4(f). Complex structures associated with siliciclastic biolaminites

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Siliciclastic biolaminites result from biosedimentary accretion due to interaction of mat growth and siliciclastic sediment deposition. They are characterised by millimetre-scale alternating layers of microbial mat material and fine-grained sand- to silt-sized sediment, reflecting repeated cycles of mat growth, sediment deposition and burial, and renewed mat growth *sensu* Gerdes et al. (2000a). Siliciclastic biolaminites usually develop flat, parallel laminations, but excursions to more domal structures and wavy-crinkly laminations occur.

Upon subaerial exposure, the surface mat layers of biolaminite successions may undergo desiccation and shrinkage and develop shrinkage cracks of variable size and shape, ranging from isolated, lenticular and spindle-shaped types to networks of decimetre-scale polygonal cracks with upturned and overgrown margins (Fig.4(c)-6A). Within a package of biolaminite, shrinkage cracks may be observed at several levels indicating multiple repetitions of mat growth, shrinkage and cracking during biosedimentary accretion. When, at wide cracks, desiccation and shrinkage advance from the crack margins into the top portion of the biolaminite succession, thick packages of biolaminite may be upturned, forming an upturned margin (Fig.4(c)-6B).

Microbial growth, triggered by uprising groundwater in wide cracks may span the crack opening and encroach upon the margins, leading to overgrown margins. Alternating mat growth and upturning of crack margins, for example during tidal high and low water, respectively, may lead to complex structures along the crack margins. Depending on the rates of the processes involved, resulting structures may range from rather simple (Fig. 4(c)-6C) to highly irregular (Fig. 4(f)-1, -2) examples. Complex structures reflect a non-equilibrium system of quasi-concomitant growth, destruction by desiccation, deformation by repeated upturning, and renewed overgrowth.

When compared to modern examples, identification of 'complex structures' in ancient laminated siliciclastic successions may argue for: (1) the biogenicity of the deposits; (2) an intertidal environment, where continuous/episodic shrinkage and growth closely accompanied cyclic accretion of mat-sediment doublets; (3) processes involving continuous and repeated occurrences of shrinkage, upturning and overgrowth until the margin structure is completely sealed by new and continuous mat layers.

