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Artikel: Depositional trends in the Valdorbia Section (central Italy) during the Early Jurassic, as revealed by micropaleontology, sedimentology and geochemistry

Kapitel: Sedimentology

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6. Sedimentology

In the Valdorbia area some gravity-flow deposits and other detrital beds were deposited during the middle and upper parts of the Early Jurassic (Fig. 14). Therefore, a brief summary of the main depositional features is necessary here for interpreting the depositional setting. Such deposits can be summarized as: a) calcareous turbidites; b) hummocky cross-stratified (HCS) deposits; and c) winnowed levels.

6.1 Calcareous turbidites and associated gravity-flow deposits

6.1.1 Description

Fine-grained calcareous turbidites, slump and pebbly mud-flow deposits are common in the Valdorbia section (Elmi 1981b; Monaco 1992). Coarse-grained turbidites are very rare (Fig. 15a). The fine-grained turbidites consist of white or yellowish calcisiltites and fine-grained calcarenites, ranging in thickness from 10 to 160 cm (Fig. 15b). In the field, sharp-based turbidites show a very uniform lateral continuity. Intervals b and c of Bouma are predominant, while the normal grading (a of Bouma 1962) is rare. Unidirectional current-ripples and bottom marks (mainly scour, tool and impact marks) are locally present and indicate a prevalent SE-NW direction of turbidity-flow deposits. Water-escape structures, which are common in siliciclastic counterparts and rare in pure carbonates (Lowe 1982), are present in calcareous turbidites of Valdorbia area, since the clay content reaches about 10–15% in the finer fraction (Ortega-Huertas et al. 1993) (Fig. 15b). Amalgamation of calcareous turbidites is very common at the transition of the COR-MS; amalgamated calcarenites show parallel laminations and can reach 160–180 cm in thickness. Texturally the calcareous turbidites are packstones and rudstones with abundant muddy matrix. The carbonate grains consist mainly of echinoderm and bivalve fragments, muddy intraclasts and micritic peloids; radiolarians, oolitic and oncolitic grains and other skeletal fragments are also present in some beds.

Pebbly mud-flow deposits consist of abundant fine-grained carbonate material (calcilutite) and a varying proportion of matrix-supported muddy intraclasts, chert fragments and various type of skeletal grains (echinoderms, ammonite and belemnite remains). In the upper part of Corniola unit, debris flows and pebbly mud-flows are locally associated with muddy slumps (see Einsele 1991).

6.1.2 Age

Turbiditic deposits are abundant in the lower part of the Valdorbia section and they decrease in frequency and in thickness in the upper part of the section. They are represented mainly by low-density turbidites in the Upper Domerian, by high-density, sandy turbidites and mass-flow deposits at the Domerian/Toarcian boundary – where amalgamation phenomena are also present – and by low-density, sandy to silty turbidites in the Lower Toarcian (black shales interval). Like in the Upper Domerian (Emaciatum Zone), in the Lower Aalenian muddy slumps and "heterogeneous" pebbly mudstones (sensu Colacicchi & Baldanza 1986) are again common. At the base of the Marne del M. Serrone Formation (Domerian/Toarcian transition) planar-bedded gravity flow deposits show low-angle curvilinear lamination and HCS in the upper part of a single bed.

