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Late Pleistocene relic Ultisols and Alfisols in an alluvial fan complex in coastal Tuscany

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ABSTRACT

Detailed stratigraphic, sedimentary facies and palaeosol analyses were performed on an outcrop on Late Quaternary deposits in the coastal area of Tuscany. The outcrop was selected as representative of one of the major Quaternary alluvial fan complexes of Central Italy, the ancient Cecina river fan, and as showing contrasting, if related, palaeosols. The oldest relic palaeosol was identified as an Ultisol, representative of the most developed soil type normally found as relic soil in Italy, and about whose possible ages only approximate interpretations presently exist.

OSL dating set the whole succession of sediments, palaeosols and geomorphic surfaces into a firm chronological setting. As a result, evolution of the Cecina fan complex in Late Pleistocene could be fully reconstructed. Assessment of the age of the relic Ultisol produced results contrasting with current interpretations, showing how such a soil type can have developed in Italian conditions in a relatively short time, i.e. since about MIS 5d.

1. Introduction

Relic palaeosols are defined as having existed as surface, live soils for long times, going through varying environmental conditions but experiencing no or limited erosion and deposition, thus preserving the main characteristics produced by long pedogenesis. They represent unique opportunities to investigate the time required for formation of the most developed palaeosols.

Knowledge of the time required for certain palaeosols to form is of major significance for their use in stratigraphy. Firm palaeosol chronology may bridge the gap between landform stratigraphy and unconformity-based sedimentary stratigraphy, allowing correlation of landform surfaces and buried unconformities.

In many temperate to subtropical, moist areas of the world, the most developed relic soils that are commonly found are classified as Ultisols (Soil Survey Staff, 1999). This position gives Ultisols a special significance in landform stratigraphy.

Ultisols were introduced in Soil Taxonomy (Smith, 1986, p. 226) to differentiate Argillic soils occurring in, respectively, glaciated and non-glaciated parts of U.S. territory. “Non-glaciated” was intended as mostly free from glacial surface rejuvenation processes, including high rates of aeolian deposition. A detailed study by Saif et al. (1997) revealed a fine–scale correlation between the southern boundary of loess deposition and the northern boundary of Ultisols in Ohio, USA.

Ultisols were thus conceived as having started forming earlier than Holocene and having experienced little rejuvenation, a definition very close to that of relic soils. Conversely, this definition is of little use for buried soils: base saturation (BS), the main diagnostic character for Ultisols, rarely survives burial, and is unsuitable for buried palaeosol classification (Yaalon, 1971; Krasilnikov and Calderón, 2006).

Dating of Ultisols is fairly limited in the literature. In moist subtropical climates, where they are most frequent, both numerical dating (Pai et al., 2003; Driese et al., 2007) and landform stratigraphy (Markewich and Pavich, 1991; Tsai et al., 2007) suggest Ultisols to be mostly relic soils. Two related studies based on landform stratigraphy (Bockheim et al., 1996; Lindenburg et al., 2013) support the above hypotheses and further indicate the importance of rainfall, over temperature, in determining timing and rates of Ultisol formation. In the Mediterranean, Ultisols are

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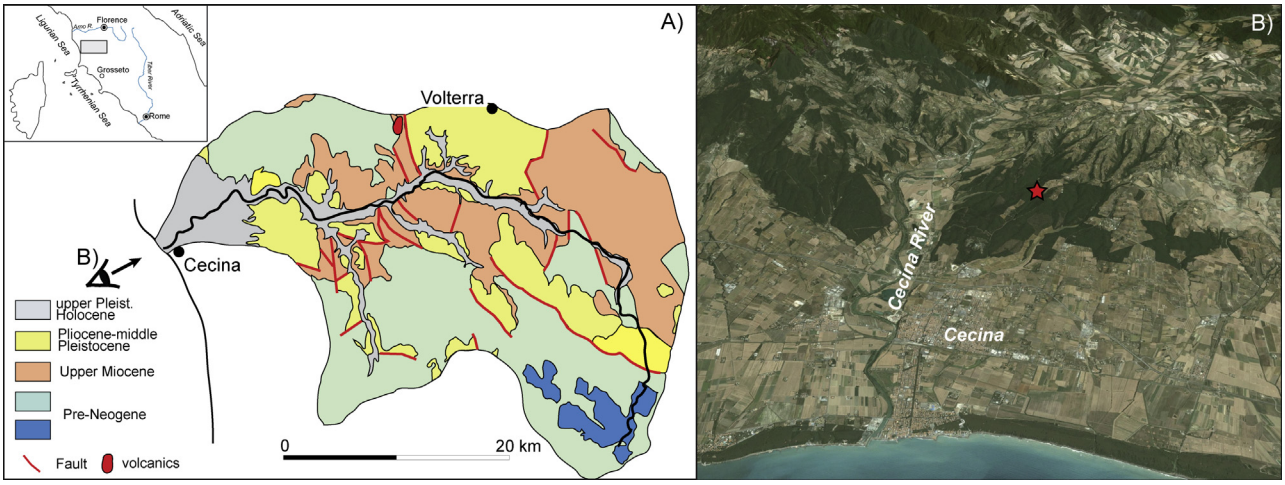

