Received: 10 April 2021 | Revised: 18 March 2022 | Accepted: 5 April 2022
DOI: 10.1111/bre.12669

RESEARCH ARTICLE

Basin Research IAS EAGE WILEY

Bottom currents on a pelagic carbonate platform: Mounds and sediment drifts in the Jurassic succession of the Sciacca Plateau, Western Sicily

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Funding information
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Abstract

The stratigraphic succession in the San Vincenzo Gorge (Saccense Domain, western Sicily) documents deposition on a vast pelagic carbonate platform, the Sciacca Plateau, during the Middle and Late Jurassic. This succession caps a peritidal limestone (Inici Formation), which underwent extension during the Western Tethyan Early Jurassic rift phase, and displays a set of unique features, which have never been previously reported on a Tethyan drowned platform. The upper part of the *Bositra* limestone (late Bajocian-early Oxfordian *p.p.*) comprises elongate convex-up, mound-shaped bodies, made of thin-shelled bivalve wacke- to grainstone, a few tens of metres across and producing a topographic relief of up to 10 m. Planar beds within the mound cores are seen to thin out laterally with tangential downlaps along sections perpendicular to the mounds' longer axes, and the mounds are in lateral association with concave-up bedsets. Following halt of the *Bositra*-dominated deposition and demise of mound accretion, the draping units inherited an antiformal geometry. The mounds are interpreted as being part of a sediment drift, produced by bottom currents sweeping the Plateau top, the source areas being sediment-depleted sectors now documented by extremely condensed and hiatus-ridden sections, with parallel-sided beds. Following draping and partial levelling of the submarine relief by the Knobbly limestone (?middle Oxfordian/early Kimmeridgian-late Kimmeridgian), the Coquina limestone is locally a thick (>20 m) ammonite/brachiopod rudstone (Tithonian *p.p.*). This unit displays evidence for lateral accretion, with large-scale clinoforms dipping up to 12°, and is interpreted as a mud-poor, bioclastic-gravel drift, with the action of bottom currents being apparently linked with a bloom of cephalopods. This is an early-cemented deposit, where clotted, micropeloidal fabrics document the calcification of microbial communities and are followed by growth of early diagenetic fibrous calcite. The description and interpretation of the mounded *Bositra* limestone and of the clinostratified Tithonian limestone are the main focus of this

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paper. The San Vincenzo Gorge outcrop displays similarities with pelagic shelves, like the Upper Chalk basin of northern Europe.

KEYWORDS

bottom currents, Jurassic, “mound”, pelagic carbonate platforms, Sicily, sediment drift

1 | INTRODUCTION

The Mesozoic stratigraphy of western Sicily is characterized by carbonate (limestones and dolostones), marly and cherty deposits that were sedimented across a complex depositional system of carbonate platforms and slopes, and deep-water basins, which developed at the rifted margin of the African Plate (Figure 1) (Di Stefano et al., 2013). The deepest basins (Imerese and Sicanian Domains) were initiated in the Late Permian (Catalano et al., 1995, 1996, 2000). To the West of the Sicanian Domain lay a vast carbonate platform, with rich marginal reefal facies in the Upper Triassic, followed by peritidal sediments through most of the Lower Jurassic (Di Stefano et al., 2015, and references therein). In the Early Jurassic, rifting fragmented the carbonate platform (Inici and Siracusa Formations), producing a system of pelagic basins and escarpment-bounded pelagic carbonate platforms (Hyblean, Trapanese and Saccense [named after the main town in the area, Sciacca] Domains) (see also Basilone, 2009, 2020; Bertok & Martire, 2009; Di Stefano et al., 2013; Jenkyns, 1971). The post-Pliensbachian Jurassic of western Sicily is world famous for its condensed pelagic facies, overlying the extended and drowned carbonate platform (Inici Formation) (Jenkyns, 1970; Wendt, 1963, 1965, 2017). Other areas survived as peritidal carbonate platforms (Panormide Domain) throughout the Jurassic (Figure 1) and the Cretaceous, albeit with phases of temporary emersion or drowning. The Saccense Domain of south-western Sicily represents the African foreland and the most external segment of the orogenic belt (Maghrebian Chain; Catalano et al., 2000; Elmi, 1980, and bibliography therein), and is composed of moderately deformed Meso-Cenozoic carbonate rocks covered by Neogene and Pleistocene mixed carbonate/siliciclastic, terrigenous clastic, hemipelagic and evaporite deposits (Sheet 619 “Santa Margherita di Belice” of the 1:50,000 Geological Map of Italy; Di Stefano et al., 2013). Our study area, the San Vincenzo Gorge, is located in the south-eastern slopes of Mt. Magaggiaro. Structurally it belongs to the Mt. Magaggiaro-Pizzo Telegrafo Unit (Di Stefano & Vitale, 1993), and it represents a ramp anticline originated by a south verging thrust system active since middle Pliocene time, having Mesozoic carbonates at its core (Figure 2).

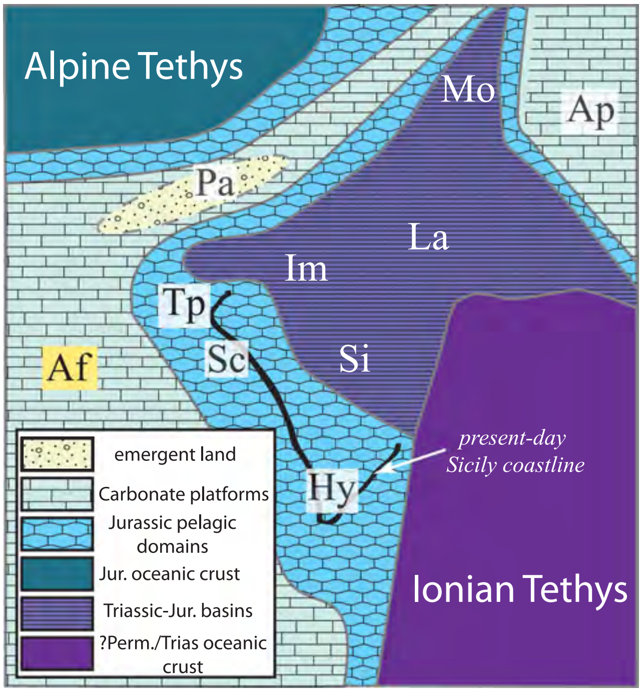

FIGURE 1 Middle Jurassic palaeogeographic domains of a region centred by Sicily, in the hypothesis of a “bridge” linking Africa with Adria. Af, African craton; Ap, Apulian platform; Hy, Hyblean; Im, Imerese; La, Lagonegro; Mo, Molise; Pa, Panormide; Sc, Saccense (study area, this paper); Si, Sicanian; Tp, Trapanese. Modified after Zarcone et al. (2010). The outline of present-day Sicily is open as the northeastern tip of the island (Peloritani Mts.) is an exotic terrane of uncertain palaeogeographic provenance

Tectonic extension and drowning of the Inici platform in the Pliensbachian produced a vast fault-bounded pelagic carbonate platform, the Sciacca Plateau (Muraro & Santantonio, 2002, 2003). Within the general picture of a drowned intrabasinal high capped by a thin pelagic succession, the San Vincenzo area of the Sciacca Plateau displays quite a remarkable set of unique features, which have not previously been reported from such a setting in the Tethyan Jurassic. They were introduced by Muraro and Santantonio (2002, 2003), and are mentioned in Di Stefano et al. (2013). These features include elongated mound-like bed packages, up to about 30 m across along shorter axis by >~50 m (longer axis, less well exposed), made of thin-shelled bivalve (*Bositra*) wacke- to grainstone (late Bajocian-early Oxfordian *p.p.*), and an up to 20-m-thick ammonite coquina, locally with clinoforms (Tithonian *p.p.*). Their description and palaeoenvironmental/sedimentological

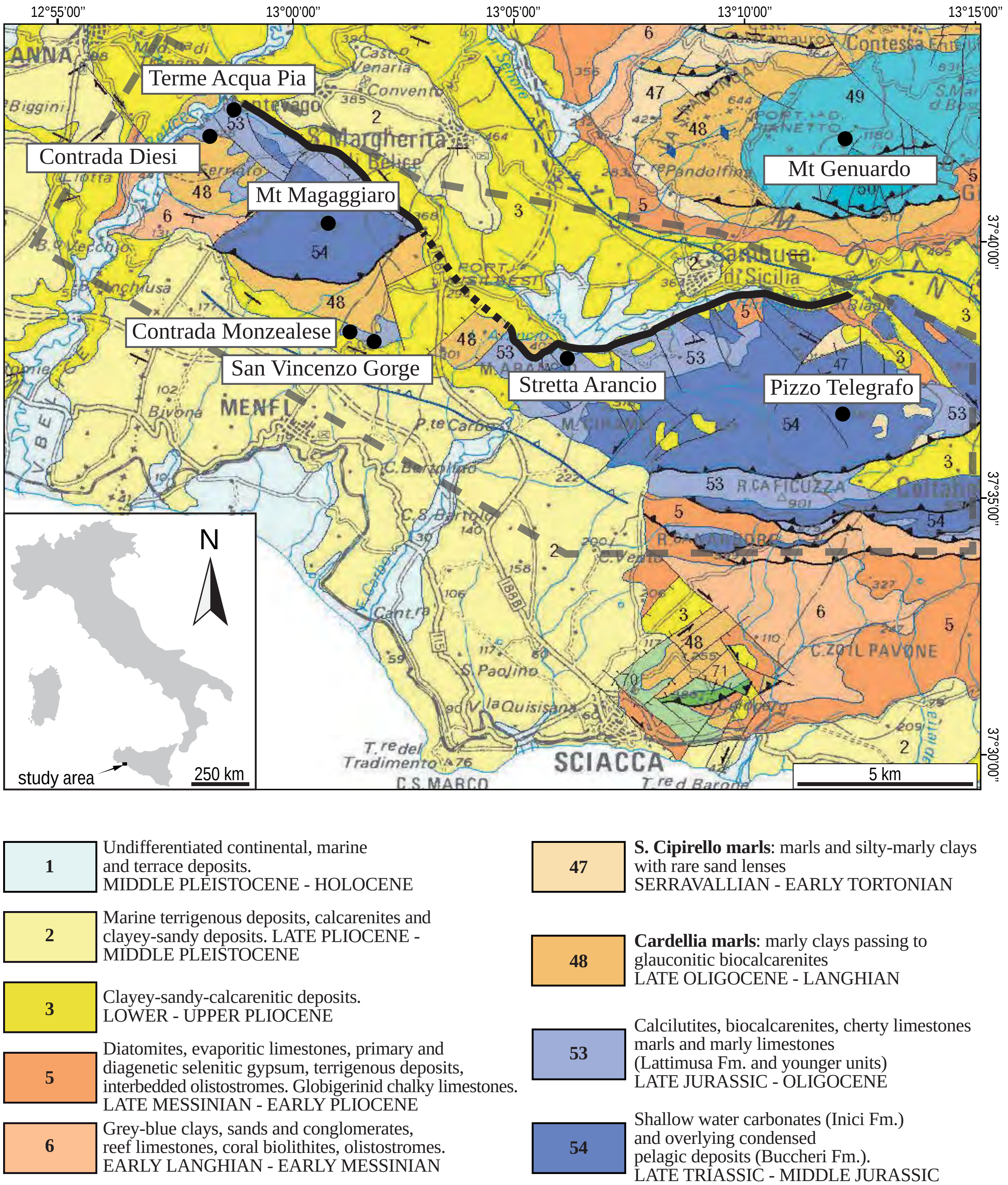

FIGURE 2 Excerpt, and numbering of lithostratigraphic units falling within the perimeter of the study area (dashed), after the Geological Map of Sicily by Lentini and Carbone (2014), with key localities mentioned in text. The spot named San Vincenzo Gorge is the area of Figure 4b,c, and includes the logs of Figure 6. Black line is the inferred Jurassic northern margin of the Sciacca Plateau (dashed where hypothetical/buried)

interpretation are the main scopes of this article, based on fieldwork and the use of ammonite biostratigraphy. A comparison with possible analogues, described in the Northern European Upper Chalk of Normandy and Denmark and in the subsurface of the North Sea and Baltic Sea, is herein attempted for the *Bositra* mounds.

The processes (reworking of sediment) and products (mounded intervals, sediment drifts, clinoforms), discussed in this paper, make the Jurassic Sciacca Plateau a possible reference area for modelling carbonate sedimentation on large drowned platforms in a pelagic environment, on land and in the subsurface. Our Sicilian case example demonstrates that large intrabasinal highs, like the Sciacca Plateau, could store within their perimeter the sediment reworked by currents. In contrast, on smaller scale highs, the re-suspended sediment was "wasted" and redeposited in surrounding basins.

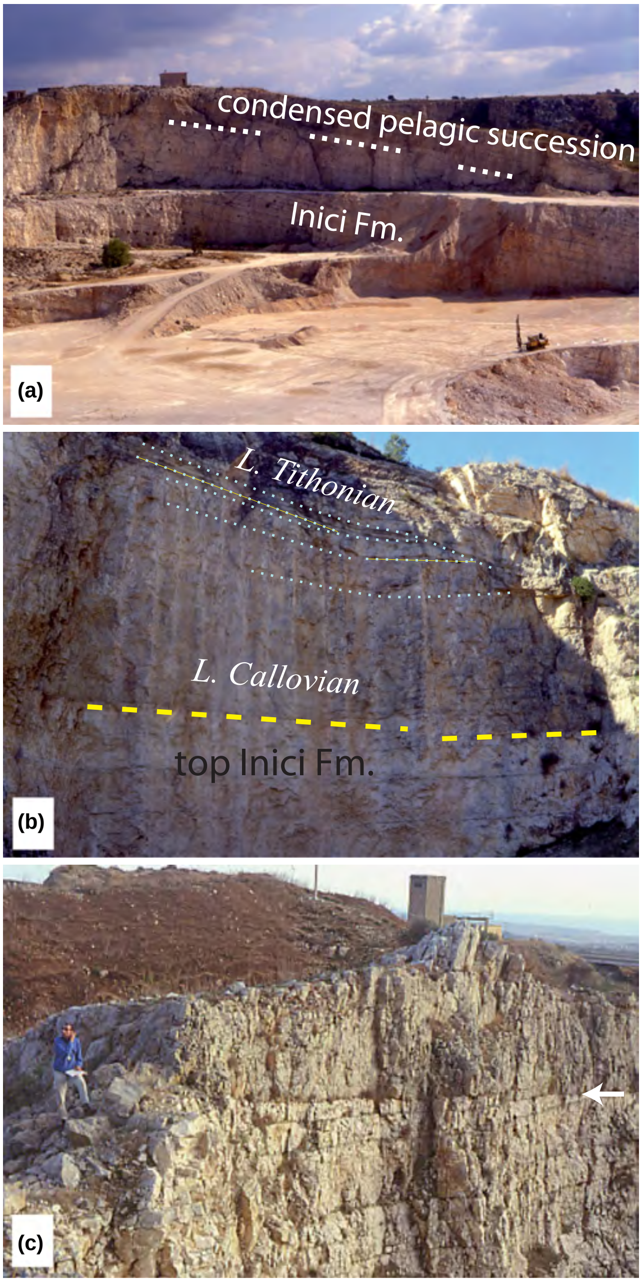

FIGURE 3 (a) Paracomformable Inici Fm./condensed pelagic Sciacca Plateau succession, with parallel-sided beds (thin, non-mounded succession) at Contrada Diesi (Diesi Quarry); (b) Terme Acqua Pia: downlap/pinch-out of lower Tithonian condensed pelagites towards edge of the Sciacca Plateau, facing the Mt. Genuardo Basin (Knobbly limestone unit missing); (c) angular drowning unconformity at Contrada Monzealese (Monzealese Quarry: Di Stefano et al., 2002), with planed off rotated beds in the hanging-wall of a syndepositional normal fault in the Inici Fm., capped by hardground (arrow)

2 | THE SACCENSE DOMAIN

The post-drowning (i.e., post- Inici Fm.) Jurassic succession across the Saccense Domain indicates pelagic sedimentation on the Sciacca Plateau (Muraro & Santantonio, 2002), which is evidenced by a thin carbonate succession where typical deeper water sediments like Middle-Upper Jurassic radiolarian cherts and allochthonous gravity flow deposits, characteristic of hanging-wall block basinal successions, are missing and are replaced by chert-free, often extremely condensed deposits. This thin pelagic succession has been grouped in the Buccheri Formation in Sheet #619 of the 1:50,000 Geological Map of Italy (Di Stefano et al., 2013). Synsedimentary faults in the Inici Fm. and angular unconformities at peritidal/pelagic (Inici/Buccheri Fms.) contacts indicate the Plateau experienced pre-drowning extension, being made of several fault blocks, locally tilted, all planed off by a laterally continuous erosional surface and capped by an hardground (Di Stefano et al., 2002) (Figure 3c).