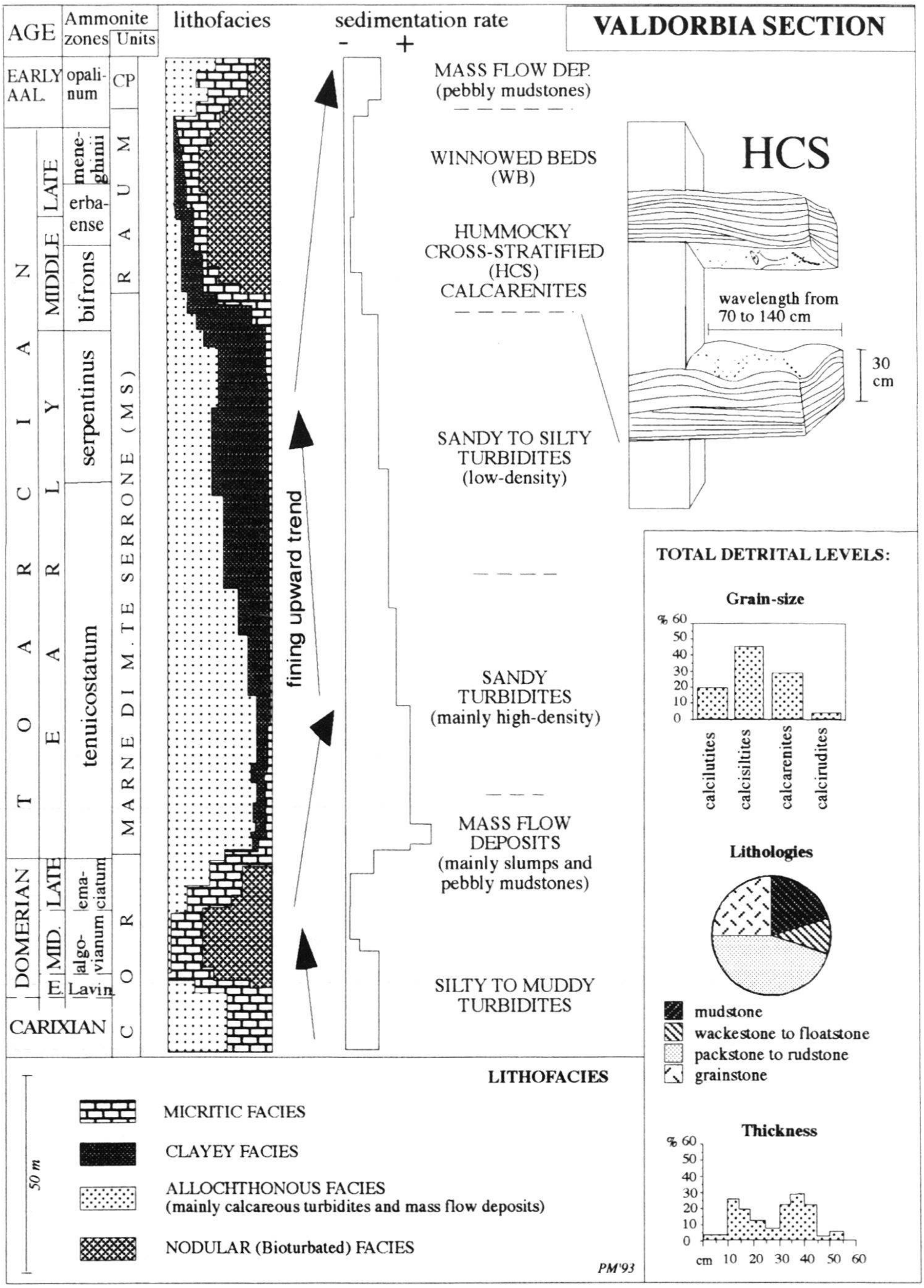
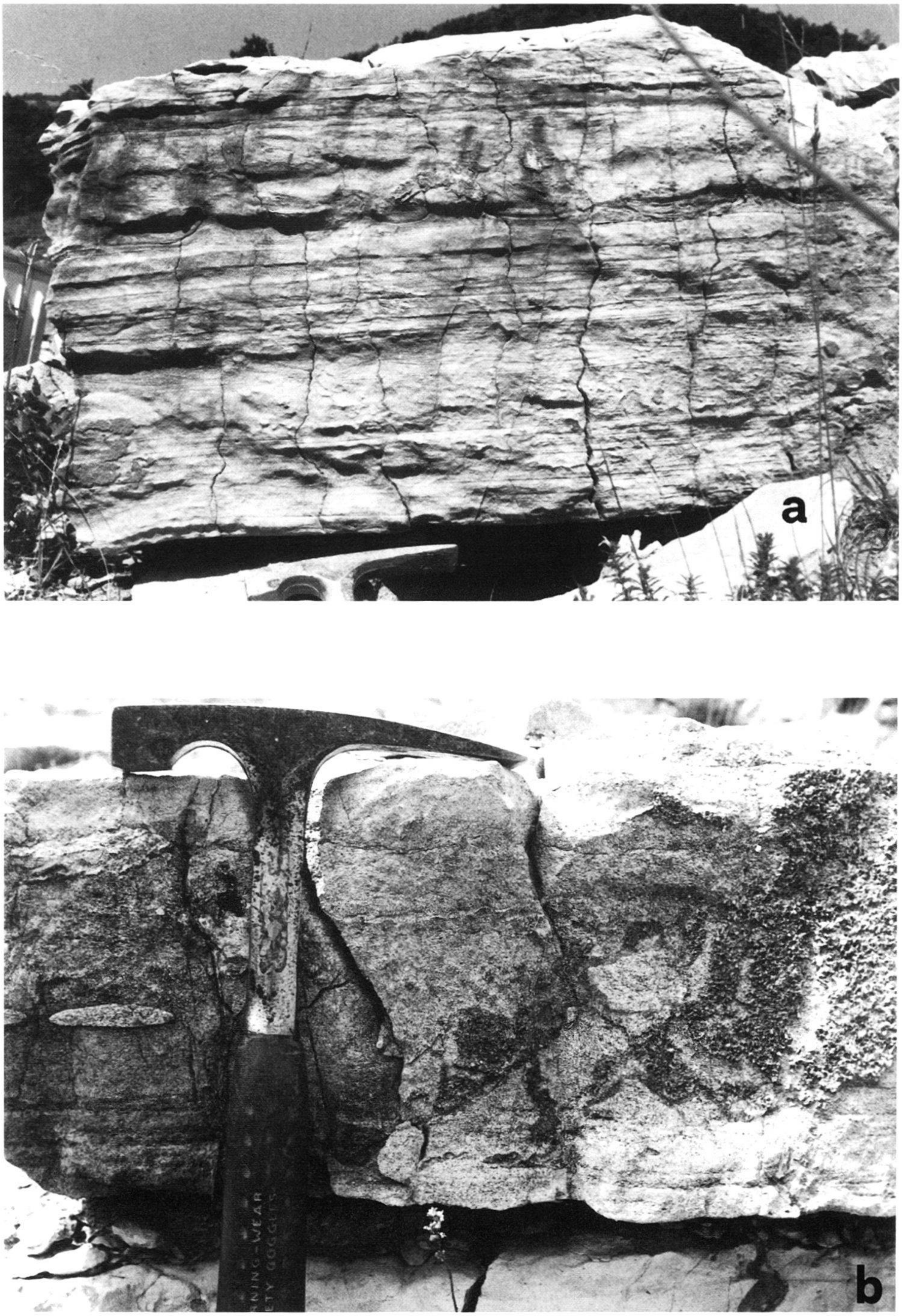


