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Facies and sequence stratigraphic modeling of a Upper Pliocene–Lower Pleistocene fluvial succession (Valdelsa Basin, central Italy)

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ABSTRACT

This paper illustrates the results of sedimentologic and stratigraphic analyses of the upper Piacenzian–Gelasian fluvial succession exposed in the Neogene–Quaternary Valdelsa Basin (central Italy). The succession shows a cyclothemic stacking of gravelly, sandy and muddy lithofacies organized into four monogenic facies associations (A–D). These record depositional environments ranging from braided to low-sinuosity river channels to flood basins. Associations A–D attest to lowstand (A–B), transgressive and high-stand (C–D) depositions in a full cycle of base-level variations. In each association, internal erosional surfaces separate early transgressive association C from the late lowstand association B. The systematic B/C channel scouring is interpreted as the result of a high water/sediment discharge ratio determined by a decrease of coarse-grained sediment supply to the fluvial systems during rise of base level. This erosive surface is conceptually analogous to the ravinement surface sculpted by wave erosion during the transgressive, landward migration of a shoreface. The late transgressive and highstand mud-dominated association D records the flood basin, a depositional environment indicative of a high base level which transformed a former channel belt in a plain dominated by fine-grained sediment settling, bio- and pedoturbation. The studied succession records rhythmic variations of base level and sediment supply to the fluvial systems, in turn regulated by different-rank relative fluctuations of Piacenzian sea level. In this perspective, concepts of sequence stratigraphy and facies analysis are exploited for producing a reliable fluvial sequence stratigraphic model.

1. Introduction

Since the early popularization of the Exxon sequence stratigraphy (Wilgus et al., 1988), sedimentary geologists opened a lively discussion on the concept of depositional sequences (see reviews in Emery and Myers, 1996; Catuneanu, 2006; Miall, 2010). The significance and origin of erosional unconformities bounding Exxon-type sequences and the role of alluvial systems in sequence aggradation extended the discussion to the fluvial geomorphological and sedimentological communities (Blum, 1990; Miall, 1991; Blum, 1993; Schumm, 1993; Wescott, 1993; Miall, 1996; Blum and Törnqvist, 2000; Bridge, 2006; Gibling, 2006). The complexity of fluvial dynamics, though not being the main focus of the early Exxon models, appeared to have been largely overlooked for its role in building up the stratigraphic record (Wright and Marriott, 1993; Shanley and McCabe, 1994; Blum and Törnqvist, 2000; Rhee, 2006). In its spatial and temporal development the fluvial system is affected by the interplay of physiography, tectonism, climate and eustasy (Shanley and McCabe, 1994) which results in a complex behavior of rivers in terms of erosion and sedimentation (Schumm, 1977, 2005). This complexity, therefore, makes reference to classic “sequential” concepts, such as accommodation, base-level and bounding unconformity, of uncertain value in the stratigraphic interpretation of the fluvial record (Schumm, 1993). This is why the sequence stratigraphy approach to fluvial successions should be based on as many case studies as possible before it may become a well-established tool for stratigraphic analysis in non-marine settings (Blum and Törnqvist, 2000; Postma and Holbrook, 2003; Rhee, 2006). This paper describes the facies analysis of an Upper Pliocene (Piacenzian)–Lower Pleistocene (Gelasian) fluvial succession characterized by a well-developed and laterally continuous rhythmic stacking of conglomerates, sandstones and mudstones. The aim of the study, therefore, is to discuss the cyclic control on the sedimentary facies and key stratigraphic surfaces in producing a reliable fluvial sequence stratigraphic model.

