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ENVIRONMENTAL CHANGES IN THE BOIANO INTRAMONTANE BASIN (MOLISE, ITALY) SINCE THE TIMES OF ANCIENT *BOVIANUM (IVTH CENTURY BC)*

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ABSTRACT: The ancient Samnitic and Roman towns of *Bovianum*, located at the base of the northern slope of the Matese Mountains and partially extending within one of the most depressed sectors of the Boiano intramontane basin, were strongly influenced by historical palaeoenvironmental changes mainly due to climatic and man-induced variations and subordinately to the effects of historical seismicity. These changes influenced the evolution in time of the urban settlement layout extensions, which shifted alternatively towards the Matese slope and its piedmont area and the plain. In particular the Samnitic-Roman *Municipium* (IV century B.C.-I century A.C.) was located mainly within the piedmont area and only partially within the plain, while other smaller settlements were founded at the top of the palaeosurfaces of Mt. Crocella and Civita. From the I to the IV century A.C., the Roman *Colonia* expanded both towards the plain and the slope, thanks to the reclamation of the most depressed sectors of the plain, as well as to slope terracing and buildings, respectively. After the IV century A.C. and up until the XIX-XX century AD, the plain sector was gradually abandoned, while the urban areas were mainly concentrated at the top of the Civita paleosurface and within the piedmont area. Within the last two centuries the plain was newly occupied, conversely the Civita settlement was gradually abandoned. With the intent of investigating the main palaeoenvironmental changes and their causes, an integrated multidisciplinary analysis of the morpho-stratigraphical and historical-archaeological data was carried out. Facies analyses of two core successions, retrieved from the central area of the modern village of Boiano, and a critical review of archaeostratigraphical records of older archaeological excavations, allowed for the identification of 10 archaeostratigraphical units. The sedimentary succession intercepted by the core located at the base of the piedmont area base of the Matese slope was made up of alternating layers of paleosols, debris cone deposits and man-induced fills, the succession coming from the core located in the plain sector, instead, by alternating layers of paleosols and fluvial marshy-deposits. The tephro-stratigraphic data allowed to chronologically constrain the uppermost 7 to 9 m thick portion of the Boiano filling (named Boiano upper fill) to the Later Upper Pleistocene-Holocene. Archaeological data from older excavations and the archaeological remains included in the core successions then allowed to date most of the aggradation and waterlogging phases recognized in the piedmont area and plain sector, respectively. At least three debris cone deposition phases could be recognized which are chronologically constrained prior to the IV century A.C., between the IV century A.C. and the Middle Age and between the XVI and XIX centuries AD, respectively, and can be most likely correlated with the well documented periods of climatic deterioration known as the Iron Age, the Dark Age (IV-IX centuries AD) and the Little Ice Age (XVI-XIX centuries AD), respectively. Likewise debris deposition, as well as waterlogging affected the plain mainly during the above mentioned periods and can be certainly -at least partially -attributed to the mentioned periods of climate deterioration characterized by increased rainfalls and consequent rising of the ground water level. Waterlogging events, however but could have been favored also by tectonic subsidence, caused by the earthquakes which affected the Boiano area during the III-II century B.C. and in 853, 1456 and 1805 AD.

Keywords: Geoarchaeology, Archaeostratigraphy, Historical environmental changes, Climatic controls, Molise.

1. INTRODUCTION

The role of climatic changes and human actions in shaping the Mediterranean landscapes has been strongly debated as of the study carried out by Vita Finzi (1969) on the Holocene evolution of Mediterranean valleys. He argued that climatic changes were the main control factors for the major phases of Holocene alluviation and related palaeoenvironmental changes. The fluvial succession which laid down during the most important period of Late Holocene alluvial aggradation is generally known as *Younger Fill* and dates back to a time period that spans from the Classical age (2.5 ka BP) to the end of the Late Antiquity Age (1.3 ka BP) (Vita Finzi, 1969). During this period most of the Classical to Late Roman settlements and towns in the Mediterranean were affected by several phases of alluviation which were frequent cause of their destruction or partial burial and the consequent need to rebuild or relocate elsewhere (Pope & van Andel, 1984; Ortolani & Pagliuca, 1994; Giraudi, 1995; Allocca et al., 2000; Ortolani & Pagliuca, 2003; Pope et al., 2003; Wilkinson & Pope, 2003; Giraudi, 2005; Amato, 2006; Giraudi et al., 2007). A last important period of alluvial aggradation affected the Mediterranean valleys from the 16th to the 19th century AD-during the Little Ice Age (Lamb, 1995; Baroni & Orombelli, 1996; Orombelli & Ravazzi, 1996; Bond et al., 2001; Cronin et al., 2003; Mann, 2003; Mayewski et al., 2004; Rosskopf et al., 2006; Giraudi et al., 2007).

During these two periods, within the low-lying zones of the intramontane basins of the Apennine chain, the rise of underground water level led to the formation and expansion of marshy and lake environments (Giraudi, 1989; Berglund et al., 1996; Zolitschka et al., 2000; Giraudi, 2004; Roberts et al., 2008; Magny et al., 2011; Magny et al., 2012), while shorelines, especially those including major river mouths, registered a strong progradation (Aucelli & Rosskopf, 2000; Aucelli et al., 2011; Pappone et al., 2011; Amato et al., 2013; Rosskopf & Scorpio, 2013). Based on other studies (Pope & van Andel, 1984; Messerli et al., 2000; Amato et al., 2010b) the above mentioned changes could have been caused by human impact on the environment due to deforestation, cultivation and pasture purposes or, simply, overgrazing. Finally, according to other authors (see Barker et al., 1978; Bintliff, 1982; de Menocal, 2001; Barker & Hunt, 2003; Berglund, 2003; Amato, 2006; Hunt, 2006), land use changes could have contributed to such environmental changes; however, climatic changes are thought to be the most likely primary control factor. One of the zones of the Mediterranean area that provide a better record of the possible relationships between human actions and environmental changes are the intramontane basins. Their infillings frequently give good evidence of depositional or even erosional events and are often consistent in archaeological remains. This permits integration of geomorphologic, stratigraphic and palaeoenvironmental records with archaeological and historical data. Therefore, it allows identifying and chronologically constraining the possible influence of climate changes and human actions on Mediterranean landscape evolution, while assessing related possible cause-effect relationship. To improve our knowledge concerning the processes and causes responsible for recent environmental changes, we carried out an integrated study on the Boiano basin, named after the major village of Boiano therewith located in the central sector of the basin at the base of the northern slope of the Matese Mountains (Fig. 1). The modern village buried archaeological layers of Samnitic to Roman age (referring to the ancient *Bovianum*) and Middle Age to Modern age. These archeological layers are object of recent and current archaeological research (see Ceglia, 2005b; De Benedittis et al., 2008) focusing especially on the development and extension of *Bovianum* in historical times, without considering palaeoenvironmental and climatic perspectives.

In order to assess historical environmental changes which have affected *Bovianum* in time and, especially, the influence of climatic changes, historical seismicity and human activities, our study focuses on the archaeostratigraphic and facies analysis of the uppermost, ca. 10 m thick, part of the Boiano basin infilling, which makes up the substratum of the Boiano urban area and surroundings. The latter was investigated by means of two recently drilled core successions (see below) and the sedimentary successions intercepted by some small artificial trenches and archaeological excavations.

2. GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

The Italian Apennine chain (Fig. 1B) hosts several intramontane basins mainly located along its axial zone and generally NW-SE and NE-SW oriented. These basins started to form during the compressional phase of Plio-Quaternary tectonics (Corrado et al., 2000; Patacca & Scandone, 2007; Amato et al., 2011) and subsequently evolved under the control of extensional tectonics, which has been active at least since the Middle Pleistocene (Corrado et al., 1997; Di Bucci et al., 2002; Di Bucci et al., 2005; Amato et al., 2011). From a structural perspective, these basins can be defined as tectonic depressions (graben or semi-graben), bordered and intersected by strike-slip and normal faults (Corrado et al., 2000; Galli & Galadini, 2003; Di Bucci et al., 2005; Amato et al., 2011). These faults are in part still active and responsible for the historical seismicity and for the overall or partial subsidence of the basins (Galli et al., 2002; Galli & Galadini, 2003; CPTI, 2004; Galadini & Galli, 2004, Amato et al., 2012).

From a geomorphological perspective, these basins are characterized by flat alluvial plains, many of which have been drained thanks to land reclamation interventions (Chouquer et al., 1987; Giraudi, 1989; Barker & Hunt, 2003; Giraudi, 2004). The plains are generally located within a mountainous to hilly landscape and are characterized by border slopes whose piedmont areas have undergone huge and widespread aggradation over time, mainly due to alluvial fan deposition and the formation of colluvial, scree talus and cones.

