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# SEDIMENTS OF SMALL LAKES ALONG CREEKS IN NORTHERN APENNINES (NW-ITALY) AS EVIDENCE OF ANCIENT SLOPE INSTABILITY

**Abstract**: Dagnino D. & Montanari C., *Sediments of small lakes along creeks in Northern Apennines (NW-Italy) as evidence of ancient slope instability.* (IT ISSN 0391-9838, 2015).

In the last decades the erosion of some creeks in the Ligurian Apennines has revealed sediments of stagnant waters rich in plant remains. These small "fossil lakes" represent the effects of phases of slope instability that caused barrages from landslides at different times, since at least 10,000 BP until the 19$^{th}$ century. This paper presents a review of studies in the central Ligurian mountains concerning the formation of temporary ponds along streams, which is documented for different sites in this area for prehistoric times, the Middle Ages and later. It also aims to deepen - by means of biostratigraphyc analysis - the knowledge of a site along the creek Rio Dell'Orso, near the village of Senarega (710 m, Scrivia Valley, NW-Italy). There, erosion has exposed sediments of a disappeared lake, containing logs, branches and pollen. A small basin has formed, after a landslide that had dammed the stream in prehistoric times, for an estimated period of about three centuries. Radiocarbon dating allowed to attribute the deposits to a period around 4000 BP. More than 40 branches and trunks were identified and pollen analysis was carried out. Among the macroremains, silver fir (*Abies*) clearly prevails in number and size; also *Fagus and Fraxinus* were identified. Even within the pollen assemblages, unfortunately rather badly preserved, the silver fir is dominant in all layers. These data are consistent with what is known about the Holocene history of the Ligurian Apennines: also the upper Scrivia Valley was long characterized by forests dominated by silver fir with beech, which were still widespread throughout the region until the Roman period and the Middle Ages.

Key words: Biostratigraphical archives; Palaeolakes; Landslides; Archaeobotany; N-Apennines, NW-Italy.

**Riassunto**: Dagnino D. & Montanari C., *Sedimenti di laghetti scomparsi lungo torrenti dell'Appennino settentrionale come tracce di instabilità dei versanti.* (IT ISSN 0391-9838, 2015).

Nell'Appennino Ligure, negli ultimi decenni, l'erosione di alcuni torrenti ha messo in luce depositi di acque stagnanti più o meno ricchi di resti vegetali. Queste tracce di "laghetti fossili" rappresentano gli effetti di fasi di instabilità dei versanti che hanno causato frane di sbarramento in epoche diverse, da 10.000 BP al XIX secolo. Questo contributo offre una panoramica dello stato dell'arte per i rilievi della Liguria centrale e approfondisce, su basi biostratigrafiche, le conoscenze sul sito di Senarega (710 m, alta Valle Scrivia, Genova): presso questo piccolo borgo medievale, l'erosione del Rio dell'Orso ha messo in luce un antico deposito lacustre costituito da circa un metro di sedimenti contenenti tronchi, rami, polline. Datazioni radiocarboniche permettono di riferire questi sedimenti ad un periodo intorno a 4000 BP. Un piccolo bacino deve essersi formato in seguito ad una frana che ha sbarrato il corso del torrente in epoca preistorica, per un periodo stimato di circa tre secoli. Più di 40 tra rami e tronchi sono stati identificati e sono state condotte analisi polliniche di quattro livelli. Tra i macroresti di specie arboree, *Abies* prevale nettamente per numero e dimensioni; altre essenze identificate sono *Fagus* e *Fraxinus*. Anche nell'ambito dei complessi pollinici, piuttosto mal conservati, l'abete bianco risulta prevalente in tutti i livelli. Questi dati concordano con ciò che si sa della storia olocenica dell'Appennino Ligure per la cronologia di attribuzione: anche questa valle, come la vicina Val Vobbia, più a SW quelle del gruppo del M. Beigua e tutto l'Appennino settentrionale, è stata a lungo caratterizzata da abetine con faggio che nell'Età Romana e nel Medioevo erano ancora ampiamente diffuse in tutta la regione. Anche il fenomeno della formazione di laghetti temporanei lungo i torrenti è abbastanza documentato per queste aree, dalla preistoria al Medioevo e anche più recentemente.

Termini Chiave: Archivi biostratigrafici; Laghetti fossili; Paleofrane; Archeobotanica; Appennino Ligure; *Abies*.

## INTRODUCTION

Events of environmental instability (e.g. slope instability, landslide, alluvial phenomena) seem to be increasing in Italy over recent years and in some cases their effects are catastrophic. These events are usually attributed to recent climate changes, which can in turn be ascribed both to natural climate cycles and human activity. Similar episodes have surely occurred even in the mid-late Holocene, a period

