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FIRST REMARKS ON LATE PLEISTOCENE LACUSTRINE DEPOSIT IN THE BERCETO AREA (NORTHERN APENNINES, ITALY)

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ABSTRACT: Bertoldi R. *et al., First remarks on Late Pleistocene lacustrine deposit in the Berceto area (Northern Apennines, Italy).* (IT ISSN 0394-3356, 2004).
During a geognostic survey performed by the *Servizio Difesa del Suolo* of the Emilia-Romagna District Administration in correspondence to the Berceto village (Northern Apennines, Parma Province), a lacustrine sequence of about 25 metres was found in the borehole Berceto SPz2.
This paper shows the preliminary results coming from the analysis of the Berceto lacustrine deposit and suggests the morphological setting that may have contributed to the origin and development of the lake.
The geological and geomorphological surveys highlight that the landslides are the prevalent processes affecting the Berceto slope. The lacustrine sequence is a part of the filling of a trench that lies behind the dormant rotational rock slide involving the upper part of the slope.
The entire core is 50 metres long. Sedimentologic, pollen and microscopic analyses, the latters carried out on thin polished sections by both optical and scanning electron microscope (SEM), together with radiocardon datings, allowed its division into 7 units and permitted us to obtain their features, ages and some inferences on their formation.
From the top to the bottom of the core, a first unit (0-4.30 m) represents material reworked by the strong anthropic use of the place. Below it, a level of peat (unit 2; 4.30-6.10 m), represents the ending of the lacustrine basin. It records a floristic phase characteristic of the middle-lower Postglacial of the Northern Apennines.
The unit 3 (6.10-9.20 m), together with the subsequent units 4 (9.20-17.00 m) and 5 (17.00-31.00 m), represent the real lacustrine deposit. The presence of laminated structures is the main feature of this sequence. Both clastic graded millimetric laminae and couplets of dark and pale clayey ones are present. They are evident in unit 5 and begin vanishing proceeding towards the top of the sequence (unit 4), being almost completely destroyed in correspondence to unit 3. The units are affected by deformations of different types (penecontemporaneous and/or post-depositional) and extent, occurred either very close or far from the water-sediment interface. The lacustrine sequence developed during the Upper Pleistocene.
Below the lacustrine deposit, a breccia (unit 6; 31.00-48.00 m) is present. It represents a weathered cover derived from the rocks outcropping in the area, subsequently involved in mass wasting processes of the slope. It is probably related to the rotational rock slide affecting the western side of the Berceto area, that may have represented the natural dam of the ancient Berceto lake. The uppermost portion of the breccia contains a clayey matrix that may have waterproofed the bottom of the lake. The last unit 7 (48.00-50.00 m) may represent the substratum of the deposit and the Berceto landslide.
On the basis of the results of the whole study, it is possible to refer the formation of the lake starting from a geomorphologic context of the Berceto slope very similar to the present one. In such a situation, the movements of the Berceto landslide determined the presence of a trench, in which the lake progressively developed. The landslide movements started in the Upper Pleistocene and continued in the Holocene up to the development of the present hollow of Berceto.

RIASSUNTO: Bertoldi R. et al., Note preliminari sul deposito lacustre tardo pleistocenico di Berceto (Provincia di Parma). *IT ISSN 0394-3356, 2004).*
Un sondaggio (Berceto Spz2) eseguito dal Servizio di Difesa del Suolo della Regione Emilia Romagna nel corso di una campagna geognostica condotta in corrispondenza del paese di Berceto, posto alla sommità di un versante a cavallo tra le valli dei Torrenti Baganza e Manubiola nel settore parmense dell'Appennino settentrionale, ha individuato una sequenza lacustre dello spessore di circa 25 metri.
Lo scopo di questa nota è di illustrare i risultati preliminari derivanti dall'analisi del deposito lacustre di Berceto e di ipotizzare, anche sulla base degli elementi morfologici dell'area, lo scenario che potrebbe aver portato alla formazione del lago.
La sequenza rinvenuta costituisce parte del riempimento di quella cha si presenta come una blanda depressione, orientata circa NNE-SSW, occupata dal paese di Berceto. La depressione è l'espressione morfologica di una trincea determinatasi nell'evoluzione della frana rotazionale quiescente in roccia che interessa la porzione altimetricamente più elevata del versante che da Berceto degrada, verso NW, fino al corso del Torrente Manubiola. Gli elementi morfologici rilevati hanno permesso di determinare come l'intera area sia interessata, prevalentemente, da morfogenesi gravitativa, che si esprime attraverso la presenza di numerose frane quiescenti di tipo complesso, condizionate dai caratteri litologici e strutturali delle rocce affioranti.
La carota recuperata nel sondaggio Berceto Spz2 misura una lunghezza totale di 50 metri. Su di essa è stata condotta una dettagliata analisi, implementata da osservazioni sia al microscopio ottico sia al SEM di sezioni sottili tagliate nelle parti della sequenza lacustre che hanno conservato le strutture più significative per l'interpretazione della genesi del deposito. Unitamente a ciò è stata condotta un'analisi palinologica preliminare del deposito e sono state effettuate una serie di datazioni radiocarbonio su materiale organico prelevato a differenti livelli entro la carota stessa.
Complessivamente gli studi condotti hanno permesso di suddividere l'intera carota in 7 unità. Dall'alto verso il basso è stata individuata una prima unità (0-4,30 m) costituita da una breccia siltoso-argillosa polimittica che è il risultato del rimaneggiamento dovuto all'attività antropica. A questa fà seguito l'unità 2 (4,30-6,10 m), uno strato di torba alla cui base è presente un sottile livello di sabbie ricco di resti vegetali. Questa unità presenta un contenuto floristico tipico del Postglaciale medio-inferiore dell'Appennino settentrionale, mentre non è rappresentata la storia paleobotanica dell'inizio dell'Olocene e quella dell'Olocene medio-superiore. Questa mancanza è forse giustificata dall'evidente rimaneggiamento dell'intero livello; infatti la torba si presenta in un cattivo stato di conservazione, con chiare indicazioni di ossidazione e frantumazione.
Con il sottostante intervallo costituito dall'unità 3 (6,10-9,20 m) compare la sequenza di chiara origine lacustre. Si tratta di un deposito massivo generalmente siltoso e localmente costituito da sabbie molto fini di colore grigio chiaro, con intraclasti di colore da grigio palli-