The Boiano basin is one of the major intramontane tectonic basins of the Molise sector in the Apennine chain. These basins are located within a narrow NW-SE elongated deformation belt, extending for ca. 40 km between the Isernia and Sepino plains (Fig. 1C), and are filled with thick Quaternary successions of marshy to lacustrine, volcaniclastic and alluvial deposits (Russo & Terribile, 1995; Brancaccio et al., 2000; Di Bucci et al., 2002, 2005; Coltorti et al., 2005; Aucelli et al., 2011; Amato et al., 2012; Orain et al., 2012).

The geological evolution of these basins has been strongly controlled by extensional fault systems since the Middle Pleistocene (Corrado et al., 2000; Di Bucci et al., 2002; Di Bucci et al., 2005; Patacca & Scandone, 2007; Amato et al., 2011), some segments of which are currently active (Valensise & Pantosti, 2001; Galli et al., 2002; Galadini & Galli, 2004) and responsible for the main earthquakes recorded in the Molise Apennine (Galli & Galadini, 2003; CPTI, 2004).

The Boiano basin is located at ca. 500 m a.s.l. between the Matese and Montagnola di Frosolone carbonate massifs and the siliciclastic Sannio hills (Fig. 1C). It is ca. 4 km large and elongated for ca. 20 km in the NW-SE direction, and is drained by the Biferno River that flows to the Adriatic Sea (Rosskopf & Scorpio, 2013).

The modern urban area of Boiano is located at elevations of 480-500 m a.s.l. in one of the most low-lying sectors of the basin, while remnants of more ancient settlements are located on the Matese slope and along its piedmont area, at elevations between 500 and 1000 m a.s.l. (Fig. 2).

The Matese slope is characterized by a step of flat surfaces, located at elevations between 1400 and 700 m a.s.l. These surfaces are interpreted as palaeosurfaces, i.e. remnants of gently-rolling ancient landscapes, mostly carved in bedrock and now hanging at different

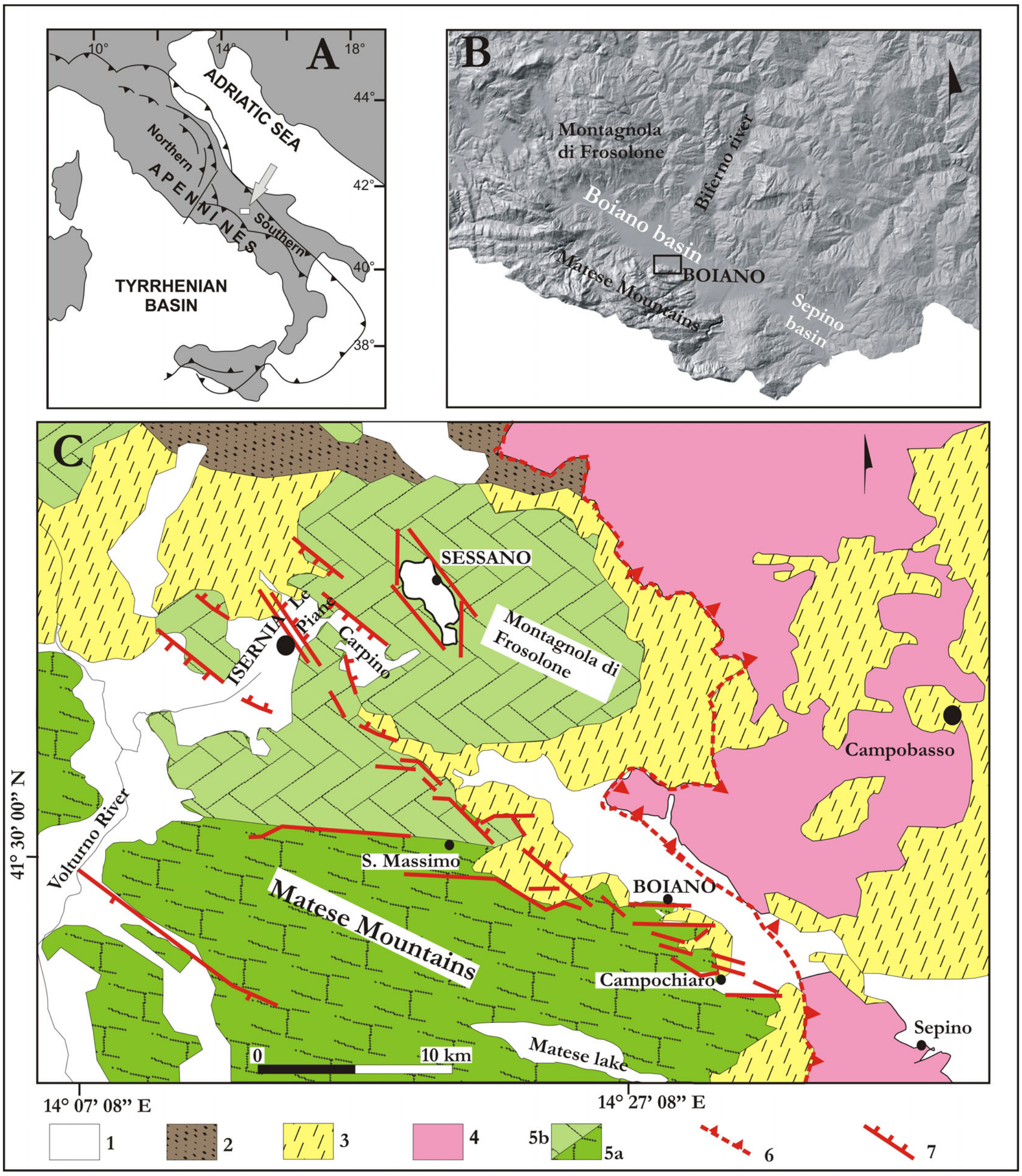

Fig. 1 - A) The structural sketch map of Italy and location of the study area; B) Digital elevation model of the sector of the Apennine chain including the Boiano basin; C) Geologic sketch map derived from sheet 405 (Campobasso) of the new geological map of Italy at scale 1:50,000 (CARG Project, Geological Survey of Italy, ISPRA). 1: continental sediments and volcaniclastic deposits (Late Pleistocene-Holocene); 2: foredeep and piggy-back siliciclastic deposits (Miocene); 3: clays, marls and limestones (Sannio Unit, Upper Cretaceous-Miocene); 4: clays, marls and limestones (Molise pelagic successions, Oligocene-Miocene). 5: limestones, dolomites and marls of carbonate platform (a) and slope facies (b) (Triassic-Miocene); 6: main thrusts; 7: main extensional faults, dashed when inferred.

altitudes above the local base-levels of erosion (Aucelli et al., 2010; Aucelli et al., 2011). Their genesis is related either to prolonged periods of relative tectonic stability alternating with periods of uplift, or partially even to the interplay between steady tectonic uplift and climatic fluctuations (Aucelli et al., 2011). On top of the Civita and Mt. Crocella palaeosurfaces (Fig. 2), located at ca.750 m and 1000 m a.s.l., respectively, important archaeological remnants of Samnitic to Middle Age Age (see below) have been discovered.

The palaeosurfaces are connected to the plain by steep structural slopes, generated by high-angle faults which were active during the Quaternary and responsible for the disarticulation of the northern front of the Matese massif. The WNW-ESE trending master fault is located at the base of the slope which borders the basin southwards and crosses the SW sector of the urban area of Boiano.

