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CHEMICAL, GEOMECHANICAL AND GEOMORPHOLOGICAL ASPECTS OF KARST IN SANDSTONE AND MARL OF FLYSCH FORMATIONS IN NORTH EAST ITALY

KEMIJSKE, GEOMEHANSKE IN GEOMORFOLOŠKE ZNAČILNOSTI KRASA V FLIŠNIH PEŠČENJAKIH IN LAPORJIH IZ SEVEROVZHODNE ITALIJE

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Abstract UDC: 552.5:551.44(450)

Andrea Mocchiutti &Paolo Maddaleni: Chemical, geomechanical and geomorphological aspects of Karst in sandstone and marl of flysch formations in north east Italy

Geomphology, geomechanical and geochemical features of some caves in flysch sediments in Prealpi Giulie, Friuli, North east Italy are described.
Key words: geomorphology, geomechanics, karst, flysch, speleogenesis.

Izvleček UDK: 552.5:551.44(450)

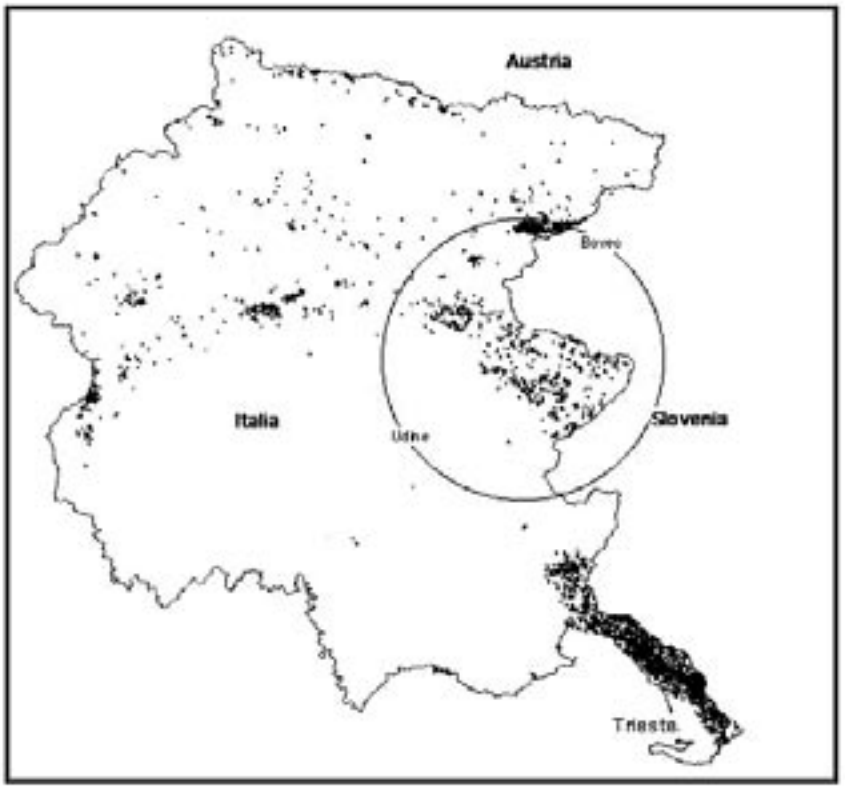
Andrea Mocchiutti & Paolo Maddaleni: Kemijske, geomehanske in geomorfološke značilnosti krasa v flišnih peščenjakih in laporjih iz severovzhodne Italije

V prispevku so opisane kemijske, geomehanske in geomorfološke značilnosti nekaj jam v flišnih sedimentih v Julijskem predgorju Furlanije, severovzhodna Italija.
Ključne besede: geomorfologija, geomehanika, kras, fliš, speleogeneza.

INTRODUCTION

Many caves are presents in flyschoid deposits. This work describes lithology, stratigraphy, geochemical and geomechanical characteristics of some caves in Prealpi Giulie (Friuli Venezia Giulia, north east Italy). These carbonatic and flyschoid deposits are dated back to Mesozoic-Eocene age.

Flysch is a marine sediment produced by the erosion of uprising and developing fold structures. These sediments mainly consist of argillaceous rocks, marls, sandstone, breccias, conglomerates and calcarenite.



Caves distribution - Friuli Venezia Giulia Region - North East Italy
Distribution des grottes dans la region du Friuli Venezia Giulia- North Est Italie
Distribuzione delle cavità nel Friuli Venezia Giulia - Nord Est Italia

The circle indicates the studied area

Fig. 1: Cave distribution.

In Monti La Bernadia the flyschoid deposits are Flysch of Grivò (Ypresiano-Luteziano) sediments, while in Natisone Valley the flyschoid deposits are: Flysch of Clodig (Maastrichtiano inf. p.p.), Flysch of Iudrio (Maastrichtiano inf.-sup), Flysch of Monte Brieka (Maastrichtiano sup. p.p.), Flysch of Cialla (Paleocene inf.), Flysch of Masarolis (Paleocene sup. p.p.), and Flysch of Grivò (Paleocene sup.- Eocene inf.).