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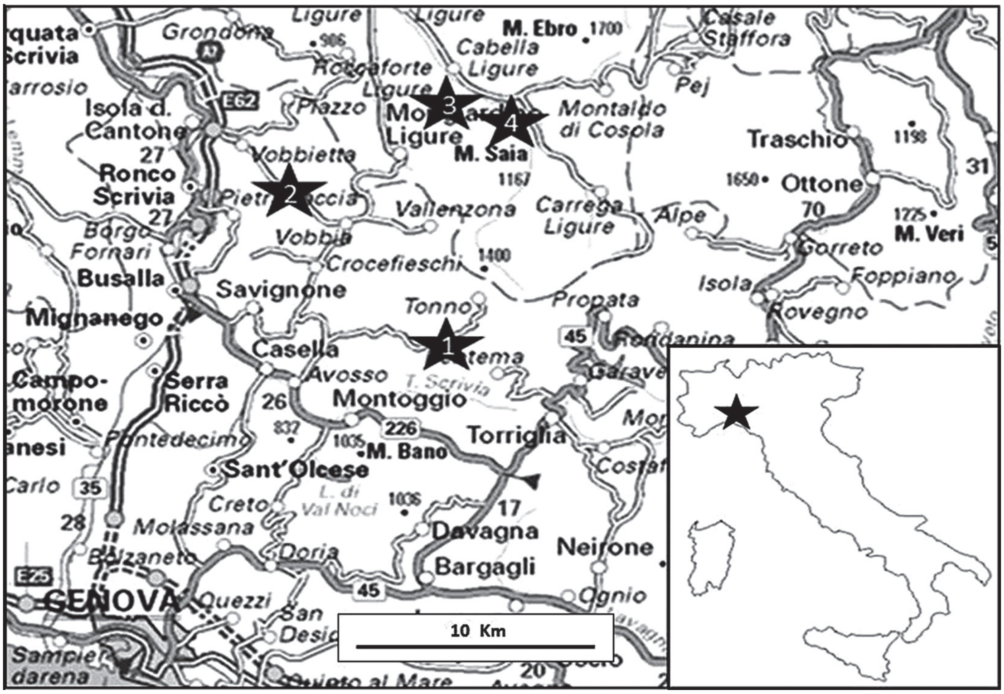


FIG. 1 - Location of the sites where evidence of disappeared small lakes are known in the Ligurian Apennines: 1) Senarega; 2) Ponte di Zan; 3) Gordenella; 4) Daglio.

characterized by very high climatic variability (Mayewski & *alii*, 2004). For ancient times, when no written documentation is available, methods of palaeoecology can be used besides the classical geologic-geomorphologic approach (e.g. Magaldi & *alii*., 2007). Palaeoenvironmental reconstructions, based both on geological and biological evidence, can establish correlations within natural phenomena, geographical and geomorphological features, human activities, trends, recurrent events. Landslides are obvious signs of slope instability and therefore they are important subjects of study by geologists, geomorphologists and applied geologists. Actually, also biostratigraphic research and particularly archaeobotany proved to be a rich source of information on past environmental dynamics, especially with regard to the dating of the events and the reconstruction of the environment in which they occurred. The evidence of past slope instability often consists of ancient silty-clayey lacustrine sediment interposed within recent coarse alluvial cover, along riverbeds; these small "fossil lakes", that represent barrages of the watercourse, are often rich in plant micro- and macro-remains, so they are very interesting palaeoenvironmental archives. In this paper we review the state of the art about a few cases of palaeoenvironmental reconstruction from sediments of landslide-dammed palaeolakes in the central Ligurian Apennines (NW Italy); furthermore, a case study that until now has been presented only to a limited audience is illustrated in detail (Dagnino & Montanari, 2012).

## GEOLOGIC AND GEOMORPHOLOGIC SETTING

The upper Scrivia Valley (Ligurian Apennines, NW Italy) is characterized by turbidites both calcareous and pelitic-arenaceous from Upper Cretaceous (Calcari di Monte Antola and Flysch di Busalla, respectively) and late and post-orogenic deposits of the Tertiary Piedmont Basin from the Oligocene (conglomerates and sandstones), named Conglomerati di Savignone (Giammarino & *alii*., 2002). The hydrographic network shows a rejuvenation in the present sediments of the riverbeds (Cortemiglia & Pedemonte, 2005), due to erosion that highlights a deepening trend of the main stream and of some secondary basins (Vobbia, Gordenella, Agnellasca, Brevenna). This process has brought to light some ancient lacustrine deposits caused from landslides which had dammed the riverbeds at different times, at least from 10,000 BP until the 19th century (fig. 1) (Montanari & *alii*, 1985; Cortemiglia & Pedemonte, 2001, 2005; Cortemiglia & *alii*, 2004). Also the examination of historical documents reveals a number of landslides that caused damage to buildings and farmland in this area (Pedemonte & *alii*, 1995), and still today the upper Scrivia Valley shows a lot of landslides, variables for their size, even not always in relation to water courses (http://geoportale.regione.liguria.it//geoviewer/pages/apps/repertorio/repertorio.html?id=492).

## REVIEW OF PREVIOUS STUDIES IN THE UPPER SCRIVIA VALLEY (NW-ITALY)

In upper Scrivia Valley several sites have been recorded in which fine lacustrine sediments are deposited in torrential riverbeds after the formation of palaeolakes due to landslides (fig. 1). Along the Vobbia creek, a tributary of T. Scrivia, at an altitude of c. 400 m a.s.l. near the "Ponte di Zan" and the medieval castle Castello della Pietra, sediments of a disappeared lake have been described and studied both for their geologic-sedimentologic features and biostratigraphic ones (Montanari & *alii*, 1985) Palynological and macrofossil analyses have highlighted the persistence of forests dominated by silver fir (*Abies*), beech and deciduous meso-thermophilous broadleaves along a profile of about 3 meters of sandy silt. A dating from wood remains (4461 ± 50 uncal. BC, Montanari & *alii*, 1985) had attributed these sediments to the Neolithic period, in agreement with the regional paleoenvironmental history known at that time. In the same paper, also a study of recent pollen deposition was carried out in the surroundings of the site, in order to refine the interpretation of the palaeo-palynological data: this has shown good congruence between recent pollen deposition and the composition of current vegetation (Montanari, 1989; Guido & Montanari, 1991; Guido & *alii*, 1997-99). Further investigation in the same site (Cortemiglia & Pedemonte, 2001), after the flood of 1999, has shown a conifer trunk about 16 metres long dated to 11,190 cal. BP (cal. 9250 BC - Beta 143343-Rsd), embedded in coeval clayey sediments (11,200 cal. BP, 9250 cal. BC - Beta 145740-Rsd), with apparent varves. This dating is much older than the previous one, suggesting that the fossil conifer woodland dates back to the Late-Glacial period. Therefore, some doubts arise about the accuracy of the more recent date, if we admit a single landslide for this site; nevertheless they both agree with the Late-Glacial and Holocene history of the silver fir in this area (see below). As the authors underline, the sliding-surface of the palaeo-landslide is visible at present on the left river slope, downstream of the palaeo-lake sediments (fig. 2). Taking into account the difference of altitude, there are several subsequent studies that seem to agree with this chronology: at Mogge di Ertola (Aveto Valley, c. 1100 m a.s.l.), pollen, wood and charcoal evidence of silver fir dated since 10,000 cal. BP testify its spread even at higher altitudes at the beginning of the post-glacial period (Guido & *alii*, 2013), and the same happened elsewhere in the Ligurian Apennines (Branch, 2004).