In addition to extensive tectonics, climatic changes have also contributed to the Quaternary evolution of the slopes bordering Boiano to the SW. During glacial periods and especially during the last one, carbonate slopes were affected by widespread slope replacement, according to the rectilinear-parallel slope recession model (Young, 1972; Brancaccio et al., 1979; Amato et al., 2010a) and the formation of thick aggradational foot

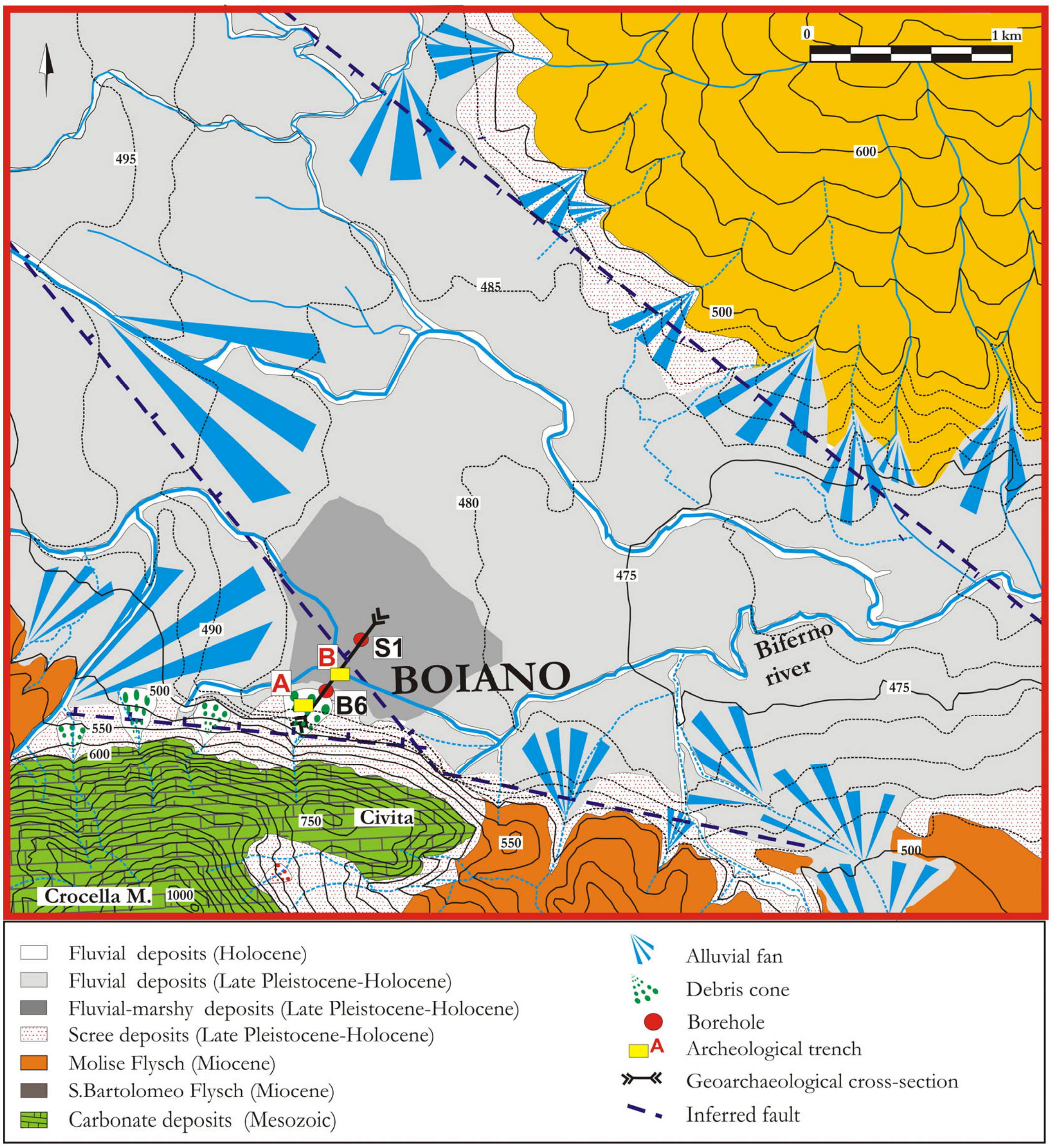

Fig. 2 - Geological-geomorphologic sketch map of the south-eastern sector of the Boiano basin including the village of Boiano. A: location of the S. Erasmo-S. Chiara church archaeological excavations, B: location of the Calderari archaeological area.

slopes. The latter are made of two generations of scree deposits: the lower one, generally well cemented and with openwork texture, and the upper one, generally loose and matrix supported. The latter can be dated most likely to a period that spans from the Last Glacial Maximum to the Holocene (Pappone et al., 2012), as it contains the Neapolitan Yellow Tuff tephra dated to 15 ka BP (Deino et al., 2004).

The Matese front in the Boiano area is dissected by some gully incisions, which have contributed to build small debris cones along the southern border of the basin, and some of these extend to the Boiano urban area (Fig. 2). Several springs feed minor watercourses and are partially captured for drinking water distribution.are situated at the base of the border slope. Major watercourses coming from the border slopes have generated gentle alluvial fans extending partially within the plain (Fig. 2). As the urban center of Boiano is located within one of the most low-lying areas of the plain, it has a very shallow groundwater level and, therefore, is poorly drained. Surface waters coming from the mountain slope are mainly drained by the Calderari stream -which is also partially fed by the outflows of the Maiella springs and crosses directly the urban area- and by the Spin channel which is most likely of anthropogenic origins and derives part of the waters in the Calderari stream (Fig. 3). Finally, the SE sector of the Boiano village is drained by the Biferno River which takes its origins from the Biferno springs (H in figure 3) and receives the waters of the Calderari stream.

Two recently drilled boreholes in the urban center of Boiano allowed to investigate the Boiano fill succession up to a depth of 160 m (Amato et al., 2012; Orain et al., 2012; Pappone et al., 2012). The two boreholes S1 and B6 (Figs. 2 and 3), 160 m and 73 m deep, respectively, are located at ca. 100 m from each other and at 482 m and 484 m a.s.l., respectively, with the B6 core being located closer to the border slope of the plain.

A detailed stratigraphic and facies analysis was performed on the core successions and the most significant levels were investigated by means of tephrostratigraphy, palinology and $^{40}Ar/^{39}Ar$ radiometric dating (Aucelli et al., 2011; Amato et al., 2012; Orain et al., 2012; Pappone et al., 2012). The investigated part of the Boiano basin infilling reaches the Middle Pleistocene (Marine Isotopic Stage 13, i.e. MIS13) and is made of three units: a *Lower Unit* of lacustrine-palustrine origin, chronologically constrained between the MIS 13 and the MIS 10 (500 ka BP-350 ka BP), a *Middle Unit* of fluvial-marshy origin, constrained between the MIS 10 and the MIS 9 (350 ka BP-250 ka BP) and an *Upper Unit* made of fluvial-marshy sediments and Late Pleistocene to Holocene in age (Boiano Synthem, according to Pappone et al., 2012). Thanks to the presence of the Neapolitan Yellow Tuff layer (15 ka BP, Deino et al., 2004,) the Boiano Synthem could be divided into two sub-units that are Late Pleistocene and Late Glacial to Holocene in age, respectively. A comparison of the two borehole successions allowed identifying a high angle, NW-SE oriented fault which passes between the two boreholes and crosses the urban center of Boiano (Fig. 2). This fault has been active at least during the Middle Pleistocene, as evidenced by the vertical displacement of the correlated Ar/Ar dated tephra layers recognized in both cores (Amato et al., 2012). Instead, it is not clear if it has been active also during Late Pleistocene and Holocene and whether it is currently active. The documented high historical seismicity of the Boiano area may support this hypothesis. At least seven historical earthquakes occurred in 346, 848, 1293, 1315, 1349, 1456 and 1805 AD, are documented (CPTI, 2004). At least the ones occurred in 346, 848, 1456 and 1805 AD caused damages in several villages located within the Boiano and Sepino basins (Pescatore et al., 2004; De Benedittis, 2012). In addition, Galadini et al. (2002), Galli & Galadini (2003) and Galadini & Galli (2004) identified an earthquake which is chronologically constrained between the III and II century B.C. and which damaged the Ercole-Quirino Sanctuary of Campochiaro, located circa 3 km SE of Boiano.

3. MATERIAL AND METHODS

In order to improve the currently available data on chronology and stratigraphy of the younger part of the Boiano infilling as well as on the recent palaeoenvironmental evolution of the basin, we investigated in detail its uppermost portion matching it to the abovementioned Late Glacial-Holocene sub-unit. This subunit, 7 m and 9 m thick in the B6 and S1 cores, respectively, is mainly made of alternating fluvial, debris slope and palustrine deposits, and is characterized by several unconformities and soils and is partially rich in archaeological remnants. In particular, we analyzed this sub-unit in order to define color, texture, grain features (size, shape, composition), fossil content, sedimentary and diagenetic structures, according to the methods illustrated in Tucker (2011). On the basis of lithofacies, unconformities and soils, the two core successions were subdivided into stratigraphic units (US, *sensu* Tucker, 2011). According to the Soil Survey Staff classification (2010) concerning soils formed in aggradational and, typically, in archaeological contexts (Cremaschi, 2000), we defined the soils as buried soils and, in accordance with Daniels (2003), as multiple soils. In cases in which such buried soils were only made of very thin pedogenic horizons developed on their parent materials, they have been defined as buried pedogenetic horizons, according to the Soil Survey Staff classification (2010).