do a grigio scuro. La sottostante unità 4 (9,20-17,00 m) è rappresentata da un deposito siltoso, di colore grigio-giallastro, con struttura caotica. Si rinvengono livelletti costituiti da lamine chiare e scure spesso di aspetto evanescente, deformate in modo duttile e, localmente, sabbie fini contenenti resti vegetali. L'analisi dei pollini contenuti nelle due unità 3 e 4 ha permesso di ricostruire una sequenza di eventi con un certo grado di coerenza, attribuibili verosimilmente al Tardiglaciale. Il contenuto della porzione medio-inferiore del sub-intervallo palinologico definito dalle unità 3 e 4 rimanda ad un periodo con caratteristiche cilimatiche glaciali di tipo stadiale cui segue, nella parte alta, un periodo di tipo interstadiale. Datazioni radiocarbonio effettuate su campioni prelevati a 6,20 e 11,65 metri, hanno restituito valori rispettivamente di 11.150±70 ^{14}C yr B.P. e 14.480±50 ^{14}C yr B.P. e collocano le unità in periodi con condizioni climatiche come quelle prospettate dall'analisi palinologica, in accordo con le suddivisioni climatostratigrafiche per il Pleistocene superiore, proposte da RAVAZZI (2003). I caratteri delle unità 3 e 4 suggeriscono, per la loro deposizione, un contesto di ambiente lacustre caratterizzato da una certa dinamicità. In particolare è verosimile ritenere che la deposizione risenta degli effetti di fenomeni gravitativi che hanno coinvolto direttamente i depositi laminati deformandoli e della rimozione, dalle porzioni marginali verso il centro del lago, di materiale che viene risedimentato, in occasione di afflussi importanti dal bacino di alimentazione. La deformazione penecontemporanea dei depositi risulta più evidente nell'unità 3 rispetto all'unità 4.
L'unità 5 (17,00-31,00 m) è composta da lamine gradate siltose clastiche con spessori di qualche millimetro, di colore da giallastro a grigio chiaro, e lamine argillose submillimetriche di colore grigio scuro contenenti sostanza organica, cui si associano, talvolta, lamine sottilissime biancastre. Le lamine sono sempre ripiegate e interessate da superfici di taglio, con andamento da suborizzontale a ondulato, tali deformazioni risultano post-deposizionali e non si sono verosimilmente sviluppate all'interfaccia acqua-sedimento. Le lamine argillose scure si presentano come bande millimetriche di colore bruno composte di argilla, in cui compare, in maniera diffusa, materiale siltoso. L'analisi palinologica preliminare, sebbene condotta su di un numero esiguo di spettri, e la data radiocarbonio di 29.620±290 ^{14}C yr B.P., restituita da un campione prelevato a 22,50 metri, hanno permesso di collocare la sedimentazione dell'unità 5 nel Würm medio delle Alpi (RAVAZZI, 2003). Infatti in concomitanza con la glaciazione würmiana alpina, si verificò anche nell'Appennino settentrionale un massimo di espansione dei ghiacciai, ben espresso nelle valli dei Torrenti Parma e Cedra. Nella limitrofa Val Baganza, con ogni probabilità, si instaurarono, invece, condizioni prevalentemente di tipo periglaciale. Nell'unità 5 le lamine chiaro-scure sono l'espressione di fasi di deposizione in un ambiente lacustre tranquillo, determinato da una ridottissima dinamicità delle acque del lago. A queste si associano le lamine clastiche la cui deposizione è avvenuta o in occasione dei periodi di apertura del sistema lago agli influssi esterni, o in conseguenza di fenomeni di risedimentazione per scuotimento del fondo del lago in occasione dei movimenti della frana. Le pieghe e le superfici di taglio che interessano l'unità 5, testimoniano il coinvolgimento dei depositi in deformazioni legate verosimilmente a fasi di movimento della frana in roccia di Berceto.
La successiva unità 6 (31,00-48,00 m) è costituita da una breccia a clasti centimetrici angolosi immersi in una matrice siltosa. Nella parte sommitale dell'unità la matrice della breccia diviene via via più argillosa e potrebbe aver avuto il ruolo di materiale impermeabilizzante il fondo del lago, contribuendo all'impostazione di quest'ultimo. Il deposito, fortemente ossidato, dovrebbe rappresentare una coltre derivante dall'alterazione dell'originario substrato costituito da Arenarie di Scabiazza (cfr. Arenarie di Ostia), largamente affioranti nell'area, successivamente coinvolta in fenomeni gravitativi da mettere, verosimilmente, in relazione con la frana in roccia che interessa la parte sommitale del versante di Berceto.
Negli ultimi due metri il sondaggio (unità 7; 48,00-50,00 m) si è approfondito all'interno delle Argille a Palombini di Monte Rizzone, che dovrebbero rappresentare il substrato dell'intero deposito e del movimento franoso, e che in affioramento compaiono a SW dell'abitato di Berceto.
Sulla base di quanto emerso dallo studio geomorfologico del versante e dall'analisi della carota Berceto Spz2 si può prospettare che il lago si sia formato a partire da una situazione morfologica del versante di Berceto non molto diversa da quella attuale. In un tale contesto il progressivo collasso della frana in roccia avrebbe portato all'apertura della trincea nella quale si sarebbe impostato il lago. Tale scenario prevede l'inizio dell'evoluzione della frana a partire almeno dal Pleistocene superiore e la sua prosecuzione fino all'Olocene e in quest'epoca la depressione si sarebbe progressivamente colmata fino a raggiungere l'attuale conformazione

Keywords: Late Quaternary landslide, laminated lacustrine deposit, Baganza valley, Northern Apennines.

Parole chiave: frana tardo-quaternaria, deposito lacustre laminato, Val Baganza, Appennino settentrionale.

1. INTRODUCTION

During a geognostic survey performed in correspondence to the Berceto village (Northern Apennines, Parma Province) by the *Servizio Difesa del Suolo* of the Emilia-Romagna District Administration, a lacustrine sequence of about 25 metres was found in the borehole Berceto SPz2. It is part of the filling of an hollow placed in the higher part of the slope where the village lies.

The discovery of this lacustrine sequence represents a rare and very interesting finding within this part of the Emilia Apennines, particularly for its location. Indeed lacustrine deposits from different sites in the high part of the Emilia Apennines, were sampled and studied in detail, but they were, mainly, lacustrine and/or peat sequences deposited behind glacial deposits and landforms, i.e.: lateral and frontal moraine ridges (WATSON, 1996). Detailed studies on pollen sequences and radiocarbon datings allowed the identification of the main characteristics of pollen records from across the area and to examine the chronology of similar changes in pollen stratigraphy, from the Holocene to the Late Glacial, up to 12,000 yr B.P. (BERTOLDI, 1980; BERTOLDI *et al*., 1986; CRUISE, 1990; LOWE & WATSON, 1993; MONTANARI *et al*., 1994; WATSON, 1996).

Unlike these latter, the Berceto deposit is in the middle portion of the Apennines area, where aggressive geomorphological processes, due to gravity and running waters, acted during the Holocene, prejudicing against the preservation of relict landforms and deposits.

The paper shows the preliminary results coming from the analysis of the Berceto lacustrine deposit and suggests the morphological setting that may have contributed to the origin and development of the lake.

2. GEOLOGICAL SETTING

2.1 General framework

The Berceto area is situated a few kilometres north of the Cisa Pass (Fig. 1) and is therefore close to an important transversal tectonic discontinuity (i.e. the Taro System *Auctt*.) separating the northwestern Ligurian-Emilian Apennines segment from the southwestern Tuscan-Emilian segment (BERNINI *et al.*, 1997).