Near the hamlet of Gorreto (Gordenella Valley, Alessandria, fig. 1) at an altitude of 520 meters a.s.l., the fluvial erosion has exposed silty sediments deposited as a result of damming from landslide, which took place in the Middle Ages (Cortemiglia & *alii*, 2004; Cortemiglia & Pedemonte, 2010). The thickness of the lacustrine sediments is at least 350 cm, which were deposited during three centuries. Preliminary wood and pollen analysis has demonstrated the existence of an open forest cover, mainly composed of deciduous meso-thermophilous broadleaves (*Ostrya*, *Quercus* decid., *Corylus*, *Fraxinus*, *Alnus*) and beech (*Fagus*). Sweet chestnut (Castanea) was probably cultivated in the surroundings. Among the conifers, *Abies* and *Pinus* were recorded.

Based on two conventional radiocarbon datings, performed the first at the top of the sediments (800±50 BP, cal. BP 790-660 (95% prob.), Beta 178801) and the second 80.5

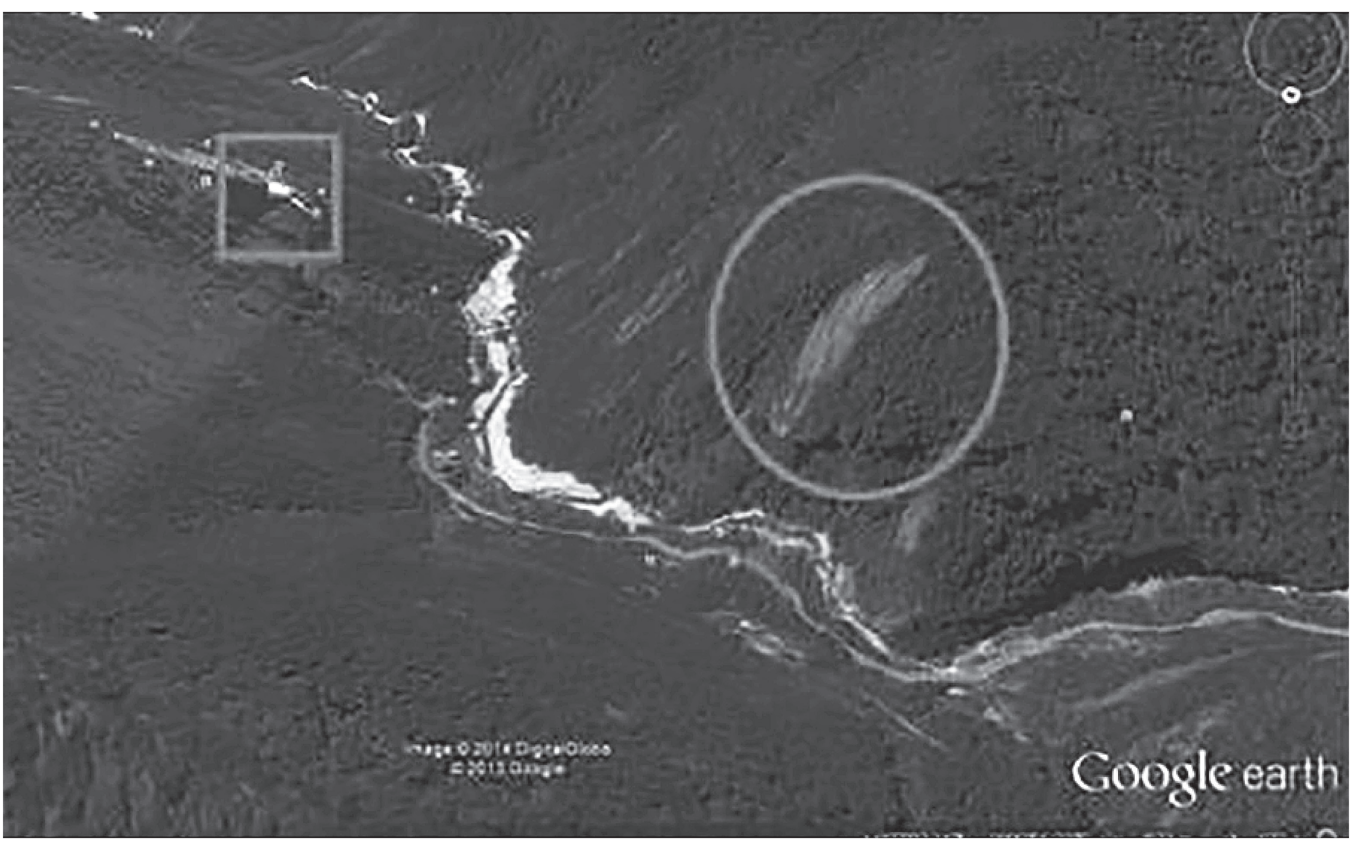


FIG. 2 - Vobbia Valley. Just downstream of the Castello della Pietra (on the right bank, in the box), is clearly visible in the left bank a sliding surface probably connected to the ancient landslide that blocked the stream around 13,000 BP (in the circle on the right).