Our palaeoenvironmental interpretations are based on the sedimentary features of the distinguished stratigraphic units and the collected historical and archaeo-stratigraphic data. With reference to the latter, first of all the archaeological content of the two cores has been analyzed from a chronologic and taxonomic perspective in order to detail the chronology of the units and the relative palaeoenvironemental changes. Subsequently the archaeo-stratigraphical data coming from the archaeological excavations of S. Erasmo -S. Chiara church and the archaeological area following part of the Calderari stream (hereinafter Calderari archaeological area) (Ceglia, 2005b; De Benedittis, 2012), were analyzed. Furthermore, we performed a critical revision of the literature dealing with historical and/or archaeological aspects of the Boiano territory paying particular attention to historical sources and epigraphs dealing with the impacts of natural or man-induced changes following earthquakes, flood events, waterlogging and land reclamation. The interpretation of collected archaeo-stratigraphical data was supported by a detailed geomorphological analysis of the territory of Boiano by means of cartographic analysis of 1:5,000 topographic sheets and field surveys.

4. RESULTS

4.1. Archaeological data

While the most ancient settlements discovered in the Boiano basin are ascribed to the Iron Age (Capini, 1980; Ceglia, 2005a; De Benedittis, 2005), the most ancient ones found within and around the modern village of Boiano are Samnitic in age and date to the IV century B.C. They include important defensive wall systems in polygonal work forming three separate structures (Fig. 3): a first small and circle-like wall structure is located at circa 1000 m a.s.l., on top of the Mt. Crocella palaeosurface (De Benedittis, 1995); a second one is found on top of the Civita palaeosurface (750 m a.s.l., figures 2 and 3) where the discovery of several black-painted pottery findings allowed to testifying the presence of a permanent settlement that stretched over the entire Civita surface (De Benedittis, 1977); a third, rectangular wall structure, much larger than the other two, extends within the piedmont area of Boiano village and the sector of the plain immediately in front of it and contributes to define the boundaries of the Samnitic *Bovianum* (Fig. 3).

The northern boundary of *Bovianum* is evidenced by wall remains which are located in the Largo Gentile and Palazzo Quaranta subsoil (C and D respectively in Fig. 3) (De Benedittis, 1995; De Benedittis et al., 2008), while the southern boundary can be located at the height of the S. Michele Arcangelo Church (550 m a.s.l., E in Fig. 3) (De Benedittis, 1977). The eastern boundary coincides with the part of the wall structure discovered near the S. Biase Church (F in Fig. 3). Finally, the western boundary of *Bovianum* is evidenced by the most im portant Samnitic wall remains discovered in the Boiano

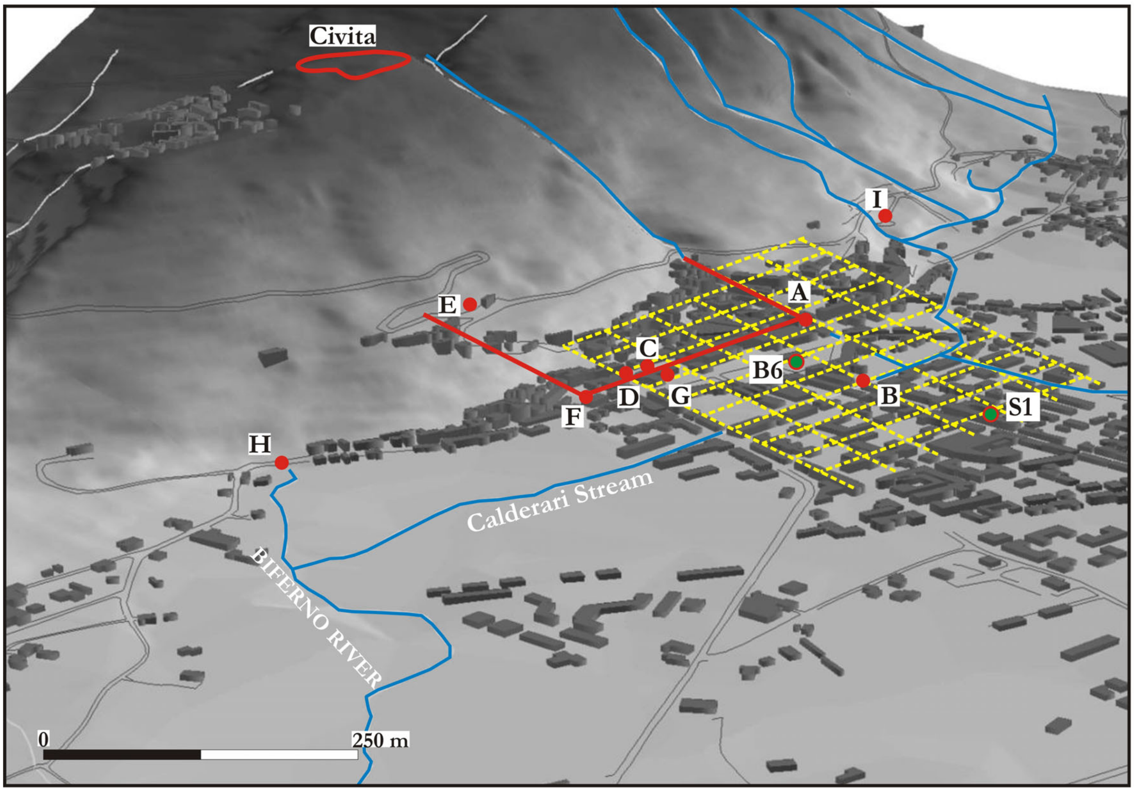

Fig. 3 - Digital Elevation Model of the Boiano area and location of the B6 and S1 cores (green circles) and the archaeological sites (A-I, red circles) mentioned in the text. A: S. Erasmo-S. Chiara Church; B: Calderari archaeological area; C: Largo Gentile; D: Palazzo Quaranta; E: S. Michele Arcangelo Church; F: S. Biase Church; G: S. Bartolomeo Church; H: Biferno springs; I: Maiella spring. The red lines and the red circle represent the remnants of the Samnitic walls structures located on the piedmont area and on the Civita palaeosurface, respectively. The third Samnitic wall structure, which is located on the Mt. Crocella palaeosurface (ca. 1000 m a.s.l.), is outside the figure. The yellow dotted grid represents the layout hypothesis of Roman *Colonia* age (I-IV centuries AD).

area up to now: ca. 15 m long, these wall remains have been unveiled during the archaeological excavation (De Benedittis, 1995; De Benedittis, 2004) carried out within the *Episcopio* of S. Erasmo (A in Fig. 3). The western boundary of the Samnitic settlement could have been influenced by the presence of the little stream which enters the plain immediately to its west, while the eastern boundary may have depended on the presence of the low lying sector of the Biferno springs (H in Fig. 3). In fact, in this way, the Samnitic settlement was partially built on the piedmont area and partially on the plain but without including its very low lying sectors.

This settlement layout of *Bovianum* certainly persisted up until the end of the II century B.C., as recorded by historical sources (*Appiano, Bellum Civile, I, 51*) that mention the presence of the three wall systems. During this period *Bovianum* was an important center and well connected to the main commercial and economical roads crossing the Apennine chain and directed towards the Tyrrhenian and Adriatic coasts. *Bovianum* was often mentioned in the writings of *Livio* on the three Samnitic Wars (343-341 B.C., 326-304 B.C., 298-290 B.C.), when the Romans conquered the Samnitic *Bovianum* without losing its importance (De Benedittis et al., 2008). The situation changed after the Social War when *Bovianum* lost its political and cultural autonomy as mentioned by historical sources describing the Sannio region as almost uninhabited and its settlements and towns as partially destroyed (Strabone V, 4, 11; Floro, Epit., I, 16, 7-8). Between the I century B.C. and the I century AD, the ancient *Bovianum* became first a Roman *Municipium* (48-46 B.C.), then a *Colonia Triunvirale Lege Iulia* (44-27 B.C.) (Lib. Col. 231, 259 L) and, finally, a *Colonia Flavia* (73-75 AD) (La Regina 1966, De Benedittis 1977, 1995). During this period the historical sources mention two colonies, named *Boianum Vetus* and *Boianum Undecumanorum* (Plinio, N. H., III, 107), which could have represented the same settlement with two chronologically different urban layouts (De Benedittis, 2004; De Benedittis et al., 2008). The Republican age settlement (I century B.C-I century AD) seems to have the same urban layout of the Samnitic settlement. Several archaeological data allow to hypothesize the presence of the urban area extending up to the slope of Civita, with the buildings located on artificial terraces (De Benedittis, 1995; De Benedittis, 2004), and its abandonment during the I century AD. In fact, the archaeological excavations in the S. Erasmo area (A in fig. 3) highlight that 2 m-thick debris cone deposits covered the Samnitic-Roman walls (De Benedittis 2004; De Benedittis, 2012). Consequently, in the years from 73 to 75 AD, the Vespasian Emperor defined a new urban layout in which the urban area extended within the plain (De Benedittis, 1977; De Benedittis, 2004), while the low lying area of the plain was reclaimed and geometrically divided (*Centuratio*) in order to distribute the lands to the XI Legion Veterans (Chouquer et al., 1987; De Benedittis, 2004). Archaeological data related to this second urban layout have been discovered in the Calderari archaeological area (B in fig. 3): here a paved Roman road (I century AD) appeared at ca. 3.5 m of depth. Considering the width of this road (9.50-9.90 m) it can most likely be identified with the *Decumanus Maximum* of the settlement (Chouquer et al, 1987; De Benedittis, 2004; De Benedittis et al., 2008). In addition, several archaeological data allow to suppose that the Calderari area was the center (*Forum*?) of the ancient village (De Benedittis et al., 2008) and the *Decumanus Maximus* was the urban area thourough-fare (De Benedittis, 1977; De Benedittis, 1998). If this interpretation is correct, the northern boundary of the *Colonia* can be extended north to the location of the S1 core (Fig. 3).