The Sciacca Plateau covers an area in excess of several hundreds of square kilometres. Due to this, it falls in the group of the so-called "Super" Pelagic Carbonate Platforms of Santantonio (1994). Jurassic rocks do not outcrop continuously in western Sicily, due to extensive cover by Neogene deposits, so it is difficult to trace the original perimeter of palaeogeographic elements, like intrabasinal highs. Research in the region, however, has revealed the presence of numerous preserved palaeoescarpment tracts with associated angular unconformities, as detailed by Santantonio (2002). One of the distinctive features of the Jurassic stratigraphy of the Sciacca Plateau is the widespread geometrically concordant nature of the Inici Fm./pelagites contact with the exception, as mentioned above, of those localities where the peritidal substrate was deformed by synsedimentary extension and associated hangingwall bed rotation due to roll-over (Di Stefano et al., 2002). Signs of continued synsedimentary deformation during the Middle and Late Jurassic are apparently missing on the Plateau, with the exception of its marginal zones (Di Stefano et al., 2015), resulting in a remarkable lateral continuity of marker beds and key surfaces in outcrop. This marks a major difference with respect to the Trapanese Domain, where a much higher degree of post-Early Jurassic extension is documented by a complex picture of stepped angular unconformities within the Rosso Ammonitico itself, and by multiple generations of neptunian dykes and associated internal breccias (Basilone, 2009; Bertok & Martire, 2009; Santantonio, 2002; Wendt, 2017). All these features suggest that the Sciacca Plateau behaved somewhat independently as a more stable structural element during most of the Jurassic.

Direct field evidence for the Plateau palaeomargins is scarce at the present state of knowledge. However, stratigraphic thinning and downlap geometries in the condensed Plateau-top succession of the Mt. Magaggiaro unit are seen in one of its northernmost outcrops (vicinities of Terme Acqua Pia; Figures 2 and 3b), about 7.3 km to the NW of San Vincenzo. According to Santantonio et al. (1996, 2017) and Galluzzo and Santantonio (2002), these features suggest pelagic platform-edge conditions (see discussion sections below). The northern and northeastern sectors of the Pizzo Telegrafo unit, also a part of the Sciacca Plateau, display evidence for synsedimentary fracturing, ranging from neptunian and volcanic dykes to in situ breccias (with fitted clasts fabrics) in the Inici Fm., to widespread angular unconformities, highlighting the post-Sinemurian phase of extension which caused the birth of the Sciacca Plateau (Di Stefano et al., 2015). In both the above case examples, the present-day geographic boundaries of the Inici Fm. and overlying Jurassic to Lower Cretaceous cover, at their contact with Upper Cretaceous/Cenozoic to Quaternary deposits, can be seen or interpreted to roughly correspond to the Plateau margins. To the East and North-East, the Mt. Genuardo unit became a part of the Sicanian Domain basin (Di Stefano, 2002) as tectonic downstepping of a marginal sector of the Plateau caused an early drowning of the Inici Fm. platform around the Rhaetian/Hettangian boundary. Demise of the benthic carbonate factory and deepening were marked at Mt. Genuardo by the deposition of pelagic and gravity flow deposits, which also embed up to 100-m-thick pillow basalts in the lower Middle Jurassic (Di Stefano et al., 2013) and include radiolarian cherts in the lower Middle and Upper Jurassic, respectively. These basalts, up to 60 m thick, are also locally found interbedded with the condensed succession on the Plateau (Di Stefano et al., 2013, 2015). Since the Mt. Magaggiaro and Pizzo Telegrafo units represent one palaeogeographic compartment, it becomes apparent that the Sciacca Plateau was bordered by a palaeomargin with an embayment facing the eastern and north- to northeastern quadrants (in present coordinates), which hosted a basin environment (see sheet #619 of the 1:50,000 Map of Italy) (Figure 2).

A continuation of the Sciacca Plateau towards the foreland areas of the Hyblean region of southeastern Sicily, where deeper-water pelagic sedimentation was dominant in the Middle and Upper Jurassic, has been postulated by several authors (Antonelli et al., 1991; Di Stefano, 2002; Patacca et al., 1979).

3 | LITHOSTRATIGRAPHY AND GENERAL GEOMETRIES OF STRATIGRAPHIC UNITS (JURASSIC-EARLY CRETACEOUS)

Stratigraphic studies on the Saccense Domain have been carried out by many authors (Catalano et al., 1995, 1996, 2000; Catalano & D'Argenio, 1978, 1982; Wendt, 1963, 1965; Di Stefano et al., 2002, 2013, 2015; Di Stefano & Vitale, 1993; Jenkyns, 1970; Mascle, 1974, 1979; Vitale, 1990, and references therein).

For the Jurassic-Early Cretaceous succession of Vallone San Vincenzo (San Vincenzo Gorge), we chose to adopt an informal lithostratigraphy (bottom to top) (Table 1), by subdividing the Buccheri Formation, from the top of the Inici Fm. to the base of the Lattimusa Fm., into its discrete components: (a) Inici Formation (Late Triassic-middle Early Jurassic *p.p.*), made of massive to poorly bedded platform carbonates (dolostones and limestones) (Late Triassic), followed by white, well-bedded limestones with *Palaeodasycladus mediterraneus* (early-middle Early Jurassic *p.p.*); (b) "Hardground" (Toarcian-late Aalenian), dark mineralised condensed level (~ 30 cm) with a high concentration of ammonites (Di Stefano et al., 2002; Pallini et al., 2004); (c) *Bositra* limestone (late Bajocian-early Oxfordian *p.p.*), massive to well-bedded grey wackestone to grainstone, with thin-shelled bivalves (Conti & Monari, 1992); (d) Knobbly limestone (middle Oxfordian/early Kimmeridgian-late Kimmeridgian), nodular to well-bedded peloidal wackestone-packstone with *Globuligerina* sp., echinoderms, belemnites, ammonites and aptychi; (e) Coquina limestone (early Tithonian *p.p.*-early late Tithonian), coarse bioclastic packstone-wackestone, with sparse whole macrofossils (facies *a*), followed by and alternating with whole-fossil (mostly ammonites and pygopid brachiopods) coquina rudstones in thick to very thick beds (facies *b*); (f) Cephalopod limestone (late Tithonian *p.p.*-?early Berriasian *p.p.*), whitish mudstone-wackestone, in decimetric to metric beds, with radiolarians, aptychi, rare to common ammonites and pygopid brachiopods, benthic forams, sponge spicules, rare gastropods, calpionellids; (g) Lattimusa Fm. (?early Berriasian *p.p.*-Valanginian), homogeneous to nodular whitish micritic limestone, with ammonites and calpionellids.

4 | STRATIGRAPHIC SECTIONS

The San Vincenzo succession is exposed in a spectacular natural cross section along a sinuous gorge (Figures 4 and 5). The facies and thickness of the post-Inici Fm. pelagic stratigraphic units are extremely variable. Three sections

TABLE 1 Lithostratigraphic units in the San Vincenzo Gorge. Thickness of the Inici Formation after Di Stefano et al. (2013). Late Jurassic ammonite zones after Cecca and Santantonio (1988)

Lithostratigraphic Units		Description	Texture	Geometries	Age	Ammonite Zones	
Lattimusa Formation (>16m)		homogeneous to nodular whitish limestone, with ammonites and calpionellids	mudstone	thin to medium, tabular beds	Valanginian -early Berriasian *p.p.*		
Buccheri Formation	Cephalopod limestone (>5,5m)	whitish limestone, with radiolarians, aptychi, rare to common ammonites and brachiopods, benthic forams, sponge spicules, rare gastropods, calpionellids	mudstone to wackestone	medium to thick, tabular beds draping inherited topography	?early Berriasian *p.p.* -late Tithonian *p.p.*		
	Coquina limestone (15,75 - ~24m)	coarse bioclastic limestone, with sparse whole macrofossils, followed by and alternating with whole-fossil (mostly ammonites and pygopid brachiopods) coquina	rudstone, wacke-to packstone	medium, tabular beds (facies *a*) clinostratified rudstone in thick to very thick beds (facies *b*)	early late Tithonian -early Tithonian *p.p.*	Microcanthum Volanense Fallauxi Semiforme ?	Facies *b* *a*
	Knobbly limestone (5-10m)	nodular to homogeneous peloidal limestone with *Globuligerina* sp., echinoderms (echinoids, crinoids), belemnites, ammonites and aptychi	wacke- to packstone	well- to faintly bedded; lateral thickness changes of intervals account for levelling of underlying topography	late Kimmeridgian-early Kimmeridgian *p.p* *Hiatus* ?middle Oxfordian	? Cavouri ?	
					Hiatus		
	Bositra limestone (~15-24m)	bioclastic limestone, with thin-shelled bivalves	wacke- to grainstone	dominantly thick tabular beds in lower part, followed by mounded interval with convex- and concave-up lens-like beds	early Oxfordian -late Callovian/ late Bajocian		
					Hiatus		
	Hardground (<30cm)	dark mineralised (Fe - Mn) condensed level with a high concentration of ammonites and metal-coated intraclasts	wacke- to rudstone	interval (a single bed) with variable thickness	late Aalenian - Toarcian	assemblage with mixed zones	
					Hiatus		
Inici Formation (200-300m)		platform carbonates (dolostones and limestones) followed by white limestones with green algae	wacke- to grainstone	thick to very thick beds (lower part, not exposed), medium tabular beds	Pliensbachian *p.p.* -Late Triassic		

(Figure 6) were measured and analysed to characterize the general depositional architecture of the local Jurassic succession, and are briefly described here.

4.1 | San Vincenzo E 3 section (SVE-3)

The SVE-3 section is located in the east-side of the gorge, corresponding to the main mound discussed in this paper. It starts off with:

- 40 cm of white, well-bedded peritidal limestone with cryptalgal lamination and *fenestrae* (top of the Inici Fm.).
- ~ 30 cm of Fe-Mn-encrusted ammonite-rich condensed level ("Hardground"), also with small (<1 cm across) ferruginous pebbles, bearing *Erycites* sp., *Tmetoceras* sp, and *Planammatoceras* sp. (Figure 7).
- 8 m of thick massive, dominantly tabular beds of grey thin-shelled bivalve packstone (lower part of the *Bositra* limestone; Figure 8), locally with broad concave-up bedsets near the top.
- 15 m of grey thick bedded thin-shelled bivalve packstone (with less common grainstone) thinning symmetrically north- and southwards to 5 m, over a distance of 25 m (upper part of the *Bositra* limestone) (Figure 9). Beds generally have a convex-up geometry, but concave-up bedsets also occur in the upper part of this unit (Figure 10).
- 0–10 cm of condensed glauconite-rich pack- to grainstone.
- 0–45 cm of *Bositra* packstone.
- 0–~1 m of *Globuligerina* wackestone, in decimetre-thick beds (base of Knobbly limestone). [The three levels above are stacked convex-up lenses wedging out within a distance of a mere few meters (Figures 8, 11, 12)].
- 3.5 m of thinly bedded wackestone–packstone, bioturbated and often recrystallized, with abundant echinoids, crinoids, assorted bioclasts, and with small ammonites (Knobbly limestone).
- 6 m of massive bioclastic packstone, strongly recrystallized, with shelter structures (facies *a* of the Coquina limestone).
- 12.5 m of whole-fossil rudstone, with a bioclastic calcarenite matrix, alternating with levels having the same

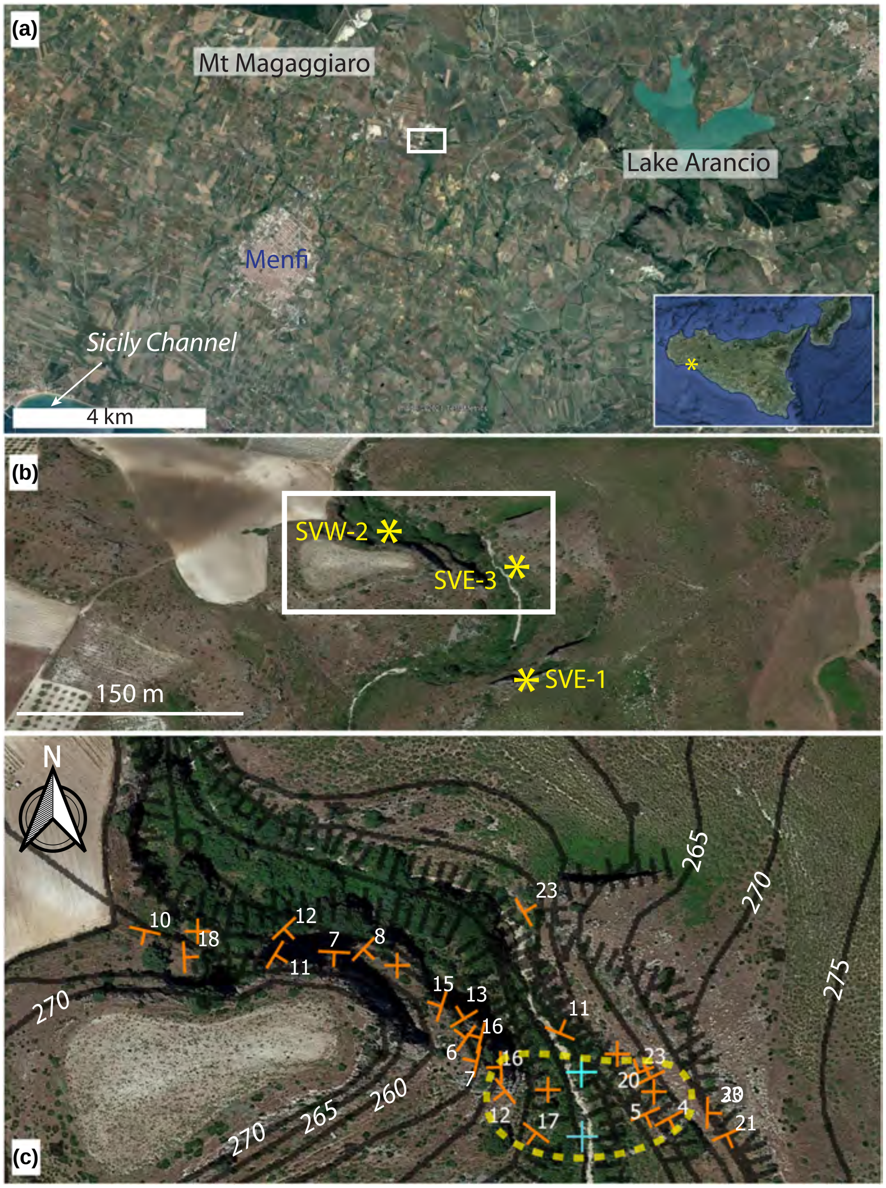

FIGURE 4 (a) Study area in south-western Sicily, with San Vincenzo Gorge in yellow rectangle; (b) the San Vincenzo Gorge, with location of the three stratigraphic sections discussed in text; (c) detail of the San Vincenzo Gorge, with attitudes (orange) of the mound-top surface: yellow dashed line is tentative outline of the main mound discussed in text. Attitudes in blue colour (horizontal) are the Inici Fm

matrix but with rarer macrofossils. The faunal content is represented by ammonites, brachiopods (pygopids), aptychi, echinoid fragments, crinoids, benthic forams, and gastropods (facies *b* of the Coquina limestone) (Figure 8). Bed thickness varies from 1 to 3 m.