Table. 1 - Main features of the lacustrine sediment samples from Senarega

| Sample | Depth (cm) | Dry weight (g) | Colour (Munsell soil color charts) | Description |
|---|---|---|---|---|
| S2 | 240 | 2,97 | 10YR 8/1<br>10YR 3/2 | Grey clay, with pointed small pebbles included |
| S1 | 210 | 1,56 | 7,5YR 6/2<br>7,5YR 3/2 | Brown clay |
| S3 | 165 | 2,26 | 10YR 7/2<br>10YR 4/2 | Brown clay (embedding the dated trunks) |
| S4 | 125 | 3,61 | 10YR 5/1<br>10YR 3/1 | Grey sand |

cm lower (870±60 BP, cal. BP 930-680 (95% prob.), Beta 178800), we can locate the end of the sedimentation in the High Middle Ages, in a climatic phase just prior to the modest cooling of the Little Ice Age. Also in this case, clues of the ancient landslide which dammed the course of the creek have been identified.

Near the village of Daglio (Agnellasca Valley, Alessandria), in the mid-nineteenth century, a pond now disappeared was formed twice along the course of the creek Carreghino, at an altitude of c. 580 m a.l.m., due to landslides (fig. 1). At the confluence of the Rio Robè, the toponym "Cappella del Lago" (literally "Lake Chapel") and a small aedicule, in addition to a large detachment niche, are nowadays the sole witnesses of a temporary basin which probably lasted only a few years (Pedemonte & *alii*, 1995). Another report concerns a small pond which would have formed around the 9th century along the creek Seminella (Busalla) (Cortemiglia & Pedemonte, 2010).

## NEW DATA FROM THE SITE OF SENAREGA

### Study area

The site of Senarega was reported for the first time by Cortemiglia & Pedemonte (2005) and later it was presented from a palaeobotanic point of view to a limited audience (Dagnino & Montanari, 2012). It belongs to the Brevenna Valley, a secondary basin of Scrivia Valley, that is mainly characterized by limestone substrate (Giammarino & *alii*., 2002). The studied lacustrine sediments are located to the east of the village of Senarega, in the riverbed of the Rio dell'Orso, a right side tributary of the T. Brevenna, at an altitude of 710 m a.s.l., and they extend for a little more than 60 m in a stretch, where the creek flows towards the North (fig. 1 and fig. 3).

### Features of the sediments

The lacustrine sediments are about 1 m thick, and the layers are inclined by 37° with respect to the current bed.

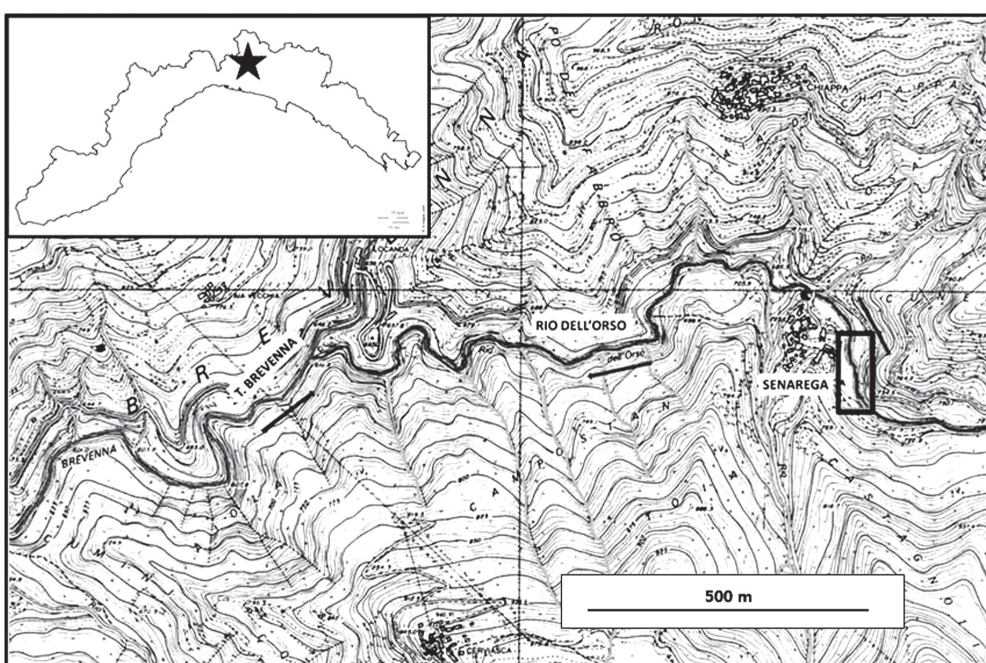


Fig. 3 - Location of the studied site, along the Rio dell'Orso, near Senarega; the area of the finding of lacustrine sediments is included in the rectangle.