Fig. 14. Sedimentological trends and realtionship among turbidites, gravity flow deposits and HCS beds.


a
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6.1.3 Interpretation

Turbidites and associated gravity-flow deposits indicate that extensional faulting was still active in some areas of Umbria-Marche basin during the Domerian/Toarcian boundary, the early part of the Early Toarcian and the Toarcian/Aalenian transition (Pialli 1969 a,b; Centamore et al. 1971; Elmi, 1981b; Cecca et al. 1990) causing instability of the sea floor.

The coarse-grained turbidites studied – showing a basal unit with inverse grading and/or imbrication, overlain by a planar or cross laminated arenitic layer – could have been deposited by high-density turbidity currents (Lowe 1982; Eberli 1991). In the fine-grained turbidites these features are lacking (Lowe 1982). Faint parallel laminations, overlying a short normal graded interval, seem to indicate that fine-grained turbidites were deposited from low-density turbidity currents. During deposition from such currents, only a few faint sedimentary structures are produced, which makes it difficult to distinguish them from pelagic deposits (Piper & Stow 1991). Echinoderm and peloidal calcisiltites interbedded in the upper Corniola and MS (including black shales) could be deposited from silty turbidity currents, generated by slumping of an unconsolidated material (silt and/or mud), or they may form as the end member of a long-travelled turbidity current (Einsele 1991; Eberli 1991). The planar-bedded gravity-flow deposits that show low-angle curvilinear lamination and HCS in the upper part of a bed (lower part of MS Formation, Domerian/Toarcian transition) could be referred to a new interpretation of Mutti (1992). According to Mutti somes types of hummocky cross-stratification that are located at the top of thick gravity flow beds may be related to oscillatory regimes induced by catastrophic gravity-flow deposits in confined, shallow seas, and, consequently, is it possible that these HCS are not related to meteorological phenomena (Mutti 1992).

6.2 Hummocky cross-stratified (HCS) deposits

6.2.1 Description

The Valdorbia section contains sharp-based calcarenitic beds, 15–40 cm in thickness, showing "hummocky cross-stratification" (HCS) in the sense of Harms et al. (1975) (Fig. 14).

In the Valdorbia area a complete HCS sequence consists of three divisions (Monaco 1992):

1 Bivalve and echinoderm basal lag;
2 Hummocky cross-stratified division;
3 Calcisiltite-lutite division with oscillatory ripples.

