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Geology and sedimentary facies of the Pliocene succession of the Baronia Mountains (Ariano Basin, southern Italy)

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An up to 1500 m-thick clastic succession, the late Zanclean Baronia Synthem, has been analysed in detail in the Ariano wedge-top Basin (southern Apennine, Italy). In the Baronia Mountains the studied sediments are well exposed and laterally mappable due to young uplift and exhumation and rest unconformably on a complexly deformed pre-Pliocene substratum formed by Triassic to Miocene allochthonous units. The Baronia Synthem has been resolved into seven facies associations that are representative of distinct fluvial, deltaic, nearshore and offshore depositional environments and can be grouped into lowstand, transgressive, and highstand systems tracts. Using an integrated approach comprising original geological field mapping at 1:10,000 scale, conventional sedimentary facies analysis and a sequence stratigraphic approach, this paper provides a detailed description and interpretation of facies associations and new insights on the stratigraphic architecture and the geological history of this portion of the basin fill.

Keywords: southern Apennines; sequence stratigraphy; Ariano Basin; Pliocene; Baronia Synthem

1. Introduction

This study deals with the clastic deposits that crop out in the Baronia Mountains, southern Italy (Figure 1), with special attention on the upper Zanclean sedimentary succession. The study area is located in the external sector of the southern Apennines, which evolved within the general framework of Africa–Europe major plate convergence in Late Cretaceous to Quaternary times (e.g. Boccaletti et al., 1990; Doglioni, 1991; Schettino & Turco, 2011 and references therein) and consists of a salient NE-verging thrust and fold belt. The imbricate thrust system comprises tectonic units derived from the Cretaceous to Neogene portions of the Lagonegro–Molise Basin, the Miocene Numidian and Irpinian palaeo-domains, and late Miocene-Pleistocene wedge-top *basin successions* (Bonardi et al., 2009; Di Nocera et al., 2006; Patacca & Scandone, 2007; Vezzani, Festa, & Ghisetti, 2010; Vitale & Ciarcia, 2013 and references therein). On the outer sectors of the Southern Apennines, Pliocene to Pleistocene alluvial, deltaic and platform deposits within different small sedimentary basins distributed along the strike of the belt, unconformably overlie the deformed Mesozoic to Cenozoic units and are extensively exposed (e.g. Giannandrea, Marino, Romeo, & Schiattarella, 2014;

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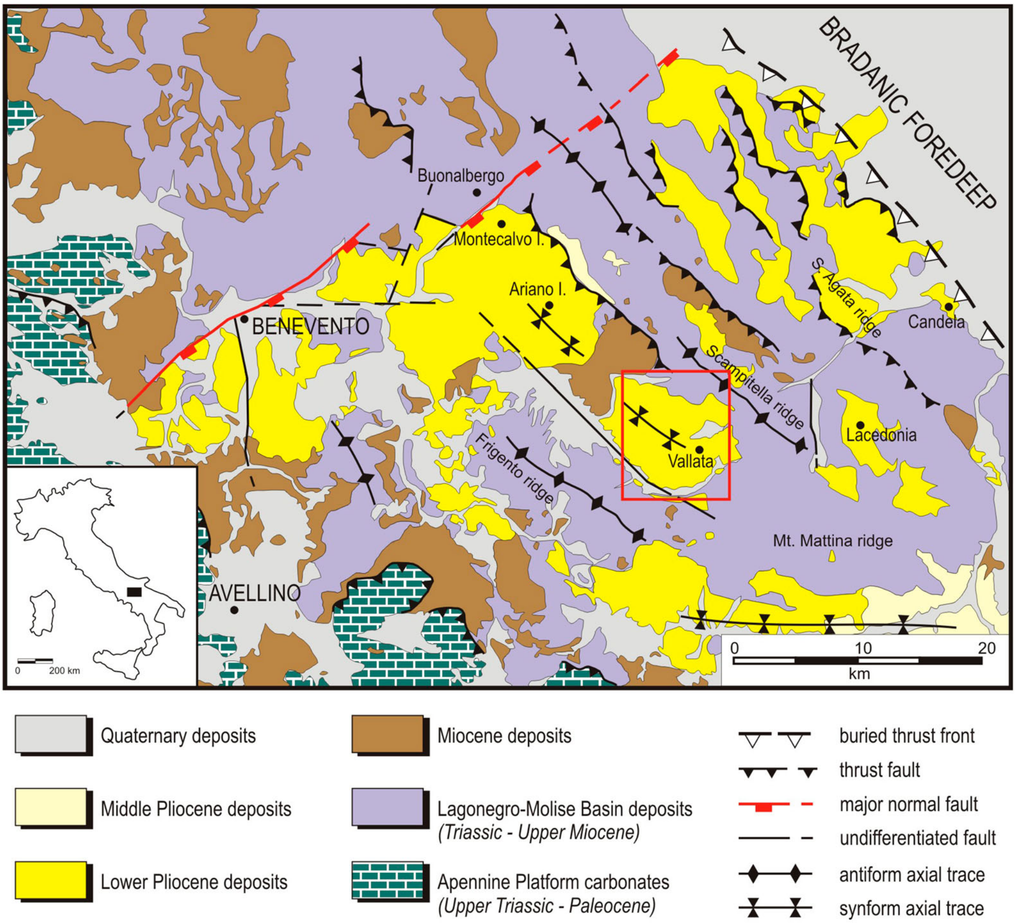

Figure 1. Outline geological map of the Southern Apennines (after Bonardi et al., 2009, modified) showing the main geological framework of the Ariano Basin and location of the study area (hollow box).