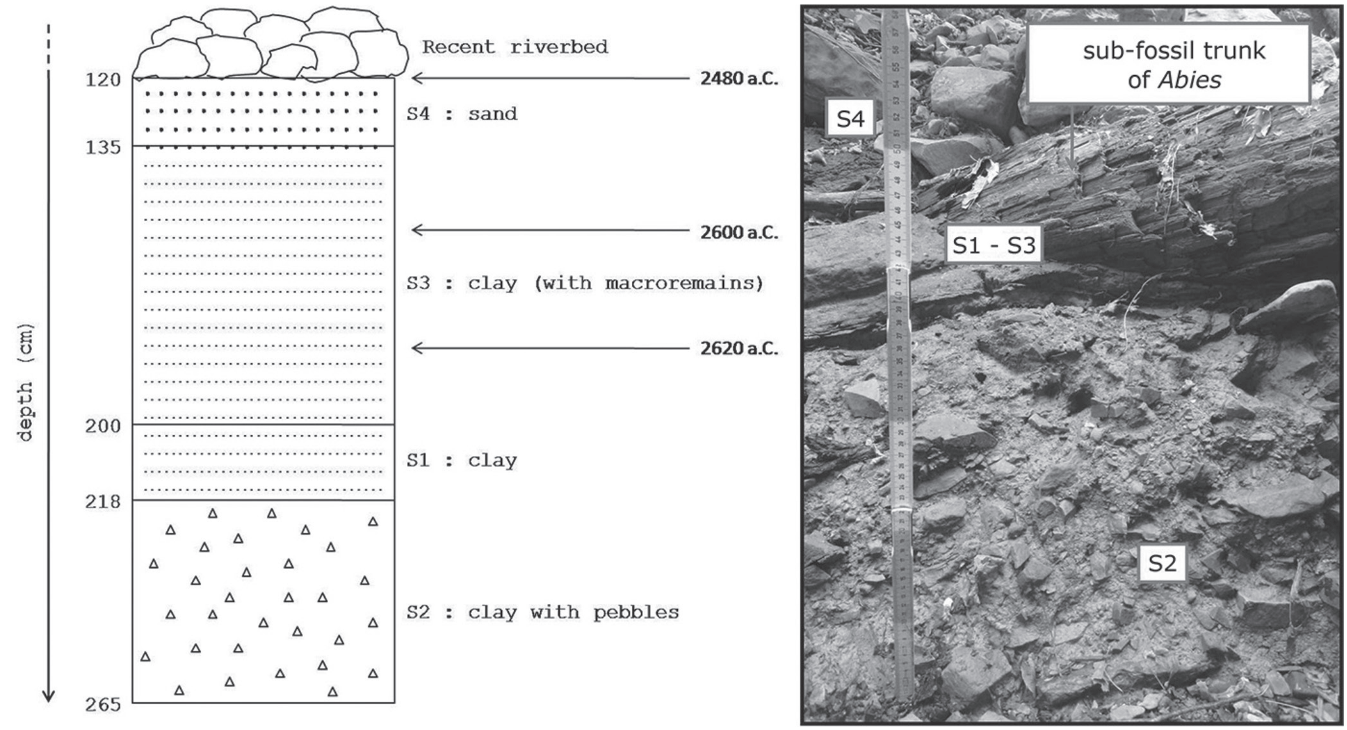


FIG. 4 - Stratigraphic column of the sediment outcropping (left) and a photograph of a representative section of the column (right) in which the deepest layer (S2) is clearly visible, characterized by coarse material embedded in a fine matrix and probably connected to the landslide event which resulted in the formation of the pond.

The top of the sequence is placed at a depth of 120 cm with respect to the surface of the current pebble riverbed. Starting from the top, a sandy layer 15 cm thick is observed; the bulk of the sediment appears instead as a rhythmic deposit of siltyclay layers 1-2 cm thick, alternating with thin deposits rich in organic matter 0.5-1 cm thick; therefore, several varves can be easily recognized locally (fig. 4). In the main part of this package of sediments (from 135 to 200 cm depth) numerous plants macroremains crop out; they are tree trunks and branches, driven parallel to the sediment layers. The deepest part (200 to 218 cm depth) instead is constituted solely by silt deposit. At the base of the pack of lake sediments a colluvial slope deposit is found, consisting of eterometric (1-10 cm) sharp limestone stones, that are embedded in a clay-silt matrix. This layer has an average thickness of 50 cm (218 to 260 cm depth).

Three calibrated radiocarbon dating are available; they were performed on wood samples of silver fir that were located at the top of lacustrine sediments, at 35 and 55 cm deep respectively. These data allowed to date the upper layer of the sediment (from 120 to 175 cm depth) to a period between 2480 BC and 2620 BC, whereas the total duration of the phase of lacustrine sedimentation is estimated to be about 300 years (Cortemiglia & Pedemonte, 2005; Cortemiglia, 2012).

## MICROREMAINS ANALYSIS

Four sediment samples for pollen analysis were taken from the section, approximately 100 g each (from the deepest, named $S_2$, $S_1$, $S_3$ and $S_4$; tab. 1; fig. 4). For the extraction and concentration of palynomorphs the standard methodology has been employed (treatment with HCl, HF, NaOH, Na hexametaphosphate, Moore & Webb, 1983). The pollen sum for the calculation of pollen percentages includes only plants from dry environments (TLP, Total Land Plants), in order to avoid possible over-representation from wetland plants. The pollen concentration was calculated as FPA (Absolute Pollen Frequency), i.e. in relation to the dry weight of the sub-samples used (Accorsi & Rodolfi, 1975).

## MACROREMAINS ANALYSIS

A lot of plant macroremains were found along the part of the riverbed which showed lacustrine sediments. They consisted of trunks and branches, even rather large (a few metres), brought to light by the fluvial erosion. All wood macroremains embedded at least partially in the sediment and visible at the time of the survey (2011) were numbered, photographed and sampled; therefore, the collection must be considered as bulk, unlike that for pollen analysis; however, as mentioned above, the trunks are prevailingly contained in the layer $S_3$ (fig. 4); overall we have collected and examined 46 wood samples (each of few $cm^3$). Moreover, some lightly burned wood remains were observed.