These two Apennine sectors mainly differ in the degree of tectonic uplift that involved them. While the NW sector is almost completely overthrust by External Ligurian Sequences (MARRONI *et al*., 2002), the SE sec-

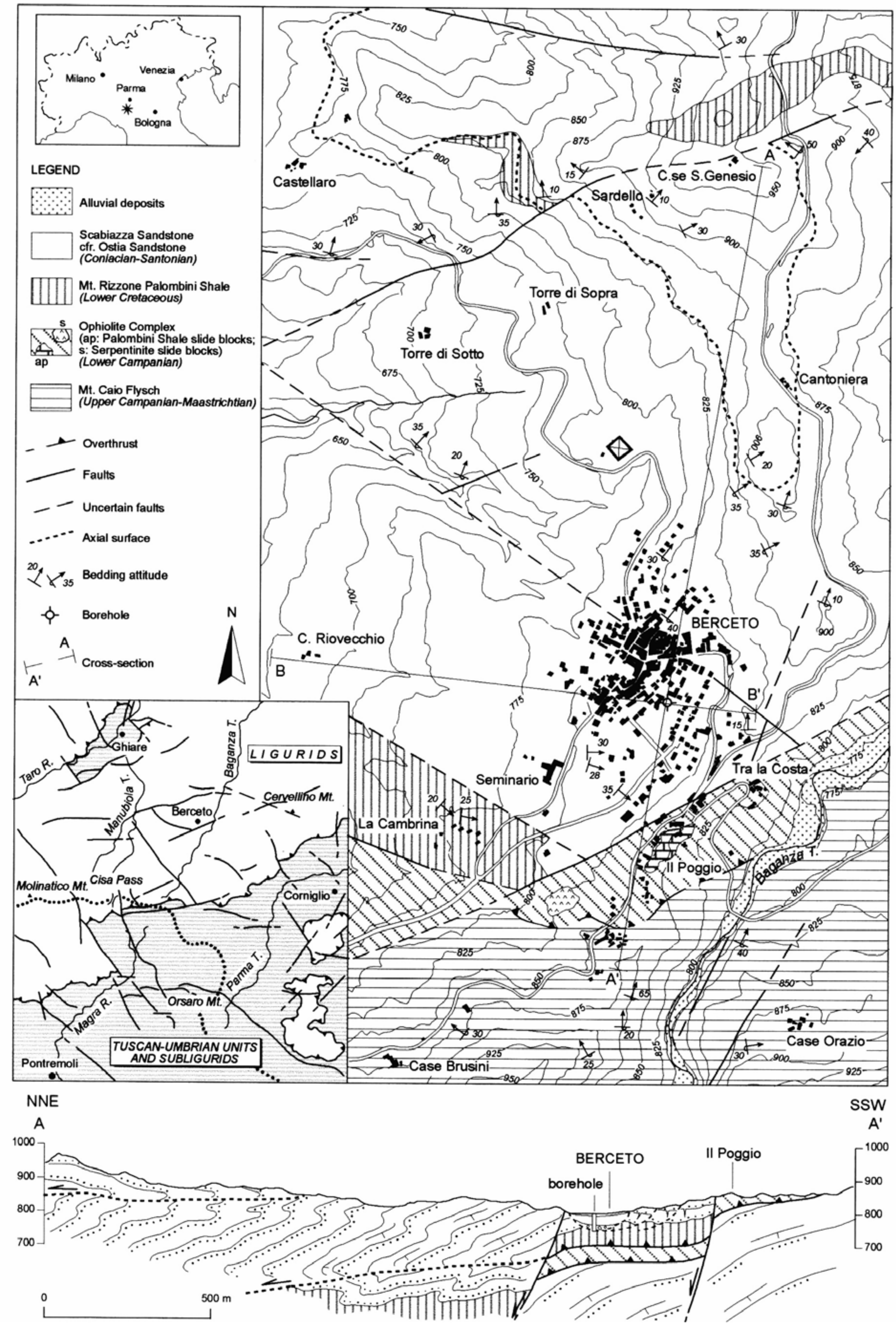

Fig. 1 - Geological map of the Berceto area (for the cross-section BB' see Fig. 3).

tor is more exhumated and amply exposes the underlying Subligurian Units and the deeper Foredeep Units characterised by a NE-verging thrusting.

The tectonic uplift of the Tuscan-Emilian segment, clearly visible in the structural feature of the Macigno outcropping along the main Apennine backbone, was formed in the Pleistocene (ARGNANI *et al*., 2003). The uplift of the backbone is accompanied by an extensional tectonic regime developing NW-SE fault systems responsible for the grabens on the Tyrrhenian side of the Apennines (BERNINI & PAPANI, 2002).

Corresponding to the Cisa Pass transversal lineament, the outcroppings of the Tuscan and Umbrian Units are interrupted towards NW by a general NW axial plunging of the folding (BERNINI & VESCOVI, 2002) and by transtensive SW-NE faults, with sinistral strike-slip components (VESCOVI, 1988).

2.2 Tectonic evolution of the Berceto area

The area of the village of Berceto, close to the divide between the torrents Manubiola and Baganza, is obliquely crossed by a high-angle fault with left-handed transpressive kinematics, and a SW-NE direction binds a tectonically uplifted area to the NW (Fig. 1).

Near Berceto, it is thus possible to identify an S-verging recumbent anticline, affecting the Scabiazza Sandstone, cut by a sub-horizontal thrust surface which formed during the NE-verging Neogene thrusting.

The recumbent anticline involving the Scabiazza Sandstone is indicated in the geological structural map in Fig. 1 illustrating its axial trace separating the normal limb of the Sardello-Case San Genesio area from the overturned limb on which the northern outskirts of the town of Berceto are situated. The stratigraphically lowest lithofacies in the unit, rich in sandstone layers, outcrops in correspondence with the normal limb, while the outcrops of the overturned limb, where the northwestern part of the village sits, are characterized by the overlying marly lithofacies. In the rest of the town, the formation is only visible in excavations and appears to belong to a normal limb uplifted by faulting. Here the Scabiazza Sandstone, which is heavily fractured, presents limited thicknesses and stratigraphically follows the Palombini Shale of Mt. Rizzone (VESCOVI, 2002), which is well exposed in an excavation located slightly SW of the Seminario (Fig. 2) and also found in the borehole drilled in the village (Fig. 1).

It is therefore clear that the main portion of the village is located on a tectonically greatly uplifted normal limb and thus heavily eroded, phenomenon which obviously also involves the underlying Mt. Caio Flysch. This uplifting developed NE-trending transtensive faulting and SSW-NNE normal faults, characterized by low magnitude of offset; also present are NW-SE trending normal faults, which are likely to fall within the framework of the extensional tectonic regime which is well developed in the Apennine inner sector. This tectonic framework provides a boundary for an area where low thicknesses of Scabiazza Sandstone overly substantially shaly units (i.e.: Palombini Shales of Mt. Rizzone and shales of the Ophiolitic Complex).