Fr.	name	municipality	Locality	Entrance elevation m.	Length m.
323	*Grotta Nuova di Villanova*	*Lusevera*	*Villanova*	*566*	*7090*
2175	*Grotta Egidio Feruglio*	*Lusevera*	*Villanova*	*602*	*3000*
1649	*Grotta di Montefosca*	*Torreano*	*Montefosca*	*770*	*284*
483	*Grotta Star Cedat*	*S .Leonardo*	*Altana*	*350*	*1185*
2013	*Grotta sotto chiesa di S. Andrea*	*Pulfero*	*Goregnavas*	*740*	*388*
43	*S. Giovanni d'Antro*	*Pulfero*	*Antro*	*348*	*4000*
2907	*La Mitica*	*Savogna*	*Cepletischis*	*525*	*335*
61	*Grotta di Taipana*	*Taipana*	*Taipana*	*800*	*90*

Tab.1: Caves in flysch formations in Bernadia mountains range and in Natisone valley

STRATIGRAPHY OF GROTTA NUOVA DI VILLANOVA

In the Grotta Nuova di Villanova (Monti La Bernadia area) 12 samples of marl under the big calcarenitic megabed of Grivò of Flysch sediments were analyzed. The marl and sandstone are sampled at the cross section fig.4 and described in the first stratigraphy column fig.7 in Ramo Principale at different levels from the top to the bottom and named: V1, V2, V3, V4, V5, V6, V7, V8, V9, V10, while V13 and V14 are sampled on the calcarenite megabed at the top of the second stratigraphy column fig.7. Three different lithologies are evidenced in these stratigraphy columns: marl, sandstone and calcarenite. On the top of the marl there is a white somewhat calcitic layer 5 cm thick (samples V2 and V11); this layer is evident in many places in this cave and it will be studied in detail. Stratigraphy column n°2, fig. 7 is near the main cross section and the lithology is the same, we analysed four samples: V11, V12,V13,V14.

The thickness of sandstone and marl layers is between 2 cm. and 20 cm., while the sandstone / marl ratio is 0,5 (column fig.7) and 0,9 (column fig. 7). A samdstone / marl ratio < 1 is typical of silicoclastyc distal turbidite with limestone megabeds (Bouma facies D_2).

LA MITICA'S STRATIGRAPHY

Stratigraphic column of Grotta Mitica is different, because there are more little calcarenite beds in between marl of Flysch of Clodig. Othervise La Mitica there are three different lithologies: calcarenite, marl and sandstone; at the top of the sequence there is large calcarenitic megabed, the sample are identify: C1, C2, C3, C4, C5, C6, C7. The sandstone / marl ratio is 0,6.

GROTTA STAR CEDAT

The cave develops at the contact calcarentie – marl, there is no sandstone on the cave walls; the sample (SC1) indicates marl with 60% of limestone.

EPIGEOUS KARST MORPHOLOGY IN FLYSCH FORMATIONS.

There is a wide range of epikarst morphologies in flysch, this particular karstic phenomenon is mainly located on sand stone lithotype but with some analogies with the same morphotype found usually on calcareous rocks.

In these areas there are dolines, little karren and microforms.

CAVES IN FLYSCH

In the last few years some geomorphological observations inside caves in Flysch leaded to the following considerations:

- Calcarenite beds in the flysch formation are seats of a diffused Karstic phenomena, in particular it has been noted that a greater number of caves is set up in contact between the carbonate beds and the lower marls and sandstone of the flysch.
- The analyses of the internal morphology of the caves, characterized by the contact marls-limestone, points out some common features

Fig. 2: Microforms on sandstones.