## RESULTS

The pollen analysis has focused on samples $S_2$, $S_1$ and $S_3$ (fig. 5 and fig. 6); sample $S_4$ is omitted in the diagram, being

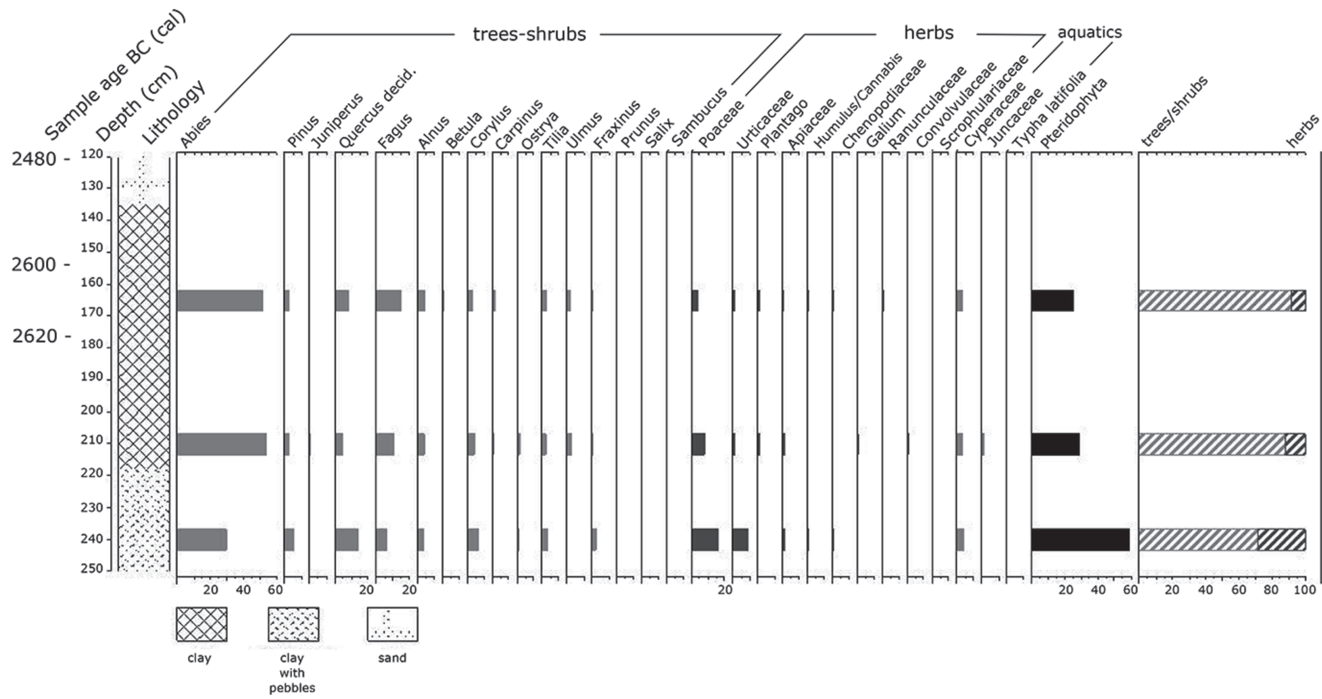


Fig. 5 - Pollen diagram: histograms represent percentages of selected pollen taxa, divided into three levels examined (S3: 165 cm depth; S1: 210 cmdepth; S2: 240 cm depth). The last histogram refers to the percentages of tree, shrubs and herbs.

very poor in pollen. In all the samples, however, the pollen grains were scarce and poorly preserved, making it difficult their identification, in some cases. The corrosion of pollen can be attributed to fluctuations in the water level of the river, resulting in exposure to air and oxidation of the grains contained in the sediments.

Overall, we identified 926 grains (588 of which are terrestrial angiosperms - Total Land Plants, TLP). The modest pollen concentration (FPA) allows to obtain statistically reliable information for those samples for which the counts have achieved at least a few hundreds of grains ($S_1$, FPA = 6560; $S_3$, FPA = 10326), while the results must be considered indicative for $S_2$ (FPA = 1935).

The pollen analysis has allowed the identification of 30 taxa, consisting of 16 trees/shrubs and 14 herbs (the latter comprising three hygro-hydrophilous taxa and the group of Pteridophyta, which were excluded from the pollen sum). In each levels the percentage of tree species were greater than 70%, and the most abundant species was *Abies*; this is confirmed by the finding, during the pollen analysis, of a lot of microscopic wood fragments with anatomic features corresponding to silver fir, and by macroremains.

The analysis also included non-pollen palynomorphs (NPP), fairly abundant in the samples (fig. 6): we found some fungal spores, among which *Ustulina deusta* type was very abundant and also *Alternaria* and *Cirrenalia* were found.

Microcharcoals, unlike the pollen grains, were very abundant in all levels, in particular those belonging to the class size between 10 and 50 µm. The level richest in microcharcoal is undoubtedly the deepest, $S_2$.

Xilological analysis has been carried out on 46 wood samples. They were attributed to three taxa, namely Abies (24 samples), Fagus (14 samples) and Fraxinus (6 samples); only two samples remained unidentified, due to their poor state of preservation.