Longhitano, 2008; Pieri, Sabato, Loiacono, & Marino, 1994; Zavala, 2000). Recently, based up on detailed work on the stratigraphic record of these Plio-Pleistocene wedge-top basin fills, Ascione, Ciarcia, Di Donato, Mazzoli, and Vitale (2012) envisaged that in late Zanclean to early Pleistocene times subsidence and basin development shifted progressively from northwest to southeast in response to the progressive lateral migration of a slab tear within the subducting Adriatic lithosphere. In this framework, the Pliocene Ariano Basin was the northernmost of these wedge-top basins (Ciarcia & Vitale, 2013 and reference therein). The basin-fill succession (Ariano Supersynthem) displays an overall wedge-shaped cross-sectional geometry, with the thickness increasing significantly in the northwest direction (i.e., towards the so-called Benevento-Buonalbergo fault, a southeast-dipping synsedimentary normal fault bounding the basin to the north; Ciarcia & Vitale, 2013; Mazzoli, Szaniawski, Mittiga, Ascione, & Capalbo, 2012). Due to an intervening major unconformity, Amore et al. (1998) have subdivided the stratigraphy of the Ariano Supersynthem into two discrete allostratigraphic units (Figure 2): the Baronia Synthem (Zanclean) and the Sferracavallo Synthem (Piacentian). Published biostratigraphic data from the sediments exposed in the study area (Amore et al., 1998; Matano & Staiti, 1998), indicate that they can be assigned to the late Zanclean and, therefore, they are part of the Baronia Synthem.

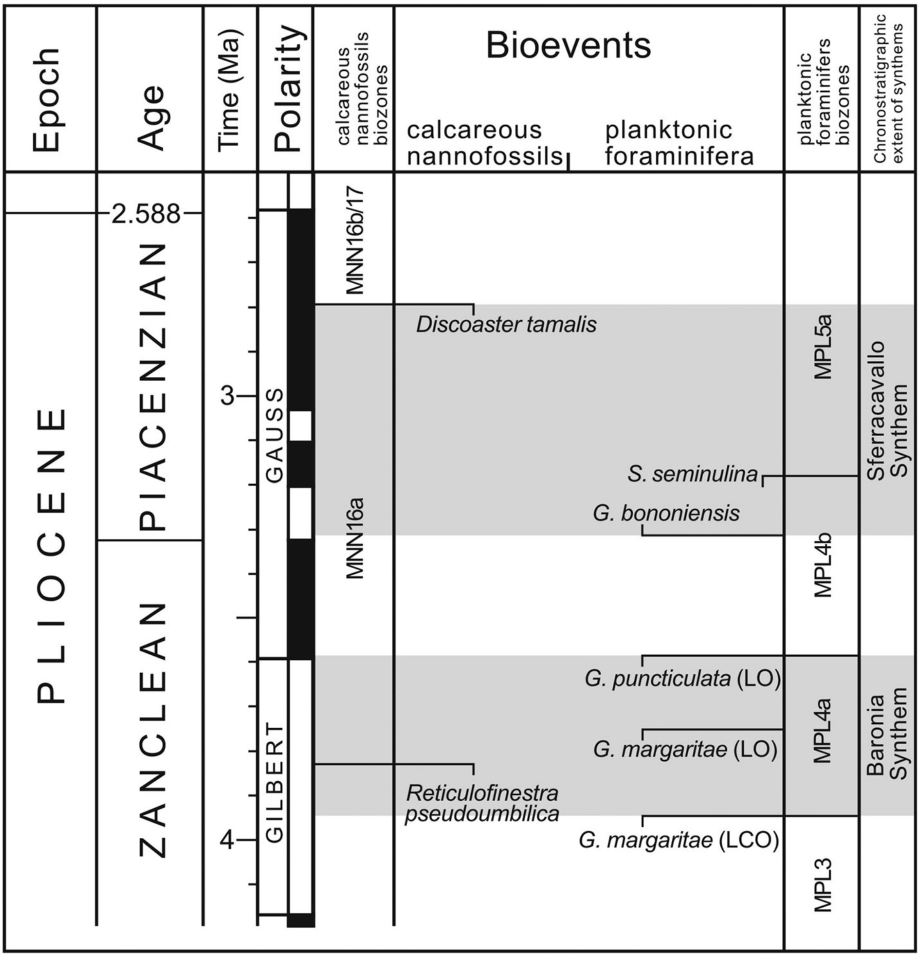

Figure 2. Estimated bio-chronostratigraphic extent of the Baronia and Sferracavallo Synthems of the Ariano Basin. Calcareous plankton bio-magnetostratigraphy derived from the original scheme of Cita (1975), Raffi and Rio (1979), Rio, Raffi, and Villa, (1990) integrated and chronologically calibrated by various authors (Lourens, Hilgen, Laskar, Shackleton, & Wilson, 2004). The Astronomical Tuned Neogene Time Scale (ATNTS) is after Lourens et al. (2004).

Most of the previous studies on the Pliocene successions exposed in the Ariano Basin have focused on their regional distribution, large-scale depositional trends and tectono-stratigraphic organisation (Chiocchini, Conato, & Valletta, 1971; Di Nocera et al., 2006 and references therein; Mazzoli et al., 2012). However, few attempts have been made to provide a detailed sedimentary facies analysis (Aiello, Barra, Ciarcia, & Torre, 2005; Cantalamessa & Di Celma, 1997; Ciarcia & Vitale, 2013; Di Celma, 1995) and, as a result, a number of important questions on the depositional environments, palaeogeographic evolution, patterns of accommodation and sediment accumulation through the time as well as the sequence stratigraphic framework still remain. This research provides a sedimentary facies analysis of the late Zanclean deposits exposed in the Baronia Mountains, an account of their sequence stratigraphic architecture and defines a clearer picture of the complex evolution of this sector of the basin.