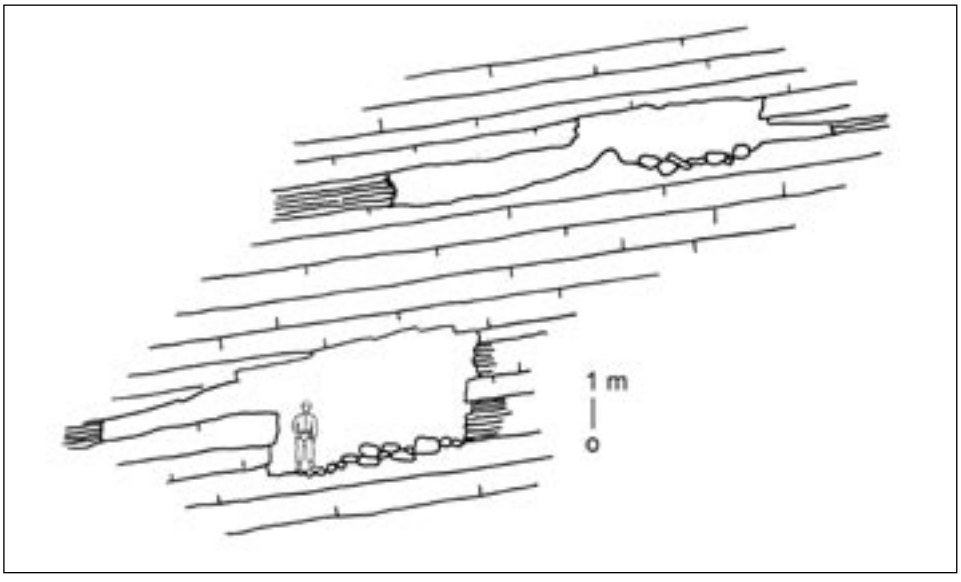


Fig. 3: Cross section of Grotta Sotto la Chiesa S. Andrea,

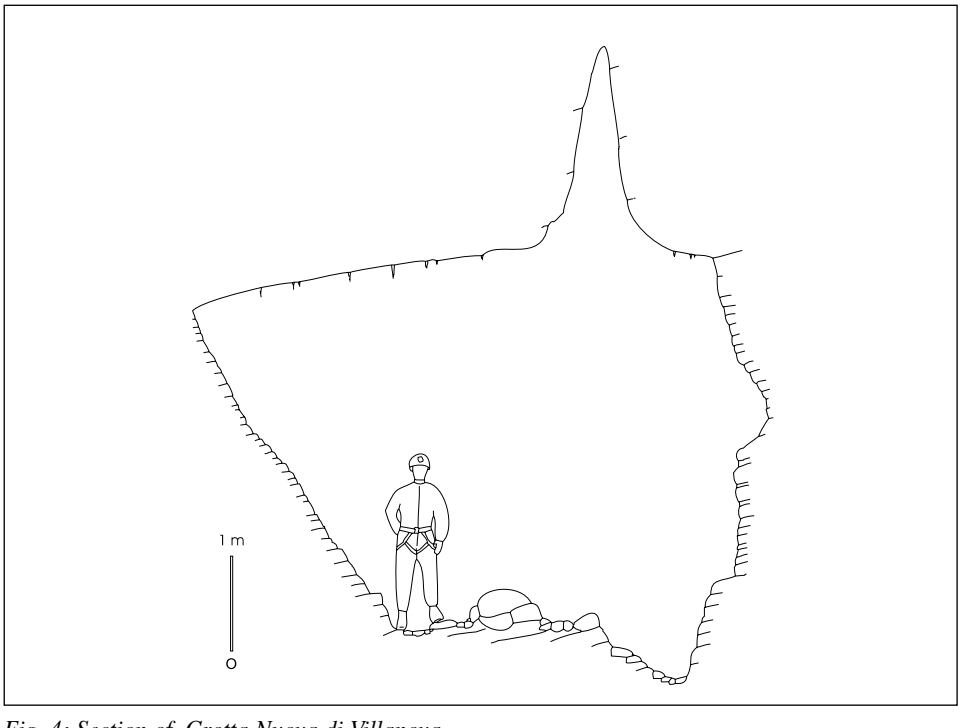


Fig. 4: Section of Grotta Nuova di Villanova,

Fig. 5: Marly claystone, sandstone beds in Grotta Nuova di Villanova.

Fig. 6: Calcarenite bed in Grotta Nuova di Villanova.

Some important questions arise following the first geomorphological studies:

the values and influence of chemical content of calcium carbonate in marl and sandstone.

the importance of geotechnical parameters of the rock mass.

Now we try to answer these and others questions about karst in flysch formations analyzing these parameters:·

- Stratigraphy
- Chemical analyses
- Mineralogy
- Geomechanic Classification
- Tectonic

Fig. 6: Calcarenite, marlyclaystone, sandstone beds in Grotta La Mitica.

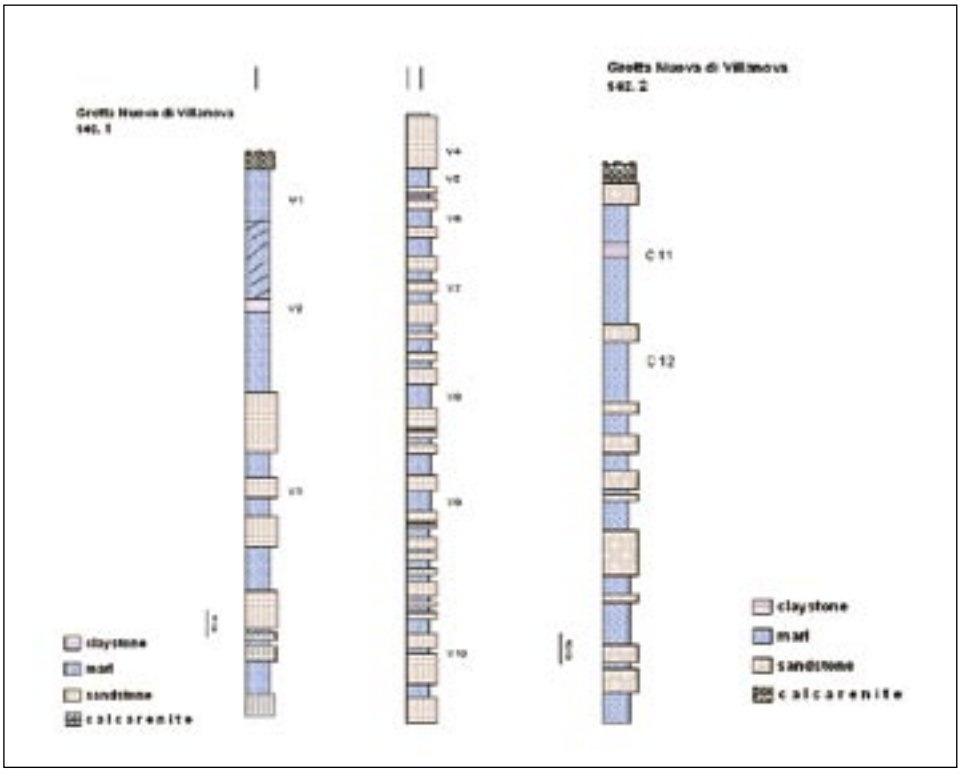


Fig. 7: Stratigraphy of Grotta Nuova di Villanova.