These features predisposed the gravitative movements towards NW, probably accompanied by down-slope rotational slides during the Quaternary morphogenesis evolution of the Berceto area.

3. GEOMORPHOLOGICAL SETTING

The Berceto village lies at 830 m a.s.l., in correspondence to the divide between the Baganza and Manubiola torrents, this latter being a tributary of the Taro River, and is located in the middle Apennines not far from the main glaciated terrains during the Upper Pleistocene (FEDERICI & TELLINI, 1983; GNGFG, 1988).

The Berceto slope, which runs westwards, extends between the village itself and the Manubiola

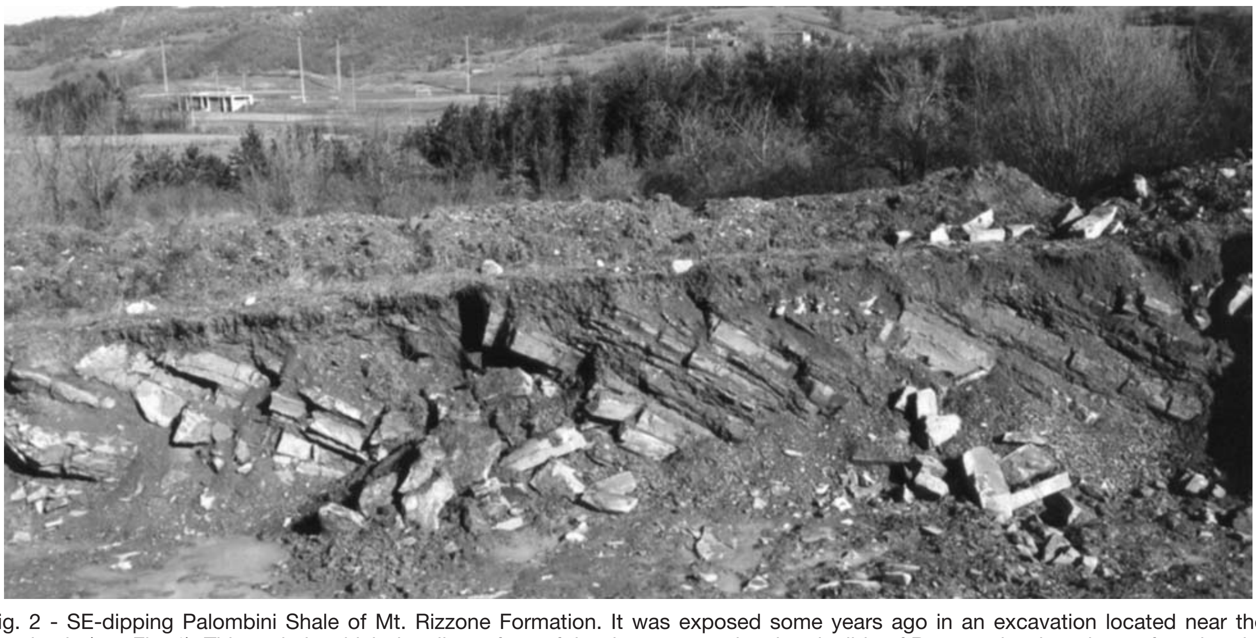

Fig. 2 - SE-dipping Palombini Shale of Mt. Rizzone Formation. It was exposed some years ago in an excavation located near the *Seminario* (see Fig. 1). This rock, in which the slip surface of the dormant rotational rock slide of Berceto developed, was found at the bottom of the Berceto Spz2.

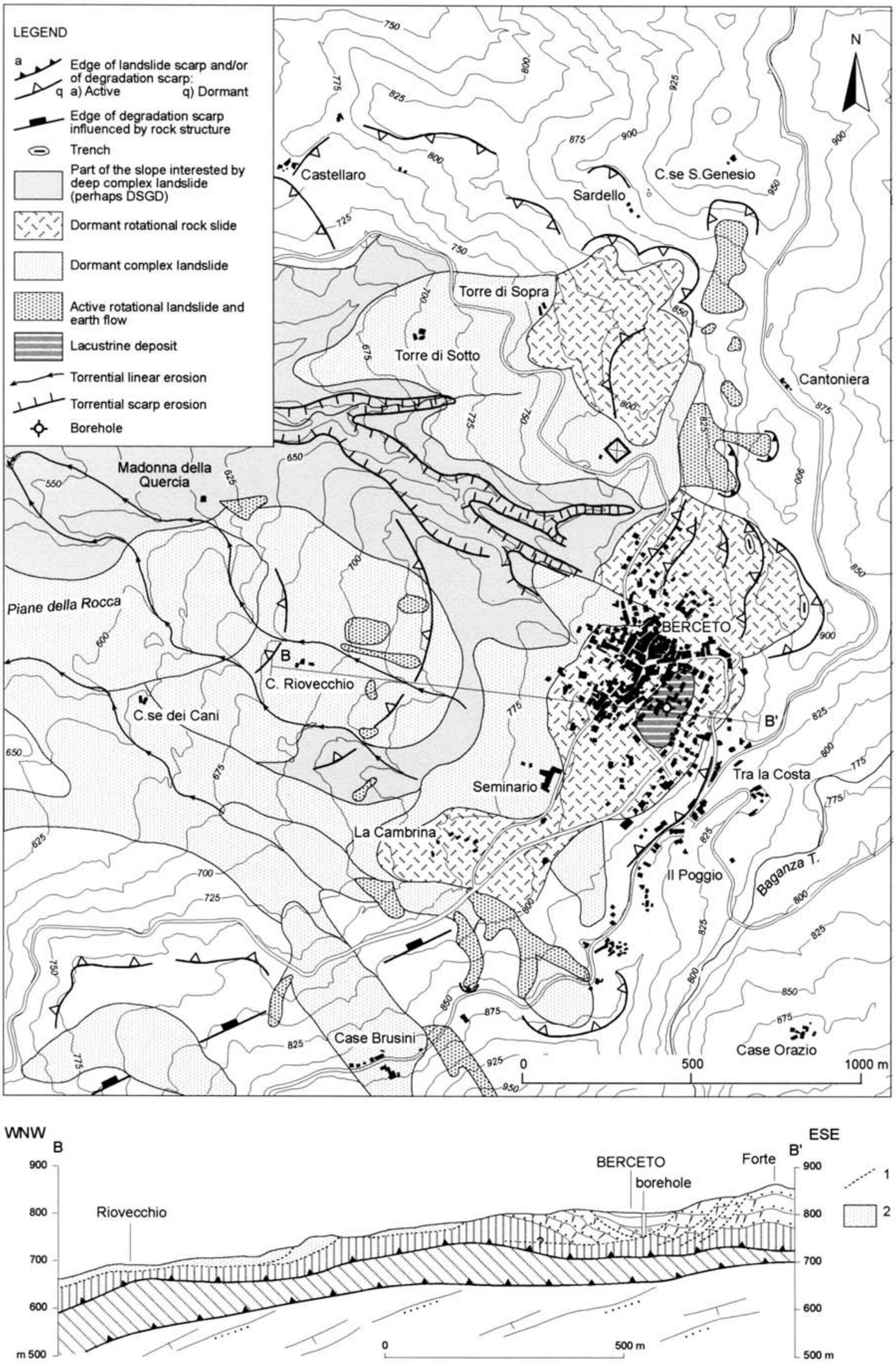

Fig. 3 - Sketch map of the main geomorphological features of the Berceto area. Legend of the cross-section BB': 1) sliding surface of landslide, 2) landslide body; for the geologic symbols used in it see the legend of Fig. 1.