2. Study area and methodology

The sedimentology and stratigraphic architecture of the late Zanclean deposits exposed in the Baronia Mountains were examined over an area encompassing approximately 100 km^2. Methods used to carry out the 1:20,000-scale geological map of this study (Main Map) include original field mapping at 1:10,000 scale of the main facies associations recognised in the Baronia Synthem and compilation of several detailed logged sections from high-quality outcrops. This approach, as opposed to one that deals with informal lithostratigraphic units, is intended to extract greater sedimentologic detail from the outcrop belt. As described below, the sedimentary succession has been subdivided into seven facies associations. An individual facies association defines a particular depositional environment and comprises an array of physically and genetically related facies that are differentiated by grain size, bed configuration, lateral extent of beds or bedsets, bed thickness, grain sorting, and the presence or absence of primary sedimentary structures. To further advance facies interpretations and palaeogeographic reconstruction, palaeocurrent trends were obtained from imbricate pebbles, channel-margin orientations, cross-beds, asymmetric ripple crests, and lateral facies trends and analysed using the freeware programme EZ-ROSE by Baas (2000). Measurements taken from beds dipping more than 15° were first corrected by restoration of planes on a stereonet. Statistical data in rose diagrams include the number of measurements per diagram (*n*). Since this study was focused on specific aspects of the late Zanclean succession, the pre-Pliocene and Quaternary strata exposed in the study area were examined only in reconnaissance fashion during our field surveys and are not treated in detail here.

3. Pre-Pliocene Bedrock

In the study area, sediments of the Baronia Synthem rest unconformably onto a deformed substratum formed by Mesozoic to Miocene allochthonous successions of the Lagonegro–Molise basinal domain (Frigento, Fortore and Daunia tectono-stratigraphic units) and overlying wedge-top Messinian sediments (Torrente Fiumarella-Anzano Molasse Synthem) of the Altavilla Supersynthem.

The Frigento, Fortore and Daunia units are strongly deformed and thrusted eastward upon the buried Apulian thrust system (Basso et al., 2002). A detailed description of the different sedimentary successions forming these three units is provided by Di Nocera et al. (2006). Sediments of the Torrente Fiumarella-Anzano Molasse Synthem (Di Nocera et al., 2006) rest unconformably on those of the Lagonegro–Molise basinal domain and include fluvio-lacustrine conglomerates and clays, and thinly bedded turbidite sandstones and marly or clayey siltstones interbedded, in the upper part of the sequence, with volcaniclastic layers (Matano, 2002).

4. Baronia synthem: facies associations and environmental iinterpretations

Sedimentological analysis of the Baronia Synthem has been undertaken by subdividing its sediments into seven main facies associations (labelled FA-1 to FA-7) that can be found grading into or interfingering with one another. All facies association, in order to be recognised and mapped, had to show the same characteristics over an interval at least 10 m thick and with significant lateral continuity. The seven facies associations identified in the study area are: (i) braided fluvial channel conglomerates (FA-1); (ii) floodplain sandstones, siltstones and conglomerates (FA-2); (iii) mouth-bar gravelly sandstones (FA-3); (iv) transgressive beachface lag deposits

(FA-4); (v) shoreface sandstones (FA-5); (vi) offshore-transition siltstones and silty fine sandstones (FA-6); and (vii) offshore mudstones (FA-7).

4.1. *Facies association 1 (FA-1): clast-supported conglomerates (braided fluvial channel deposits)*

4.1.1. *Description*

This facies association is documented at the base and at the top of the Baronia Synthem (Figure 3(a)). Bedding in the conglomerate is weak to well-defined, medium to thick, and locally lenticular. Component clasts are well-rounded and their size varies from pebble to cobble to boulder. The matrix consists of fine to very coarse sand. Clasts are composed dominantly of sandstones and limestones and subordinate marls, quartzites, siltites and cherts that reflect a local source, clearly deriving from the erosion of the accreted terranes forming the southern Apennine thrust-belt (Matano, Critelli, Barone, Muto, & Di Nocera, 2014; Torre & Ciarcia, 1995).

Structureless, crudely bedded conglomerates (facies *Gh*, first defined as facies *Gm* in Miall, 1977; all codes from Miall, 1996) represent the most abundant facies within FA-1. This facies comprises clast-supported, disorganised to crudely normally graded coarse pebbles and cobbles with a common *a(t)b(i)*-imbrication. The matrix is locally abundant and consists of coarse-grained sand. Crude stratification is subhorizontal and is defined by variations either in clast size or in degree of clast sorting. Individual beds, ranging from 0.3 m to 2 m in thickness, are laterally discontinuous and generally show clear evidence of erosion at the base, commonly on a scale of several decimetres. Cross-bedded conglomerate (facies *Gp* and *Gt*) may occur in this facies association but is largely subordinate. In sections transversal to the palaeotransport direction, planar cross-bedded conglomerates (facies *Gp*) occur as isolated sets, as thick as 1.5 m, of inclined strata ($15^\circ - 20^\circ$) that are delineated by subtle variations in clast alignment, grain size or matrix content. Trough cross-stratified conglomerates (facies *Gt*) occur as solitary sets characterised by concave upward lower bounding surfaces and ranging from several centimetres to 1.5 m in thickness and from 4 m to 7 m in width.