Fig. 1. Geological and geomorphological setting; A) location map and schematic geology of Cecina river catchment; B) Prospect view, looking to north-east, of the lower reaches of Cecina river valley and coastal plain; the main preserved part of the Cecina fan complex is on the right, with outcrop location marked by star; from Google Earth.

much less common and always considered as palaeosols. In the Guadalquivir basin of Spain (Espejo Serrano, 1985; Núñez and Recio, 2007; Saldaña et al., 2011) a consistent body of Ultisols is referred to Late Pliocene.

In Italy, Ultisols cover limited surfaces, but are not rare. The national soil data base (Costantini et al., 2013b) records 14 Soil Typological Units (STUs) as Ultisols, representing 0.25% of Italian soil cover. In Italian landform stratigraphy, Alfisols are often found on the lowest major terrace, in both river and marine sequences, and Ultisols on the next higher one. Application of both eustatic and climatic terrace development models has considered Ultisols as generically referred to MIS 7.

Filocamo et al. (2009) interpreted the second lowest marine terrace of Southern Calabria as being of MIS 7 or older age. On this terrace, Scarciglia et al. (2006) describe strongly weathered Alfisols, classified as such due to resupply of exchangeable bases from overlying recent sediments. Sauer et al. (2010) describe Ultisol-like soils on terraces along the Ionian coast of Lucania. These terraces are not dated, but are the youngest, in a well-studied terrace flight, which can be definitely said to be older than MIS 5.

Widespread evidence of Alfisols forming in Italy later than MIS 5 is available (Ajmone Marsan et al., 1988; Amorosi et al., 1996; Eppes et al., 2008; Costantini et al., 2009; Sauer et al., 2010). The absence of numerical dating, however (Carnicelli and Costantini, 2013), has prevented serious discussion of the Ultisol/MIS 7 assumption, eventually replaced by reference to "Early to Middle Pleistocene" (Napoli et al., 2006).

When moving from river or marine terraces to alluvial fan contexts, the concept of terraced surfaces acquires complexity. Palaeosol investigation may be very useful, even as a leading stratigraphic criterion (Wright and Alonso Zarza, 1990). This use requires, however, firm soil age models, backed by numerical dating.

In coastal Tuscany (Fig. 1), Alioto and Sanesi (1986) and Mori (1986) described an Ultisol on a surface interpreted as the highest in a series of eustatic marine terraces (Mazzanti and Sanesi, 1986).

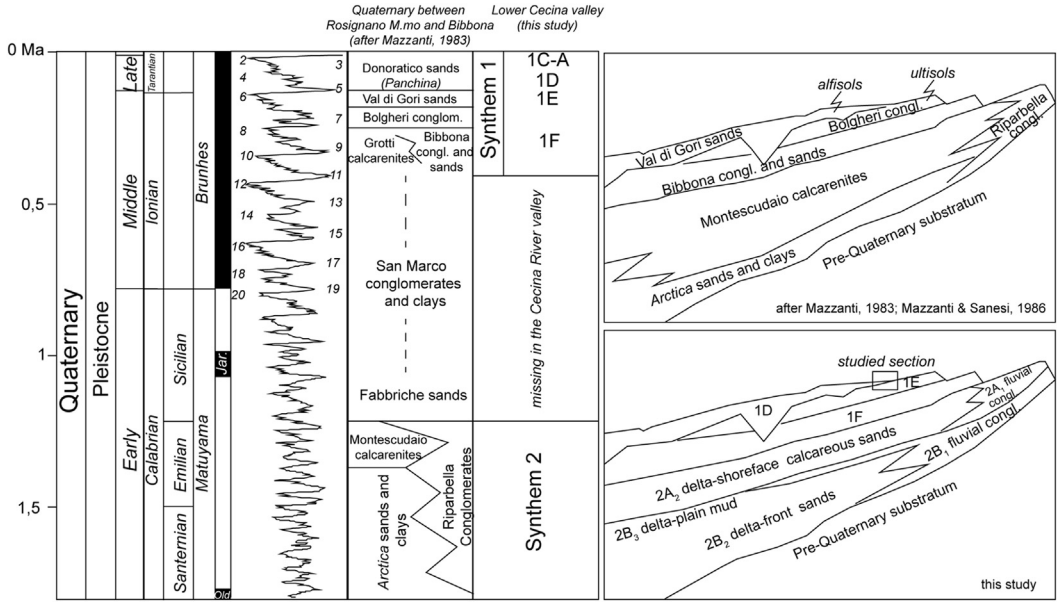

Fig. 2. Chronostratigraphic schemes of the Quaternary succession in the Cecina coastal area, comparing previous reconstructions with the subdivisions adopted in this study.