Torrent, (represented in the tectonic sketch map of Fig. 1). The geomorphologic survey highlights that the landslides are the prevalent processes on it.

The most landslides, apart from some small active ones, are dormant and of complex type (Fig. 3). They are rotational and/or roto-translational slides, with relatively deep surface of movement, and earth-flows, especially in the SW part of the slope.

In the detachment area, corresponding to the divide between Manubiola and Baganza Torrents, dormant rotational rockslides involving Scabiazza Sandstone and Palombini Shale of Mt Rizzone formations prevail (Fig. 3). On these landslides lie the ancient portion and most of the new portion of Berceto village.

A mild hollow, with a long axis oriented approx. NNE-SSW and with an extension of about 30x10^3 m^2, takes up the area between the village and the divide eastwards. It represents the morphological expression of the trench behind the rotational slide. The borehole Berceto SPz2 was drilled in its centre (Fig. 3) and a core of about 50 metres was extracted.

On the right side of the Manubiola valley, the lower portion of the slope presents very slow movements. In the last years they have been monitored by GPS measurements carried out by the Society of the Cisa Motorway. Recently even researchers of the Department of Earth Sciences of Modena and Reggio Emilia University have monitored them by SAR Interferometry. These movements may be the result of a Deep Seated Gravitational Slope Deformation (DSGSD) (RONCHETTI, 2002-2003) that involves part of the slope (Fig. 3).

Some geomorphologic elements, i.e. deep torrential cuts, small trenches pulled apart from scarps and small landslides placed in correspondence with the edges of the breakdown area, are the morphological expression of the existence of this large landslide (Fig. 3).

4. THE CORE BERCETO SPZ2

4.1 Description and analysis of the Berceto Spz2 core

A detailed macroscopic analysis of the core was performed. It allowed the recognition of seven lithologic units (Fig. 4). Two metres of Palombini Shale of Mt Rizzone (bedrock) were found at the bottom of the borehole. A preliminary petrographic and mineralogical study of unit 5 was carried out on thin polished sections by both optical and scanning electron microscope (SEM). Mineral analyses were made using an electron microprobe JEOL-6400 equipped with an energy-dispersive microanalytic system; operating conditions were an accelerating voltage of 15 kV and a probe current of 0 nA. They were cut in correspondence with levels where the structures are very evident.

The detailed description of the lithologic units is shown in Fig. 4.

Unit 5 shows well-preserved laminae. Some details of these sedimentary structures are presented in Fig. 5.

In Fig. 5a a sequence of clastic and dark organic laminae is shown. The clastic laminae show a quartz rich basal portion and a gradation from coarse to fine, sometimes well visible as in (Fig. 5a (1)). Substantially, they appear as thin turbidites and are like graded beds (STURM, 1979). In the clastic laminae the SEM analyses highlighted the presence of quartz, albite, Na-Ca plagioclase, calcite, dolomite, hornblende, biotite, chlorite, muscovite, sphene, Fe-Ti oxides. The matrix of the laminae is formed mainly by mixed layers of clay minerals (illite/smectite). The minerals present in the clastic laminae reflect the composition of the rocks outcropping in the area.

In the middle part of the photograph two vanishing and discontinuous dark levels are among three clastic laminae. They represent the relicts of the clayey laminae eroded by the thin turbidites (Fig. 5a (2)). The analyses of the clayey laminae show they are mainly formed by mixed layers of clay minerals (illite/smectite), with rare grains of quartz, calcite, chlorite, illite, dolomite, ilmenite and muscovite. The grains with elongated shape are arranged parallel to the layers itself.

The same features are visible in Fig. 5b too. The basal erosional boundary of a turbiditic layer (Fig. 5b (1)) is worth noting. It is highlighted by the alignment of small vanishing bodies of dark clay and by the overlaying quartz rich portion of a turbidite lamina. In the upper part of the photograph there are two turbidite layers (Fig. 5b (2)) that show very deformed basal boundaries.

These features are well reproduced in Fig. 5c that represents the prosecution towards right of the same laminae of the previous photograph. In Fig. 5c (1) load casts are shown. They are common in the loaded surfaces and they arise from the sinking of silt into dark clay, leading to the upward injection of little clayey flame structures. In Fig. 5c (2) the dark clayey lamina deformed by the overlaying clastic bed is evident. The deformation occurred during the turbidite sedimentation of the clastic lamina, which had a current flow from the right to the left of the photograph.

Where the turbidite sedimentation did not cause the deformation of the underlying clay lamina, the detailed features of the latter are visible. Fig. 5d represents the close-up of the middle part of Fig. 5b. The presence of couplets of dark and pale laminae (Fig. 5d (1)) is clear in it. Some of the pale laminae were also analysed, dolomite and mixed layers clay minerals (illite/smectite) were found.

Fig. 5e shows detail of deformed laminae in unit 5 (Fig. 4). They are affected by folding and shear surfaces. The photograph shows the very ductile character of the deformation, connected to the plastic state of this deposit.

4.2 Pollen analysis and radiocarbon datings

The pollen analysis of the Berceto Spz2 core in the interval of depth 0-31 metres was performed. The core was sampled closely and a hundred samples were taken.