Fine to very coarse-grained sandstone occurs interbedded with conglomerate as minor, laterally impersistent lenses or wedges displaying plane-parallel lamination (facies *Sh*) or planar cross-stratification (facies *Sp*). Typically, due to marked erosion by the overlying conglomerate, these sandstone beds are less than 1 m thick and laterally discontinuous.

4.1.2. *Interpretation*

The abundance of concave-upward erosional surfaces, preservation of lenticular sand bodies, and dominance of *Gh*, *Gp,* and *Gt* facies are indicative of deposition within a gravelly braided stream system in which a shifting network of unstable, low sinuosity, shallow channels were able to freely migrate laterally within a well-defined channel-belt.

Most of the *Gh* units reflect deposition by longitudinal bars (Hein & Walker, 1977; Miall, 1977; Rust, 1978; Smith, 1974). Subordinate amounts of *Gp* facies probably formed by downstream migration of large, isolated, mid-channel transverse bars (e.g. Hein & Walker, 1977; Massari, 1983; Miall, 1977; Steel & Thompson, 1983) or later modification of longitudinal bars during falling flood stage (e.g. Rust, 1978; Smith, 1970). The frequent occurrence of isolated sets of *Gp* facies within deposits of *Gh* facies is explained more easily by the second hypothesis. Isolate sets of trough cross-stratified conglomerates (*Gt* facies) have been commonly interpreted

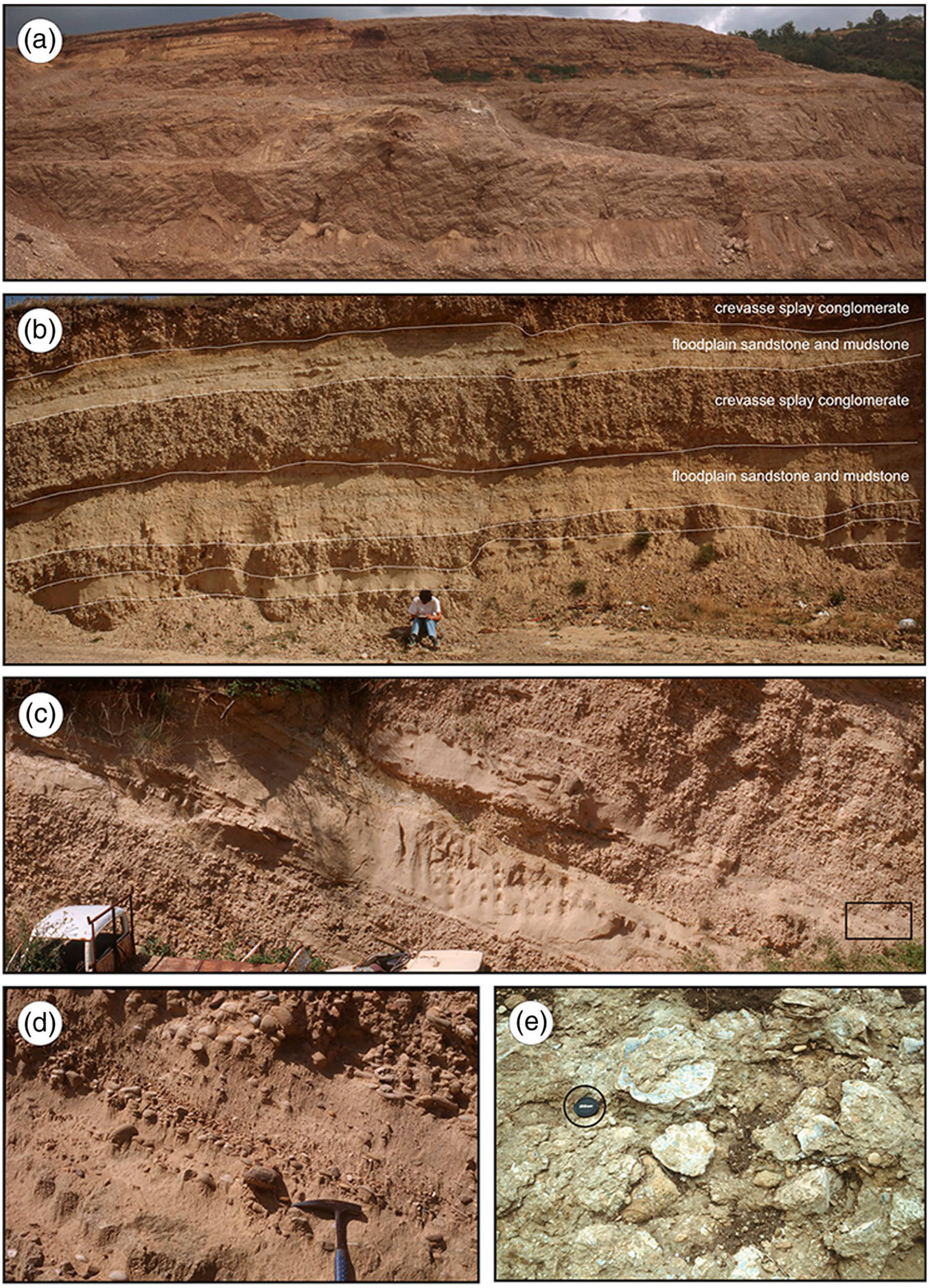

Figure 3. (Continued).

to record scour-fill features (e.g. Khadkikar, 1999; Siegenthaler & Huggenberger, 1993). The planar cross-bedded sandstones represent transverse bedforms that were presumably deposited on the surface of gravel bars during waning flood stages. The rarity of sandstone lenses or layers reflects their poor preservation potential.