Fig. 15. Calcareous turbidites of the Upper Domerian and Lower Toarcian (Emaciatum – Serpentinus Zones). **a** Amalgamated, fine-grained calcarenite, showing repetitive intervals of planar tabular bedding and convolute laminations (divisions b and c of Bouma). Current ripples are common. Domerian/Toarcian transition. **b** High density, coarse-grained calcareous turbidite showing planar bedding (lower part of bed). In the upper part faintly laminated or massive rudite level is present. Lowermost part of the Lower Toarcian (Tenuicostatum Zone).

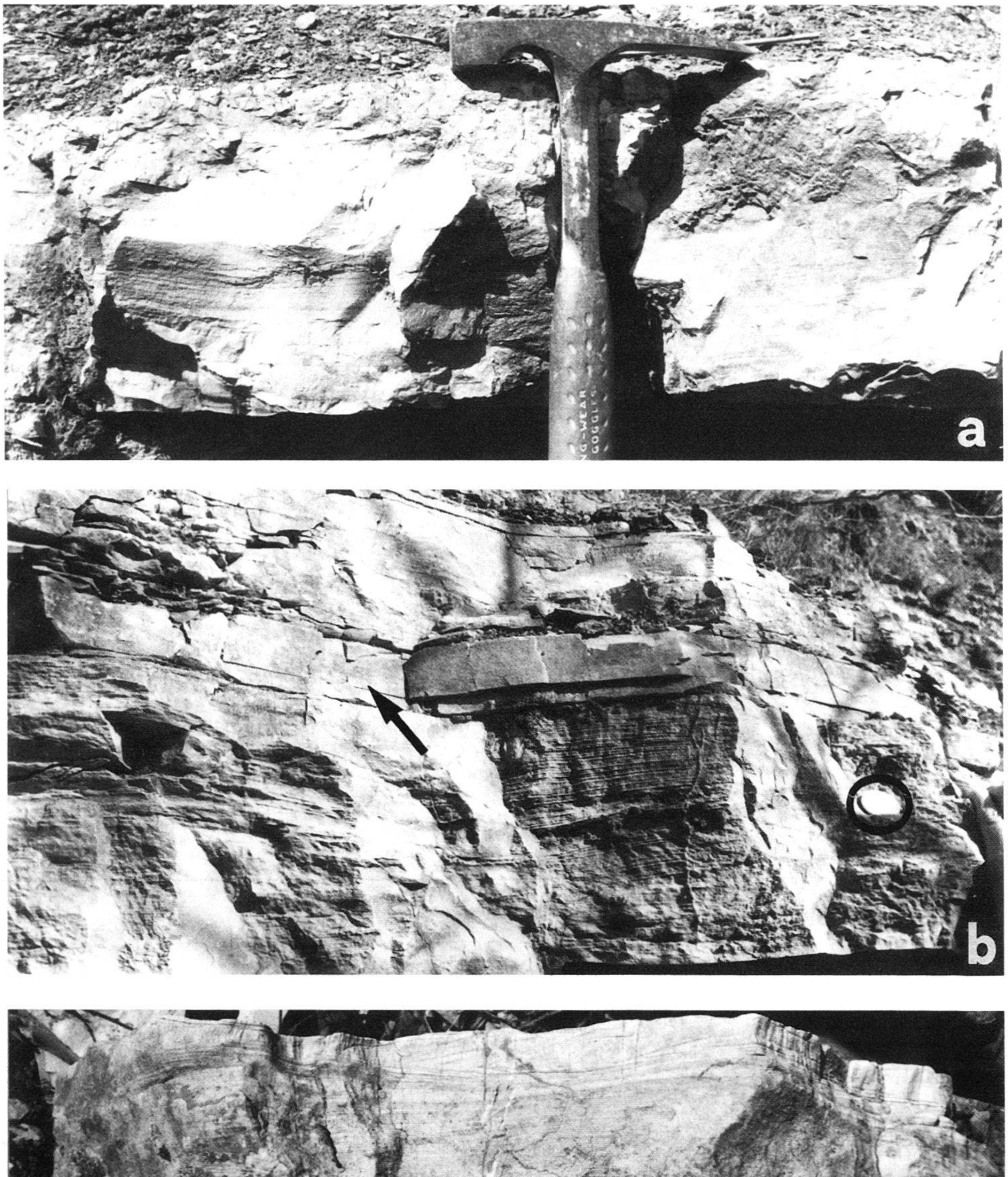
1 Coarse-grained (grain-size up to 5 cm), densely packed rudstones, and packstones (0.5 to 40 cm thick) constitute the lower part of a sequence (basal lag). The basal contact is sharp and erosive surfaces affect the underlying shales. In general the lag is discontinuous and massive, but normal grading is present. The coarse fraction is composed of bivalves (60–80% skeletal grains). At least 60% of the concave valves lie with the convexity facing up. Echinoderms, micritic lithoclasts and other invertebrate remains are also present. In thin-sections infiltration fabrics and shelter porosity occur (Kreisa 1981; Kreisa & Bambach 1982).
2 The HCS division represents the middle part of a sequence and occurs generally in thick beds (up to 60 cm thick). The elliptical domes, 50–100 cm in diameter, are generally symmetrical and display wavelengths mostly from 70 to 140 cm (Fig. 16a, b). The grain fraction consists of well-sorted, fine-grained calcareous sand and silt (average grain sizes in thin-section being between 0.05 and 0.30 mm). Texturally, they are generally matrix-poor packstones. Most grains (up to 70%) are echinoderm fragments. Micritic peloids are very abundant (locally up to 40%). Pebbles (up to 15%), fragments of benthic foraminifera, and/or radiolarians, together with thin-shelled, disarticulated bivalves ("resti filamentosi", Centamore et al. 1971) are fairly common.
3 The oscillatory ripple-bedded division (from 0.5 to about 20 cm thick) constitutes the upper part of a HCS sequence. In general it is very fine-grained (siltstone or mudstone) and pervasively bioturbated. Here trace fossils are both horizontal and vertical. The latter cut down across a bedding surface and the penetration depth can reach about 7–10 cm (Fig. 18d). Equidimensional bivalve fragments are either parallel to the bedding surfaces or were accumulated by burrowing organisms. In thin section micritic peloids and radiolarians are abundant. Oscillatory ripples, about 2–6 cm high with spacings of 6–12 cm, characterize the upper part, but asymmetrical current ripples are locally present (Fig. 16c).

