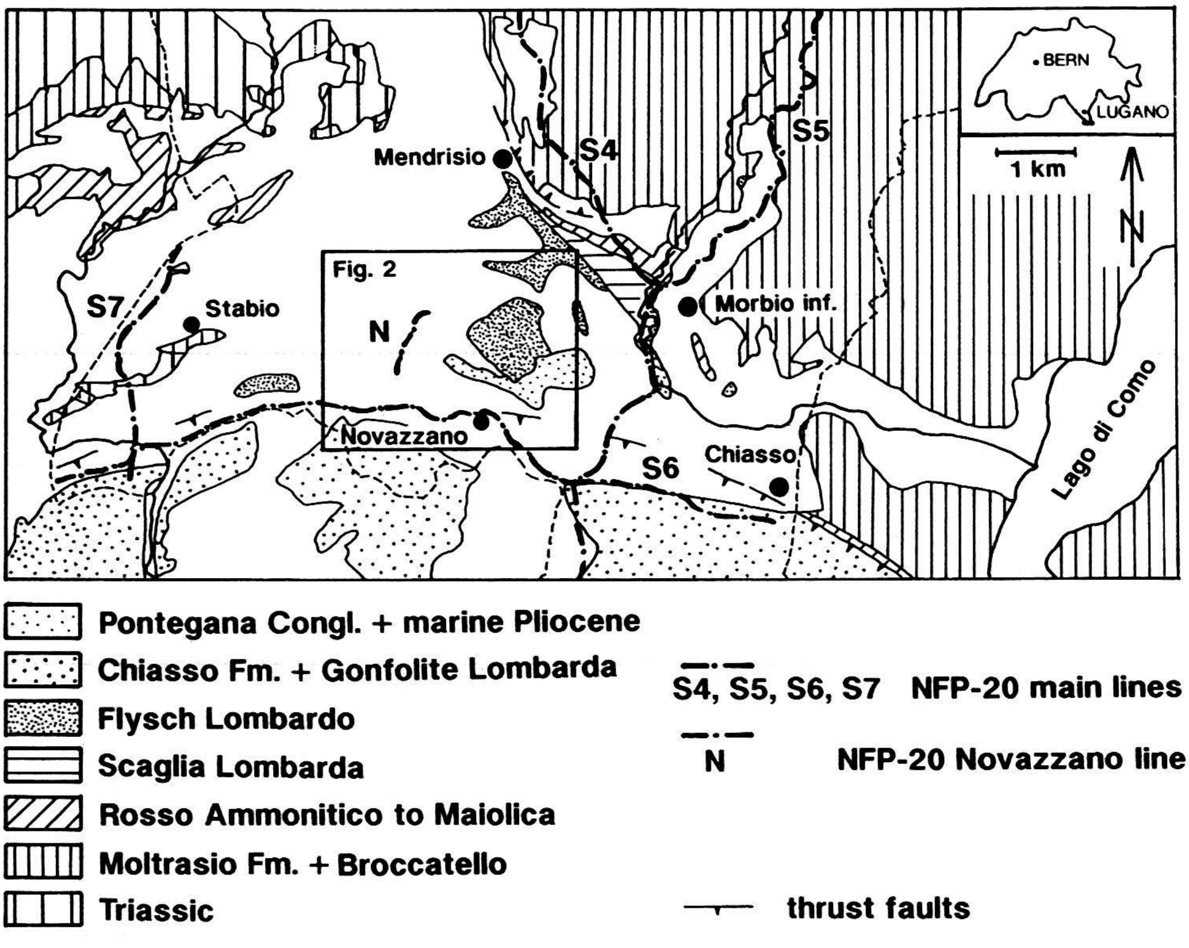


Fig. 1. Simplified geological map of the Mendrisiotto region (after Bernoulli et al. 1989).