## Paleoenvironmental reconstruction

The pollen analysis has shown that the vegetation of the valley was to be a forest, with a clear dominance of conifers (*Abies* and, in lower amount, *Pinus* cf. *sylvestris*). Deciduous trees always maintained a secondary role, and were represented mainly by *Quercus* deciduous and *Corylus*; nevertheless, considering its under-representation in the pollen record (Montanari, 1989; Guido & Montanari, 1991; Guido & *alii*., 1997-99; Guido & Montanari, 2004), *Fagus* had to be one of the main deciduous trees. The forest vegetation was probably rather closed, given the scarcity of herbaceous species, consisting mostly of Poaceae; the abundance of Cyperaceae and Juncaceae indicates the occurrence of hydrophilous vegetation along the shores of the palaeobasin. Ferns (Filicales) were very abundant, and often are the main herbaceous component; the recurrent discovery of sporangia suggests that ferns were present locally or along the waterway.

Xilological analysis detected the dominance of *Abies*, confirming what has been observed with the palynological analysis. Based on macroremains, other abundant species in the forest had to be *Fagus* and *Fraxinus*. The latter, however, is found more as wood macroremain than in pollen spectra: a certain pollen under-representation can be expected for *Fraxinus ornus* (flowering ash), which, unlike F. *excelsior*

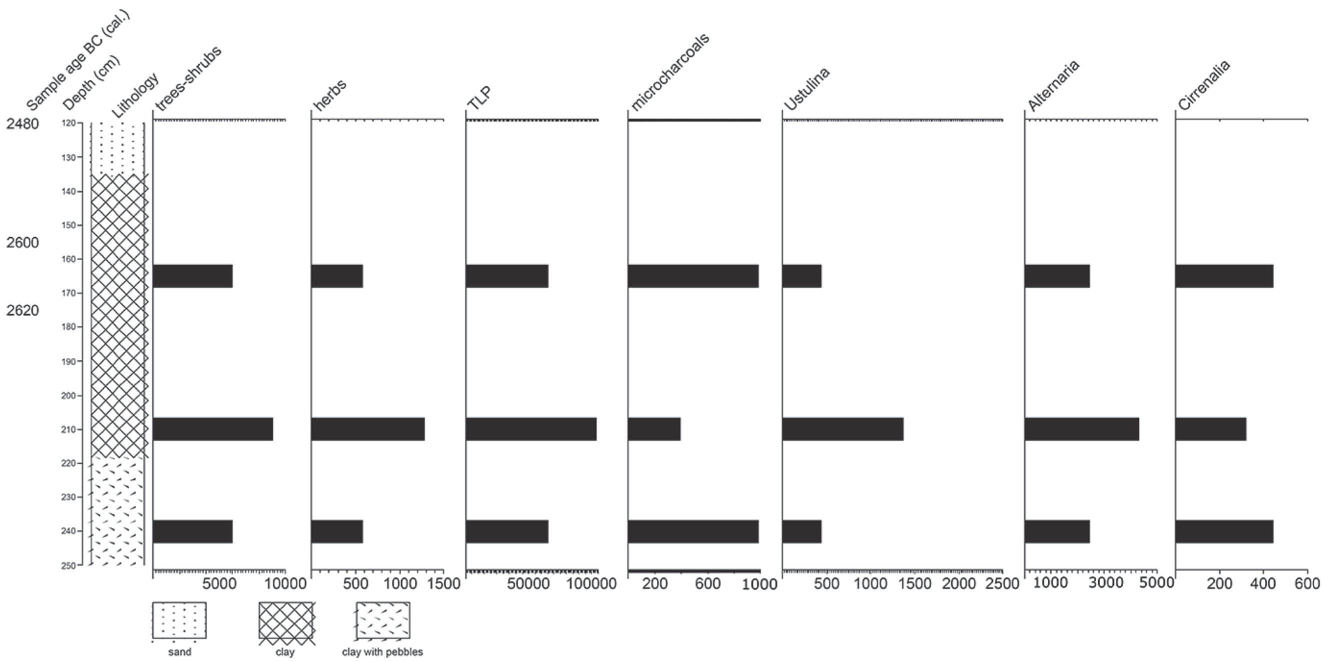


Fig. 6 - Diagram of pollen concentration: the histograms represent the concentration of pollen grains, the NPPs and microcharcoal, divided into three levels examined (S3 - 165 cm depth; S1 - 210 cm depth; S2 - 240 cm depth).

(ash), has predominantly entomophilous pollination (Guido & *alii*. 1997-99); nevertheless, on the basis of wood anatomy, the two species cannot be distinguished.

The overall picture, then, refers to a fir woodland with beech, which lasted throughout the sedimentary series.

Although the overall palaeoenvironmental image is rather homogeneous in the three levels, the deepest one (S2) was significantly richer in microcharcoal and poorer in pollen; this level refers to a silt deposit with abundant angular small pebbles which is probably an evidence of the material deposited during the landslide responsible for the formation of the ancient pond. So the abundance of microcharcoals may be an indication of fire that would have partially destroyed the fir-woodland, exposing the soil to erosion and probably contributing to cause the landslide; however, the small size of the carbon particles and the fluvial context imply the possibility of fluvial transport from afar. Moreover, in the same level, ascospores of *Ustulina deusta* are markedly more abundant: this fungal parasite causes soft rot in many tree species, including all of those found in the analysis, such as *Abies alba* (Van Geel & Aptroot, 2006; Menozzi & *alii*, 2010; Guido & *alii*, 2013). Though its find is very common in the Holocene deposits, higher percentages are in some cases related to the presence of many infected trees (Van Geel, 1978; Van Geel & *alii*, 1981; Menozzi & *alii*, 2010). So this parasitic fungus could have contributed to the weakening of the silver fir before the formation of the pond (Montanari & Guido, 2011).