Fig. 8: Grotta di Villanova.

CHEMICAL ANALYSES

Chemical analyses on carbonate content were carried out with a calcimeter on several samples. The calcimeter used is a Dietrich-Fruhling for this methodology: a sample of marl is dried in a kiln (temperature 110°C), after ten hours the marl is pulverized by a ceramics mortar and placed on the calcimeter's bottle (beuta) with HCl (1:1 concentration). The acid dissolve marl's carbonate and

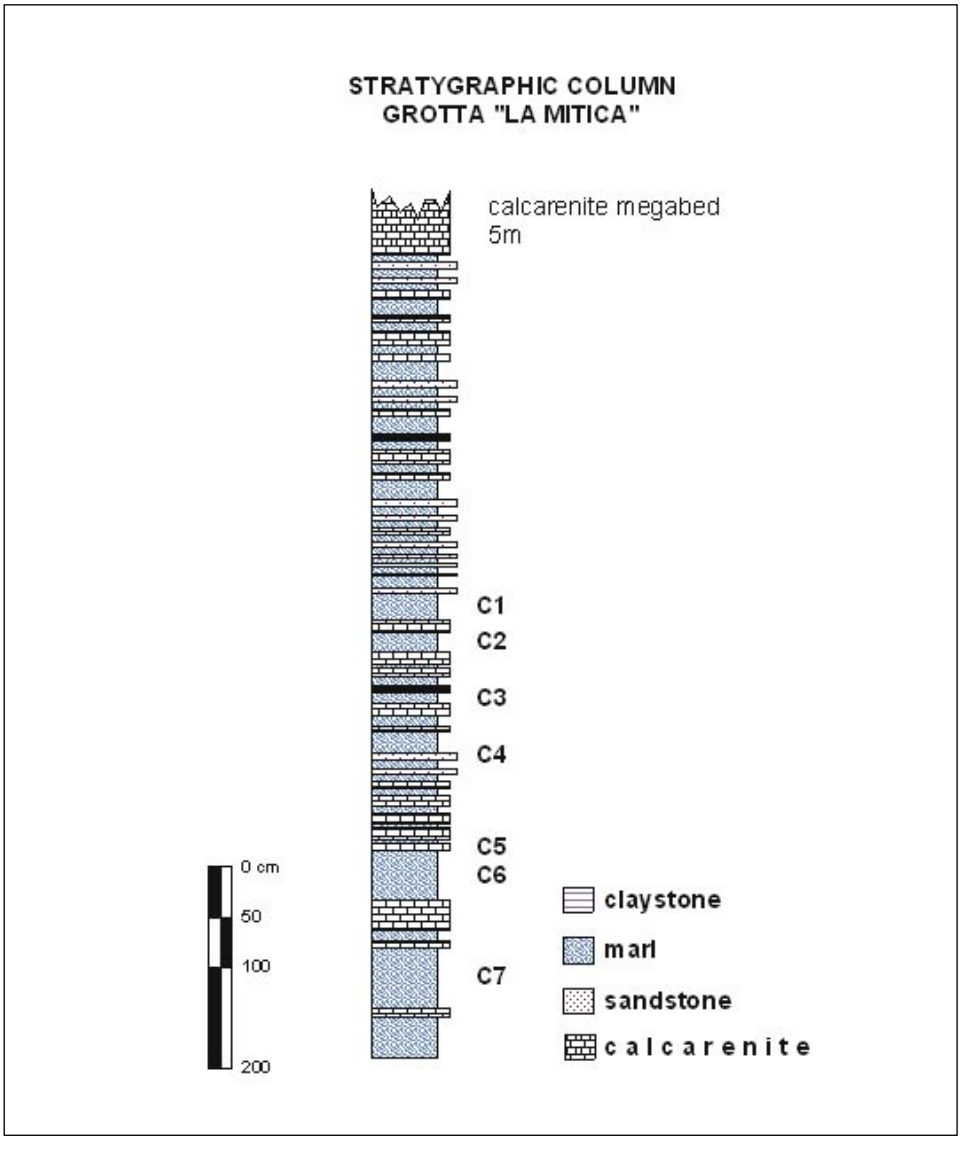


Fig. 9: Stratigraphy of Grotta La Mitica.

produce CO_2. The gas developed is proportional of carbonate concentration. The results of chemical analyses for Grotta Nuova di Villanova are displayed in the tab.3, while the samples of La Mitica are in tab. 4, only one sample is analysed in Star Cedat. We can notice that the $CaCO_3$ concentration in marl and in sandstone of all sample is high. So that dissolutive process can be important also in sandstone and marls, for these contact-cave in flysch formations. The litology and chemical composition of Flysch of Grivò seems to fit better with the dissolutive process; in fact caves have high development, for exemple the marly shale of this flysch (Grotta di Nuova di Villanova and Star Cedat) have more limestone content than in Flysh of Clodig (La Mitica), values in tab. 3 and 4.