Up to now twenty samples were examined for the general recognition of the pollen contents of the sequence. They were chosen to represent the whole interval and prepared by employing the classic methodological approach of pollen enrichment. The procedures include washing with HCl, soaking in HF, Luber technique, boiling in diluite KOH followed by enrichment procedures, in particular gravitative separation

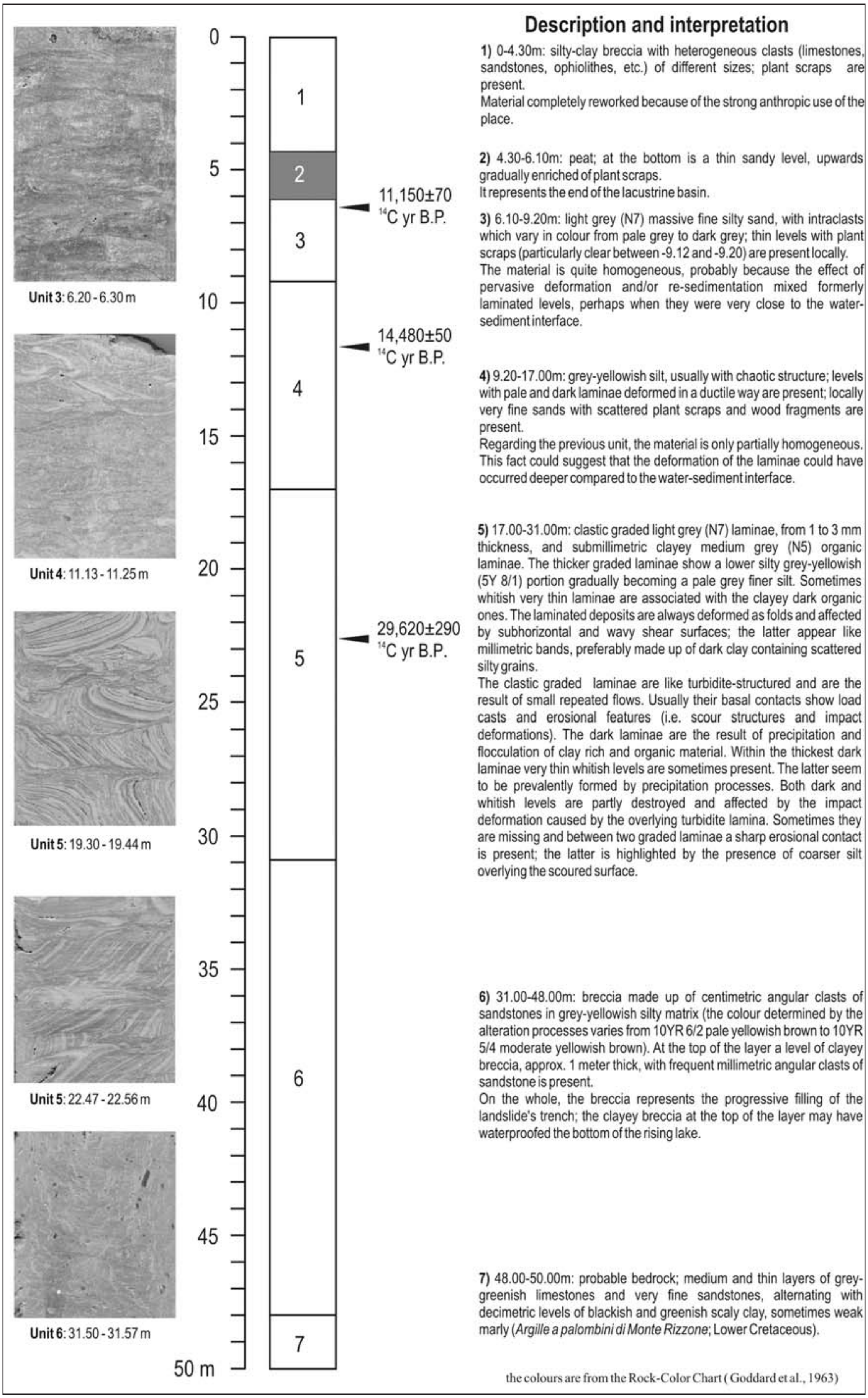

Fig. 4 - Sedimentologic characteristics of seven units making up the Berceto Spz2 core and their meaning (on the right hand), radiocarbon datings performed on organic matter (in the middle) and characteristic features of the lacustrine deposit (on the left hand) are presented.

using heavy fluids ($ZnCl_2$ at d = 2,004) and finally sonication.

On the basis of the preliminary results of the pollen analysis it was possible to delineate the first sketch of the floristic and vegetational evolution of the area and to divide the interval 0-31 metres into ***four palynological subintervals***, only partly in agreement with the sedimentologic units.

The ***first subinterval*** ranges between 0.00 and 4.40 metres. The microscopic analysis of two levels containing vegetal scraps proves the scarcity and bad state of preservation of the sporomorphs. This evidence confirms the reworking of this unit, already recognized from the sedimentological point of view.

The ***second subinterval*** corresponds to unit 2 (Fig. 4) and ranges between 4.40 and 6.10 metres. Six levels, spaced 50 cm from each other, were considered altogether. The arboreal plants (AP) prevail over the non-arboreal plants (NAP), the latter being only 20% of the pollen sum. Within the AP *Abies* clearly prevails, being represented by more than 40% of the total amount. *Quercus*, sometimes accompanied by rather low values of *Tilia* and *Ulmus*, shows lower percentages than 20%, except for the spectrum where the oaks are dominant on the silver fir. *Pinus* shows continuously decreasing percentages (from 20% to 8%) from the bottom to the top of the subinterval, whereas *Betula*, *Corylus*, *Alnus*, *Populus* and *Salix* show very low values. *Fagus* is present only in the uppermost spectrum.

The sporomorphs appear to be badly preserved in every level, especially those of *Abies*. They are dark brown, corroded, degraded and crumpled. The microscopic examination reveals that the remains of peat are represented by amorphous dark brown organic matter, almost completely oxidized. Nevertheless, frequent remains of vessels of broad-leaved trees, scarce findings of fibre-tracheids of conifers and rare cellular aggregates of epidermis-type are present.

The ***third subinterval*** ranges from 6.10 to 17.00 metres, enclosing sedimentologic units 3 and 4 (Fig. 4). Twelve samples regularly distributed along this part of the core were examined. In every spectrum the AP prevails, with *Pinus* clearly dominant. The herbaceous flora (NAP) is qualitatively and quantitatively rich. The main types such as *Artemisia*, Chenopodiaceae, Gramineae, Compositae, *Helianthemum*, Caryophyllaceae, etc., are always present and show positive and negative fluctuations.

A significative difference is recognizable between the spectra corresponding to the uppermost metre of the subinterval and those of the part below. In the former comparatively plentiful pollen grains of *Betula*, *Abies*, *Quercus* and *Corylus* are present together with *Pinus*. In the latter the arboreal flora is qualitatively poorer: only scarce findings of *Betula* and *Picea* are present, together with *Pinus. Ephedra* and *Juniperus* are almost always present.

The ***fourth subinterval***, from 17.00 to 31.00, corresponds to sedimentologic unit 5 of Fig. 4. Up to now only four out of about fifty spectra have been analysed, nevertheless some remarks can be made.

The pollen flora (AP + NAP) seems qualitatively and quantitatively poorer compared to the previous subinterval. *Pinus* becomes predominant and few other types of pollen from pioneer plants (*Ephedra, Juniperus, Hippophae*) are represented. Rare grains of *Betula* and *Picea* are present.

Organic matter was extracted from different levels of the core and then submitted to Beta Analytic Inc. (Miami, Florida, U.S.A.) in order to perform radiocarbon datings.