- 5.5 m of whitish wackestone-mudstone, with abundant radiolarians, calpionellids, crinoids, benthic forams, aptychi, gastropods, small ammonites. Bed thickness varies from 20–40 cm to 1 m (Cephalopod limestone).

4.2 | San Vincenzo W 2 section (SVW-2)

The SVW-2 section is located in the west side of the gorge, facing SVE-3 (Figures 4 and 6). The *Bositra* limestone, being the direct lateral continuation of that described in the previous section (including the mounded interval, which is about 20 m thick), is not accessible at this site, so the log starts from the top of this unit.

From bottom to top:

- up to 2 m of nodular wackestone with globigerinids and belemnites (lower part of the Knobbly limestone unit).
- up to 3 m of nodular packstone, locally peloidal, with *Saccocoma* sp., globigerinids, aptychi, ammonites, assorted granule-sized litho- and bioclasts. Whole-echinoid beds occur at different levels (upper part of the Knobbly limestone unit). *Mesosimoceras cavouri*, a prominent upper Kimmeridgian marker ammonite, occurs 0.5 m above the base of this interval, along with *Pseudowaagenia* sp. (Cecca et al., 1985). The Knobbly limestone nearly doubles its thickness in inter-mound low zones (Figures 13 and 14).

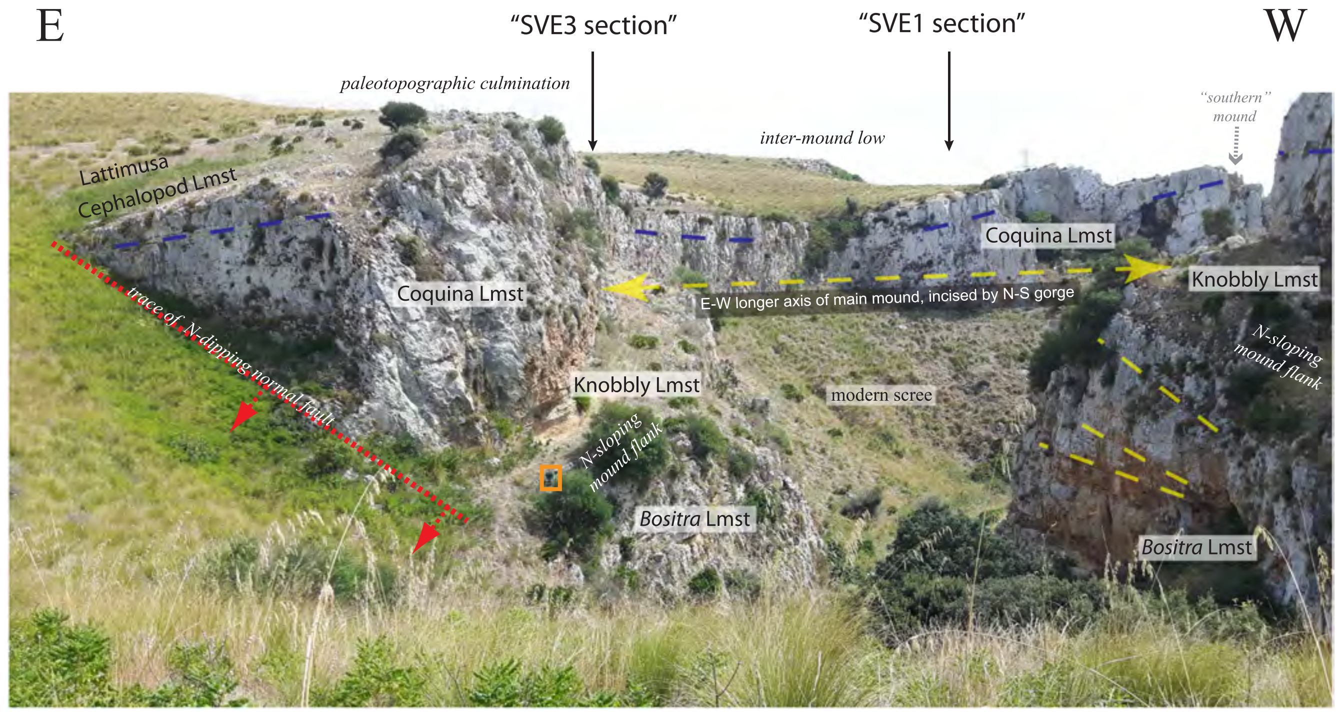

FIGURE 5 Panoramic view of the San Vincenzo Gorge, from the North, with localization of stratigraphic sections described in text. Blue dashes show antiform/synform/antiform pattern of lower Tithonian beds draping the mounded submarine topography produced by the Middle Jurassic *Bositra* limestone (yellow dashes). Orange square is centred by human being for scale

- 4.75 m of packstone with abundant echinoderm fragments, mostly crinoids (*Saccocoma* sp.), aptychi, ammonites, echinoid spines (facies *a*, lower part of the Coquina limestone).
- 11 m of shell-supported coquina (rudstone) with a packstone/wackestone matrix bearing gastropods, crinoids, ostracods and aptychi. At 10.8 m from the base of this interval, a single bed produced an ammonite assemblage with *Haploceras* sp., *Haploceras carachtheis* (Zeuschner), *Virgatosimoceras* sp., *Lytoceras* sp. and *Lytogyroceras* sp. This assemblage indicates the fourth zone of the lower Tithonian (*Semiformiceras fallauxi* Zone, *Simoceras biruncinatum* Subzone; Cecca & Santantonio, 1988) (facies *b*, upper part of the Coquina limestone).

From 19 to 20.7 m, the coquina has a different mudstone–wackestone matrix, with radiolarians, calpionellids, gastropods, calcareous sponges, benthic forams.

- ~ 50 cm of wackestone with radiolarians, calpionellids, echinoderm fragments, including echinoid spines, aptychi, benthic forams, rare small ammonites (Cephalopod limestone).

4.3 | San Vincenzo E 1 section (SVE-1)

The SVE-1 section has been measured on the east side of the gorge, about 0.1 km south of the SVE-3 section (Figures 4–6). This succession, from the top of the *Bositra* limestone, documents a lateral variation of the Upper Jurassic deposits. The *Bositra* limestone underlying the measured log also describes here a broad, albeit less spectacularly exposed than at SVE 3, convex-up structure (Figure 9).

- 2.8 m of wackestone–mudstone, locally a *Globuligerina* packstone, well-bedded (bed thickness 10–20 cm), with globigerinids, belemnites, aptychi, ammonites, assorted bioclasts (Knobbly limestone).
- 1.2 m of nodular packstone–wackestone (bed thickness 2–4 cm), with angular lithoclasts and bioclasts, peloids, ammonites, aptychi, globigerinids (Knobbly limestone).
- 6 m of wackestone–packstone (bed thickness 10–20 cm), rich in crinoids and aptychi, also with ostracods, sponges, fragments of ammonites. Levels with whole echinoids occur at 4.4, 5, and 7 m from the base of the measured log (Knobbly limestone).

- 15.6 m of bioclastic packstone, strongly recrystallized, mostly made of echinoderm debris, also with aptychi, ammonites, assorted bioclasts, peloids and gastropods. This interval has an overall massive appearance (facies *a* of the Coquina limestone). A coquina bed represents the 21.6–22 m interval, being here the single intercalation of the coquina facies *b*.
- 5.4 m of wackestone–packstone, with abundant aptychi and crinoids, also with small ammonites, gastropods, calcareous sponges, ostracods and benthic forams (facies *a* of the Coquina limestone).
- 2 m of wackestone rich in sponge spicules and crinoids, also with small ammonites, gastropods, aptychi and calpionellids (Cephalopod limestone).

In this section, the (ammonite) shell-supported deposits of the Coquina limestone (facies *b*) are missing, being replaced (with the exception of one 40-cm-thick bed) by a thickened all-facies *a* succession.

5 | FACIES AND GEOMETRIES OF THE JURASSIC-LOWER CRETACEOUS INTERVAL

This section describes the general geometries and facies of the Jurassic deposits at San Vincenzo, based on section correlation and on observations in adjacent outcrops where, despite partial cover or accessibility issues, key bed packages and surfaces can be traced with good lateral continuity.

The uppermost part of the Inici Fm. (~ 40 cm) exhibits planar beds made of peritidal limestone with cryptalgal lamination and *fenestrae*, bearing benthic forams, green algae and microproblematica (*Palaeodasycladus* sp., *Thaumatoporella* sp., Figure 15). While any further sedimentological observation is made impossible by the very limited outcrop area, finding the physical base of the studied pelagic succession is essential, as it represents an important geometrical datum (its attitude is subhorizontal), and it also provides a ~ 0 m palaeodepth constraint. Di Stefano et al. (2002) assign a middle Early Jurassic *p.p.* age to the top of this regional carbonate platform unit.

The Inici Fm. is paraconformably overlain by a dark Fe-Mn encrusted condensed level ("Hardground"), ~ 30 cm thick, with a rich ammonite assemblage (Figure 7). In the nearby locality of Contrada Monzealese, ~ 2 km west of the San Vincenzo gorge (Figure 2), this condensed bed bears a mixed ammonite assemblage with forms belonging to the two uppermost Toarcian biozones (Meneghinii and Aalensis Zones) and to all of the Aalenian biozones (Di Stefano et al., 2002; Pallini et al., 2004). This condensed level has a patchy distribution across the Sciacca Plateau.

5.1 | The *Bositra* limestone

The post-Aalenian Middle Jurassic is represented by the *Bositra* limestone, an informal lithostratigraphic unit made of grey wackestone to packstone, rarely grainstone, almost entirely formed by thin-shelled bivalves (Conti & Monari, 1992), also with rare peloids, echinoderm fragments and benthic forams (*Lenticulina* sp.) (Figure 15). This unit is naturally subdivided into two geometrically different, but compositionally and texturally quite similar, intervals (Figures 9 and 16). The lower interval consists of 8-m-thick dominantly (but see below) planar beds, parallel to the bedding in the Inici Fm., lying paraconformably on the "Hardground". The second interval is a spectacular mound-shaped bed package in the northern part of the gorge, and is separated from the former by a planar erosional surface (Figure 16). The disarticulated valves of *Bositra* consistently display a convex-up orientation in the sampled intervals, as evidenced by geopetal "umbrella" structures (Figure 8). At least one other mound-shaped body exists about 0.1 km south of the former (see SVE-1 section above, Figures 5 and 9), but it is comparatively less well exposed. The mounded interval has planar and thick beds only in its central part (~ 20 m across), which is up to 15 m thick. Laterally, these beds display beautiful pinch-out and/or tangential downlaps (Figure 11), becoming concordant and merging with the adjacent normally bedded (extra-mound) succession, which is only 5–7 m thick. This produces a relief in the order of 10–8 m. The downlapping/pinch-out beds, as well as the external surface of the mound-shaped interval, generally dip towards S-SSE, and N-NNW by up to 20°–23°, although they also display small-scale undulations (see Figure 4c). This indicates that this structure has a longer axis trending ~ 250–265 N, with beds at its flanks producing a roughly symmetrical pattern in cross section at the mound-top culmination (Figure 5). Divergent dip directions measured on the mound surface indicate bidirectional plunge of the longer axis and periclinal closures both towards the western and eastern quadrants (Figure 4c). The eastwards plunge, in particular, is also evidenced by thickness change of the mound-core sections, thinning by about 5 m towards the East over a distance of few tens of metres (the opposite sides of the gorge). While, due to the present-day topography and relatively limited outcrop, the lateral continuity and overall 3D shape of this structure cannot be fully observed, dip data suggest a roughly elliptical shape in map view of the main mound exposed in the northern sector of the San Vincenzo Gorge, with the natural cut providing a cross section sub-perpendicular to its longer

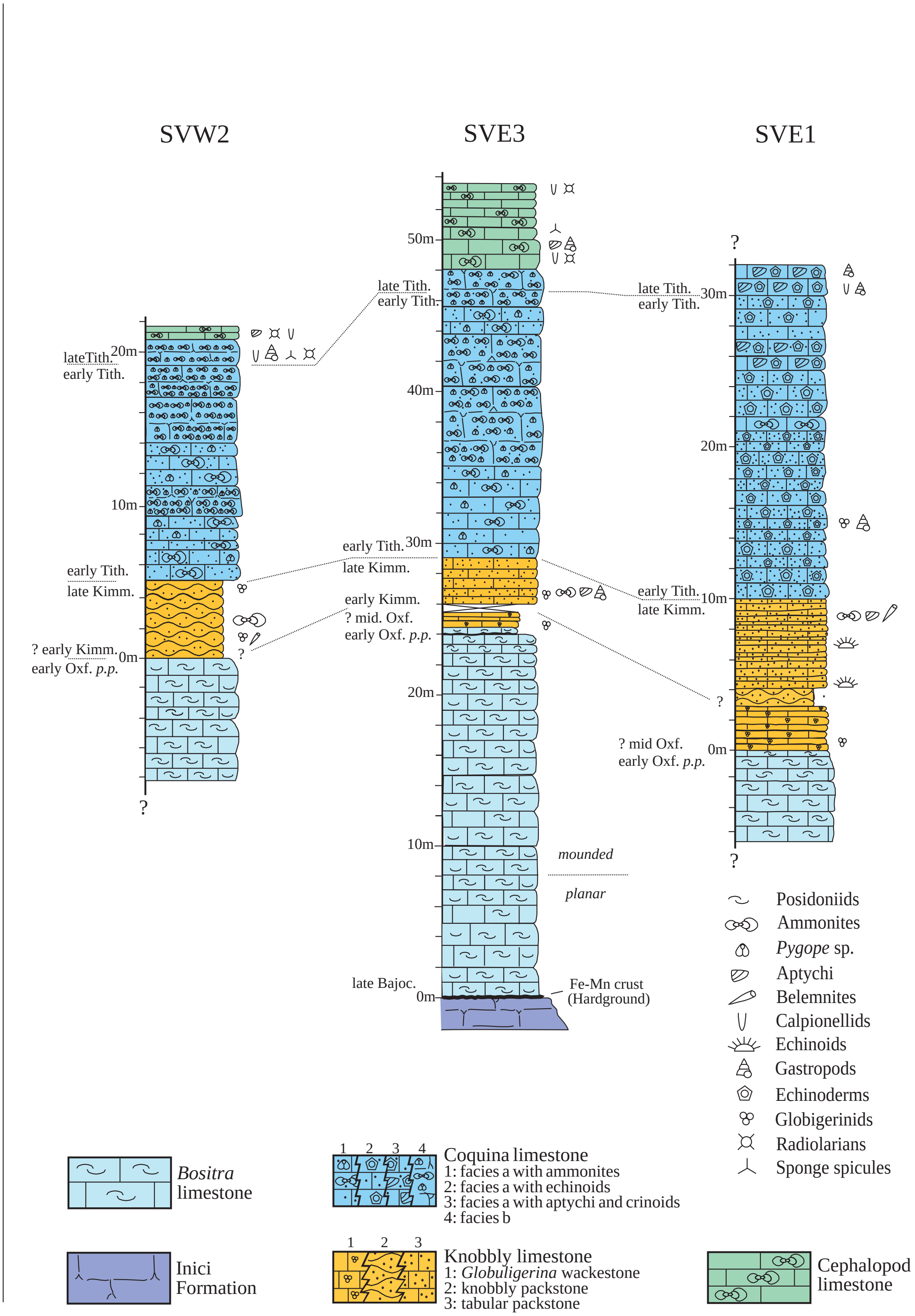

FIGURE 6 Correlated stratigraphic logs in the San Vincenzo Gorge (see text); see Figures 4 and 5 for location

axis (Figure 4c). The maximum width of the core+flanks complex along a N-S transect totals about 30 m.