Until the Late Roman Imperial period (IV century AD), the urban layout remained unchanged (De Benedittis, 1977; 2004). An epigraph, dedicated to Fabio Massimo, *rector Provinciae Samnii* from 353 to 357 AD, mentions the reconstruction of the *Secretarium* (De Benedittis, 1977; 1995). This document has given rise to the hypothesis that *Bovianum* had been strongly damaged by the 346 AD earthquake (Camodeca, 1971; Russi, 1971; Buonocore, 1992; Galadini et al., 2002; Galadini & Galli, 2004). However, as demonstrated recently by Soricelli (2009) and De Benedittis (2012), it seems that this hypothesis is likely to have been given too much emphasis.

After the fall of the Roman Empire, Boiano was affected by a strong political and cultural crisis (De Benedittis, 1977), and in the VI century AD the Longobards conquered the Sannio region. It was during this period that the urban layout gradually shifted from the plain to the slope and to the Civita palaeosurface. Later the urban area was rapidly relocated on the top of the Civita paleosurface, further to the Saracen raids and this is where nowadays the ruins dating to the XIII century AD are visible, while only a little sector of the piedmont area remained inhabited (De Benedittis, 1977).

Successively, historical sources mention Boiano (De Benedittis, 1977; De Benedittis, 2012) in relation to the earthquake occurred in 1456 AD, known as S. Barbara earthquake. One of the effects of this earthquake was the waterlogging of the urban area, as demonstrated by the S.Erasmo-S. Chiara church and Calderari area archaeological excavations (De Benedittis, 2012).

In the XVI and XVII centuries, the urban layout didn't include the most low-lying sectors of the plain and didn't extend up slope to the S. Bartolomeo Church (Muccilli, 1985). The plain was newly and permanently inhabited starting only from the XIX century, while the Civita palaeosurface was quickly abandoned (De Benedittis et al., 2008).

4.2. Archaeo-stratigraphical data

The presence of the reworked volcaniclastic products of the Neapolitan Yellow Tuff (NYT in Tabs. 1 and 2) dated to 15 ky BP (Deino et al., 2004) in cores B6 and S1 at 7 and 9 m, respectively, allowed to constrain the chronology of the upper part of the Boiano infilling (hereinafter named Boiano upper fill) and to date it to the Late Glacial-Holocene (Amato et al., 2012; Orain et al., 2012; Pappone et al., 2012). Sediment attributes and the presence of several erosional unconformities and buried soils later allowed to identify 10 stratigraphic units *sensu* Tucker (2011) (US in Fig. 4, Tab. 1 and 2) which formed in different palaeoenvironmental contexts and mainly in historical times, as evidenced by diagnostic, well-dated ceramic fragments.

The investigated succession of core B6 (Tab. 1) is made of alternating debris cone deposits (USs 2A, 3, 6 and 8), multiple buried soils (USs 4, 5 and 7A) and man-made fills (USs 9 and 10). The core S1 succession (Tab. 2) instead, is made of alternating marshy deposits (USs 2B, 4 and 7B), multiple buried soils (USs 5 and 9B) and man induced fills (US 10). The presence of diagnostic ceramic fragments within USs 4, 5 and 8 of B6 allowed the chronological constrain of these units to the IV-III centuries B.C., the I century B.C.-I century

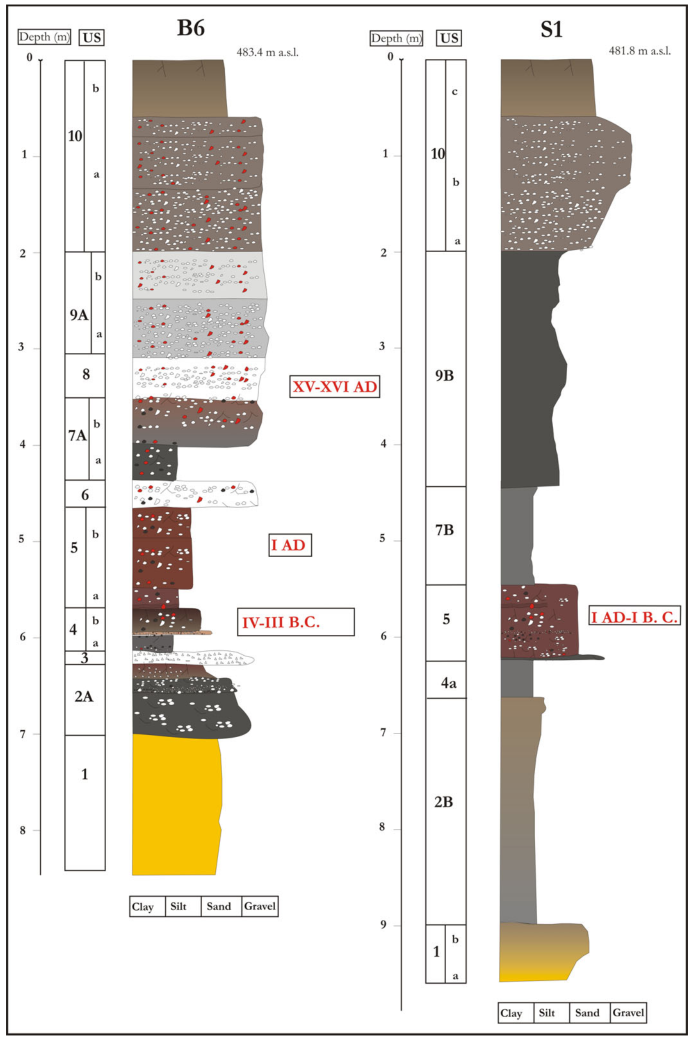

Fig. 4 - Stratigraphic logs of cores B6 and S1. For the description of sediment features and relative paleoenvironmental interpretation of the distinguished stratigraphic units see also table 1.