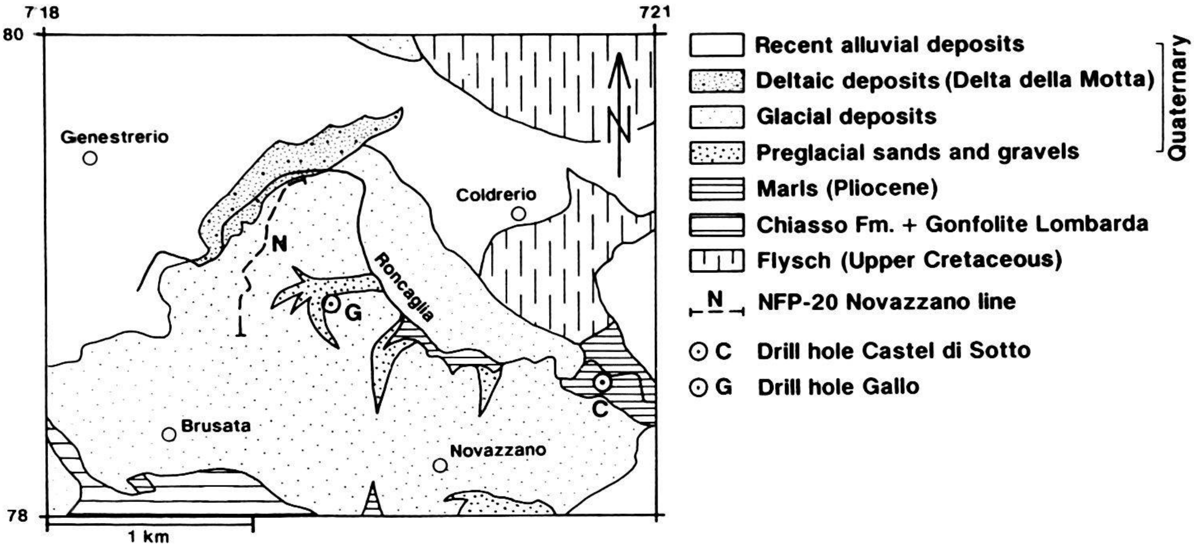


Fig. 2. Geological map of the Valle della Motta and location of the studied seismic line.

above sea level. This formation, about 70 m thick, is formed by lacustrine and fluvial sediments and was attributed to the Messinian. It overlies Campanian flysch at 190 m above sea level (Rutishauser 1986).

Further data on the base of the Quaternary and on pre-Quaternary valley fills are given by the geophysical investigations carried out on behalf of the Canton of Ticino by the Company Lerici. These geoelectrical recordings give evidence of a depression in the bedrock reaching below 100 m above sea level between the villages of Stabio and Genestrerio (Beatrizotti & Hansen 1975).

Seismic data acquisition and processing

The *field recording parameters* were the following:

Recording instrument	DFS-V
Number of channels	48
Spread details	symmetrical split
Spread length	470 m
Geophone pattern	6 linearly spaced 1.7 m
Geophone type	4.5 hz
Low-cut filter	8 Hz/18 db
Sampling rate	2 ms
Source type	VAKIMPAK weight dropper
Source spacing	10 m
No. of vertical stacks	4
Recording mode	unsummed
Multiplicity	24-fold
CDP-spacing	5 m
Date recorded	Sep. 1988

The energy source was a vacuum-assisted weight dropper using a 50 kg hammer at a hight of 1.6 m. The strike energy generated is 2,500 Nm.

The line was laid out along a dirt road providing good ground coupling for both the energy source and geophones.

During the entire survey favorable weather conditions prevailed. However, the ambient noise level was considerable. It was attributed to various sources such as

- an international railway line located at 500 m of the NE-end of the line,
- continous activities of excavators, a conveyor belt and heavy trucks in a gravel pit at a lateral distance of 500 m,
- overhead power lines,
- the line being located in a heavily industrialized and densely populated region.

As the recording instrument was not equipped with a stacker, the data had to be recorded unsummed; thus, vertical stacking had to be carried out in the processing center. However, the economical disadvantage of a four times larger amount of field data was more than offset by the data quality improvement achieved by noise reduction techniques in the processing center, prior to the vertical summing, such as amplitude balancing in the time and frequency domains.