100	*90*	*80*	*65*	*35*	*20*	*10*	*0 %*	*Limestone*
	Limestone	Marly limestone	Calcareous marl	Marl	Argillaceosu Marl	Marly Claystone	Clay stone	
0	*10*	*20*	*35*	*65*	*80*	*90*	*100 %*	*Clay*

Tab.2: Claystone and limestone classification

Fig. 9: Dietrich-Fruhling calcimeter.

Sample	Lithology	% Carbonates
V 1	Marl	37 %
V 2	Marl	46 %
V 3	Sand stone	35 %
V 4	Sand stone	38 %
V 5	Marly claystone	28 %
V 6	claystone	1 %
V 7	Sand stone	33,5 %
V 8	Marl	31,5 %
V 9	Marly claystone	29 %
V 10	Marly claystone	33 %
V 11	Marl	49 %
V 12	Marl	36 %
V 13	Calcarenite	91,5 %
V 14	Calcarenite	91 %

Tab. 3: Carbonate analysis of Grotta Nuova di Villanova.

Sample	Lithology	% Carbonates
C 1	Claystone	10 %
C 2	Calcarenite	93 %
C 3	Claystone	8,5 %
C 4	Calcarenite	91,5 %
C 5	Calcarenite	95 %
C 6	Marly claystone	18 %
C 7	Marly claystone	18,5 %

Tab. 4: Carbonate analyses of La Mitica.

Sample	Lithology	% Carbonates
SC 1	Marl	60 %

Tab. 5: Carbonate analyses of Star Cadat.

FLYSCH SANDSTONE MINERALOGY

The mineralogy was studied both from the point of view of its principal constituent parts (calcite, quartz, feldspar, clay and dolomite minerals) and its hard minerals.

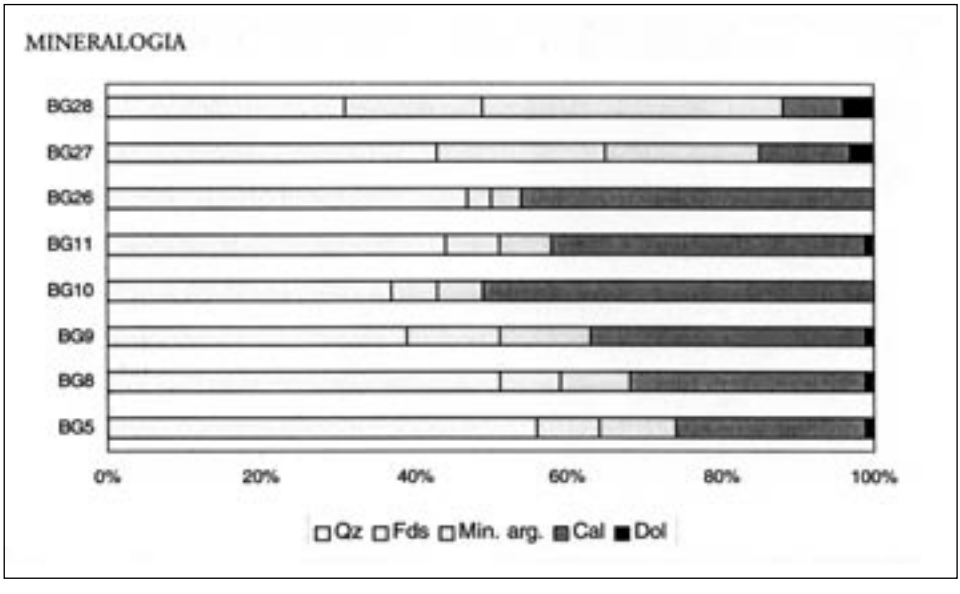
GEOMECHANICS CLASSIFICATIONS

As regards geomechanics classifications of rock mass involved in karstic phenoma of Villanova caves, many parameters have been considerated, giving a rating for each one. Physical and morphologic features have beeen studied to work out each own value.

- Orientation of discontinuities
- Spacing of discontinuities
- Condition of discontinuities
  - length
  - separation
  - roughness
  - infilling
  - weathering
- Groundwater conditions
- Rock Quality Designation (RQD)
- Uniaxial compressive strength of rock material

Shape of wedges and walls stability have been estimated throughout stereographic projections of discontinuities sets dip and dip directions.

Point Load Index Test: Marl average value 0,36 MPa



Tab. 6: Flysch mineralogy, Lenaz 2000.

BIENIAWSKI ROCK MASS RATING [RMR], 1989

Parameter	Measured value	Rating
Uniaxial compressive strength (MPa)	11.28	2
RQD (%)	71	13
Spacing (m)	0.57	11
Condition of discontinuities		15
Groundwater conditions	< 10 l/min	10

RESULTS:

Base RMR	51
Dip direction adjustment [Ic]	N/A
Adjusted RMR	51
Rock mass class	CLASS III
Rock mass quality	FAIR ROCK

ROMANA CLASSIFICATION (SMR, 1985)

SMR index for plane and toppling kinematics:	58
Q Rock mass quality	FAIR ROCK
Rock mass class	CLASSE III
Stability note	Partially stable
Rock fracture note	Some plane joint and many wedges