While the overall mounded geometries are the highlight among the large-scale geometries seen in the *Bositra* limestone, associated concave-up geometries are also seen at the top of the 8-m thick planar interval as well as within the mounded interval. In addition, two remarkable sets of concave-up beds (Figure 17) are seen in the thin lateral equivalent of the lower part of the mounded interval, north of the mound core. One concave bedset is about 16 m across in the available natural cut, and is built of a ~ 3-m-thick set of beds having a festooned geometry

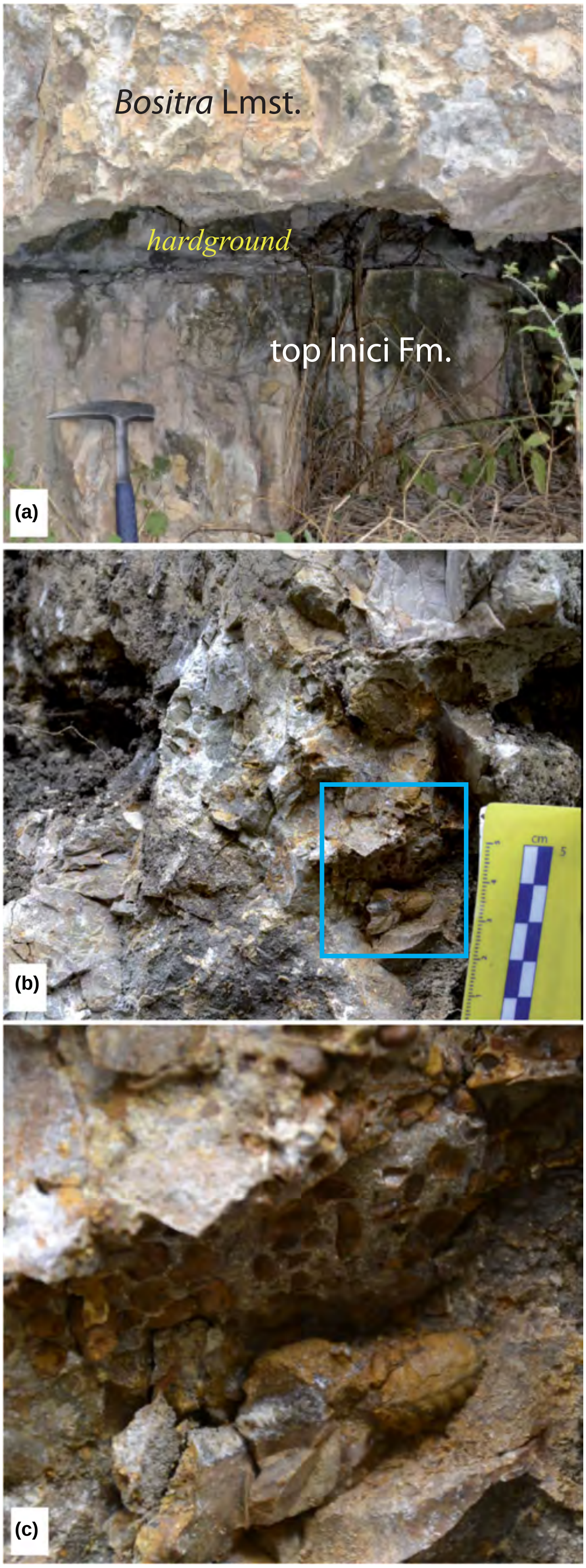

FIGURE 7 Base of the post-drowning Sciacca Plateau succession: (a) key outcrop at bottom of the San Vincenzo Gorge; (b) "hardground", a laterally discontinuous condensed level with mixed Toarcian and Aalenian ammonite assemblages; (c) detail in rectangle of (b), with *Planammatoceras* sp. and small rounded ferruginous pebbles

in cross section. A thin (~ 1.5 m) set of beds exhibiting concave-up geometries is also seen at the top of the planar interval on the western side of the Gorge (Figure 16), and it is apparently planed off by the surface separating the dominantly planar from the mounded bed packages. Therefore, the base of the main mounded interval within the *Bositra* limestone unit can be interpreted as an erosional surface (Figure 16). Another, smaller, concave-up surface exists in the upper part of the mounded interval, and is overlain by a wedge of thinning/tangentially downlapping beds, acquiring a convex-up geometry up-section, representing lateral accretion of the northern flank of the mound (Figure 11).

A small convex-up bed package caps the top of the mound core (Figure 12), enveloped by a surface dipping up to 33°, having a maximum thickness of about 1.5 m and a maximum width (in its lower part) of about 6 m, again with a symmetrical wedging out of individual beds along a N-S transect. The basal core of this bed package is made of two lens-shaped beds. The lower bed is a thin level (maximum thickness about 10 cm) rich in protoglobigerinids and crinoids, also with rhyncholites, echinoid spines, benthic forams, ostracods, bioclasts with eroded and oxidized edges, glauconite and fragments of inorganic laminated crusts. This bed is overlain by a strongly recrystallized *Bositra* pack-/grainstone lens (where micrite is only found in shelter structures), up to 45 cm thick, thinning out over a couple of meters. The upper part of this bed package is made of a convex cap of protoglobigerinid wackestone–packstone in decimetre-thick lensoid beds, with rare peloids, small ammonites, gastropods and aptychi (and no more posidoniids), and exhibiting small fractures filled with ostracod-bearing mudstone. These beds constitute a small cap to the mound crest, and represent the base of the Knobbly limestone, following the halt of the *Bositra*-dominated sedimentation and development of a hiatus surface.

In the *Bositra* limestone, fossils with biostratigraphical value are generally missing at Vallone San Vincenzo, with the exception of an upper Callovian *Choffatia* sp. (John Cope, pers. comm.) found near the top. However, in other localities nearby, the *Bositra* limestone bears spectacularly rich ammonite assemblages, making a tentative correlation possible. The base is well dated at Contrada Monzealese, less than 2 km to the west (Figure 2), where the *Bositra* limestone bears late Bajocian ammonites (the top of the unit is not exposed) (Di Stefano et al., 2002). At Terme Acqua Pia, about 7.3 km NW of San Vincenzo (Figures 2 and 3), the base of the unit yielded *Macrocephalites* sp., indicating the lowermost Callovian. At Contrada Diesi (Figure 2), the unit is a 6.75-m-thick

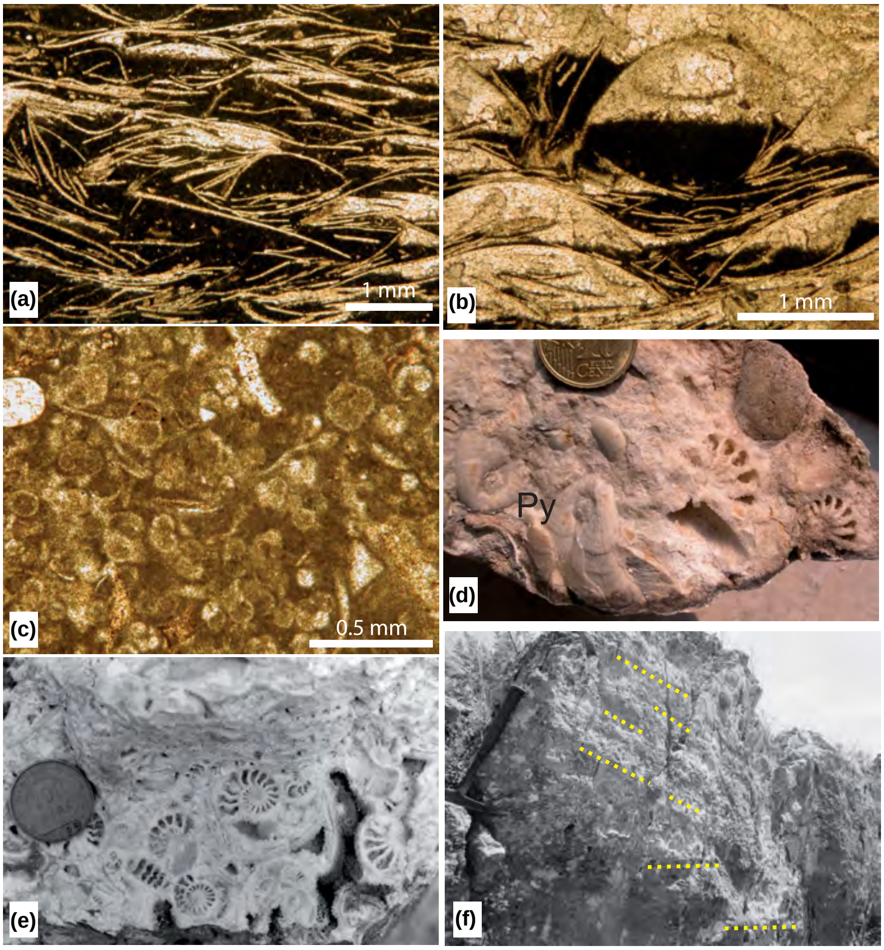

FIGURE 8 (a) Base of the *Bositra* limestone, with "umbrella structures"; (b) top of the *Bositra* limestone mound, with "umbrella structures"; (c) *Protoglobigerina* pack-/wackestone (base of Knobbly limestone); (d) ammonite/brachiopod (Py, *Pygope* sp.) coquina (Coquina limestone, facies *b*); (e) vintage photo of ammonite coquina (Coquina limestone, facies *b*), 200 Lire coin is 24 mm across; (f) vintage photo of the Coquina limestone, facies *b*, with horizontal bedded interval overlain by foreset beds; geological hammer for scale (left; 33 cm)

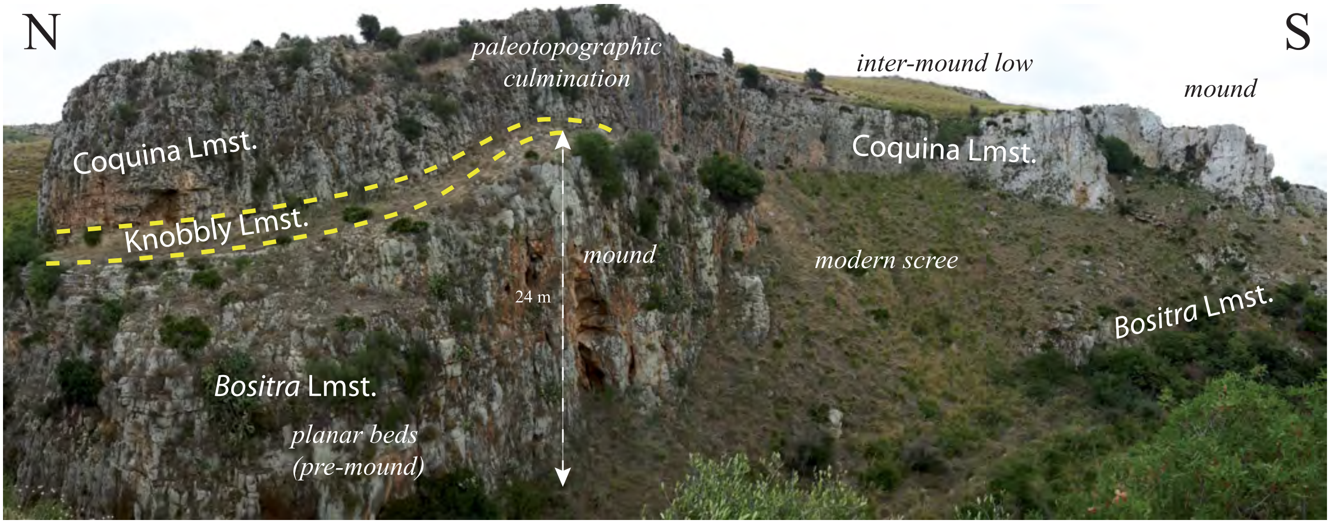

FIGURE 9 View of the main mound from western side of the gorge, with broad inter-mound low and southern mound (right)

Bathonian-early Oxfordian *p.p.* condensed ammonite-rich succession, resting paraconformably on the Inici Fm., and overlain by middle Oxfordian *p.p.* beds lacking posidoniids (Baldanza et al., 2002). Based on these correlations, we infer a general late Bajocian-early Oxfordian *p.p.* age (maximum timespan) for the *Bositra* limestone at San Vincenzo.

The age of the highest convex-up bed package is uncertain. Data from other sections on the Sciacca Plateau indicate the lowest protoglobigerinid-dominated levels immediately above the highest occurrence of posidoniids are middle Oxfordian, so we tentatively take this as the most probable correlative age.