The *data processing sequence* is outlined below:

1. Demultiplex and gain record
2. Trace editing
3. AGC, window length 300 ms
4. Spectral balancing
   spectral window increasing in 25 steps of 5 Hz from 4/10–35/55 Hz to 129/135–160/180 Hz
5. Vertical stack, 4-fold
6. Line geometry and application of field static corrections
7. AGC, window length 200 ms
8. Common depth point sorting
9. Velocity analysis
10. NMO-corrections and muting (maximum stretch allowed 175%) single velocity function applied:

time	V_{NMO}
50 ms	2000 m/s
1000 ms	3000 m/s

11. CDP-stack
12. Band pass filter 12/20–150/180 Hz

(13. Coherency enhancement filter, spatial window 20 traces)

Velocity analysis using constant velocity stacks (CVS) and constant velocity gathers (CVG) were carried out at 6 locations along the line. However, none of the velocity functions derived, yielded better results than the function used for an early brute stack and determined from a simple refraction analysis aiming at the calculation of the field static corrections.

Data processing was carried out at the Institute of Geophysics, Swiss Federal Institute of Technology, Zurich, on a VAX-780 based PHOENIX seismic processing system.

Results and geological interpretation

In the seismic profile (Fig. 3) four zones with different reflectivity patterns can be distinguished:

1. an uppermost zone with very low reflectivity;
2. a highly reflective zone characterized by very long continuous reflections forming a basin-like feature between CDP 20 and 80;
3. a very low reflective zone underlying the basin structure of zone 2; in the upper part of this zone the rare reflections are subparallel to the very pronounced reflections of zone 2;
4. the lowermost zone with some discrete reflections.

The lowermost zone (4) represents the bedrock into which a valley is cut and infilled by the three overlying formations. It consists probably of Flysch sediments which crop out further to the east in the Valle della Motta (Fig. 2). The northern shoulder lies at a depth of about 0.20 sec (~ 280 m), whereas the southern one at depth of about 0.15 sec (~ 210 m). The bottom of the valley appears to be at about 0.35 sec (~ 490 m below the topographic level of 350 m, i.e. 140 m below sea level).

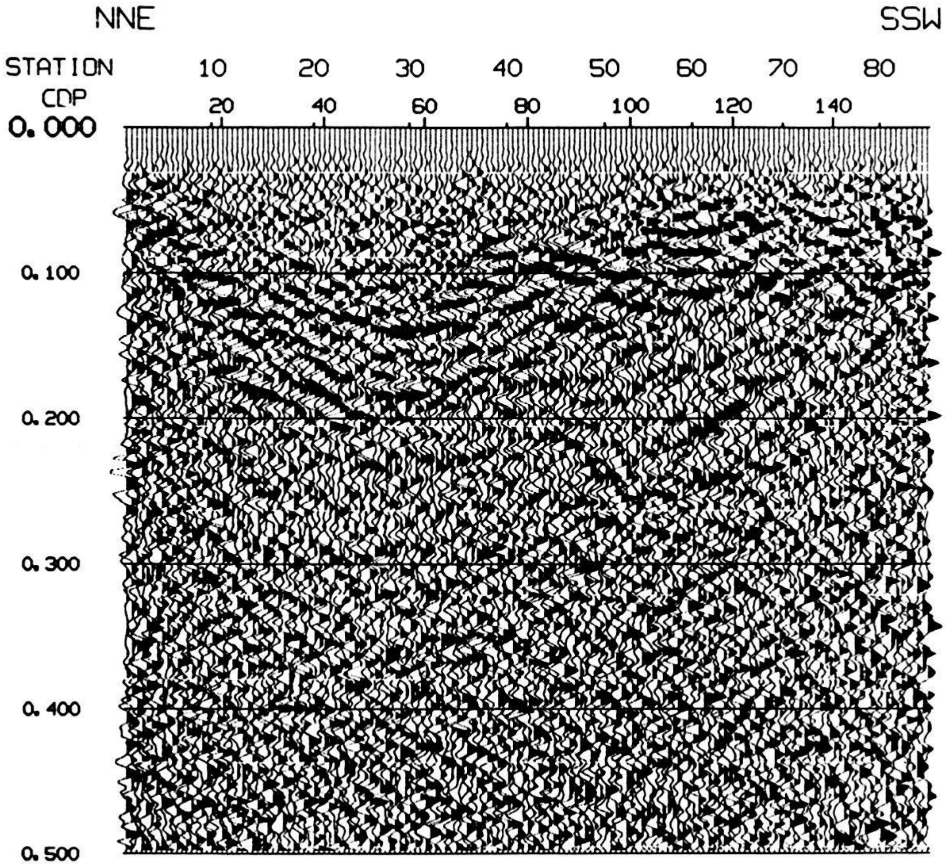
The three units infilling the ancient valley are interpreted, from top to bottom, as follows:

1. A Quaternary cover up to 140 m thick. In the SSW part it may consist of glacial deposits, in the central and the northern part (over the ancient valley) of an alternation of glacio-fluvial sediments and sands (which can be compared with the Sabbie di Casate, Longo 1968).
2. Along the whole profile the Quaternary deposits are thought to be underlain by Pliocene argillaceous marls and sands up to about 140 m thick.
3. According to its seismic character the third formation up to about 220 m thick may possibly consist of coarser detrital sediments (sandstones with interbedded conglomerates) which appears as concordant with the overlying marls. This probably clastic formation may tentatively be compared with formations which underlie the Pliocene in the Po plain such as the post-evaporitic formations of Messinian or early Pliocene age (e.g. Sergnano Formation or Caviaga Formation) described by Rizzini & Dondi (1978), Mattavelli et al. (1983), Dondi & D'Andrea (1986), and Quattrone, Rogledi & Longoni (1990). The upper part of this section of 220 m may correspond to the 70 m of continental sediments described by Rutishauser (1986) from the borehole of Castel di Sotto (Fig. 2).

An alternative correlation may be made with the Pontegana Conglomerate (Heim 1906, Vonderschmitt 1940, Longo 1968), but the stratigraphical position of this formation as it was defined by the cited authors may have to be revised.

Discussion and conclusions

1. The seismic profile of the Valle della Motta shows evidence of an ancient valley. Because of the subhorizontal stratification in the valley the filling must be younger than the last important Alpine deformation (Pieri & Groppi 1981, Bernoulli et al. 1989, Bernoulli et al. 1990) but older than the deposition of the Lower Pliocene marine marls, therefore the age of the infilling can bee interpreted as late Messinian. Taking in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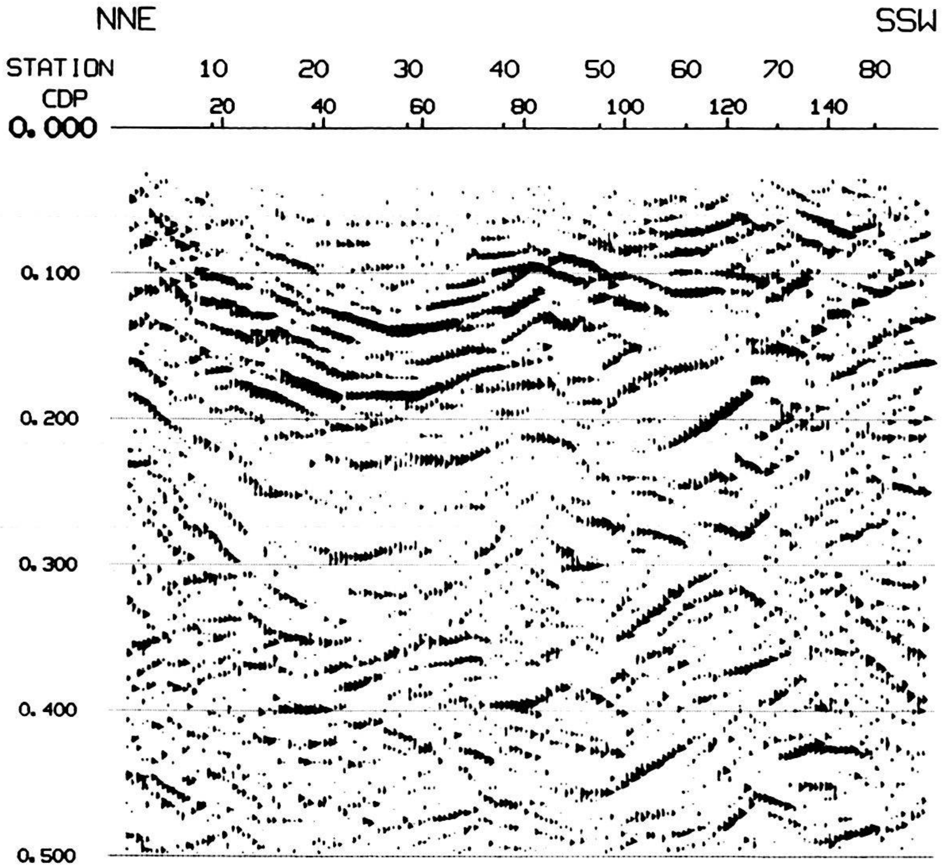
3a