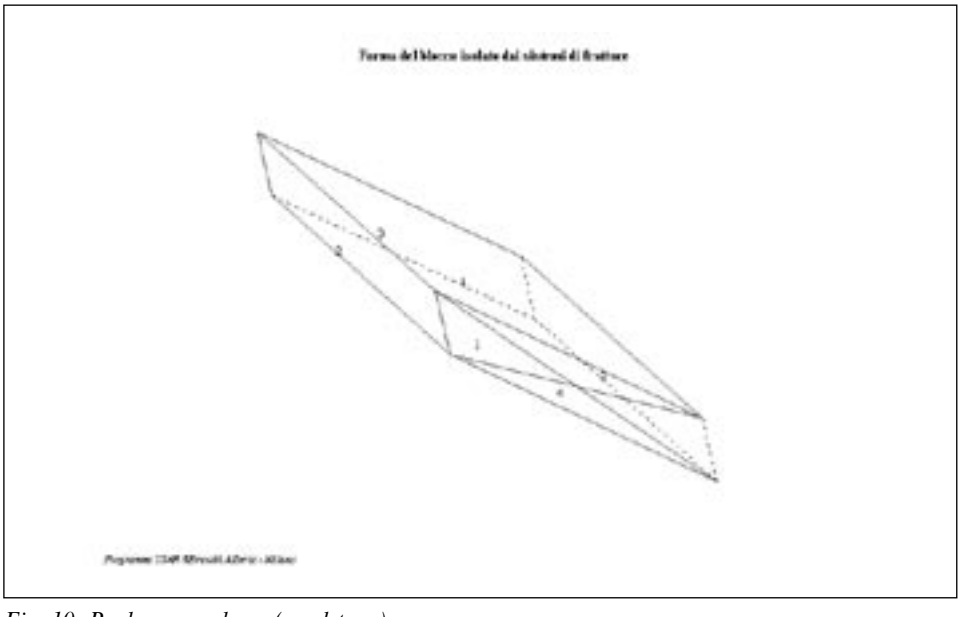


Fig. 10: Rock mass volume (sandstone).

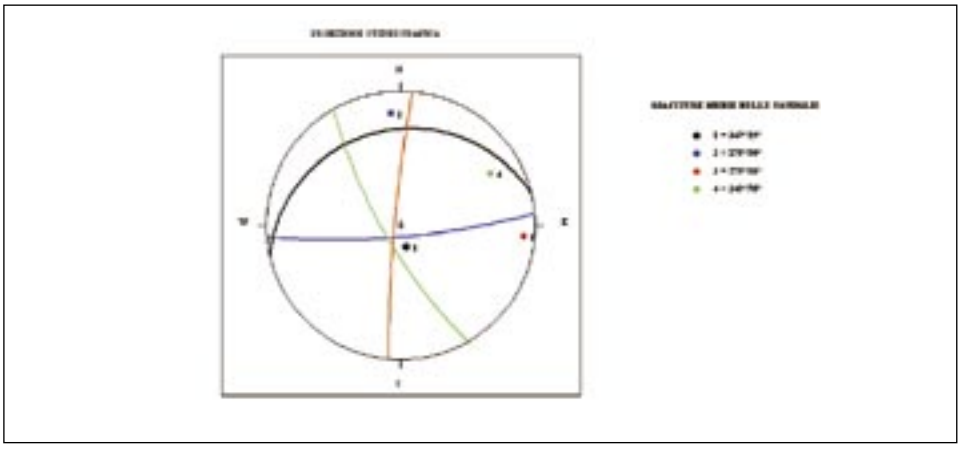


Fig. 11: Stereographic projections of discontinuities sets.

FLYSCH CAVES PATTERNS, SOME EXAMPLES:

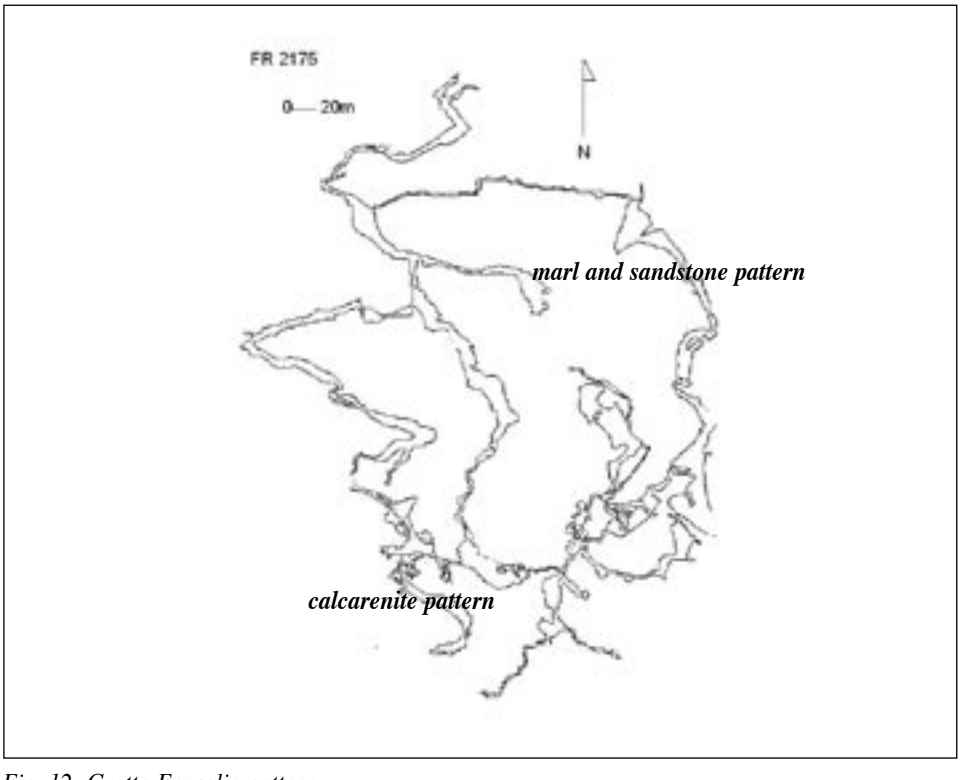


Fig. 12: Grotta Feruglio pattern.