FIGURE 10 View from the North of the main mound, with internal concave-up and convex-up bedsets, developed in the upper part of the *Bositra* limestone. Note antiformal geometry of draping younger formations, thinning of the Knobbly limestone at mound culmination, and two broad concave-up bedstacks lateral to the mound. Rectangle indicates area of Figure 11a

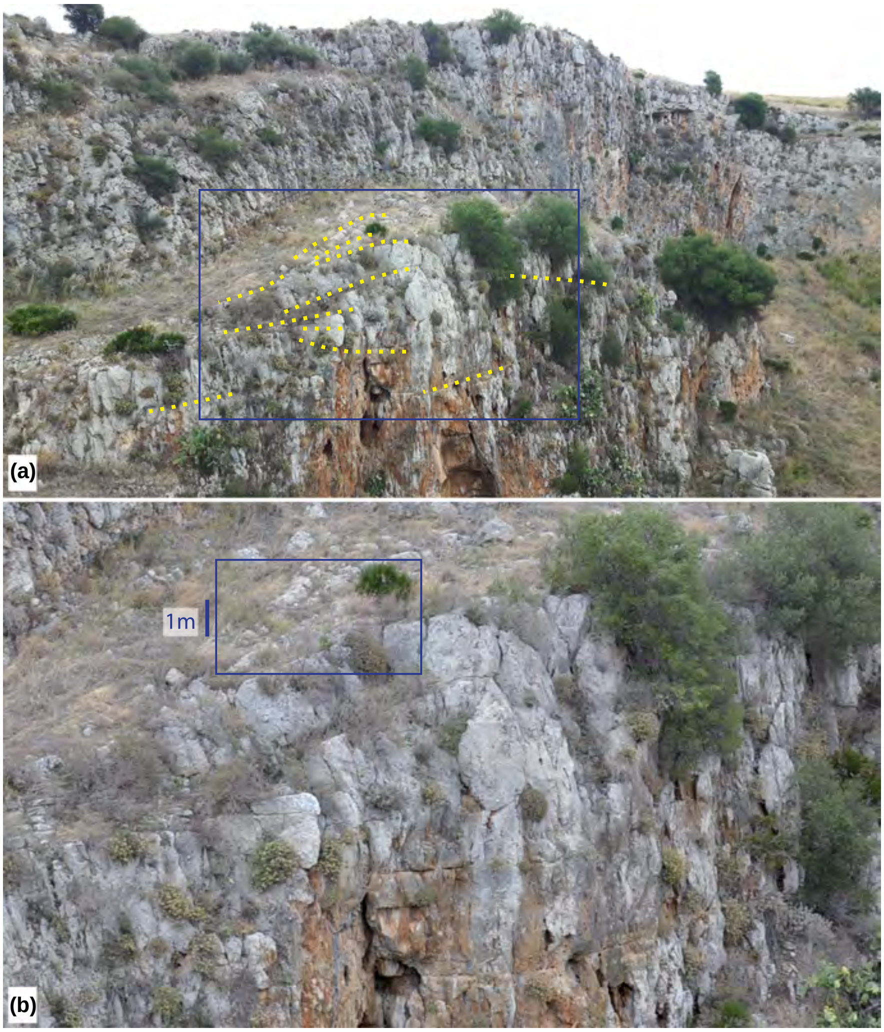

FIGURE 11 (a) Detail of the mound area: yellow dots are bedding surfaces; rectangle indicates area of (b); (b) note concave-up bedstack acquiring a convex-up geometry upwards, and downlap/pinch-out of mound beds towards the north (left). Rectangle indicates area of Figure 12

5.2 | The Knobbly limestone

The Knobbly limestone unit is made of strongly bioturbated wackestone to echinoderm-rich packstone, with ammonites, aptychi, belemnites (common in the lower 2 m), abundant protoglobigerinids, assorted unidentifiable bioclasts and peloids (Figure 15). Bed thickness ranges from 1 to 40 cm. Beds with whole echinoids occur at different stratigraphic levels (Figure 14).

The Knobbly limestone conformably drapes and partially levels the pre-existing topography, doubling its thickness from 4.5 m, on the culmination of the main mounded

FIGURE 12 Top of the *Bositra* mound (1—*Bositra*-supported grainstone), capped through a discontinuity surface by lensoid convex-up beds representing the basal facies of the Knobbly limestone (2, 3—*Protoglobigerina* packstone; 4—peloidal packstone). Geological hammer in white circle

FIGURE 13 Western side of the gorge, north-sloping mound flank, with thickening of the Knobbly limestone. Rectangle is field of Figure 14e

Bositra interval, to ~ 10 m at its flanks within a distance of 20–30 m. In doing so, it forms a broad syncline as dip passes from 21° to 6° towards the extra-mound zone (Figure 13).

The knobbly appearance is due to enhancement by selective weathering of a patchily cemented and bioturbated primary texture. Sudden lateral/vertical changes from well-bedded intervals (20–40-cm-thick) to knobbly beds (2–6-cm-thick), having the same composition and texture, are often seen in outcrop (Figure 14). Trace fossils include *Thalassinoides*.

Besides *Mesosimoceras cavouri* (Gemmellaro), mentioned above, *Pseudowaagenia* sp. and *Nebrodites* gr. *cafisii* (Gemmellaro) also occur in this unit. They point to an early Kimmeridgian *p.p.* (not basal)-late Kimmeridgian age for the Knobbly limestone (Cecca et al., 1985). Although the lower part (few decimetres) is barren, a middle Oxfordian age cannot be theoretically excluded for the posidoniid-free *Globuligerina*-rich level found at the base (see above). Above this basal level, however, the absence of hardgrounds and lack of macrofossil concentration strongly suggest that the barren interval cannot be an extremely condensed level representing the time spanned by several Oxfordian and basal Kimmeridgian ammonite biozones. We therefore conclude that the Knobbly limestone starts at San Vincenzo with a thin level of possible middle Oxfordian age, followed by a hiatus spanning the late Oxfordian and possibly the earliest Kimmeridgian, and overlain by a lower Kimmeridgian *p.p.* to upper Kimmeridgian bed package representing the bulk of the unit.

5.3 | The Coquina limestone

The Coquina limestone unit is made up by two interfingered facies: (*a*) coarse bioclastic packstone–wackestone, strongly recrystallized, with abundant echinoderm fragments (mostly crinoids—*Saccocoma* sp.), locally with sparse macrofossils (ammonites, aptychi, pygopid brachiopods); (*b*) whole-fossil (mostly ammonites and pygopid brachiopods) coquina rudstone (coquina facies), also with aptychi, echinoid fragments, crinoids (*Saccocoma* sp.), rare bivalves, gastropods and benthic forams (Figure 8). The matrix is a bioclastic packstone or wackestone, very similar to facies *a*. The shells, generally <5 cm across, are either empty, with thick calcite cement rims, or have geopetal structures, except for the body chamber, indicating that in most instances no crushing of the chambered whorls occurred during or after their deposition. The ammonites usually rest with their equatorial plane parallel to bedding. Cements in inter-shell spaces are isopachous calcite. Bed thickness typically varies from decimetric levels (facies *a*) to >1-m-thick massive beds (facies *b* and facies *a* at SVE-1). As the filling of cavities by cements is often incomplete, the coquina is an extremely porous deposit. Porosity is primary, fossil-related, as with cephalopod phragmocones, or brachiopods with closed valves. Due to this, pores are large (cm-scale) and generally not interconnected. No secondary porosity, due to partial leaching (moldic porosity), is observed. The uncompacted/uncrushed nature of empty macrofossils strongly suggests that the coquina is an early lithified deposit.

Southwards (SVE-1 section) in the normally bedded succession the coquina facies *b* is virtually absent and is replaced, as noted above, by bioclastic packstone of facies *a*.

While facies *a* normally consists of planar beds (e.g., SVE-1 section), facies *b* shows lateral accretion

FIGURE 14 Knobbly limestone: (a) detail of nodular levels; (b) whole echinoid; (c) section of belemnite rostrum (arrow); (d) general aspect of the unit showing interbedded homogeneous intervals; (e) thickening of beds and syncline due to change of attitude at the transition from mound flank to inter-mound low

geometries at various scales. The basal portion of the Coquina limestone, corresponding to facies *a*, overlies the Knobbly limestone conformably. However, the overlying beds of facies *b* follow through an angular unconformity evidenced by westward-dipping large-scale clinoforms, inclined up to about 12°, in turn locally exhibiting foresets (Figures 8f and 13). The total thickness of the unit changes as a result of both lateral accretion processes and the inherited topography (the irregular top of the *Bositra* limestone) on which it accumulated. The longer axis of the mound (ca. E–W) in the *Bositra* limestone, as displayed in the main San Vincenzo Gorge natural section, was roughly orthogonal to the strike of clinoforms, which have a dip direction ~ 280°, and the Coquina limestone becomes consistently thinner towards the west (i.e., in the sense of progradation: 18.5 m, SVE-3 section, to 15.75 m, SVW-2 section). Parallel to the circa N-S strike of clinoforms, the extra-mound sections of the Coquina limestone vary due to greater accommodation space, being thicker to the north (~ 22 m—additional field observations outside logged sections) and south (21 m, SVE-1 section), eventually resulting in levelling of the mound-related submarine relief.

Facies *a* lacks biostratigraphically useful fossils. In facies *b*, the collections—across the whole study area—of *Simoceras aesinense* (Meneghini), *Pseudohymalaytes steinmanni* (Haupt), assorted perisphinctids, *Usseliceras* sp. (?), *Haploceras* sp., *Haploceras carachtheis* (Zeuschner) (the most common form), *Virgatosimoceras* sp., *Lytoceras* sp., *Lytogyroceras* sp., and *Micracanthoceras* sp. all indicate the third to fifth zones of the early Tithonian, and the earliest late Tithonian (according to Cecca & Santantonio, 1988; and bibliography therein). Based on its stratigraphic position, facies *a* could correspond, where it underlies facies *b*, to the first and second zones of the early Tithonian, but should range throughout the early Tithonian at sites where it replaces facies *b* completely.

5.3.1 | Microbialites

Facies *b* of the Coquina limestone is typically a clean rudstone. Thin-section analysis (Figure 18) reveals that fine-grained sediment is essentially relegated within sheltered cavities, typically ammonite phragmocones, and/or forming small pockets in confined inter-shell pores, and consists of mudstones bearing crinoids (including *Saccocoma*), juvenile ammonites and small gastropods. It can be observed that the geopetal sediment is everywhere capped by mm-thin laminated micropeloidal mud displaying clotted fabrics, so that the internal sediment/cement boundary is a zone marked by the clotted interval.

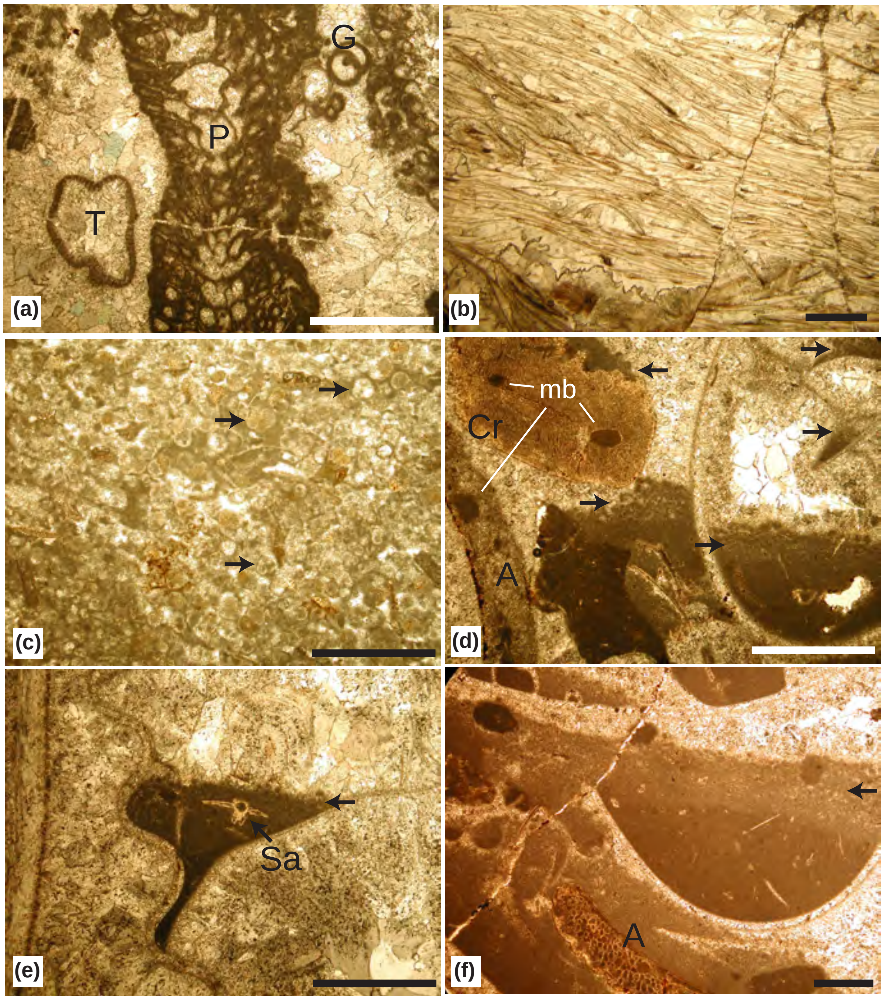

FIGURE 15 (scale bar = 1 mm)—(a) Top of the Inici Formation: grainstone/recrystallized micropeloidal packstone/cementstone (T—*Thaumatoporella* sp., P—*Palaeodasycladus* sp., G—gastropod); (b) *Bositra* grainstone 3 m below mound top; (c) bioclastic packstone with *Protoglobigerina* (arrows); (d) Coquina limestone, facies *b*: geopetal mud in ammonite phragmocone, capped by clotted fabrics (arrowed); these also occur in pocket of mud matrix and as a coating of crinoid (Cr) ossicle, with microborings (mb); aptychus (A) is also microbored; (e) *Saccocoma* (Sa) in geopetal mud infilling of ammonite phragmocone, capped by clotted fabrics (arrow); (f) Coquina limestone, facies *b*: geopetal mud in ammonite phragmocone, capped by mm-thick clotted fabrics (microbialite—arrow; A- *Lamellaptychus*, with microtubular shell layer)

This clotted interval is seen to grade into cloudy fibrous, isopachous cement (also bearing sparse ghosts of micropeloids), having clear crystal terminations, whereas clear calcite mosaic crystals are only seen in the central parts of the larger cavities. In cavities devoid of internal sediment, the clotted fabrics overlie the ammonite calcitic pseudotest directly. Clotted fabrics are generally interpreted as an evidence for cementation of microbial communities. Calcite mineralization typically starts affecting bacterial cell walls, and then progresses through cementing together cell colonies (Chafetz, 2013; Riding, 2000, and references therein). This preliminary description envisages bacteria thriving in cryptic micro-environments, colonizing the sediment/pore-water interface within geopetal cavities (e.g., internal sediment in cephalopod phragmocones) and also in inter-shell spaces.

5.4 | The younger units

The Cephalopod limestone unit is made of whitish mudstone-wackestone, in 20–40-cm to 1-m-thick beds, with aptychi, rare to common ammonites, pygopid brachiopods, echinoderms, benthic forams, sponge spicules, rare small gastropods, radiolarians and calpionellids. The total thickness ranges from 50–60 cm to 5.5 m. The age of this unit is late Tithonian *p.p.*-?early Berriasian *p.p.*

Overlying it, only the lower member of the Lattimusa Fm. crops out at San Vincenzo, made of nodular whitish micritic calpionellid-rich limestone, with less common ammonites and brachiopods, echinoderms, globigerinids and radiolarians. Macrofossils are much more sparse here than in units below. The maximum exposed thickness is about 16 m. This part of the unit ranges through the ?early Berriasian *p.p.*-Valanginian time interval, based on calpionellid, calcareous nannofossil and ammonite stratigraphy (Baldanza et al., 2002).