In the other two levels the presence of microcharcoals is still good, although lower than in the deepest one; the simultaneous presence of abundant microcharcoals and the presence of burned wood may be related to the fire assumed for the deepest level.

## DISCUSSION

The events that have led or accompanied the formation of these small temporary ponds along several rivers of Liguria can be easily framed in the regional Holocene history. At present, we have a lot of data, mostly palynological, but also relating to macroremains (wood, charcoal) that bear witness to a complex history, either climatic and biological and of human exploitation of environmental resources. The relationships that can be suggested between the formation of these ephemeral ponds and paleoenvironmental events are mainly to landslides, forest fires and anthropogenic management of vegetation and geomorphology.

Interestingly, the palaeoenvironmental reconstructions of the sites described above are in agreement with each other and with the new case study of Senarega. For example, despite the most recent dating of the Vobbia Valley sediments is doubtful and the altitude is significantly lower (400 against 730 m a.s.l.), the palaeoenvironmental picture obtained from pollen analysis is similar, except for the lower amount of beech, in Vobbia pollen spectra.

Extensive palynological studies carried out in other parts of Ligurian Apennines (Cruise, 1990; Branch, 2004; Guido & *alii*, 2004; Molinari & *alii*, 2008; Cruise & *alii*, 2009; Guido & *alii*, 2009; Guido & *alii*, 2013) have repeatedly documented the role of silver fir as dominant woodland species in sediments related to ages between 11,500 and 2000 years

BP. However, in most recent sediments the presence of *Abies* is increasingly rare. The comparison with the present vegetation, consisting of thermophilous deciduous forests which, at these low altitudes, lack altogether both *Abies* and *Fagus*, can suggest a cooler and wetter climatic context than the current one, for the periods in which the ponds were depositing these sediments. Silver fir can thrive even a few metres above sea level (Giacobbe, 1950) and there are a lot of evidences that suggest a wider range of habitats occupancy in the past for this species (Montanari & *alii*, 1997; Colombaroli & *alii*, 2007; Mariotti Lippi & *alii*, 2007; Bellini & *alii*, 2009; Guido & *alii*, 2013). Nonetheless, silver fir has dramatically reduced its distribution in the midlate Holocene. Some authors placed the beginning of Abies disappearence around 6000 BP for different regions of Europe (Tinner & *alii*, 1999; Keller & *alii*, 2002; Wick & Möhl, 2006; Colombaroli & *alii*, 2007; Bellini & *alii*, 2009; Savelli & *alii*, 2013). However, this process took place gradually, so there are abundant remains of silver fir in more recent sediments (e.g. Senarega site), and up to the Middle Ages (Branch & *alii*, 2003; Guido & *alii*, 2003; Guido & *alii*, 2013). It was suggested that some local extinctions of silver fir were due to increasing of fire activity (Tinner & *alii*, 2000; Colombaroli & *alii*, 2007) and human activity (Maggi, 2000; Carcaillet & Muller, 2005), also in very recent times (Vrška & *alii*, 2008). Nevertheless, even climate may have played an important role in the decline of silver fir; in particular it was detected a climate trend towards aridification and warming over the last three millennia (Sadori & *alii*, 2013), but some authors demonstrated an earlier beginning of the aridification phenomena, such as 5500 BP ( Jalut & *alii*, 2009) and 7700 BP (Peyron & *alii*, 2011). However, sites like these small streams, with a particularly humid mesoclimate, seem less useful for general climatic comparisons.

Elsewhere, in central Italy, a case of a watercourse dammed by an ancient landslide has been recently detected and studied with similar methods, for the mid-Holocene (Savelli & *alii*, 2013); in that case, however, the sediments were much more thick and the lake lasted over seven thousand years, owing to the formation of a stable dam of calcareous breccia (8990-8550 cal BP); the cause of the slope instability was attributed there to an increase in precipitation at a continental scale.

Several investigations on the climatic implications of landslide recurrence have been described in literature on various European regions, among which, in particular, are Austria, Great Britain, Italy, Norway, Poland, Spain and Switzerland (Soldati & *alii*, 2004). Although some situations of increased landslide activity in the mid-late Holocene are attributed to human activity (e.g. Dapples & *alii*, 2002; Polemio & Lonigro, 2013), it is possible to think about a correlation between climate instability and landslides triggering during the Holocene. This time interval, indeed, was characterized by very high climate variability (Zak & *alii*, 2002; Mayewski & *alii*, 2004; Drysdale & *alii*, 2006).

## CONCLUSIONS

The information from palaeoecology investigations proved once again to be useful to complete the geological hypotheses concerning palaeo-landslides by providing both indirect and direct datings, and palaeoenvironmental pictures which are basic to interpret possible causes and evidence of ancient slope instability (e.g. vegetation cover, climate changes, human activities). Moreover, this knowledge can act as an important tool for studying and forecasting current slope instability.

Obviously, there are different scales of analysis, from the strictly local phenomena up to the regional and continental levels. The examples shown here belong to a local level, to which the environmental effects are not always easily correlated to global events (e.g. global climate change). Moreover, even the more detailed studies often leave open the question of if and how far human activities have a responsibility in this regard.

The site of Senarega is another good example recording the geomorphological and vegetation dynamics that characterized the Ligurian Apennines and much of southern Europe in the mid-late Holocene, also contributing to illustrate the history of the postglacial expansion and subsequent decline of silver fir (*Abies*). This site also provides a further evidence of how the process of damming of rivers due to landslides, resulting in the formation of small lakes today disappeared, have been a reality quite common during the Holocene rather than isolated episodes.

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