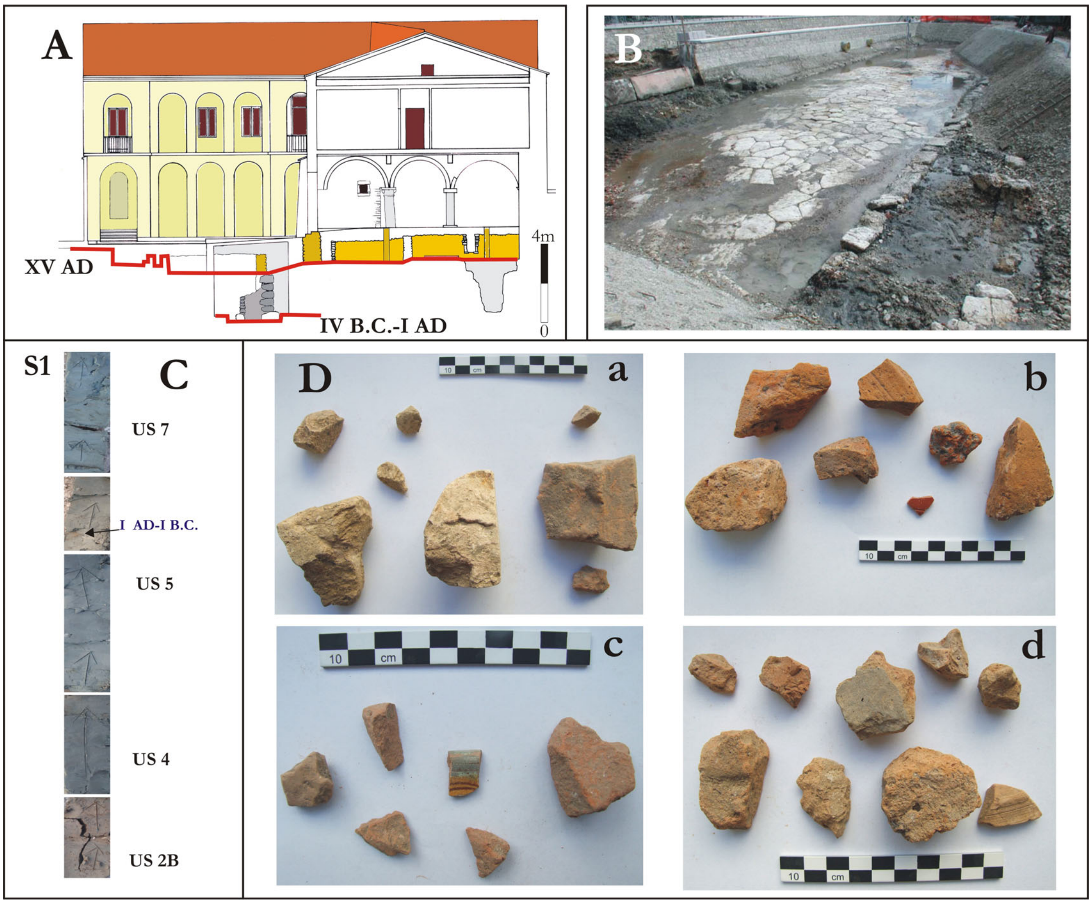

Fig. 5 - Figures and photos illustrating some of the most significant archaeo-stratigraphic and archaeological data. A: archaeological cross section of the S. Erasmo-S. Chiara Church archaeological area (modified from De Benedittis, 2012); B: Roman paved road unveiled in the Calderari archaeological area (from Ceglia, 2005b); C: upper part of S1 core succession, characterized by fluvial marshy sediments and buried soils with Roman ceramic fragments; D: pottery fragments from cores B6 and S1: a) B6: Samnitic-Roman age (IV-I century B.C.), b) S1: Roman age (I century B.C.-I century A.D.), c) B6: XVI century A.D., d) B6: Modern and Contemporary age.

AD and the XV-XVI centuries AD, respectively. In addition, the presence of modern-day finds and contemporary artifacts within the man-made fills of USs 9 and 10 allowed dating them to the last two centuries. The collected chronological and stratigraphic data allow to date most of the Boiano upper fill to historical times, testifying a high sedimentation rate for the last 2.5 ka BP, similar to those recorded in many other sectors of the Apennine chain and of the Mediterranean area (*Younger Fill*, after Vita Finzi, 1969). The archaeo-stratigraphic data is evidence of the fact that the sedimentation was essentially fluvial-gravitational in core B6 and fluvial-marshy in core S1. In addition, two further interesting archaeo-stratigraphic successions described in De Benedittis et al. (2008) and in De Benedittis (2012) confirm that slope deposits are laterally heteropic to marshy sediments towards the plain. The archaeological excavation in the S. Erasmo-S. Chiara Church area (A in Figs. 2 and 3), located in the axial sector of the small debris cone affecting the modern village of Boiano, showed that the western Samnitic-Roman walls (IV century B.C.-I century AD), founded at ca. 3 m beneath the present floor, are covered by 2 m thick debris cone deposits (Fig. 5A).

These debris deposits are made of two units, which are separated by man-made deposits and by the ruins of the S. Chiara Church, destroyed in 1456 AD by the S. Barbara earthquake (De Benedittis, 2012). The two distinguished phases of debris cone deposition are chronologically constrained between the I century AD and the Middle Age, and after the XV-XVI centuries AD and can be correlated to stratigraphic units US 6 and US 8 of core B6, respectively.

Conversely, the Calderari archaeological area, located in the central sector of the modern village of Boiano (B in Figs. 2 and 3), showed that the Roman *Colonia* paved road (I century AD) (Fig. 5B) has been covered by ca. 2 m thick clayey-silty deposits (Ceglia, 2005b) which most likely were related to fluvial-marshy environments and testify the waterlogging of the area after the IV century AD. This road is located ca. 1 m below the present groundwater level. According to Frezza (1579) and De Benedittis (2012) the village of Boiano suffered marshy conditions also in 853 AD and after the S. Barbara earthquake. The deposits documenting these two waterlogging events form the subunits 7B and 9B of core S1. These data could confirm the hypothesis that the sector located north of the Calderari stream subsided also during the Middle Age and Modern Ages.

Age	US		Depth (m)	*Description*	*Facies interpretation*
	10	b	0-0.60	Coarse-medium sands with sub-rounded to sub-angular polygenic gravels, dark-brown clayey-silts matrix supported, especially on the top where several millimeter-sized root fragments are present.	*Soil developed on man-made fills*
		a	0.60-1.95	Sub-rounded to sub-angular polygenic (mainly carbonatic) gravels and coarse sands, brownish and greyish silty-clay matrix-supported. High content of ceramic, charcoal, vegetable and bone fragments, especially concentrated in the bottom part. Near the top the matrix is prevailing and the size of the gravels decrease until to 1 cm. The archaeological contents are shown in Fig. 5Dd.	
	9A	b	1.95-2.50	Coarse and medium sands with sub-rounded to sub-angular carbonatic coarse gravels, brown silts and fine sands matrix supported, especially concentrated in the top part. Presence of several ceramic and cement mortar fragments of modern age.	*Buried soil developed on man-made fills*
		a	2.50-3.05	Sub-angular to surrounded carbonatic coarse gravels and coarse sands, dark brown and dark-grey silty sands matrix supported. Presence of several ceramics and cement mortar fragments of modern age.	
XVI cen. AD	8		3.05-3.65	Openwork sub-angular to angular coarse gravels and coarse sands, mainly made by calcareous debris, ceramic and cement mortar fragments of the XVI century AD. The archaeological contents are shown in Fig. 5Dc.	*Debris cone deposits*
	7A	b	3.65-4.00	Angular to sub-rounded coarse gravels and sands, mainly made of calcareous debris, ceramic and cement mortars fragments, dark-brown clayely silts matrix supported. Presence of vegetables and charcoals remains.	*Buried soil developed on fluvial-marshy deposits*
		a	4.00-4.40	Dark grey silty clays with angular to sub-rounded gravels and sands mainly made by calcareous debris and ceramic fragments. Presence of charcoals and organic matter	
	6		4.40-4.70	Sub-rounded to angular gravels and sands mainly made by calcareous debris and ceramic remains, dark-brown silty clays matrix supported. Presence of vegetables remains and charcoals.	*Debris cone deposits*
I cen. B. C.	5	b	4.70-5.50	Dark-brown clayey silts with sub-rounded and angular gravels and coarse sands. Several ceramic fragments of I century B.C. are present together with vegetable and charcoal fragments. The archaeological contents are shown in Fig. 5Da.	*Buried soil developed on fluvial-marshy deposits*
		a	5.50-5,70	Laminated millimeter thick layers of dark-grey clayey silts and sandy-silts. Several reddish-oxidized nodular concrections are present	
IV-III cen. B. C.	4	b	5.70-6.00	Brown clayey-sandy silts with sub-angular to sub-rounded coarse sands and gravels, mainly made of calcareous debris, potteries and cement mortar fragments of IV-III centuries B.C. Several millimeter to centimeter-sized charcoal and vegetable fragments are present, especially at 5,90-6,00 m. The archaeological contents are shown in Fig. 5Da.	*Buried soil developed on fluvial-marshy deposits*
		a	6.00-6.25	Laminated millimeter thick layers of brown-grey sandy silts and dark-grey clayely silts. Several reddish and dark oxidized nodular concretions are present.	
	3		6.25-6.30	Open-work angular and sub-angular calcareous gravels	*Debris cone deposits*
	2A		6.30-7.00	Angular to sub-angular calcareous coarse gravels, clayey silts matrix-supported, mostly concentrated toward the top.	*Debris cone deposits pedogenized at the top*
< 15 ka BP	1		7.00-8.30	Grey-yellow silty sands mainly made of volcaniclasts (ashes and pumices).	*Reworked Neapolitan Yellow Tuff*

Tab. 1 - Description, archaeological constraints and facies interpretation of the stratigraphic units of B6 core succession.