NNE
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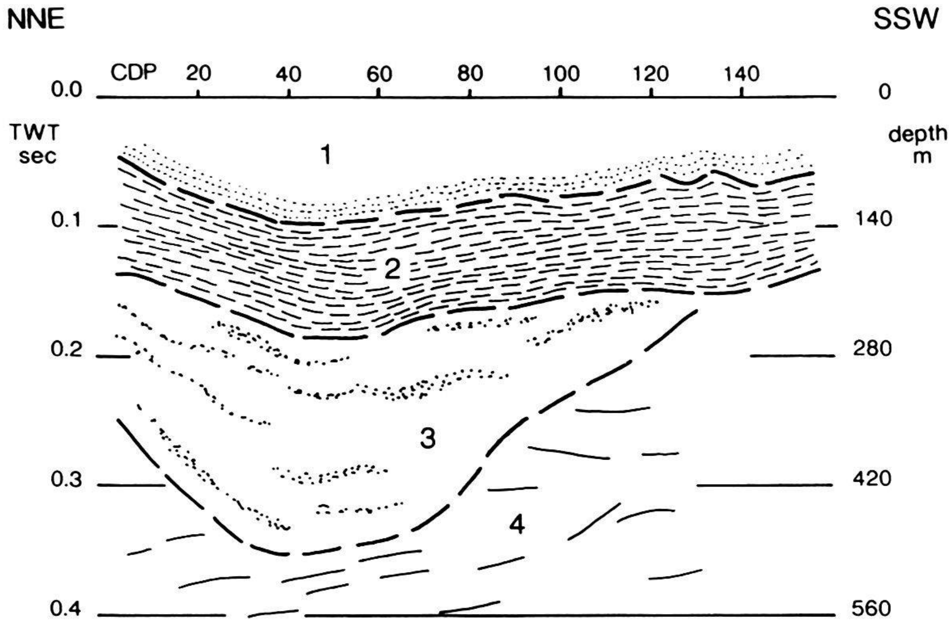
3b



3c

Fig. 3. (a) seismic profile (non migrated, for data processing see text), (b) "GOLD section" = geophysically objective line drawing (non migrated) and (c) geological interpretation of the Valle della Motta section.