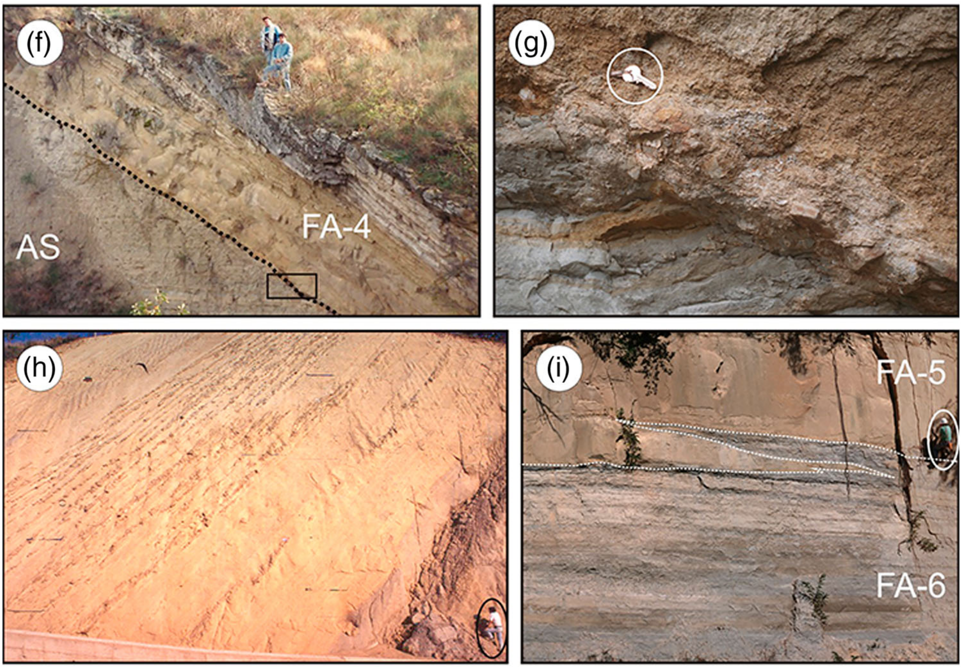

Figure 3. Representative field photographs of some of the main facies associations of the Baronia Synthem. (a) Distant view of monotonous, dominantly pebble- to boulder-size conglomerates of FA-1; (b) crevasse splay conglomerates separated by laterally continuous floodplain mudstones and sandstones in FA-2; (c) shore-normal cut of FA-3 (land to the left) showing sandstone beds that interfinger with, and wedge out into, conglomerates; (d) zoomed image of the boxed area shown in the lower right corner of (c), illustrating layers of wave-worked pebble conglomerates dominated by blades and discs and displaying a well-developed seaward dipping imbrication. (e) Close-up view of scattered boulders, pebble and shells (FA-4) interpreted as a transgressive lag deposit formed during shoreface retreat. Large shells are randomly oriented and dominated by Oysters and Pectens whereas pebbles and cobbles are frequently characterised by lithophaga bores (a 6.5 cm in diameter lens cap for scale); (f) panoramic view of FA-4 sediments resting with conspicuous discordance on Upper Messinian sediments of the Altavilla Supersynthem (AS); this sharp and scoured surface (dotted line) is interpreted as a wave-cut ravinement surface; (g) zoomed image of the boxed area shown in (f), displaying a detail of the ravinement surface. Conspicuous components of coarse fossiliferous deposits blanketing the unconformity surface including broken and variably abraded shell material and graywacke pebbles from erosion of the substrate in a matrix of comminuted bioclastic debris (circled key for scale); (h) panoramic view of the sand-prone shoreface sediments of FA-5. Note circled person for scale; (i) general view showing bioturbated siltstones and silty fine sandstones (FA-6) passing into shoreface sandstones (FA-5) through rather abrupt vertical and lateral facies transitions highlighted by a white dashed line. Person (circled) for scale.

4.2. *Facies association 2 (FA-2): sandstones and siltstones with interbedded conglomerates (floodplain deposits)*

4.2.1. *Description*

This facies association is composed primarily of alternating sand, silt and mud *(Fl)*, and parallel laminated silts and clays (*Fm*) with root marks and plant debris. Intercalated in these fine-grained sediments are sheet-like, single-storey sets of clast-supported pebble to cobble conglomerates that range from several tens of centimetres to 2 m in thickness and display flat or small-scale irregular bases (Figure 3(b)).

4.2.2. *Interpretation*

Facies Association 2 is interpreted as deposited in a low-energy floodplain environment serving as settling basin for fine-grained overbank sediments that pass over levees during floods. In this setting, sheet-like conglomerate beds dispersed within finer-grained floodplain sediments probably represent crevasse-splay deposits laid down within proximal parts of the overbank area during exceptional floods (e.g. Mader, 1985).

4.3. *Facies association 3 (FA-3): interfingering conglomerates and gravelly sandstones (mouth-bar deposits)*

4.3.1. *Description*

This facies association forms a facies belt located in the transitional zone between subaerial (FA-1 and FA-2) and submarine (FA-5) environments and its typical feature is an interfingering of layers of conglomerate and gravelly sandstone that dip gently in a seaward (northeastward) direction (Figure 3(c)). Most of the conglomerate beds are organised in both channelised and non-channelised bedding units and are composed of a pebble and cobble assemblage, commonly with a disorganised, chaotic fabric. Individual beds range from 30 cm to 2 m in thickness, are clast-supported, and show a rather variable degree of sorting. The matrix consists of medium- to coarse-grained sand. Occasionally, pebble conglomerates displaying moderate to excellent size- and shape-sorting organised into well-stratified layers also occur. They are clast-supported but loosely packed, with interstices either open, or filled with medium- to coarse-grained sand. Bedding is well-defined by changes in gravel-size mode.