6 | INTERPRETATION

6.1 | Onset of pelagic sedimentation

The drowning of the Inici platform and its conversion into a pelagic carbonate platform are recorded in different fashions across the Sciacca Plateau. Marino and

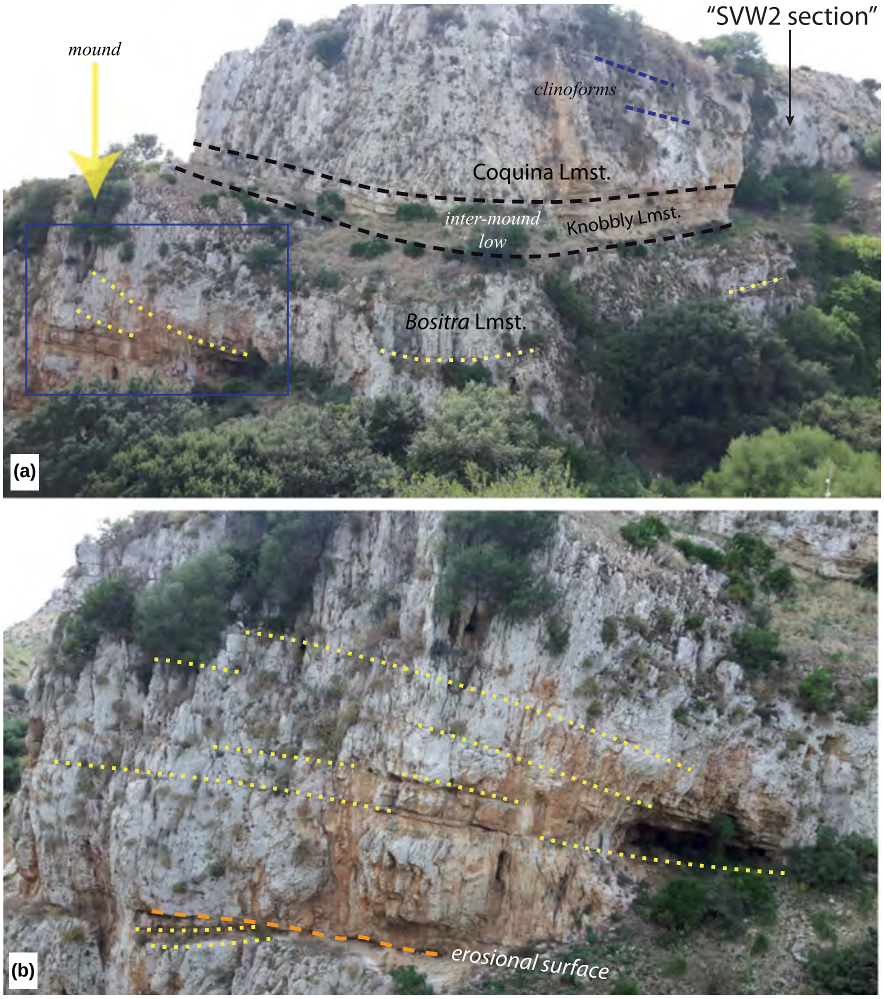

FIGURE 16 View from the North of the western side of the gorge. (a) The mounded *Bositra* limestone passes laterally to a palaeotopographic low, marked by thickening of the Knobbly limestone. Note lateral accretion of lower Tithonian clinoforms towards the western quadrants. Rectangle indicates area of (b); (b) bedding from mound core towards the north (right), with downlap/pinch-out of beds at mound flank, corresponding to the beds seen at opposite side of the gorge (Figure 11b)

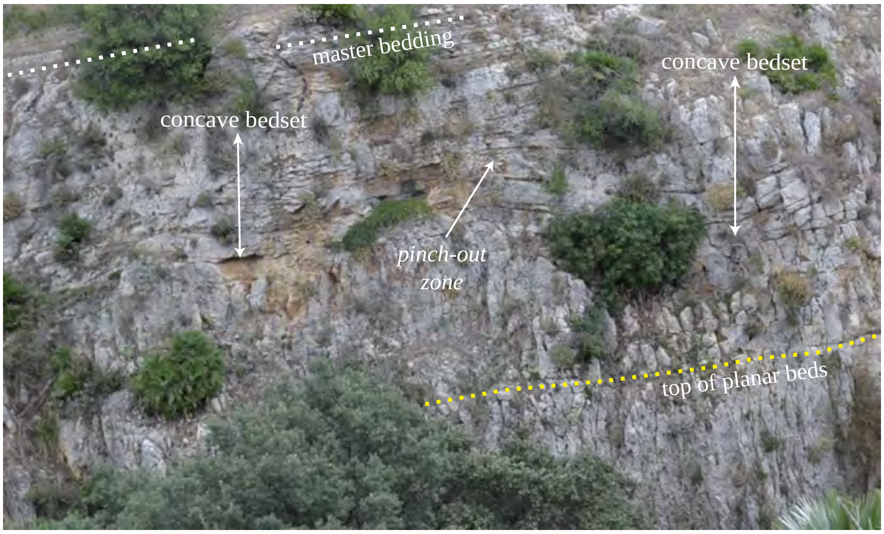

FIGURE 17 Detail of the *Bositra* limestone, lateral to the mound core, showing the geometries of beds forming two broad concave-up stacks in the upper part of the unit

Santantonio (2010) stress how submarine topography and erosion govern the preservation potential of syn- and early post-drowning deposits across the flat top of an intrabasinal high. This often results in the absence of the syn-drowning deposits, and in a laterally variable age of the lowest preserved pelagic deposits resting on the peritidal substrate. The Sciacca Plateau is a good case example of this puzzling pattern of patchy sedimentation and preservation of early post-drowning deposits.

The drowning unconformity ranges from a paraconformity to an angular unconformity (Figure 3). This latter

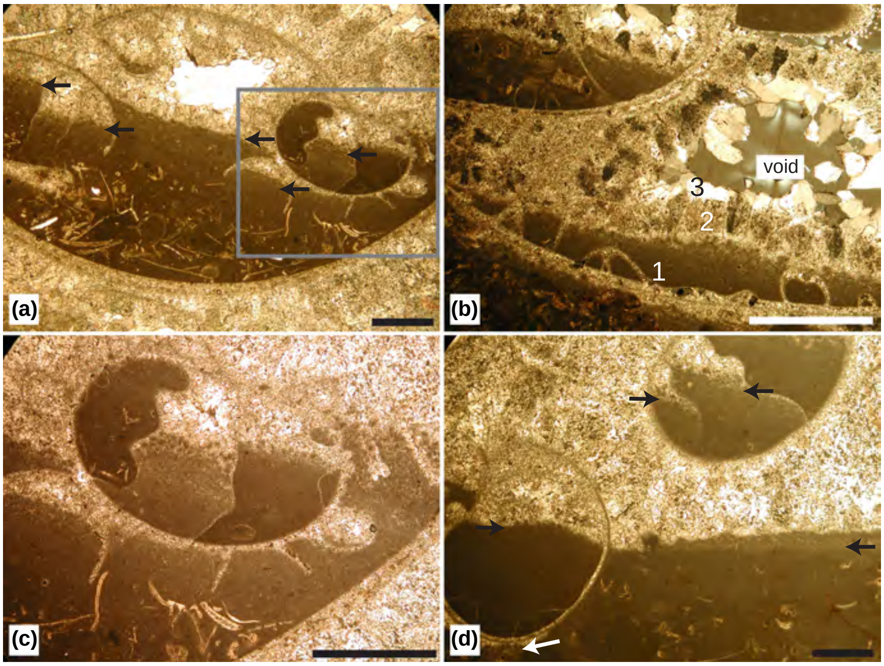

FIGURE 18 (scale bar = 1 mm)—(a) Coquina limestone, facies *b*: fragment of larger ammonite with ponded infill of *Saccocoma*-rich mud capped by clotted fabrics (microbialite, arrowed), bearing smaller ammonites with partial infill of chambers, also capped by microbialite; rectangle is area of (c); (b) Coquina limestone, facies *b* (crossed Nichols): ammonite phragmocone, with (1) microbialite encrusting pseudotest, (2) layer of cloudy isopachous fibrous calcite and (3) clear crystal terminations passing to drusy calcite or void; (c) detail of micropeloidal clotted fabrics (microbialite) within ammonite; note gradual passage to cloudy cement zone, bearing sparse ghosts of micropeloids; (d) clotted fabrics capping pocket of preserved *Saccocoma*-rich mud matrix and geopetal infill of ammonite phragmocone (black arrows) at the transition to cementstone microfacies, and also encrusting ammonite pseudotest (white arrow)

geometry has been interpreted by Di Stefano et al. (2002) as an evidence of pre-drowning erosion, possibly in subaerial conditions, of roll-over structures in the extended peritidal limestone. Due to poor outcrop conditions of the Inici Fm., any further consideration on this subject is impossible at San Vincenzo.

The late Toarcian-Aalenian age of the ammonite assemblages found in the “Hardground” capping the lower Pliensbachian top of the Inici limestone indicates that a hiatus of about 10 My (Haq, 2018) exists at the base of the pelagic succession. However, sparse thin patches of pre-“Hardground” crinoid-brachiopod-belemnite wackestones (possible syn-drowning deposits) are found locally on the Plateau. They were given a Pliensbachian *p.p.*-Toarcian *p.p.* age by Di Stefano et al. (2002). This narrows the duration of the hiatus, placing the drowning event in a time slice (early? Pliensbachian) of widespread carbonate platform demise in the Western Tethys (Blomeier & Reijmer, 1999; Franceschi et al., 2019; Marino & Santantonio, 2010; Morettini et al., 2002; Santantonio, 1993; Schirolli, 1997).

Above the “Hardground”, the Middle and Upper Jurassic deposits across the Sciacca Plateau display a facies mosaic that is rarely seen on Tethyan drowned platforms, with some of the features seen at San Vincenzo representing unique occurrences.

6.2 | The mounded *Bositra* limestone

The mound-shaped *Bositra* bed package differs from mudmounds as reviewed in Bosence and Bridges (1995) in a number of respects, including the following: (a) absence of a core made of sessile or encrusting organisms acting as sediment bafflers or trappers or binders (see below, discussion on posidoniid bivalves); (b) absence of any obvious kind of microbial structure (microbial mats, thrombolites, stromatactis, stromatolites, etc); (c) lack of any major difference in texture, fabrics, structure, and biota from core to flanks, and with respect to the surrounding ambient sediment.

The mode of life of *Bositra* has been strongly debated for decades, and different palaeoecological interpretations have been proposed to explain the widespread occurrence of these organisms in the Tethyan realm from Toarcian to the Oxfordian, both in thick basinal successions and on pelagic platforms. They have been interpreted as nektoplanktonic organisms (Jefferies & Minton, 1965), as benthic organisms (Kauffman, 1978, 1981; Pompecky, 1901) or as pseudoplanktonic living in “pendent” position attached to floating wood or seaweed (Duff, 1978; Stanley, 1972), or to living or dead floating ammonite shells (Seilacher & Westphal, 1971). Investigations in the Umbria-Marche region, based on functional morphology studies, facies analysis, and stratigraphical distribution of two different species, *Bositra buchii* and *Lentilla humilis* (Conti & Monari, 1992), seem to exclude a planktonic mode of life for Jurassic Tethyan thin-shelled bivalves (see also Molina et al., 2018, and references therein, and Tomašových et al., 2020). Having said that, posidoniid bivalves could hardly have acted as sediments bafflers or trappers or binders, nor do we see at San Vincenzo any evidence for a constructional strategy, which should be revealed by a range of morphotypes or species of the bivalve itself across the mound (see Liassic bivalve biostromes from the Moroccan High Atlas as described by Wilmsen & Neuweiler, 2008, for contrast). The densely packed texture of *Bositra* beds, however, could have had a stabilizing effect on the depositional slopes. Pelagic stratigraphic units dominated by thin-shelled bivalves are ubiquitous across the Tethys in the Middle Jurassic (this being indeed one of the reasons why these were believed by some to be planktonic organisms) and these bivalves are nowhere known to form any autochthonous biogenic mound.

Having excluded an autochthonous biogenic origin for the Sicilian mounds, an alternative interpretation must take physical processes into account, their products at the sea bottom being sediment drifts. Our field observations include the following: (a) shell-supported levels are dominant; early cementation is possibly indicated by the uncrushed nature of posidoniid shells and the presence of isopachous cement rims (Tomašových et al., 2020); (b) tractive bedforms, like foresets and cross-bedded sets, are generally absent, suggesting no bedload transport; (c) mud is generally present, and mud-supported textures are not that uncommon in the mound. Since posidoniid shells had to be evenly sedimented all across the Sciacca Plateau, we must infer that the skeletal build-up to form mounds was due to repeated phases of selective (as controlled by grain size and bivalve shell buoyancy) removal/re-suspension and resettling of the bottom sediment. Molina et al. (2018) cite a small, low-relief “thin-shelled bivalve build-up” from the Bajocian of Southern Spain (Betic Cordillera). This is a lensoid bed, but has external and internal geometries and sedimentological features quite unlike our Sicilian example. These authors discuss the opportunistic strategy of these organisms, and the changes in oxygenation and nutrient availability which controlled their distribution at specific stratigraphic levels. They interpret their “build-up” as autochthonous, having developed in low-energy conditions, and not due to local hydrodynamics.

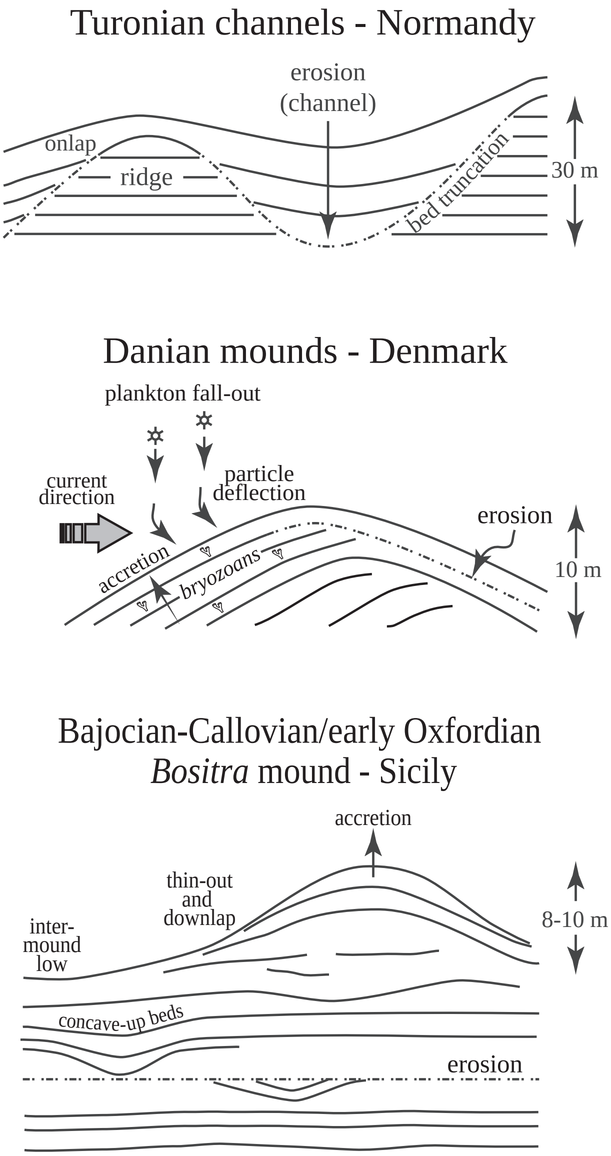

FIGURE 19 The three types of mounds/ridges, developed in pelagic deposits, discussed in this paper. The Normandy Chalk example represents an end member where the submarine topography is essentially due to erosional processes, while the Sicilian mounds, at the polar opposite, show no evidence of bed truncation at their flanks, and are abiotic constructional forms. The Danian mounds are essentially constructional, their growth being due to the interplay of planktonic fall-out, weak currents, and the proliferation of bryozoan colonies (see text for references). Inspired by Quine and Bosence (1991)