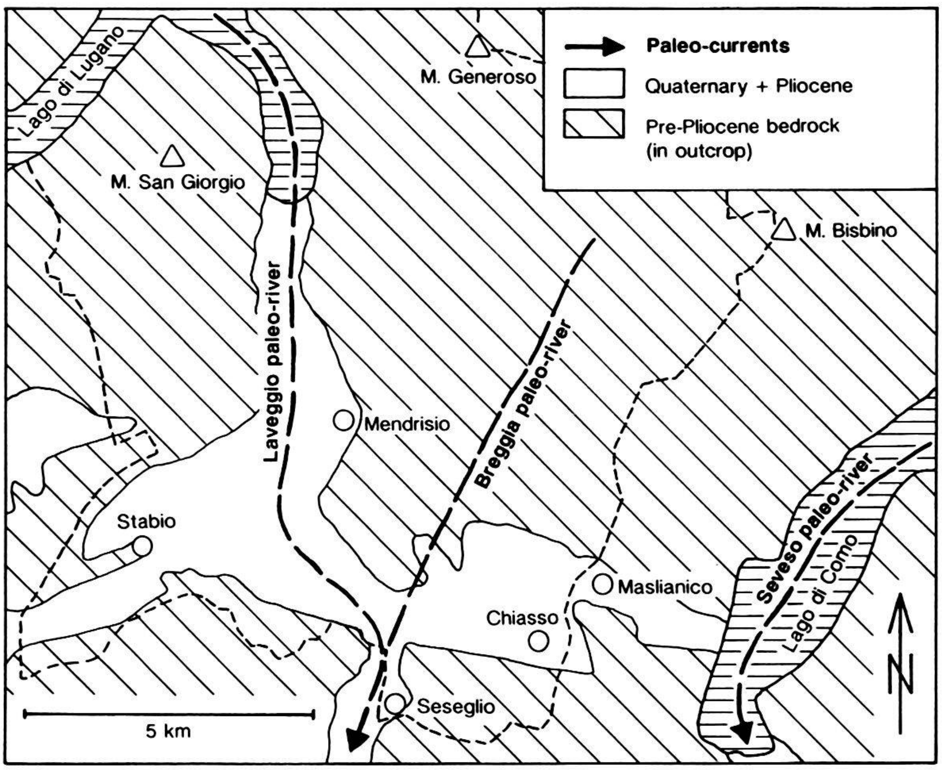


Fig. 4. Paleocurrents and pre-Pliocene bedrock in the Mendrisiotto.

account as proposed by ROGENMOSER (1981) a general uplift of 400 m for the whole Mendrisiotto region after the deposition of the marine Lower Pliocene marls, the canyon would have been eroded at late Messinian time down to a base of 540 m below sea level, well in line with other submerged valleys below the prealpine lakes on the southern side of the Alps (BINI et al. 1978, FINCKH 1978, RIZZINI & DONDI 1978, CORSELLI et al. 1985, NIESSEN 1987 and CITA et al. 1990).

2. The ancient valley of Novazzano proves the existence of an important N-S trending hydrological pattern (Fig. 4) which may have developed along a preexisting tectonic system with the southern branch of the Lugano line (BERNOULLI 1964). The continuation of the valley at Novazzano in late Tertiary time may be found below the passage at Seseglio (Fig. 4), where the bedrock is found below the actual sea level (BEATRIZOTTI & HANSEN 1975). An alternative continuation through the passage at Maslianico can be excluded by the fact that Liassic limestones were encountered in a drillhole in the middle of the small plain at 110 m above sea level (Swiss coordinates 724.500/078.020; DELLA TORRE 1990, oral comm.).

3. The results of our investigations clearly show that Quaternary deposits do not always directly overlie the Oligo-Miocene or older bedrock. There are intercalated not only Pliocene marls but also late Messinian clastic deposits which may be correlated with deposits in the Po plain found in a similar stratigraphic position.

The seismic section gives precise indications about the thickness of each formation and some information about their probable lithology. The thick valley infill with probably detrital, late Messinian sediments may be an important aquifer.

Acknowledgments

This study – proposed by the Museo cantonale di storia naturale, Lugano – was carried out within the framework of the Swiss National Research Program NFP-20 on "The Deep Geological Structure of Switzerland" supported by the Swiss National Science Foundation (grants 4020–10822, 4020–10903). We thank the seismic crew from the Institute of Geophysics, ETH Zürich for their field work, P. Riva and G. Zanini for the permission to cross their property, Istituto geologico cantonale, Studio Leoni & Gisy, P. Oppizzi, P.C. Pedrozzi and P. Amman for unpublished data concerning the Valle della Motta, Studio Della Torre – Como for the information about the borehole at Maslianico and Daniel Bernoulli, Georges Gorin and Peter Lehner (Program Director NFP-20) for critical review and improving the English.

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Manuscript received 21 November 1990
Revision accepted 4 June 1991