Sandstone and pebbly sandstone intercalations are either cross-stratified or with diffuse plane-parallel lamination. Blades and disc-shaped clasts, displaying a pronounced seaward-dipping a- and b-axis imbrication, are both concentrated in isolated clumps and dispersed throughout (Figure 3(d)).

4.3.2. *Interpretation*

The relatively poor sorting and disorganised fabric suggest that relatively rapid deposition from non-cohesive debris flows is a likely origin for these gravel-rich deposits. Post-depositional modification by moderate wave activity resulted in the excellent size- and shape-sorting displayed by some of the conglomerate beds. As such, these deposits probably reflect the growth of fluvially emplaced mouth-bar deposits partially reworked by waves in front of an intricate distributary-channel network (e.g. Kleinspehn, Steel, Johannessen, & Netland, 1984). Sediments interpreted as mouth-bar deposits in fluvial dominated/wave-modified systems, somewhat analogous to those occurring in this study, have been described earlier by Marzo and Anadon (1988), Rigsby (1994), Rasmussen (2000), Longhitano (2008), and Amorosi, Bracone, Di Donato, Rosskopf, and Aucelli (2009).

4.4. *Facies association 4 (FA-4): wave-winnowed lag deposits (transgressive beachface deposits)*

4.4.1. *Description*

Volumetrically this facies association is a relatively minor component of the Baronia Synthem, but its composition and stratigraphic position are distinctive. These deposits, up to 15–25 m thick, are restricted to the lower part of the Baronia Synthem, where they rest on a major erosion surface and come in two laterally interfingering variants: (1) chaotic mixture of conglomerates and thick-shelled fossil molluscs, and (2) bioclastic calcarenites. The first variant, also encountered in the Trevico 1 exploration well at the base of the Baronia Synthem, is characterised by polymictic conglomerates. Clasts are predominantly well-rounded and of pebble to boulder size and commonly affected by bioerosion and dotted by *Lithophaga* borings. Sorting is very poor, fabric is absent, and the unit may be clast and/or matrix supported. The matrix is a poorly sorted mixture of granules, shell fragments, and fine- to coarse-grained sand. Whole bivalve shells (Ostreidae, Pectinidae and Cardidae), barnacles and shark teeth are locally present with most of the bivalve shells strongly fragmented and abraded to various degrees (Figure 3(e)). The second variant consists of massive, thoroughly bioturbated or well stratified, medium- to very coarse-grained bioclastic calcarenites (Figure 3(f) and 3(g)).

In general, sediments of this facies association are represented by the first variant where the basal surface truncates the subjacent nonmarine conglomerates or the Meso-Cenozoic sediments of the substrate and grade laterally into the second variant where the immediately underlying deposits are represented by heterolithic sediments of the Miocene Altavilla Supersynthem.

4.4.2. *Interpretation*

According to Cantalamessa and Di Celma (1997), the basal surface marks a wave ravinement surface cut by wave action at the toe of a retreating shoreface during the transgressive stage of the cycle. The facies association overlying this surface represents a high-energy nearshore setting and its location between alluvial or substrate deposits and overlying offshore deposits indicates that it may be related to transgression. As such, it is interpreted as a transgressive winnowed lag (e.g. Cattaneo & Steel, 2003; Clifton, 2003; Walker & Plint, 1992), which was derived from wave reworking of the underlying substrate as transgression proceeded and the sea advanced over the land. The marked lateral changes of this facies association, mainly with respect to thickness, internal organisation, mean grain size, and fossil content, most probably are the result of an interaction between an articulated morphology of the basal truncation surface and the changing lithology of the immediately underlying deposits.

4.5. *Facies association 5 (FA-5): cross-stratified, plane parallel-laminated, and thoroughly bioturbated sandstones (shoreface deposits)*

4.5.1. *Description*

The bulk of this facies association comprises yellowish-grey, weakly consolidated, fairly well-sorted sandstones of quartzo-feldspathic composition (Matano et al., 2014) with intercalations of centimetre- to decimetre-thick mud layers, decimetre-thick mudstone-prone heterolithic intervals, and thin conglomerate layers containing either extrabasinal or mud rip-up clasts (Figure 3(h)). Constituent lithofacies include variably bioturbated sandstones within which dominant sedimentary structures are planar, swaley and trough cross-stratification, as well as plane parallel-lamination and current ripple-lamination.

High-angle planar cross-stratified sandstone beds represent the most abundant lithofacies in this association. They typically occur in 0.2–1 m thick sets forming cosets as much as 8 m in thickness and separated by decimetre scale intervals of wave-rippled sandstones rhythmically interstratified with very thin mudstone drapes. Individual sets of cross-strata are commonly amalgamated and defined by low-angle erosion surfaces. Foresets, dipping at angles between 15 and 25°, are locally marked by alignments of small mud chips showing an updip decrease in size. Bioturbation is usually minimal, apart from sparsely scattered burrows.

The swaley cross-strata described herein occur as multiple concave-upward scours that cut into each other and are draped and filled by gently undulating and upward-flattening lamina sets. Small pebbles, granules, angular to well-rounded mud clasts, and broken shell material may also occur either scattered through the sand or concentrated into small pods and thin discrete lags on the scoured basal contacts.