6.2.2 Age

Although HCS beds are present in the upper part of gravity-flow sedimentation during the Domerian/Toarcian boundary interval, these deposits characterize the Middle Toarcian (Bifrons Zone and lower part of Erbaense Zone), when turbidites and associated gravity-flow deposits are lacking.

6.2.3 Interpretation

Hummocky cross-stratification, characterized by generally unoriented, low-relief hummocks and swales with wavelength about from 70 cm to 4 m, is considered to be diagnostic of shallow-marine storm environments, well below fair-weather wave influence and above effective storm wave base (see the extensive literature reported in Walker 1984; Duke 1985; Monaco 1992). For deep water environments see Prave & Duke (1990). In shallow, confined fan deltas, characteristic coarse-grained gravity-flow deposits with planar-bedding show hummocky cross-stratification in the upper part of a bed that is not related to meteorological phenomena such as storms that are rare in some paleolatitudes (Mutti 1992). On the basis only of primary structures of calcarenites the latter interpretation could apply to the Domerian/Toarcian transition when gravity flow deposits were abundant, but it does not apply to the Middle Toarcian in the Umbria-Marche basin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where turbidites and gravity-flow deposits are lacking. Moreover, textures of autochthonous sediments, trace fossils, microfaunal assemblages and geochemical parameters (Ortega-Huertas et al. 1993) seem to confirm a shallowing of the sea floor during the Middle/-Upper Toarcian towards the major storm wave base level where oscillatory flow was dominant. Evidence of oscillatory flow near the sea bottom is found in the shelter porosity and in characteristic abrasion surfaces on some stout biconvex benthic foraminifera (Lenticulina) in the Middle Toarcian interval.

During the early Mesozoic, the large ocean to the east of "C"-shaped landmass of Gondwana – the Tethys Ocean – was ideal for hurricane generation (Marsaglia & Klein 1983). Combined winter storm and hurricane systems dominated the shallow seas of northern Europe including Germany (Bloos 1982), southern Spain (Molina et al. 1987), Morocco (Ager 1974) and other areas (see Duke 1985) during Jurassic time. The Umbria-Marche area, during the Jurassic, was located in an intermediate paleolatitudinal position, between a hurricane-dominated system to the south, and a mixed winter storm/ hurricane-dominated one to the north, and in every case was prone to large hurricanes.