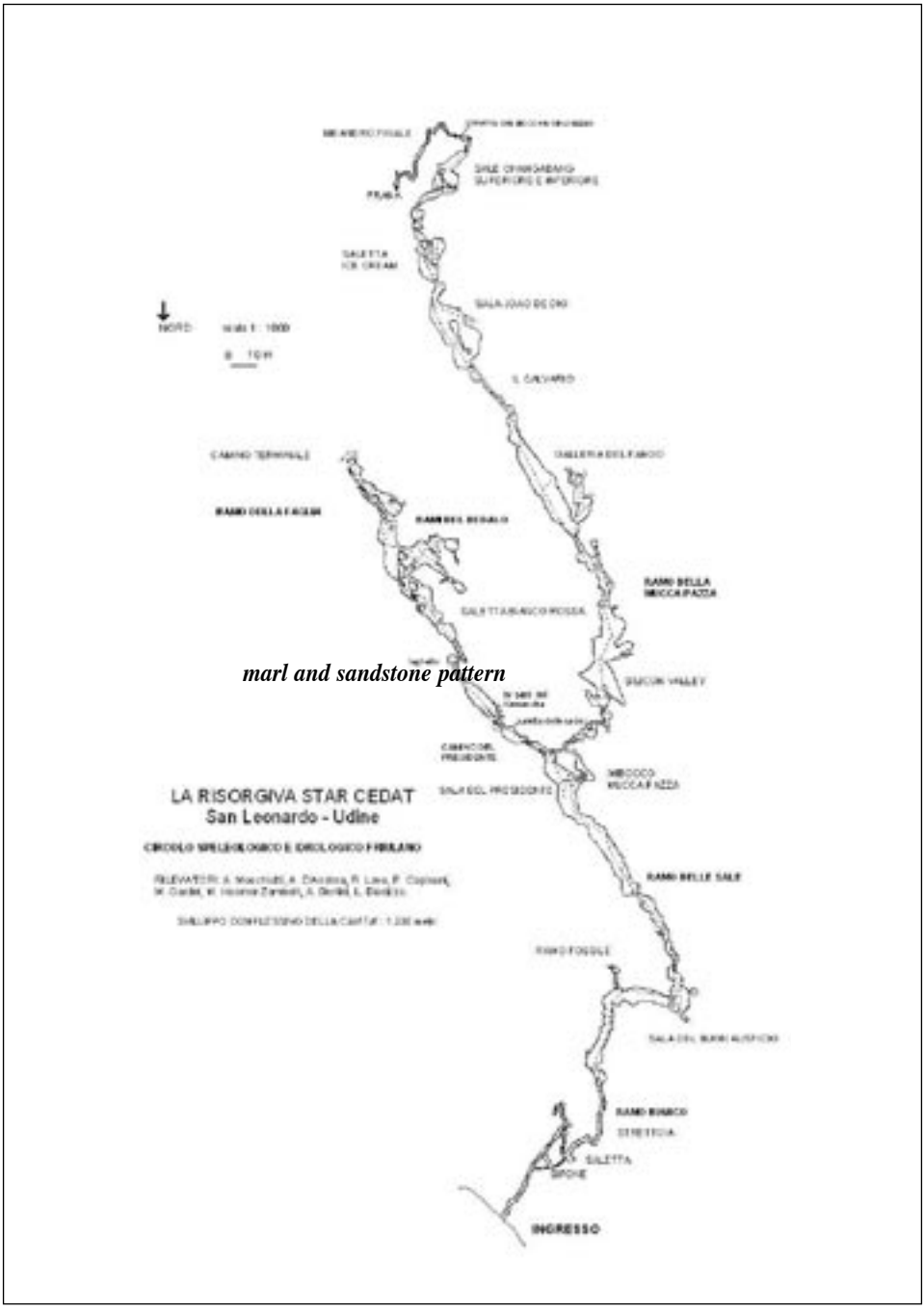


Fig. 13: Star Cadat pattern in marl and sandstone.