6.3 | Sediment drifts in the pelagic environment, and possible analogues to the *Bositra* limestone at San Vincenzo

Over the years, numerous studies have been published, demonstrating the unevenness of sea-bottom morphology in the epeiric Chalk Basin of Northern Europe, which was previously viewed as a site of tranquil sedimentation, with dominant fall-out of plankton but also with variable percentages of benthic organisms, in a low-energy pelagic environment. These studies describe the lateral coexistence of constructional and erosional features at various scales in the Upper Cretaceous-Danian Chalk of Denmark, Normandy (France) and the North and Baltic Seas

(Anderskouv et al., 2007; Esmerode et al., 2007; Quine & Bosence, 1991; Surlyk & Lykke-Andersen, 2007) (Figure 19). A natural hierarchy exists across the structures observed, both in the subsurface, as documented through seismic reflection surveys, and in outcrop. Larger scale (tens to hundreds of kilometres) sediment drifts constitute positive topographic features, adjacent to areas where section thinning and erosion are prevalent. Surlyk and Lykke-Andersen (2007) describe a time-persistent, Upper Cretaceous (Maastrichtian) moat/drift system in the subsurface of the Kattegat sea, with an estimated length of ~ 200 km. Relief at any given time slice between the moat and the top of the drift would be <~120 m. The moat is interpreted as corresponding to the main flow axis of bottom currents running parallel to a slope flanking a tectonic inversion zone. The adjacent drift running parallel to it, and ~ 20 km wide, would have been built in a fashion similar to a levee. Reflectors within the drift itself show complex internal geometries, with smaller scale (hundreds of metres across or less) positive mound-like features, vertically stacked or randomly migrating, and intervening lows. The equivalent in outcrop of these latter features is described by Anderskouv et al. (2007). The Danian mounds in the Chalk, like those beautifully exposed along the famous coastal outcrop of Stevns Klint in eastern Denmark, form a stratigraphic complex where some of the geometrical features of other Cretaceous examples, including their dimensions, are exposed in cliff sections. The mounds themselves form elongate bodies that are roughly elliptical in plane view, are up to 110 m long and a few tens of metres across and document local sea bottom relief in the order of 5–10 m (Bjerager & Surlyk, 2007). This is also the scale of the Sicilian examples. While the Cretaceous Chalk was an almost pure nanno-ooze, the benthic fauna (notably bryozoans) is more abundant in the Palaeocene. The geometries of individual mounds, which include a gentle flank and a steep thicker bedded flank, are therefore interpreted as due to the interaction between the hydrodynamic regime and an active benthic carbonate production, including varying feeding and growth strategies of the organisms colonizing the mound crest and flanks.

Given the origin of an uneven sea-bottom topography in the Chalk basins as a result of the interplay between rates of pelagic sedimentation, benthic production (Danian mounds), and development of syndepositional faults (Surlyk & Lykke-Andersen, 2007), on the one hand, and the action of bottom currents, on the other, different end-member geometries are expected wherever the relative importance of each of these processes varies. The "Concave-down structures" in the Upper Cretaceous Chalk of Normandy, described by Quine and Bosence (1991), document the development of channels, separated by ridges, whose flanks are erosional surfaces—with laterally truncated beds—onlapped by the inter-ridge sediment. Such features document an end-member setting where submarine erosion is dominant (Figure 19). The reflector geometries discussed by Surlyk and Lykke-Andersen (2007) indicate, as we mentioned, a close relationship between sediment removal/erosion and sediment build-up. In the Danian bryozoan mounds, genuine scour surfaces with onlaps are very rare, while 3D accretion geometries are by far dominant. Scouring of intermound lows is, however, locally described by Lykke-Andersen and Surlyk (2004).

All the above-mentioned papers utilize the term "mound" throughout, in a non-genetic sense, for both allochthonous and partly in situ positive bodies, the same option used here and in earlier reports on our structures (Muraro & Santantonio, 2002, 2003). Partial similarities with the lower upper Maastrichtian mounds (Anderskouv et al., 2007) include the zero (Sicily) to minor (Denmark) active role played by benthos in generating the positive forms. Similarities with the Danian mounds include the dominance of macroskeletal benthic material (posidoniid bivalves in Sicily, mainly bryozoans in the Chalk), set in a pelagic mud-grade matrix, and the overall dominance of accretion over erosional surfaces. These latter, however, do exist also at San Vincenzo, mostly in the form of planar surfaces, like the surface separating the dominantly planar from the mounded bed packages (Figure 16). Bivalve shells, as mentioned earlier, were conceivably instrumental in stabilizing the mound flanks at San Vincenzo, much like the diverse benthos seen in the Danian chalk.

According to Anderskouv et al. (2007), bottom currents can affect the trajectories of chalk particles, and thus shape the sea bottom topography in a mud-dominated pelagic basin, in two main fashions: (a) by resuspending and eroding sediment at the sea bottom and (b) by imparting an horizontal component on the falling particles. Either process depends on whether current velocities are below or above a critical erosion threshold, with "significant erosion" starting with currents having a velocity of 23–27 cm/s measured 20 m above the seabed (Anderskouv et al., 2007). The lateral deflection of micron-sized falling particles with a sub-erosive bottom current would produce higher sedimentation rates on up-current mound flanks, resulting in a style of lateral migration that is opposite to that of a bedform in a siliciclastic system, where greater accumulation takes place at sites of lowest flow velocities (lee sides). The 3D growth style of the *Bositra* mound at San Vincenzo cannot be fully established due to limited outcrop. The main gorge, which is roughly oriented N-S, shows a nearly perfectly symmetrical pattern of accretion within the mound, and no "steep" vs "gentle" flanks are recognizable. While this paper focuses on positive structures (mounds) of the *Bositra* limestone, these existed closely linked with negative structures represented by concave-up bedsets (Figures 10 and 17). These latter do not, however, originate from obvious scour surfaces, as no evident bed truncation can be observed, and draping is by far dominant over onlap. The resulting picture is that of a setting where streams of relatively low-velocity, dominantly sub-erosive bottom currents removed/resuspended sediment from the flow axes, building "levees" (elongated mounds) at their flanks.

6.4 | The Knobbly limestone

The Knobbly limestone drapes the former unit, only partially levelling the inherited sea-bottom morphology through bed thickening at inter-mound lows. This unit marks the disappearance of thin-shelled bivalves, while echinoderms became the major contributors of skeletal material. None of the geometries (erosional and constructional) found in the *Bositra* limestone exists in this formation. While the disappearance of posidoniids was a palaeobiological event (see above), the switch to an echinoderm (echinoids, crinoids) calcarenite facies could indicate a local environmental/circulation change on the Plateau, possibly linked with raised trophic levels (Föllmi et al., 1994).

6.5 | The Coquina limestone, the Cephalopod limestone and Lattimusa Fm.

The Coquina limestone is an impressive accumulation of cephalopod (and, subordinately, brachiopod) shells. Typically, on a pelagic carbonate platform, the striking concentration of fossils is the result of lowered sedimentation rates. This does not appear to be the case with the Coquina limestone, as accumulation rates of this unit, in the order of 4–5 m/My, are nearly one order of magnitude higher than those of the classic PCP successions of the Apennines in the Tithonian (Cecca et al., 1985, 1990; Farinacci et al., 1981; Santantonio, 1993). These are actual accumulation rates, since the uncrushed/undeformed nature of fossils, the isopachous fibrous cement rims (Figure 18), as well as the presence of calcite pseudotests in the ammonites indicate that this deposit underwent extensive early cementation and is virtually uncompacted. As noted earlier, extensive cementation had to be fostered by the widespread colonization of hollows in buried skeletons and other cryptic spaces by microbial communities. The occurrence of a complete succession of ammonite biozones throughout facies *b* suggests persistence of the peculiar conditions which determined its deposition over a period of about 3 million years (Haq, 2018).

FIGURE 20 Clinoforms of the Coquina limestone downlapping sub-horizontal Knobbly limestone at inter-mound low

The age of the base of this facies corresponds to the third biozone of the early Tithonian, an age characterized by repeated, severe short-term sea-level drops, as originally identified by Haq et al. (1988). Santantonio et al. (1996), Gill et al. (2004) and Cipriani et al. (2019) interpreted these eustatic fluctuations as being the cause for the synchronous, punctuated occurrence of deep-photic zooxanthellate corals or even euphotic-zone forms (Cipriani et al., 2019) on PCP tops in the Apennines. On the Sciacca Plateau, fluctuating sea level could have produced perturbations of the ambient energy, locally resulting in more vigorous bottom currents, which led to the accumulation of a shell-supported rudstone deposit.

As of yet, no evidence for deposition under photic conditions has been reported in the condensed pelagic succession of the Sciacca Plateau, following drowning of the Inici limestone. This could be due to thermal subsidence in post-rift times, a result of cooling of this Western Sicilian sector of the African continental margin, where a major early Middle Jurassic phase of volcanism is documented all across the Trapanese, Sicanian and Saccense palaeogeographic domains.

The overwhelming abundance of cephalopods is unusual, and we interpret this as due to an increase of nutrients. These were brought by those same currents that were responsible for the distinctive facies and texture of the deposit, possibly paired with the effects of upwelling along the plateau margin. Following a unit having dominantly draping geometries (Knobbly limestone), the Coquina limestone built a new submarine topography through the active growth of its clinoforms (Figure 20).

The Rogoźnik Coquina in Poland (Pieniny Klippen Belt), covering much of the lower Tithonian, shows similar features (Kutek & Wierzbowski, 1979, 1986). Not only is the sedimentology of the deposit comparable, but also its thickness and faunal composition, with the Tithonian ammonite assemblage documenting a strong influx of typical Mediterranean forms (e.g., Simoceratids). The above authors also concluded that the exceptionally rich fossil content could not be attributed to reduced sedimentation rates.

The last two micritic units (Cephalopod limestone and Lattimusa Fm.) mark the comeback of dominantly draping geometries, which was triggered by a biological event, the bloom of calcareous nannofossils, which is recorded across the whole Western Tethys (Bosellini & Winterer, 1975; "Kuenen event" of Roth, 1987; Bartolini et al., 1996; Cobianchi & Picotti, 2000).

7 | GENERAL DISCUSSION: JURASSIC GEOGRAPHY, STRUCTURE AND ENVIRONMENTS OF THE SCIACCA PLATEAU

The Middle and Upper Jurassic deposits across the Sciacca Plateau are floored by a drowning unconformity postdating a subaerial exposure, which records the halt of shallow-water carbonate platform sedimentation (Inici Fm.) in the Pliensbachian. While this drowning marks the onset of pelagic carbonate platform conditions, it is troublesome to define here the post-drowning deposits as strictly "pelagic" (i.e., produced by a planktonic carbonate factory). We are dealing in fact with deposits which are either dominated by bivalves (posidoniids), or bear a significant, to major at certain stratigraphic levels, proportion of benthos, mostly in the form of echinoids and crinoids, or are entirely built by shells of nektonic organisms. In addition, the Knobbly limestone is thoroughly bioturbated, including *Thalassinoides* burrows, a trace fossil which is generally found in shelf environments (Frey & Pemberton, 1984), both siliciclastic and carbonate.

Sediment composition, sedimentary structures, and fossil organisms all suggest similarities with examples known in the geologic record of shelves characterized by a mix of pelagic, nektonic and benthic assemblages, often in relatively shallow water conditions. One striking example is the Upper Chalk of northern Europe, documenting pelagic deposition at depths as shallow as 50 m, with fossil assemblages dominated by cephalopods, echinoderms, bivalves, sponges, brachiopods and bryozoans (Stow et al., 1996). This Chalk represents "shelf settings that have no modern equivalent" (Stow et al., 1996), being in fact pelagic shelves. One of the major differences with our Sicilian examples is the overall sedimentation rates, which are lower than those of the Cretaceous Chalk. The Blake Plateau in the Atlantic offshore of northern America, based on descriptions by Pinet and Popenoe (1985), represents perhaps another example of these peculiar shelves, at least in its initial stage.

When we pair the features seen at San Vincenzo with stratigraphic and facies data from other parts of the Sciacca Plateau, an interesting picture of the post-drowning history of this palaeogeographic element emerges. This section focuses on the two units, the *Bositra* limestone and the Coquina limestone, which display the higher degree of lateral variability, paired with a unique set of sedimentological and palaeontological features.

7.1 | The concept of current-swept intrabasinal highs

The general concept of a current-swept intrabasinal high has, since the pioneer papers by Jenkyns (1971) and Bernoulli and Jenkyns (1974), often been evoked in order to explain section condensation and hiatuses that are so common on pelagic carbonate platforms across the Tethyan Jurassic. The action of currents in these settings has therefore been traditionally envisaged as generating negative features: the absence or thinning of individual stratigraphic intervals, a result of removal of loose sediment from the sea bottom. Other than the concentration of macrofossils (cephalopod shells) to form possible lag deposits, no mention of any positive features, like sediment drifts, produced by such currents has been made for the condensed pelagic caps of drowned Tethyan platforms.

The Sciacca Plateau hosts a Middle and Upper Jurassic pelagic succession that, besides exhibiting the inner-platform to platform-edge lateral facies and thickness changes expected on a pelagic platform (Cipriani et al., 2019; Galluzzo & Santantonio, 2002; Santantonio et al., 1996) (Figure 21), displays locally thickened sections due to the occurrence of bottom current-related positive features, like the mound-shaped geometries and drifts described in this paper. In our view, the areal extent of the platform-top could itself be the primary factor determining whether the sediment swept by currents on an intrabasinal high would be preserved on the high itself, or be lost and redeposited from suspension in an adjacent basin. As the Sciacca Plateau is at least a few hundred square kilometres in extent, one to two orders of magnitude larger than Apenninic PCPs, it was less prone to net sediment waste, being instead capable of storing reworked sediment on the platform top. Esmerode et al. (2007) cite condensed successions in the lower upper Maastrichtian Chalk of the Danish Basin subsurface, lateral to the mounded drift complexes, interpreted as the winnowed source-areas for adjacent drift accumulations. On the Sciacca Plateau, sectors like the

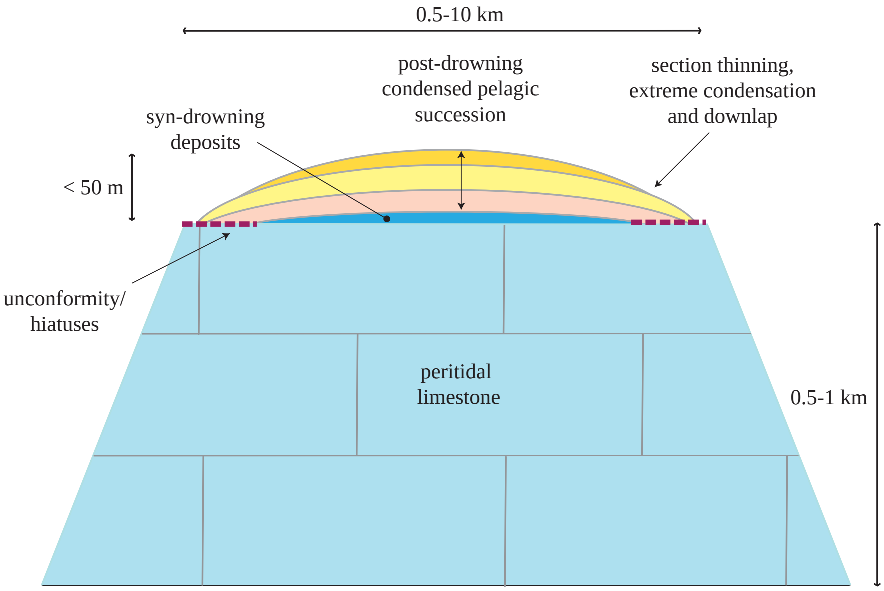

FIGURE 21 Cartoon showing the typical dimensions (not to scale) of a Jurassic PCP, and geometries of the platform-top succession ("Panettone" model). The succession overlying the pre-drowning substrate is ideally a convex-up lens, with thinning and low-angle downlaps towards the platform edges. Syn-drowning and early post-drowning deposits may or may not be preserved on the platform top, the latter case producing a drowning unconformity. Condensed pelagites (post-drowning deposits) are shades of brown, representing stratigraphic units, and are at their thickest away from platform edges

Contrada Diesi Quarry section (Figures 2 and 3), with its coeval condensed, ammonite-rich, parallel-bedded succession bearing multiple hardgrounds (Baldanza, 2002; Marino et al., 2004), were conceivably a preferential site of focusing of erosive bottom currents, and remained so for more than 10 million years. Similarly, in the coeval succession measured at Lago Arancio (about 5 km ESE of San Vincenzo; Figure 2), the interval from the top of the Inici Formation to the base of the Lattimusa Formation is made of parallel-sided beds and is only about 10.75 m thick (Figure 22).