Age	US		Depth (m)	*Description*	*Facies interpretation*
	10	b	0-0,50	Dark brown clayey silts with angular to sub-angular calcareous gravels mostly concentrated toward the top.	*Soil developed on man-made fill*
		a	0,50-2,00	Sub-rounded to sub-angular polygenic (mainly carbonatic) gravels and coarse sands, brownish and greyish silty-clay matrix-supported. Presence of high contents of ceramic, charcoal, vegetable and bone fragments, especially at the base.	
	9B		2,00-4,50	Laminated dark and grey silty clays very rich in organic matter with veru abundant millimeter-sized root fragments, mostly concentrated toward the top	*Buried soil developed on marshy deposits*
	7B	a	4,50-5,50	Laminated green-grey clays very rich in organic matter and green-orange oxidized nodular and platy oxidations (Fig. 5C).	*Marshy deposits*
I cen AD- I cen B.C.	5		5,50-6,30	Green-grey silty clays and sub-angular to sub-rounded calcareous gravels. Several ceramic fragments dating from the I century B.C. to the I century AD, and charcoals are present. The archaeological contents are shown in Fig. 5Db	*Buried soil developed on marshy deposits*
	4	a	6,30-6,50	Dark-grey silty clays very rich in organic matter, burnt woods and charcoals, mostly concentrated at the top (Fig. 5C)	*Marshy deposits and burning layer*
	2B		6,60-9,00	Laminated green-grey clays very rich in organic matter and green-orange oxidized nodular and platy oxidations. (Fig. 5C)	*Marshy deposits*
< 15 ka BP	1	b	9,00-9,50	Grey-greenish clayey silts very rich in volcanoclasts (pumices and ashes)	*Buried soil developed on reworked Neapolitan Yellow Tuff*
		a	9,50-9,60	Yellow-orange silty sands mainly made of volcanoclasts (ashes and pumices)	

Tab. 2 - Description, archaeological constraints and facies interpretation of the stratigraphic units of S1 core succession.

5. DISCUSSION

In order to illustrate the main Holocene palaeoenvironmental features and changes recorded by the stratigraphic units that form the Boiano upper fill, a ca. SW-NE oriented geological section, crossing cores B6 and S1 and the archaeological excavations of S. Erasmo-S. Chiara Church and of Calderari area, has been constructed (Fig. 6).

Starting from the reworked volcaniclastic layer of the Neapolitan Yellow Tuff (US 1), the section crossing the two cores B6 and S1 clearly evidences the repeated lateral heteropy of slope deposits to marshy plain sediments. In the sector located near the southern border of the plain (B6), two generations of debris cone deposits (USs 2A and 3) have been deposited before the IV-III centuries B.C. while, at the same time, marshy sediments (US 2B of S1) accumulated in the sector located northward, Unfortunately these portions of the core successions do not contain chronological constraints allowing to better define the periods of sediment accumulation.

The first Holocene chronological constraint is found in the US 4A of core B6 (Tab. 1) and is related to the IV-III centuries B.C. the period of the Samnitic *Bovianum*, during which the three wall systems described in section 4.2 were constructed. Therefore, US 4 most likely represents the buried soil of the Samnitic *Bovianum*, the layout of which persisted unchanged until the I century AD, and didn't extend to the more central sector of the plain, i.e. the sector located northward to core B6. This hypothesis is supported by the fact that the US 4 of core S1 (Tab. 2) lacks archaeological remains and is mainly made of a buried soil developed on marshy deposits. In figure 6 the supposed correlation of US 4 with the base of the Samnitic walls present in the subsoil of the S.Erasmo-S.Chiara site, is shown. In addition, the centimeter charcoal rich layer present within the USs 4 of both cores can be interpreted as a burning layer and, by hypothesis, be correlated with the fires documented for the period of the Social Wars (305 B.C., 89 B.C.), which could have affected also *Bovianum*. Between the Samnitic age (IV-III centuries B.C.) and the Roman *Municipium* Age (I century B.C.), a tendency to waterlogging seems to affect both sectors, as evidenced by the deposition of laminated clayey-silty sediments, very rich in organic matter and oxidized nodular and platy concretions (US 5a of core B6 and US 4 of core S1). This first period of waterlogging could have been caused by natural and/or man-induced changes. Considering natural processes as driving cause, the hypothesis of climate changes as possible control factor is not supported by available regional palaeoclimatic data. Therefore, rather than invoking climate changes, it is possible to relate by hypothesis this period of waterlogging to the subsidence induced by the earthquake occurred in the III-II centuries B.C., which affected the Boiano basin and, especially, the Ercole Sanctuary of Campochiaro (Galli et al., 2002). Alternatively, the social crisis that characterized this period, could also have favored the degradation of surface drainage causing or favoring waterlogging. In

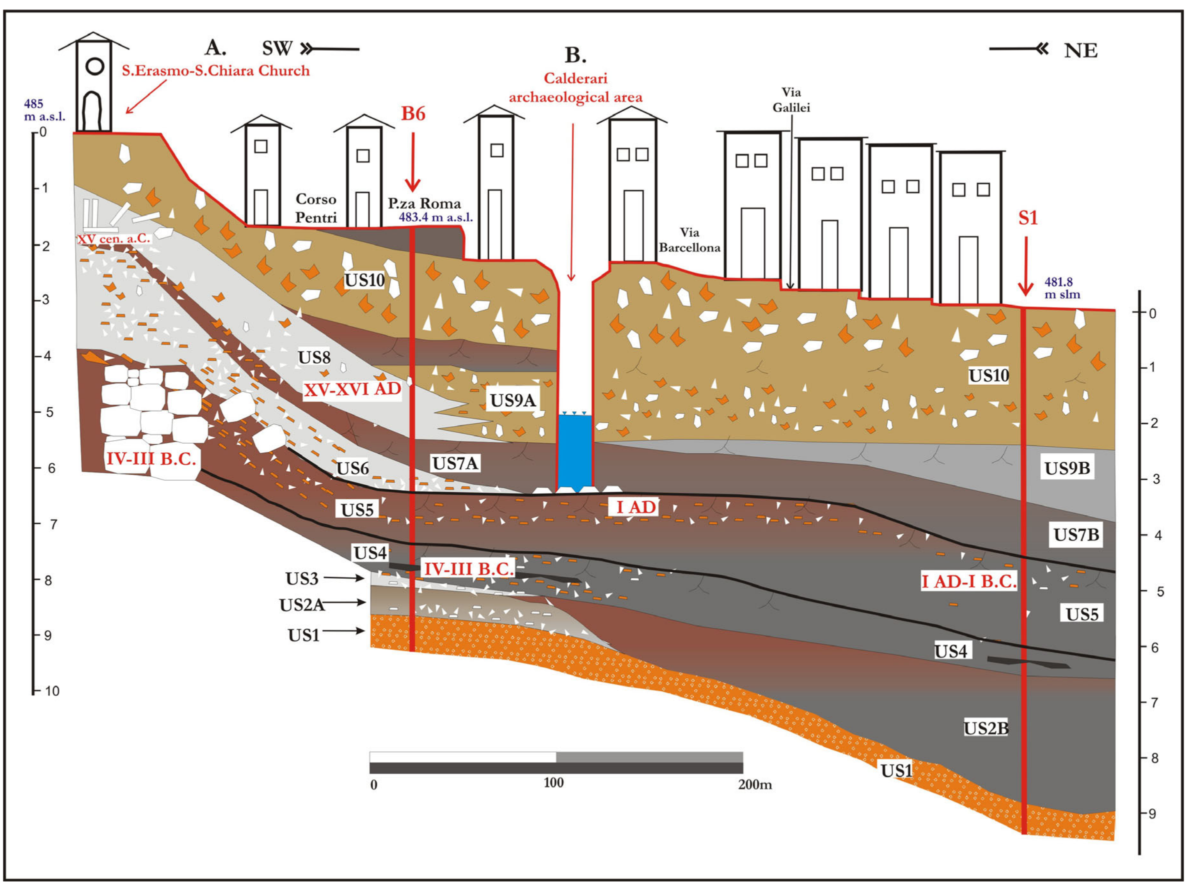

Fig. 6 - Geological cross-section through cores B6 and S1 and the archaeological excavations of S. Erasmo-S. Chiara Church and Calderari area. For location see figure 2.

the I century AD the urban and sub-urban areas of *Bovianum* were completely reconstructed and the ancient *Colonia* reached its maximum extension both towards the plain and the slope. More precisely, according to the reconstruction of the Boiano Roman *Colonia* proposed by Ceglia (2005b) and De Benedittis et al. (2008), the city layout extended beyond the S1 core (as confirmed by archaeological remains in US 5), with the paved road discovered in the Calderari area representing its center., Also the low-lying sectors of the plain most likely underwent land reclamation in this period and were geometrically subdivided in parcels for agricultural and social purposes (*Centuratio*), as demonstrated in Choquer et al. (1987). The slope and piedmont areas were subjected to strong land-use changes, including terracing and building.