2. General setting and sequence stratigraphy

The Valdelsa Basin (central Tuscany, Fig. 1A) is an intermontane depression stretching in a NW–SE direction for about 60 km, confined by two main ridges. To the southwest the Mid Tuscan Ridge consists of limestones, mudstones, sandstones and ophiolites (Ligurid units) thrusted onto Paleozoic metasediments, in turn covered by Triassic evaporites and limestones (Tuscan units). On the opposite Albano–

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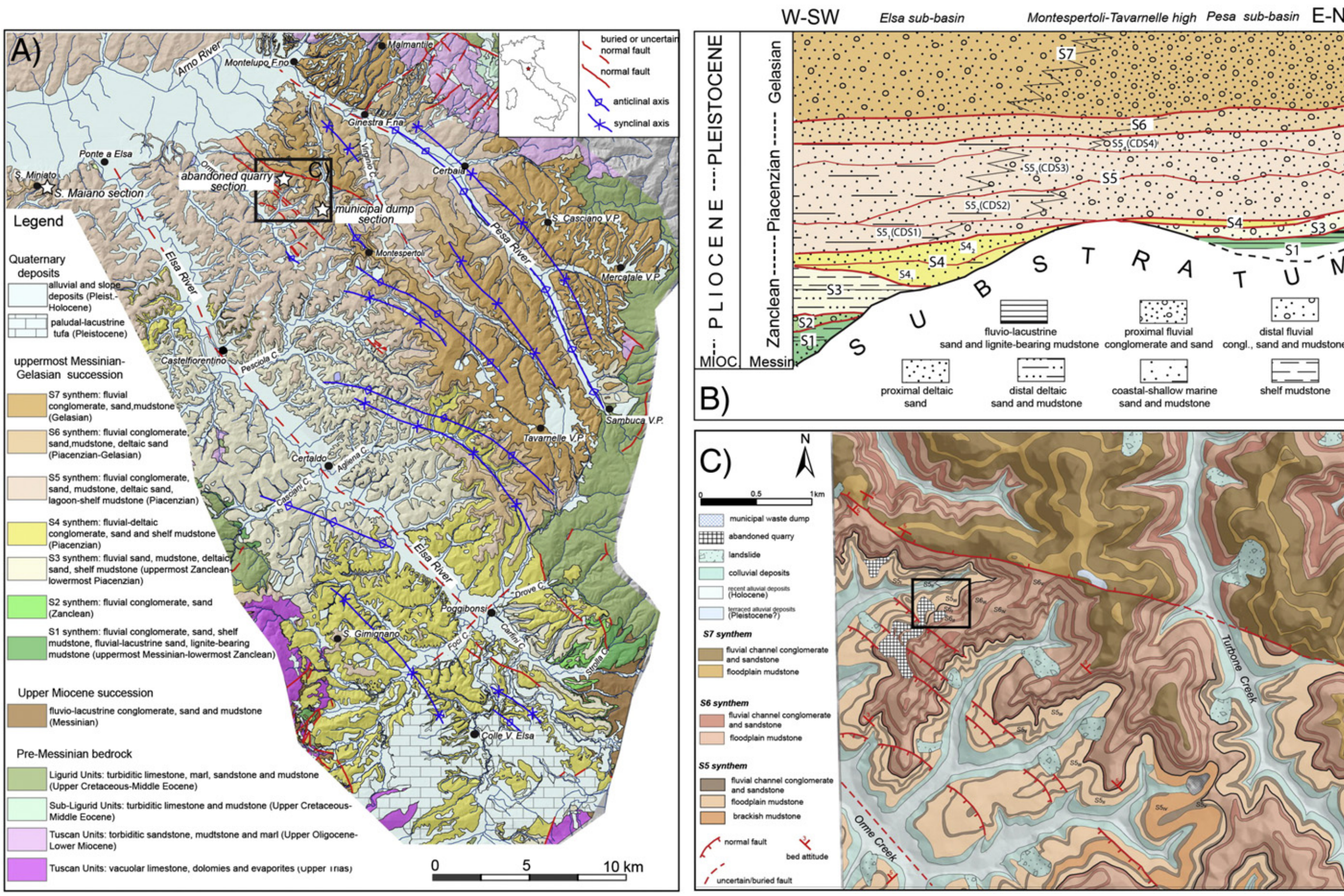

Fig. 1. A) Geological map of the Valdelsa Basin (after Benvenuti et al., in press) with location of the study area and some stratigraphic sections discussed in the text; B) stratigraphic scheme of the uppermost Miocene–lower Pleistocene succession filling the Valdelsa Basin: the Montespertoli–Tavarnelle buried high subdivided the basin in two adjacent depocenters during the deposition of S1–S3 synthems resulting inactive during the deposition of S4–S7 synthems (see discussion in Benvenuti et al., in press). Due to the occurrence of internal, low-rank unconformities, the S4 and S5 synthems have been further subdivided in sub-synthems; C) detailed geological map of the study area, the boxed area includes the abandoned quarry where the ten logs (see Figs. 3, 4) have been measured.