6.3 Winnowed beds (WB)

6.3.1 Description

Discontinuous, matrix-poor deposits are present in the RAUM unit in the upper part of the Middle Toarcian. A vertical sequence, from 0.5 to 15 cm thick, includes (from the bottom to the top): a wackestone, a packstone level and (locally) a grainstone. This inversely graded sequence overlies, without erosional surfaces, the undisturbed, autochthonous mud of the Rosso Ammonitico unit. The grain fraction is often monotypic and formed by concentrations of whole or nearly whole, thin-shelled or costate bivalve (up to 30 mm in diameter). Bivalve shells are densely packed, directly stacked upon each other and lie parallel to the bedding, generally with concave side up (50–60% of the total shells). Shelter porosity is common and matrix/clast ratio decreases upward.

6.3.2 Age

Winnowed beds are rare at Valdorbia. They are found exclusively in the RAUM unit in the upper part of the Middle Toarcian and in the lower part of the Upper Toarcian (Monaco in press a and b).

6.3.3 Interpretation

Periodic storms produced intense bottom-shear conditions, well below the normal wave base (WB in Fig. 14). During the storm peak the soft mud of the sea-floor was eroded and scattered together with shells of living or dead organisms. This process also exhumed

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Fig. 16. Sharp-based hummocky cross-stratified calcarenites (HCS), Middle-Upper Toarcian (Bifrons-Erbaense Zones). **a** Sharp-based HCS bed displaying wavelenght of about 100–120 cm; the uppermost part is fine-grained (mud) and pervasively bioturbated. **b** Small scale and erosive HCS laminae. The cm-thick muddy level in the center (see arrow) represents the characteristic "yellow level" (185.7 m). See coin inside the circle. **c** Oscillatory ripples and erosive ondulatory laminations are present in the upper part of a HCS sequence; current ripples are also common.

the previously semi-lithified mud and buried shells. The strong oscillatory-flow regime at the sea-floor induced a winnowing of finer sediment (the matrix is moved away) and formed a sequence with a characteristic upward trend: a wackestone, a packstone and then a grainstone in the upper part (Brenner & Davies 1973; Specht & Brenner 1979; Kreisa 1981). In other cases due to continuous oscillatory flow on the sea floor, variable periods of non-sedimentation and/or erosion occurred (hiatus), with the exhumation of firmground (or hardground) during the Middle Toarcian (Monaco in press c).

Wavy laminites, interbedded with graded rhythmites, are described also in the Toarcian black shales of NW-Greece and are interpreted as storm deposits formed by direct wave action (see Walzebuck 1982).

6.4 A vertical trend from turbidites to HCS and WB deposits

In the studied section some different trends are recognized:

- a The first is present in the COR unit from the Carixian to the lower part of the Lower Toarcian. Meter-scale cycles of fine-grained calcareous turbidites, due to low-density flows, evolve gradually in coarse-grained, m-thick turbidites and gravity flow deposits (Fig. 14). Amalgamated, high-density turbidites contain reworked skeletal grains of a carbonate platform environment. This detrital sedimentation represents an increase in supply in the Valdorbia area, probably related to local tectonics that influenced the M. Catria-Valdorbia area. A tectonic elevation in the M. Catria area probably involved a deepening in the Valdorbia one in the upper part of the Early Jurassic when the bottom of the Valdorbia basin reached the maximum depth (Monaco 1992, Tab. 1). Another interpretation is that the thickening and coarsening up during the Domerian (Fig. 14) could be related to a sea-level fall (Farinacci et al., 1981; Hallam 1988).
- b Coarse-grained calcarenitic turbidites in the COR/MS units transition are overlain by fine-grained calcisiltitic turbidites in the upper part of the MS Fm. (Lower Toarcian, Tenuicostatum – Serpentinus Zones, Fig. 14). The thickness and the grain size of detritic beds decrease going upward. This fining-upward trend seems to indicate a reduction of a local tectonic activity and a uniform depth of the sea-floor.
- c A shallowing-upward trend characterizes the Lower Toarcian – Middle/Upper Toarcian interval. Fine-grained turbidites, abundant in the MS Formation are overlain by sharp-based HCS deposits and WB beds in the RAUM unit (Fig. 14). This shallowing-upward trend may be related to a progressive sea-level fall in the Middle/Late Toarcian (Hallam 1988) that is general in the Umbria-Marche area. Microfaunal assemblages reflect this progressive shallowing-upward trend and indicate a transition from a sea-floor comparable to an upper bathyal/outer shelf environment in the Early Toarcian, to an outer- middle shelf in the Middle/Late Toarcian.

7. Trace fossil assemblages

7.1 Burrowing during authigenic sedimentation

- a COR Unit. The lower part of the COR unit is very weakly bioturbated by small horizontal traces and Chondrites forms are common. During the Late Domerian, in con-