At the level of very fine sand, just below the boundary between units 2/3, a sample containing scraps of plants was extracted at 6.20 metres. It supplies a date of 11,150±70 ^{14}C yr B.P. corresponding to 13,390-

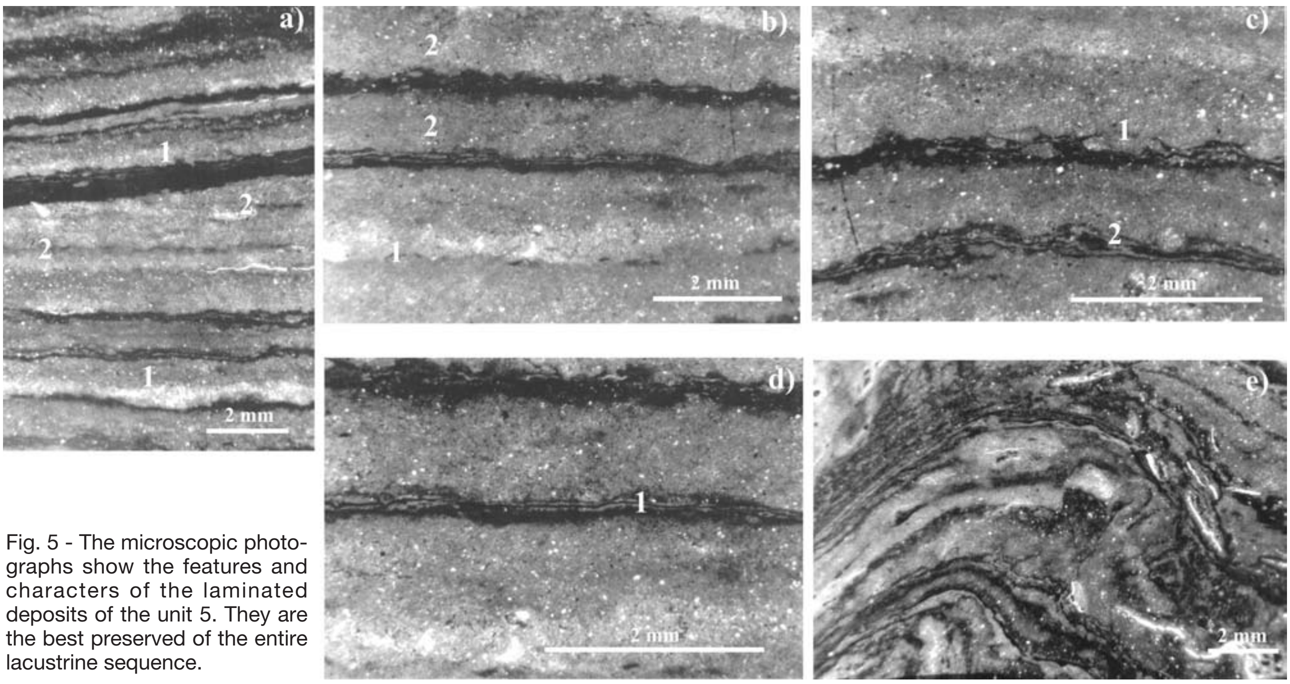

Fig. 5 - The microscopic photographs show the features and characters of the laminated deposits of the unit 5. They are the best preserved of the entire lacustrine sequence.

13,240/13,220-12,900 cal ^{14}C yr B.P. (Beta 178882). In unit 4 a sample was extracted at 11.65 metres. It contained scraps of plants and small wood fragments. It provides a date of 14,480±50 ^{14}C yr B.P., 17,705-17,000 cal ^{14}C yr B.P.(Beta 181866). Finally organic matter was extracted at 22.50 metres from a dark lamina in unit 5. It supplies a date of 29,620±290 ^{14}C yr B.P. (Beta 181867).

Although the results of the pollen analyses are still preliminary in type, they show a sequence of floristic-vegetational events, which permits the possibility of reconstructing the climatic evolution of the area, corresponding to an interval of the Upper Pleistocene-Holocene period, even if with some gaps, especially in the upper part.

Indeed the first subinterval (corresponding to unit 1 of Fig. 5) suffered a hard reworking which did not give any meaningful result from pollen analyses and the second one (corresponding to unit 2 of Fig. 5) presents wide gaps. The latter records a floristic phase characteristic of the middle-lower Postglacial vegetational development of the Northern Apennines (BERTOLDI, 1980; LOWE & WATSON, 1993), as proved by the well-known prevalence of *Abies* and the almost complete lack of *Fagus*. Furthermore, they seem to lack the onsets of the Holocene and undoubtedly of the middle-upper Holocene paleobotanical history. On the other hand, the bad state of preservation of the sporomorphs together with the remains of peat clearly oxidized and broken up mean that the peat level likely underwent one or more events of reworking.

The results obtained from the pollen analysis of the third subinterval appear to be more organized. Well-preserved pollen grains permitted the reconstruction of a sequence of events. The pollens of the flora and vegetation of the higher part of the subinterval are characteristic of interstadial periods, likely of the Lateglacial interstadials, whereas those of the lower part of stadial ones. This evidence is supported by the radiocarbon datings performed on the samples at 6.20 and 11.65 metres. Indeed, the dating of the first sample is referable to the late glacial interstadial of the climatostratigraphic subdivisions proposed by RAVAZZI (2003), deriving from the improvement of the chronostratigraphy of the Late Glacial from OROMBELLI & RAVAZZI (1996). The dating of the second sample refers to the "early late glacial" (RAVAZZI, 2003), corresponding to the Oldest Dryas, in which more than one glacial stadial are reported for the different sectors of the Alps (MAISCH, 2000).

At present, few remarks can be made on the fourth subinterval. The small number of the pollen spectra analysed does not permit us to characterize it completely from the floristic and vegetational point of view. Nevertheless, the analyses performed highlighted a paleo-environment of glacial type, as the radiocarbon dating at 22.50 metres confirms. Indeed, it is included in the middle-Pleniglacial stadial-interstadial phase of the Alps (RAVAZZI, 2003) when also in the Northern Apennines the glaciation took place, e.g. in the close Parma valley the glaciers had the great development (FEDERICI & TELLINI, 1983).

4.3 Remarks on the sequence of the core

The borehole reached the Palombini Shale of Mt Rizzone outcropping close to Berceto (Fig. 1). It goes down two metres in this formation which represents the bedrock (Fig. 4).

Above the bedrock, there is a breccia (unit 6 in Fig. 4) that in our opinion represents a weathered cover derived from the Scabiazza Sandstone, and subsequently involved in mass wasting processes of the slope. This deposit is probably related to the rock block slides involving the western side of the Berceto area (Figg. 1 and 3), which may have represented the natural dam of the ancient Berceto lake. The uppermost clayey breccia may have waterproofed the bottom of the lake.

Above the breccia, the lacustrine laminated sequence (unit 5 in Fig. 4) begins. Most of the laminae show clastic graded texture and represent small repeated turbidite events. They may record either the sediment influx from the catchment to the lake or the flows from the marginal parts of the bottom of the lake. The dark and pale laminae are probably produced by precipitation and flocculation of clay-rich material, during periods characterized by the lack of coarse clastic inputs.