Trough cross-stratification is present in sets up to 1 m thick, defined by bedding parallel, convex-up shells and shell fragments. It is typically unidirectional, resulting in outcrops of either tabular sets with asymptotic foresets (sections parallel to palaeoflow) or with lens-shaped to wedge-shaped sets with festoon cross-bedding (sections normal to palaeoflow).

Thoroughly bioturbated sandstones display a general paucity of primary sedimentary structures, though poorly preserved low-angle planar lamination and trough small-scale cross-stratification are locally present. Most of the bioturbation is attributed to intense reworking of the sediment and identifiable ichnofossils only include rare examples of *Ophiomorpha nodosa,* with well-defined pelleted walls, and *Thalassinoides*.

4.5.2. *Interpretation*

Occurrence of swaley cross-stratification indicates a storm-dominated depositional setting above a fair-weather wave base (Dott & Bourgeois, 1982; Leckie & Walker, 1982). Pebble-lined scours in swaley cross-stratified sandstones suggest deposition in current swept longshore troughs and rip channels (Hart & Plint, 2003). Erosively based, planar and trough cross-stratified sandstone beds record migration of two- and three-dimensional subaqueous dunes produced by strong unidirectional currents in a high-energy, storm-wave-dominated, upper shoreface setting (e.g. Harms, Southard, & Walker, 1982; Hiroki & Terasaka, 2005). According to Johnson (1977), storms were probably responsible for the erosion at the bases of these bedforms during their rising phase. The overall paucity of trace fossils further supports high-energy conditions that were unfavourable for invertebrate activity. Palaeocurrent directions derived from dip of cross strata suggest that, with respect to an inferred NW-SE-oriented shoreline, sediment transport was generally in a shoreward direction (i.e., to the SW), recording landward migration of dunes under the influence of shoaling waves. Foreset azimuth orientations directed towards the NW form a distinct secondary mode and are consistent with the activity of longshore currents. Very few foresets in cross-bedded sandstones dip in an offshore direction and may record the activity of seaward-directed rip-currents. Based on these features and the considerable variation in flow directions, this facies association is interpreted to indicate a shore attached bar-rip channel system (e.g. Hunter, Clifton, & Phillips, 1979). The intensity and uniformity of bioturbation in the massive sandstones, combined with the occurrence of relict laminated and hummocky cross-stratified intervals, indicate that bioturbated sandstones were deposited below a normal weather wave base largely during storm conditions and were subsequently bioturbated during fair-weather periods.

The combination of all these features indicates that Facies Association 4 (FA-4) reflects deposition in a weak-to-moderate energy shoreface setting broadly similar to those outlined in MacEachern and Pemberton (1992).

4.6. *Facies association 6 (FA-6): bioturbated siltstones and silty fine sandstones (offshore-transition deposits)*

4.6.1. *Description*

This facies association consists primarily of variably bioturbated silty to muddy very fine-grained sandstone beds (Figure 3(i)). The sandstone beds range from 5 to 20 cm in thickness, have lenticular geometry and may display hummocky cross-stratification or current-ripple cross-lamination.

4.6.2. *Interpretation*

Collectively, the thinly interbedded nature of the component sediments, the overall paucity of physical sedimentary structures, and the high degree of bioturbation reflect deposition of this facies association in a storm-influenced offshore-shoreface transition, between the storm and fair-weather wave bases. In this depositional environment, fine-grained sediment settled out of suspension for much of the time, punctuated by episodic influx of sand by high-energy, storm-generated waves and currents (Cheel, 1991; Dott & Bourgeois, 1982; Walker & Plint, 1992).

4.7. *Facies association 7 (FA-7): bioturbated mudstones (inner shelf/offshore deposits)*

4.7.1. *Description*

This facies association consists of massive to finely laminated, grey-blue-coloured mudstone containing thin, silty intercalations. The stratification is often obscured by the pervasive bioturbation. Fauna include both microfossils and macrofossils, such as foraminifera, echinoids, corals, scaphopods, gastropods, and bivalves.

4.7.2. *Interpretation*

The fine-grained nature of this facies association is interpreted to reflect the hemipelagic settling of clays from suspension in a low-energy, fully marine offshore setting that developed well beyond the influence of most current or wave processes and distal to sources of coarser sediment. The abundance of body and trace fossils suggests that the sea floor and the shallow subsurface were generally oxygenated, allowing epifaunal and infaunal organisms to thrive.

5. Structural features

The late Zanclean clastic succession exposed in the Baronia Mountains, between the Ufita River to the south and the Fiumarella Creek to the north, are folded into a broad, NW–SE-trending, slightly asymmetric synclinorium. This structure is possibly related with the NE–SW-oriented horizontal shortening produced by the upward propagation of deep geodynamic processes occurring within the buried Apulian Platform during the Pliocene-lower Pleistocene (Mazzoli et al., 2012). The sedimentary succession is also affected by NW–SE-trending, high-angle normal faults possibly reflecting mid-Pleistocene NE–SW extension in the axial zone of the chain (e.g. Schiattarella, 1998; Schiattarella, Di Leo, Beneduce, & Giano, 2003).