Chianti mounts, the Ligurid units are thrusted onto upper Oligocene–lower Miocene turbiditic sandstone (Tuscan units). An Upper Miocene–Lower Pleistocene clastic succession up to 2000 m thick (Ghelardoni et al., 1968) has been subdivided into seven unconformity-bounded stratigraphic units (synthems in the sense of ISSC, 1994; Fig. 1B) developed since the latest Messinian (S1 synthem), throughout the Zanclean (S2–S3 synthems), the Piacenzian (S4–S5 synthems) and the Gelasian (lower Pleistocene) (S6–S7 synthems) (Benvenuti and Degli Innocenti, 2001; Benvenuti et al., in press). These synthems reflect major relative sea-level fluctuations representing in this perspective large-scale depositional sequences (Benvenuti et al., in press; Fig. 2) in which lowstand systems tracts (LST) are represented by fluvio-deltaic conglomerates and sandstones, whereas transgressive systems tracts (TST) are typically indicated by prodelta-inner shelf mudstone occurring in the middle-upper part of the synthems. The highstand systems tracts (HTS) are eventually represented by deltaic and/or alluvial sandstone and conglomerate at the top of the synthems. The S5–S6 synthems exposed in the central portion of the basin (Fig. 1B) have been recently discussed for their composite sequential architecture which responded to glacio-eustatic forcing (Benvenuti et al., 2007). Four composite depositional sequences (CDS1–4) stacked within the S5 synthem (Benvenuti et al., 2007; Fig. 2) are in turn composed of elementary depositional sequences (EDS, in the sense of Mutti et al., 1994). From the base, each EDS is characterized by fluvio-deltaic sandstone passing upward into shelfal mudstones bearing shell beds (Benvenuti et al., 2007). CDS4, recording the maximum deepening of the late Piacenzian shallow sea, includes EDSa–d (Fig. 2) which mark four successive steps in the late development of the S5 synthem.

3. Study area and methods

The study area is located in the central portion of the Valdelsa Basin at about 10 km SW from the Albano–Chianti mounts which represented the main source for the Pliocene fluvial systems (Benvenuti and Degli Innocenti, 2001; Balestrieri et al., 2013; Benvenuti et al., in press). Inactive quarries on the hilly slopes on the right of the Orme Creek, a left tributary of the Arno River (Figs. 1C, 3A) provide relatively good exposure of alternated yellow-brownish conglomerate, sandstone and grayish mudstone (Fig. 3B). NW–SE trending normal faults interrupt the lateral continuity of these deposits (Fig. 1C). Despite the fault disturbance the unconformable contact between the S5 and S6 synthems, traced out through detailed mapping over a wider area, is well visible in the quarry faces (Fig. 3B). Ten vertical logs (Fig. 4) have been measured and correlated following standardized methods of facies analysis (Dalrymple, 2010 for a review). Different facies have been grouped into two types of associations: monogenic and hybrid facies associations, respectively. Taking as a reference Mutti et al. (1994) (Fig. 5), monogenic facies associations are identified based on the repetition of single or different facies which express the autocyclic behavior of specific depositional systems within a given available accommodation space. Hybrid facies associations are characterized by the stacking of monogenic facies associations which outline changes in accommodation space, hence the role of allocyclic forcing on depositional dynamics (Mutti et al., 1994). $S5_{I–V}$ and $S6_{I–V}$ hybrid associations have been mapped in the S5 and S6 synthems, the latter erosively overlain by the S7 synthem conglomerate and subordinated sandy mudstone, which are not considered in this study (Fig. 1C). Specifically to the S5 synthem, the $S5_{IV}$ association is characterized by the occurrence of