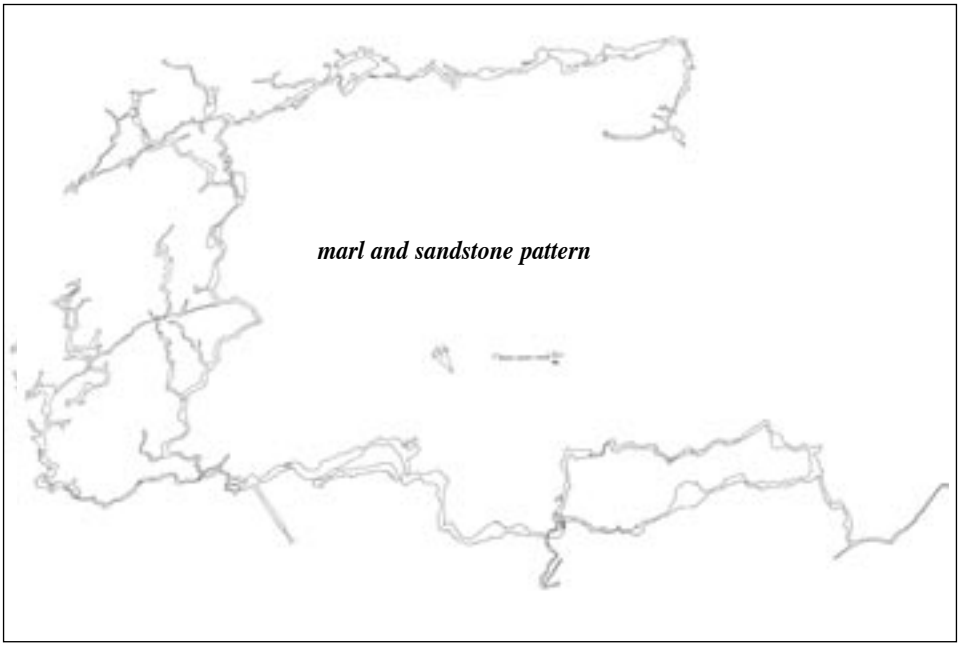


Fig. 14: Grotta Nuova di Villanova pattern.

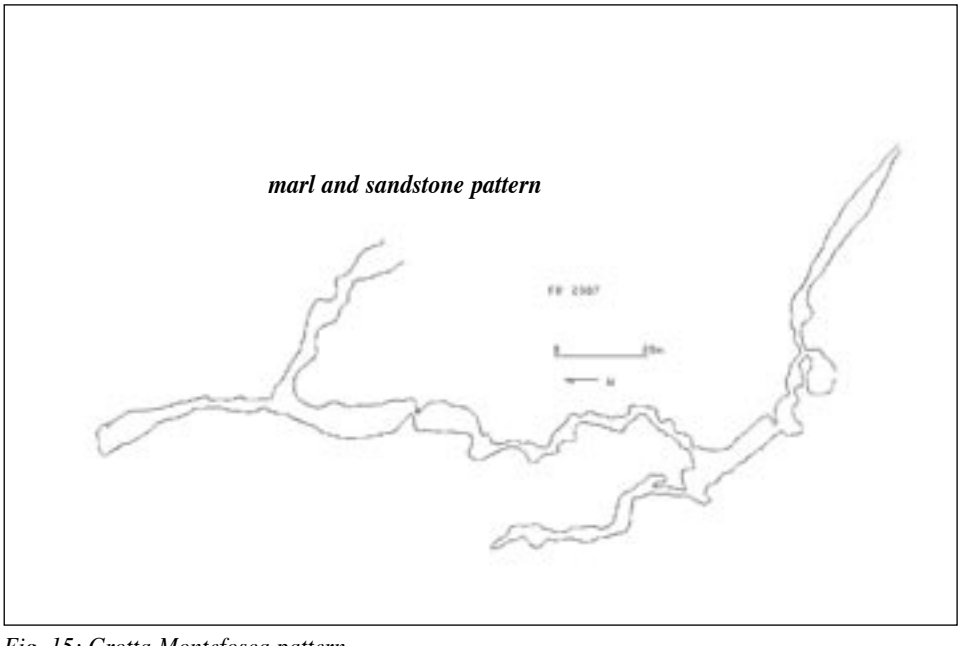


Fig. 15: Grotta Montefosca pattern.

CONCLUSIONS

The main characteristics of the karst phenomena in flysch formations have been defined within this paper.

A greater number of the caves is set up in contact between the carbonate beds and the lower marls and sandstone of the flysch.

Caves are wider and develop faster inside the marly-sandstone fraction of the flysch rather than the mere carbonates.

Caves seems to be longer in the Grivò flysch than in the Clodig flysch.

The deep range of strata usually varies from 1 to 40 degrees.

The caves plane pattern is almost always linear.

Cross sections inside caves have a rectangular or trapezium shape.

There is a wide surface karstic morphologies particularly developed on sandstone like karren and microforms.

Fig. 16: Grotta Montefosca.

ROCK MASS CHARACTERISTICS:

The rock mass has been classified as fair rock, III category according to Beiniawsky and Romana.

There is a great number of discontinuities usually parallel or orthogonal to the cave direction

Marl geomechanical conditions indicate a general detachment towards the central part of the cave (toppling) due to lithostatic pressure of the ceiling of the cave.

On the contrary sandstone and calcarenite stability is more influenced by fractures and geotecnical characteristics

Sandstone and calcarenite beds with better geotechnical characteristics are more influenced by chemical attack

CHEMICAL CHARACTERISTICS:

High carbonate content in sandstone up to 40% and sometimes in marl up to 60%

Sandstone-marl average ratio is about 0,6.

The worked out analyses indicates karst evolution on flysch formation influenced by stratigraphy, chemical composition, rock mass conditions and geotechnical values.

The karstic phenomena on flysch formations can be defined as a lithoclastic – erosive – dissolutive process.

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