6. Conclusions: late Zanclean evolution of the Baronia mountains

Active basins undergo complex spatial and temporal variations in subsidence, uplift, sediment dispersal, and source-area erosion, and these variations can produce strikingly different stratigraphic signatures over short distances. The Geological Map of Baronia Mountains (southern Italy) provides entirely revised and new cartography of the late Zanclean sediments for a large sector of the Ariano Basin giving an overview of their stratigraphy, evolution of depositional systems and adjustments to changing parameters of sediment input and accommodation space through time. In the study area subsidence rates are interpreted as having been relatively high during deposition and the resultant basin-fill is represented by a 1500-m-thick succession that consists of a suite of interfingering fluvial, deltaic, nearshore and offshore deposits. As a whole, the lateral and vertical progression of facies associations defines a third-order depositional sequence that is considered to result from the interplay between sediment supply and basin

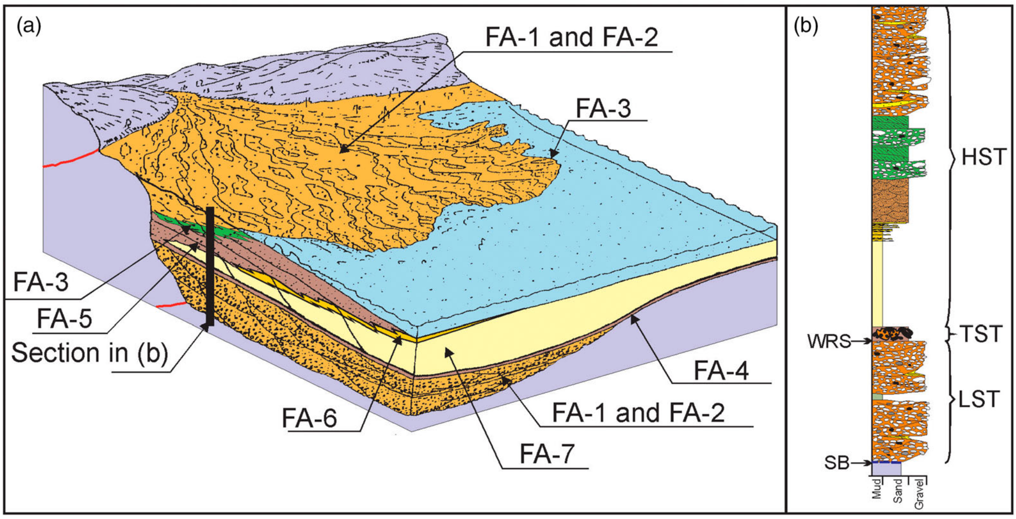

Figure 4. (a) Schematic block diagram illustrating the depositional settings and stratigraphic relationships of the Zanclean rocks in the Baronia Mountains area; (b) Schematic stratigraphic section (not to scale) showing the sequence stratigraphic framework.

subsidence and is characterised by an asymmetrical upward fining (transgressive) – to coarsening (regressive) trend of deposition (Figure 4). Based on changes in the stratigraphic stacking pattern and large-scale landward or seaward shifts in major facies belts within the study area, the following general evolutionary model for the infill of this portion of the Ariano Basins is proposed.

6.1. *Sequence stratigraphic framework and evolutionary model*

6.1.1. *Basal sequence boundary*

The origin of the Ariano Basin is linked to the beginning of a phase of marked subsidence, probably associated with north-northwest–south-southeast extension along the northern edge of the basin (Mazzoli et al., 2012). Prior to this phase, the study area was subaerially exposed and developed a regionally extensive unconformity at the top of the pre-Pliocene successions, which implies a significant period of erosion and sediment bypass.

6.1.2. *Lowstand systems tract*

The initial response to basin subsidence and creation of accommodation space resulted in deposition of clast-supported conglomerates in the thalweg of a low width-to-depth ratio, entrenched valley. These sediments rest directly over the eroded bedrock surface and, at the northern end of the study area, are seen to onlap and pinchout against the valley walls. They show evidence of deposition in a subaerial environment by a gravelly braided stream system. As summarised by Cantalamessa and Di Celma (1997) and Ciarcia, Di Nocera, Matano, and Torre (2003), this alluvial system transported towards the north-northeast sediments received from uplifted pre-Pliocene successions to the south.

6.1.3. *Transgressive systems tract*

Continuing subsidence produced a continual rise in relative sea level, landward retreat of the shoreline, and widespread marine transgression of the palaeo-Adriatic Sea, which established shallow-marine conditions across the entire study area. This rapid drowning of the subaerial landscape permitted deposition of well-cemented conglomerate and sandstone (FA-4) atop the alluvial conglomerates at the palaeovalley thalweg and directly over the basal sequence boundary on the interfluves outside the palaeovalley. The wave-ravinement surface at the base of FA-4 is the stratigraphic expression of the transgressive surface and on the interfluves it merges with the sequence boundary. As transgression progressed, the shallow-marine deposits have been overlain by a thick succession of shelf marine mudstones (FA-7), indicating a rapid deepening and decrease in both sediment grain-size and sedimentation rate.

6.1.4. *Highstand systems tract*

The upper portion of the basin fill is an overall coarsening- and shallowing-upward succession that reflects a sediment-driven regression and filling-up of the basin. This regressive portion, suggesting a significant decrease in the ratio of accommodation space to sediment supply, is manifested in the rock record by the progressive vertical transition from offshore through near shore and deltaic to fluvial sediments as a consequence of the basinward progradation of a coarse grained, braided river delta. Based on palaeocurrent measurements and lateral changes of depositional environments, a general north-easterly sediment transport direction and coastal progradation are indicated. Field mapping suggests that the overall progradational character of this portion of the studied sedimentary succession was intermittently punctuated by minor episodes of rapid transgression.

Software

The geological map and associated geological sections were compiled by scanning hand drafts as black and white TIF files, and then digitising the linework using Corel Draw X3.

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