The Roman *Colonia* layout seems to slowly decline starting from the IV century AD, when the Roman Empire fell. As a result of land degradations, together with an increase of rainfalls during the VI-IX centuries AD, the debris cone deposits of US 6 (B6 core) were laid down in the S. Erasmo church area and buried the Samnitic-Roman walls. The coseismic effects related to the 853 AD earthquake may have influenced the debris production. During this period, as also highlighted by historical sources, in the plain sector located northward to the B6 core, also including the Calderari area, marshy and fluvial-marshy deposits accumulated (US 7B of S1). This waterlogging event too, could have been caused by an increase of the relative subsidence rate of the plain, possibly linked to seismicity. Consequently to the fluvial-marshy conditions that dominated the sector of the plain northward to the Calderari stream, starting from this peri-

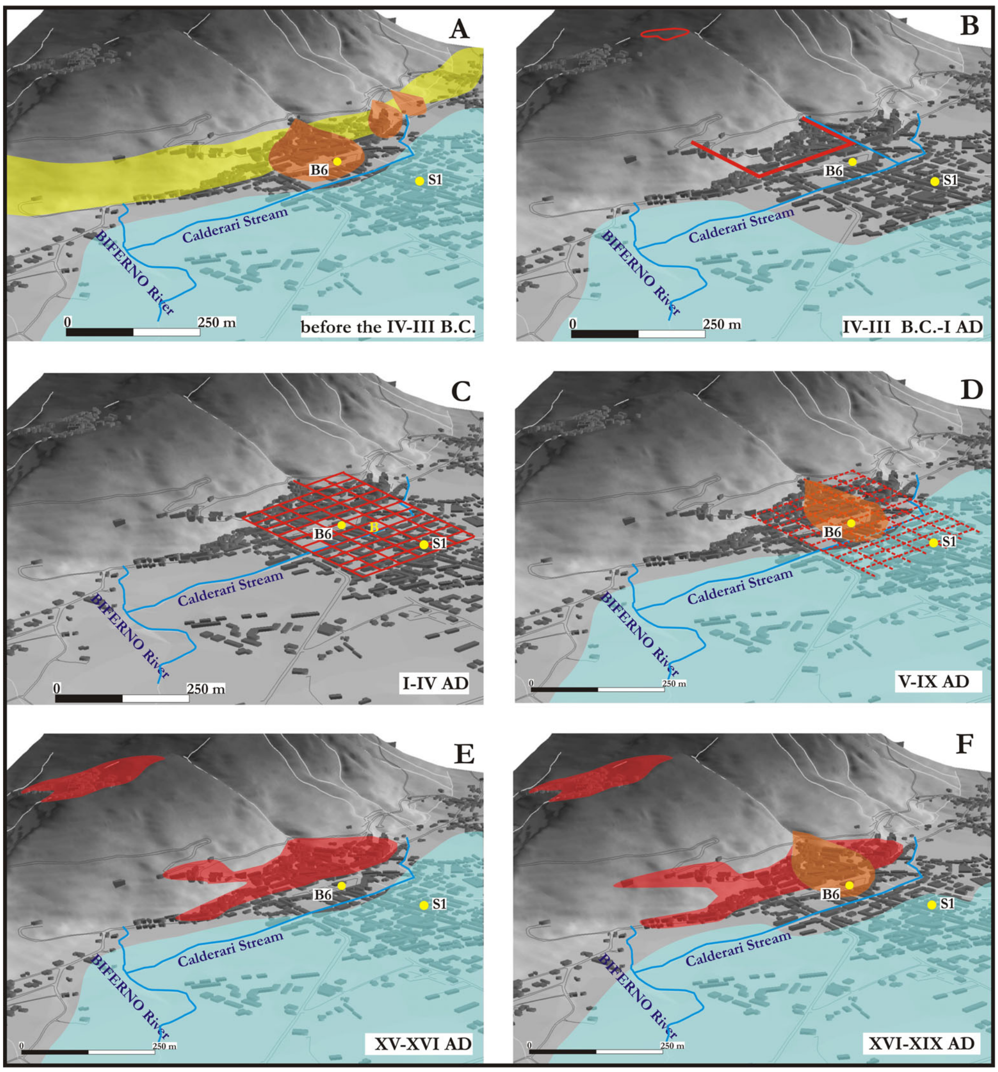

Fig. 7 - Location and extension of the urban area of Boiano, the waterlogged area and the ongoing debris production along the piedmont area during various periods, reconstructed by means of archaeostratigraphical data coming from cores S1 and B6 (yellow circles) and the examined archaeological excavations (for location see Fig. 3). Polygons in blue and orange indicate the presumed extension of the waterlogged area and the ongoing debris cone sedimentation, respectively. A) the Boiano area before the IV-III century B.C.; in yellow the aggradational piedmont zone. B) the boundaries of the Samnitic *Bovianum* and Roman *Municipium* during the time period IV-III century B.C.-I century AD, marked by the defense walls (red lines). C) the layout hypothesis of the Roman *Colonia* (red grid) with its centre, the Calderari archaeological area (B), during the I to IV century AD. D) the urban area of Boiano in the time period V-IX century AD, partially affected by debris cone sedimentation and waterlogging. E) the hypothetical expansion upslope of the modern village of Boiano (red polygon) during the XV to XVI centuries AD. F) the hypothetical extension of the modern village town of Boiano (red polygone) during the last centuries.

od and until the XIX century AD the Boiano settlement was particularly reduced in its urban extension and occupied only the piedmont area and the top of the Civita palaeosurface. In the XV century AD the 1456 AD earthquake destroyed the S. Chiara Church and most of the village of Boiano. Starting from this date, the more marginal sectors of the plain including the S. Chiara Church were interested by debris cone deposition (US 8 in B6), while the more central northward-located sector was affected by fluvial-marshy sedimentation (US 9B in S1). The debris cone deposition and the waterlogging of the plain can be related most likely to the increase of rainfalls and the decrease of temperature that characterized the Little Ice Age, which interested the Mediterranean area between the XVI-XIX centuries AD. These palaeoenvironmental changes could have been also influenced by seismic events (1456 AD and 1805 AD earthquakes), which may have caused coseismic subsidence. The tendency to waterlogging persisted until very recent times as highlights the several meters of man-made fills, which were placed in order to raise the floor during the rebuilding of the modern village of Boiano.

6. SUMMARY AND CONCLUDING REMARKS

As the collected archaeo-stratigraphic data highlight, the area of Boiano has been affected in historical times by important environmental changes evidenced by the repeated deposition along the piedmont area of scree/debris cone deposits that are laterally heteropic to fluvial marshy deposits of the plain sector in front of it.

A synthetic view of main urban and environmental changes occurred within the Boiano area in historical times is given in figure 7. This figure illustrates (sketches A-F) the location and extension of the urban area of Boiano, the waterlogged area and the ongoing debris production along the piedmont area over various periods.

Conversely, the evolution of the plain sector inside and around the historical Boiano appears to have been mainly controlled by repeated waterlogging, with exception to the Roman *Colonia* period (I-IV centuries AD), during which an important land reclamation was carried out (Fig. 7C). The waterlogged areas reached major extensions before the IV-III century B.C. (Fig. 7A) and from the V century AD onwards (Figs. 7D-F). With regards to the IV century B.C.-I century AD (Fig. 7B), instead, waterlogging reached its major extent from the III to I centuries B.C., when it affected the plain but did not interest directly the Samnitic -Roman settlement. Waterlogging could have been possibly favored by coseismic subsidence induced by the earthquakes that occurred in the II-I centuries B.C. -and in 853, 1456 and 1805 AD, respectively. In any case, the historical phases of waterlogging of the Boiano area, in our opinion, can be mainly ascribed to the increase of precipitation during the Cold Dark Age and the Little Ice Age, but probably were also influenced by the socio-political crisis that followed the fall of the Roman Empire. Consequently to these environmental changes, the Samnitic-Roman *Bovianum*, the Roman *Colonia* and the Middle Age Age settlement of Boiano changed in extension and location. As evidenced by the archaeological finds within the core S1, the Roman *Colonia* (I-IV centuries AD) extended towards the plain sector, probably beyond the actually known boundaries, consequently to the land reclamation. Subsequently, from the VI century AD to the XIX century AD, the village of Boiano progressively reduced the extension of its urban layout within the piedmont area and was partially relocated on top of the Civita palaeosurface. These changes of the urban layout have been most likely caused both by the deterioration of the plain sector due to waterlogging and the above mentioned social and political crises. A new reoccupation phase of the plain started only in XX-XXI century, when the emplacement of several meters of man-made fills and extensive land reclamation allowed improving the drainage conditions.

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