A number of parameters associated with the *Bositra* limestone are seen to change laterally across the Sciacca Plateau. The thickness ranges from ~ 3 m (Lago Arancio and Stretta Arancio), to 6.75 m (Contrada Diesi Quarry; Baldanza et al., 2002), to about 5 m at Terme Acqua Pia, and is at least 10 m (top cut by modern erosion) at Contrada Monzealese (Figure 2). The maximum thickness seen at San Vincenzo is about 24 m. The age of its lowest bed, as mentioned above, ranges from the late Bajocian (Contrada Monzealese) to the early Bathonian (Contrada Diesi Quarry), to the early Callovian (Terme Acqua Pia). Besides having an obvious hiatus at its base, the unit has internal hiatal surfaces, with several ammonite zones missing. While the general texture is overall similar, being consistently a posidoniid packstone, often recrystallized, facies changes are paired with changes in the relative abundance of cephalopods, that are especially common where the unit is thin, and rare in the thick San Vincenzo section.

According to Santantonio et al. (1996) and Galluzzo and Santantonio (2002), a whole set of parameters changes in a predictable fashion across an escarpment-bounded pelagic carbonate platform, from the most internal sectors to its edges. These parameters include thickness, bed geometry, fossil content and degree (and type) of condensation. In the most internal sub-environments, the sediment preservation potential is higher, and successions are at their relative thickest. Section thinning towards platform edges occurs also as a function of the angle of repose of sediment stacked on the platform, so that in a platform-to-basin transect, the pelagic mud cap of the drowned high must terminate laterally with a gently sloping flank, thinning-out and/or forming a downlap angle with the drowning surface of the underlying shallow-water limestone, while the escarpment carved into stiff early lithified peritidal limestone can form a steep wall. To summarize, the pelagic cap of intrabasinal highs has a general convex-up geometry (dubbed the "Panettone geometry" in Santantonio et al., 1996) (Figure 21), in analogy with the examples described by Winterer (1991) on drowned atolls in the Pacific region. While the one offered above is the general picture for a pelagic platform, the Sciacca Plateau also bears evidence for the overprinting of processes that are not documented elsewhere. The Vallone San Vincenzo sector documents the local transfer of sediment by weak, generally sub-erosive currents. We interpret the lack of traction features, and overall dominance of aggradation with respect to progradation, as being a result of sedimentation through re-settling and stack-up of the mud

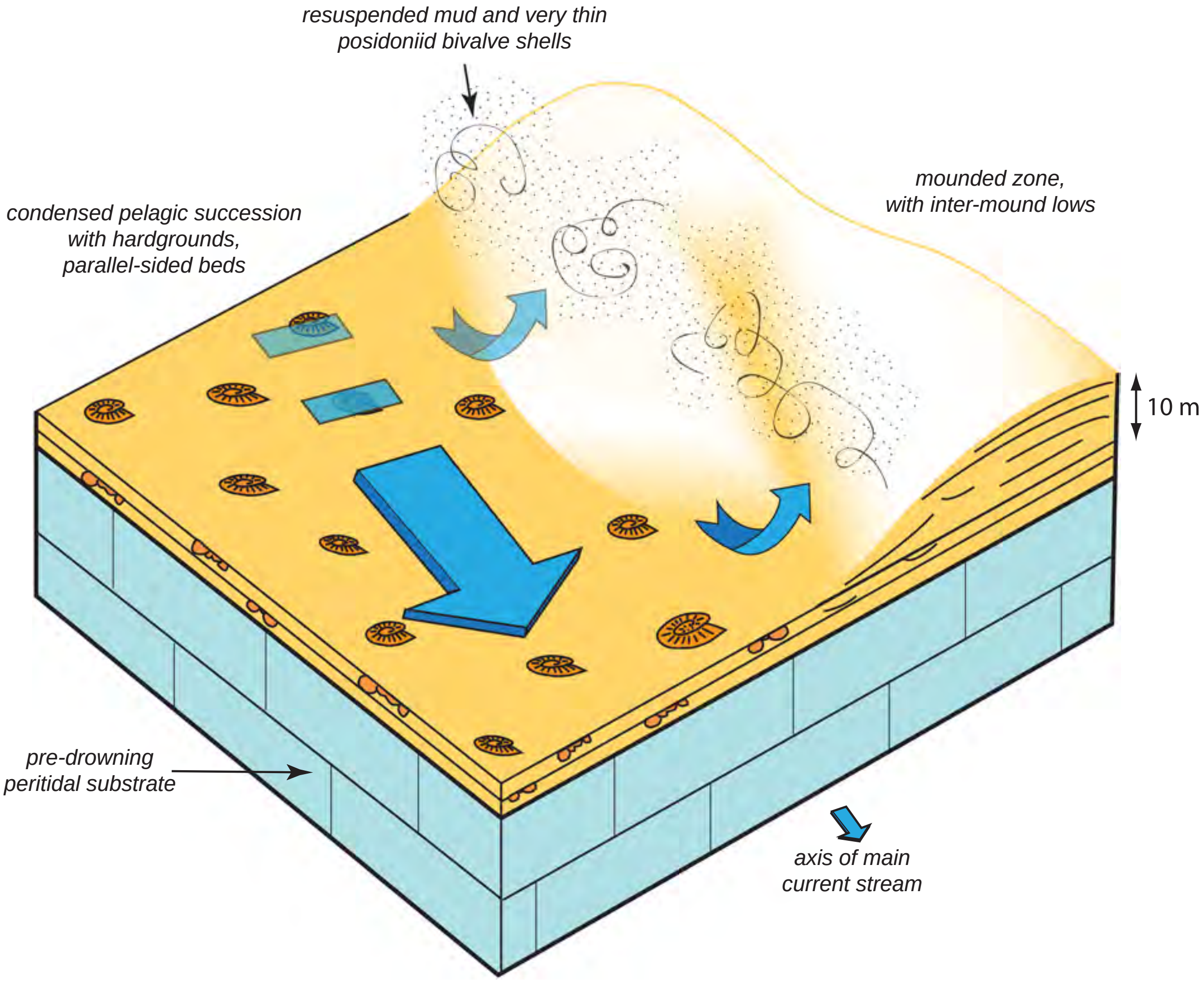

FIGURE 22 Cartoon describing the lateral relationship between zone with condensed pelagic successions (e.g., Contrada Diesi, Contrada Monzealese, Lago Arancio sections, see text and Figure 2 for location) and mounded zone with stratigraphic thickening during deposition of the *Bositra* limestone (San Vincenzo Gorge), as ruled over by the paths of bottom currents on the Sciacca Plateau. Not to scale

and very light-weight <mm-thin bivalve shells, which were brought into suspension by currents. Analogously to the *Bositra* limestone, the Tithonian succession at San Vincenzo differs strikingly from its lateral correlatives. The positive geometries produced by the facies *a* and *b* of the Coquina limestone represent a bioclastic-gravel drift where the very coarse grain-size was accounted for by the very nature of the objects involved, being mostly empty cephalopod phragmocones, generally <5 cm across. This suggests that the currents, responsible for the clinostratification in this Tithonian unit, were rich in nutrients. Biomass increase and enhanced biodiversity with respect to the flat basin floor are common on and around modern intra-oceanic seamounts, as a result of biophysical interaction of the mesopelagic fauna with local hydrodynamics (Mohn et al., 2021).

A pelagic platform is a huge object rising from the sea bottom, and as such it is the ideal locus for the breaking of mid-water currents, resulting in turbulence on the platform-top (Mohn et al., 2021). The importance of internal waves has recently been stressed in numerous papers (Pomar et al., 2012, and references therein; Morsilli & Pomar, 2012; Shanmugam, 2013; Pomar et al., 2019). In the key reference area of Ricla, in Spain (Kimmeridgian), their products are seen as event-deposits, constituted by mm- to dm-thick grainy intercalations within a mud-dominated carbonate ramp succession (Badenas et al., 2012). Solitons are the internal waves which originate wherever the pycnocline meets a submarine obstacle, like a submarine plateau. Tidal currents meeting an obstacle produce waves at the pycnocline, called internal tides (see also Li et al., 2015), which in these cases becomes a synonym with internal waves/solitons.

The peculiar geometries seen in the *Bositra* limestone and the Tithonian Coquina took several millions of years to form and therefore do not represent "event deposits". In addition, nowhere have large-scale positive structures and clinoforms (*Bositra* limestone and Coquina) ever been documented as the products of internal waves. Due to the above, while internal waves could have indeed impinged on the Sciacca Plateau margins, our first-level interpretation of the mounded *Bositra* limestone and of the clinostratified Tithonian Coquina parsimoniously envisages the action of "generic" bottom, or contour, currents as their generator. As is typical with bottom currents, both the *Bositra* limestone and the Coquina limestone document reorganization/re-shaping and/or lateral transport of autochthonous Plateau-top material, with no "foreign" components.

It is conceivable that the inception of mound building processes was due to the existence of an even subtle break in the topography of the plateau top, possibly in the form of a low-displacement synsedimentary fault (not mappable), interfering with the local hydrodynamics of bottom currents.

Assessing the palaeodepth of an intrabasinal high like the Sciacca Plateau during the Middle and Upper Jurassic is problematic, as depth-significant fossils (e.g., photic-zone organisms like algae or zooxanthellate corals) are missing, and a physical connection to a coastline obviously did not exist. While *Bositra*-rich deposits can cover a wide range of palaeodepths, and nekton-dominated (e.g., cephalopods) deposits say little about the thickness of the water column, the abundance of echinoderms (echinoids, crinoids) and brachiopods in the Kimmeridgian and Tithonian units would perhaps suggest "deep shelf " conditions, well below storm wave base, in a pelagic environment at a water depth of a few hundred metres.

8 | CONCLUSIONS

Following faulting and drowning of the Inici Formation shallow-water carbonate platform in the Pliensbachian, a huge pelagic carbonate platform was born, the Sciacca Plateau. Early post-drowning sediments are discontinuous lenses of condensed pelagic material (Toarcian and Aalenian), associated with hardgrounds and Fe-Mn crusts.

The late Bajocian to early Oxfordian *p.p. Bositra* limestone formation displays the growth of spectacular mound-like sediment drifts on a decametric scale, also associated with broad concave-up bedsets. These bodies are interpreted as being the products of the resettling and build-up of biogenic sediment brought into suspension by currents sweeping the Plateau top. The source of this material would be the sediment-depleted sectors lateral to the mounded zone, which would represent the axial zones of the main current streams, documented by a condensed succession with parallel-sided beds and frequent omission surfaces.

The ?middle Oxfordian/early Kimmeridgian-late Kimmeridgian Knobbly limestone drapes this inherited sea-bottom morphology, being a bioturbated wacke- to packstone rich in echinoderm (echinoids and crinoids) and cephalopod remains.

The lower Tithonian is represented by thick bioclastic deposits passing upwards and laterally to a shell-supported, early-cemented ammonite coquina, also with pygopid brachiopods, which displays clinostratification and migration/thinning towards the western quadrants (in today's coordinates). Besides being the products of long-lasting high-energy conditions on the Plateau top, these deposits suggest an increase of nutrients, brought by those same currents which ruled over the sedimentology of this unit, in order to account for the exceptional concentration of fossils. This concentration is not related here to any decreased sedimentation rates and episodic removal of finer-grained sediment, the common cause for the enrichment in cephalopod remains on pelagic carbonate platforms, but rather to a drastic increase of net sedimentation rates and bloom of nekton (ammonites) and benthos (brachiopods, echinoderms).

The younger units (upper Tithonian-lowermost Cretaceous) are mud-rich pelagic deposits developed in low-energy conditions, which eventually drape and even-out the sea-bottom topography as a result of increased productivity of the planktonic carbonate factory due to a worldwide bloom of nannofossils.

Evidence for build-up and/or shaping of sedimentary bodies by bottom currents in a pelagic environment recalls examples of relatively shallow water pelagic shelves known in the literature, like the Upper Cretaceous-Palaeocene Chalk of northern Europe. This is to the best of our knowledge the first example of sediment drifts, and associated sea-bottom topography, documented at this scale from a large pelagic carbonate platform.

ACKNOWLEDGEMENTS

We wish to thank several colleagues who helped us in the field in the San Vincenzo Gorge: J.W.C. Cope, P. Di Stefano, G. Mallarino, R. Manni, M.C. Marino, M. Marino, N. Mariotti, U. Nicosia, the late G. Pallini, and F.M. Petti. Piero Di Stefano is warmly thanked for introducing us to the geology of western Sicily. Mr. Ardizzone supported us in the hot field days with generous doses of his delicious "pane conzato". Angelo Cipriani helped with additional field documentation and geo-referencing. Giulia Innamorati helped with general advice during the revision process, and with her computer graphics expertise. Finn Surlyk and Kresten Anderskouv are warmly thanked for leading one of us (MS) to the Stevns Klint outcrop in Denmark in 2008, and for discussing the similarities and differences with the Sicilian examples. Chris Stevenson, Dan Bosence and one anonymous reviewer are thanked for their scrupulous scrutiny of the submitted manuscript. Financial support from Progetti Ateneo 2019 and 2020 ("Sapienza" University, Rome) to MS is acknowledged.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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How to cite this article: Santantonio, M., & Muraro, C. (2022). Bottom currents on a pelagic carbonate platform: Mounds and sediment drifts in the Jurassic succession of the Sciacca Plateau, Western Sicily. *Basin Research*, *00*, 1–29. https://doi.org/10.1111/bre.12669