The above unit 4 (Fig. 4) does not show a regular laminated structure but vanishing dark and pale laminae are still visible. These features testify to the existence of the previous sedimentary structure of the material in the same way as in unit 5.

In the following unit 3 (Fig. 4) the deformation is more pronounced, the original laminated structure is almost destroyed and the material is rather homogeneous.

On the whole, the sequence of units 5, 4 and 3 shows an increased deformation from the bottom to the top. This may be related to a unique important dynamic event or a sequence of different ones. In any case, the deformation was registered by these units in different ways. The deepest unit 5 records the deformation forming folds and shear surfaces, whereas in the upper units (4 and 3), closer to the water-sediment interface, the laminae were almost completely destroyed.

The overlaying unit 2 (Fig. 4) represents the ending of the lacustrine basin, passing from a thin sandy level to peat.

Finally, unit 1 (Fig. 4) records no stratigraphic features, because of its complete reworking. This situation was determined by the strong anthropic use of the place, especially in the 20th century.

5. FINAL REMARKS

The geological and geomorphologic surveys of the Berceto area highlighted the presence of a dormant rotational rock slide involving the area of the village, responsible for the trench at the top of the slope.

The analyses (sedimentologic, pollen and microscopic analyses) performed on the Berceto Spz2 core allow us to put forward some remarks on the meaning of the different parts of the deposit filling the trench.

In our opinion, the peat (unit 2 in Fig. 4) represents the last deposit filling the hollow. Despite the bad state of preservation both of the peat and of the above unit 1, the pollen analysis of the former allows us to refer its starting at least to the lower-middle Holocene (Boreal-Atlantic?).

The units 3, 4 and 5 (Fig. 4) represent the real lacustrine deposit. The radiocarbon dating and pollen analyses of unit 3 reveal that it deposited during the Lateglacial, probably during an interstadial period. In this latter, the lack of well-defined laminae, the massive appearance of the deposit and the presence of intraclasts suggest that the deposition was in a dynamic environment. The sedimentation may be linked either to the occurrence of landslides and/or mass wasting, directly involving laminated lacustrine deposits, or to the re-sedimentation of fine material in the central part of the lake. This latter occurrence could be linked to the re-mobilization of laminated deposits from the marginal parts of the lake, because of the impact from the renewed coarse sediment influx from the catchment to the lake.

The great similarity of the sedimentologic features between units 3 and 4 may lead to the assumption that they were involved in the same processes. Nevertheless, the possibility to recognize, in unit 4, even vanishing dark and pale laminae suggests a lower extent of the deformation. Indeed in our opinion, in unit 4 both penecontemporaneous and post-depositional deformations are present. This latter occurred when the sediment was more coherent and far from the water-sediment boundary.

Unit 5 represents the most interesting part of the lacustrine deposit. The small post-depositional folds and the shear surfaces, affecting the laminae, testify to the fact that the deposit was involved in both compressive and, likely, extensive deformations. In our opinion, these deformations may have occurred during the different phases of movement of the landslides of the Berceto slope. The sedimentologic features, together with the radiocarbon dating (29,620±290 ^{14}C yr B.P.) and the pollen analyses, suggest that the deposition was concomitant with climatic conditions of a glacial type, when in the area studied, periglacial ones were likely established. The dark and pale laminae could be the result of quiet sedimentation, perhaps decantation, linked to a dynamic of the water reduced to the minimum. The situation responsible for the formation of clastic laminae presents itself again. They either represent events of sedimentation of very fine clastic material that formed when the lake-system opened, and the sediment influx from the catchment occurred, or re-sedimentation in the occurrence of landslides activity, when the movement caused the re-mobilization of the unconsolidated sediment of the bottom of the lake.

The knowledge we currently have about the laminated lacustrine deposit does not allow us to put forward definite data concerning its meanings as regards the biological and geochemical response to factors leading to their formation. Nevertheless, the evidence on the laminae allows us to make some remarks.

The nature of the laminae, their composition and the relationships between them prove that they are clastic laminations (O'Sullivan, 1983). The couplets of dark and pale laminae are structured like varve, but it is early to advance any inference about their real meaning as annual or seasonal layered deposits. This is clear if one considers that the formation of clastic varves is very sensitive to the sediment influx and mechanisms of transport within the lake. Particularly it is regulated by the flush of the first peak discharge of the season, whose behaviour does not assure that couplets of laminae represent true varves but rather longer and shorter time intervals (Anderson & Dean, 1988). In addition, the possibility of re-sedimentation of sediment complicates the state further. In any case, even if the laminae could be considered varves they pertain to the non-glacial ones.

Unit 6 is the deepest recognized within the Berceto Spz2 core. As reported above, it is a breccia containing very weathered material from a fine facies of the Scabiazza Sandstone and it could represent either the filling of the Berceto landslide trench or an older eluvial cover. The upper part of the unit becomes rich in very fine matrix that allowed its waterproofing and the birth of the lake.

On the basis of this evidence and their meaning, we advance the hypothesis that the formation of the lake started from a geomorphologic context of the Berceto slope very similar to, although obviously not exactly the same as, the present one. In such a situation, the Pleistocene movements of the Berceto landslide determined the presence of a trench, in which the lake progressively developed. The landslide movements continued up to the Holocene and they drove to the development of the present hollow of Berceto. Essentially, the Berceto lake may be related to the dynamic of this landslide. This latter started in correspondence of the middle period of the last glaciation of the Northern Apennines and continued to develop through the Late Glacial. Analogous ancient landslide was already reported in the middle Parma valley (Carobbio landslide; 25,129±160 ^{14}C yr B.P., 17,330±110 ^{14}C yr B.P., Tellini & Chelli, 2003).

The study of Berceto Spz2 core is still in progress especially for the part concerning the real lacustrine deposit (units 3, 4 and 5 in Fig. 4). In our opinion, the detailed study of the sequence may provide useful proxy data to investigate the palaeoclimatic conditions of this part of the Northern Apennines. This information could also be important in the definition of the climatic factors, such as periods of increased rainfall, forcing the phases of activity of the Berceto slope landslides, contributing to the study carried out on this topic in the last few years for the Emilian Apennines (Bertolini & Tellini, 2001; Tellini & Chelli, 2002; 2003).

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This paper is the synthesis of the work and reflections of all the Authors, but each worked on a specific

part of the paper. P. Vescovi took care of the geological setting of the area, while A. Chelli and C. Tellini dealt with the geomorphologic setting and the landslides of the Berceto area. The description, analysis and interpretation of the Berceto Spz2 core is the result of the work performed by A. Chelli, C. Tellini and P. Vescovi together. R. Bertoldi and R. Roma dealt with the pollen analyses and their paleoclimatic interpretation. The opinions of all the Authors are synthesized in the final remarks.

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