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Figures

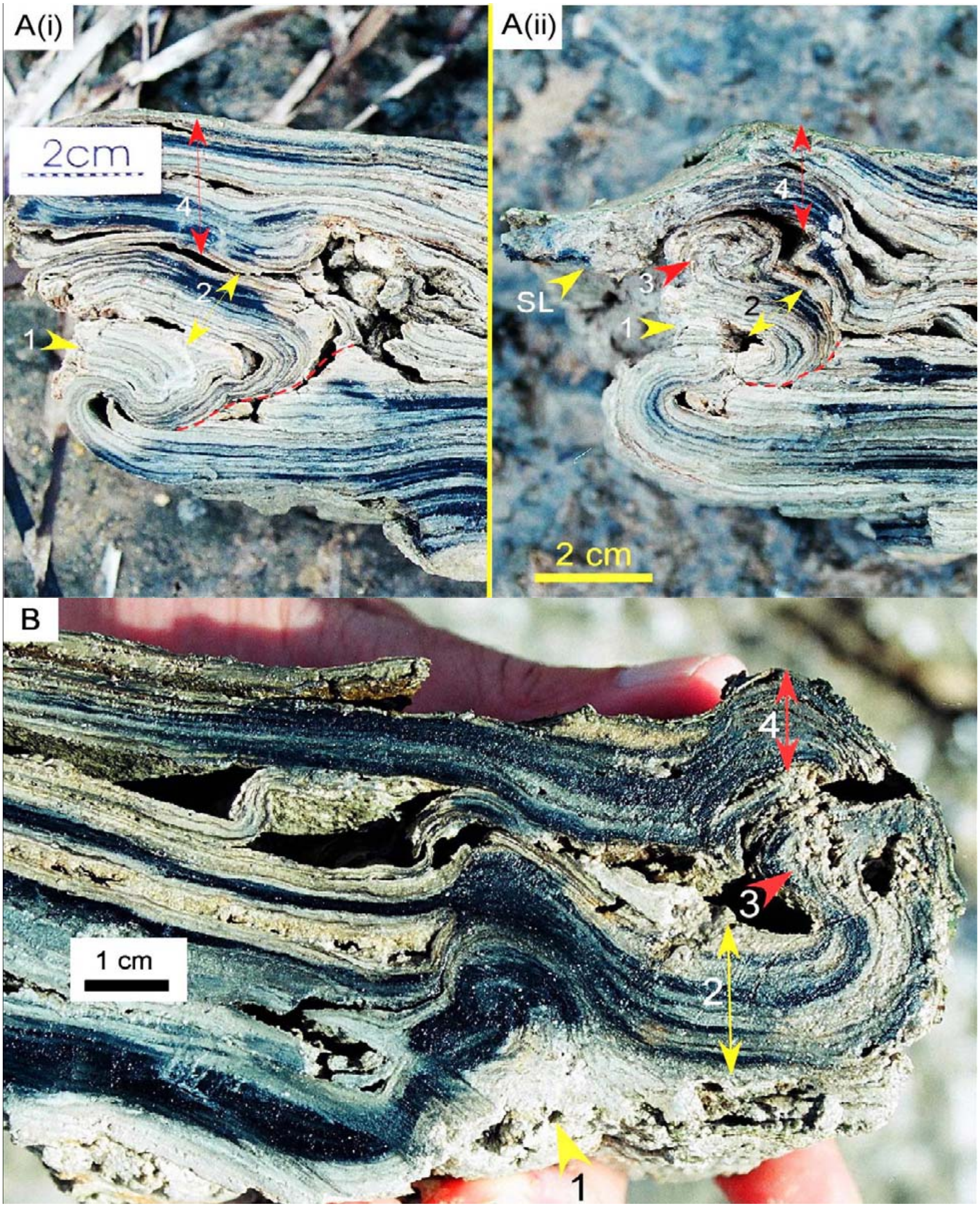

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Figure 4(f)-1: Complex features resulting from continuous/episodic cracking, upturning of crack margins and concomitant mat growth; modern example from Tunisia.
(A) Sections across overgrown crack margins as developed along polygonal cracks in biolaminite (see Figure 4(c)-6A). Photos A(i) and A(ii) show internal structures resulting from cracking, upturning of crack margins and concomitant mat growth. Continuous overgrowth and overfolding of evolved upturned polygon edges may develop complex structures distinct from the rather simple structures of upturned and overgrown incipient margins as presented in Figure 4(c)-6C. Dashed lines indicate discontinuity of the flat lamination against the overturned evolved structure. A(i) is a section across the edge of a biolaminite polygon showing rolled-up structures related to continuous processes of microbial growth, shrinkage and overgrowth around the crack-edge. Note initial upturned margin (1) overgrown by a first generation of microbial layers (2). The resulting structure of the edge is Z-shaped and overfolded to a horizontal attitude. Overlying microbial layers (4) form the next step of overgrowth and fossilize the structure. A(ii) shows two superposed generations of upturned and overgrown edges developing a vertical meandering structure. The first upturned and overgrown edge (1 and 2) is overturned into a horizontal attitude before formation of the new edge (3). The overgrowing microbial layers (2) undergo shrinkage themselves and a second short upturned margin is formed (3), again overgrown by microbial layers (4), which completely seal the structure and which adjoin laterally to a sedimentary layer (SL) deposited between the polygon edges. (B) Section across the edge of a polygonal shrinkage crack in biolaminite. The structure shows lateral and vertical transitions between two successive overgrown crack-edges. The first (1) is completely overgrown by a stack of continuous microbial layers (2) which themselves undergo a new stage of shrinkage, upturning (3) and overgrowth by new microbial layers (4), leading to the formation of a new upturned margin structure. Repeated cracking, upturning and overgrowth may lead to successive and superimposed ‘antiformal structures’ which may be confused with tectonic folding or softsediment deformation (i.e., due to slumping or dewatering). Locality: Bhar Alouane, Mediterranean coast of southern Tunisia; environment: intertidal zone, regularly flooded during high tide. Photos: E. Bouougri and H. Porada.

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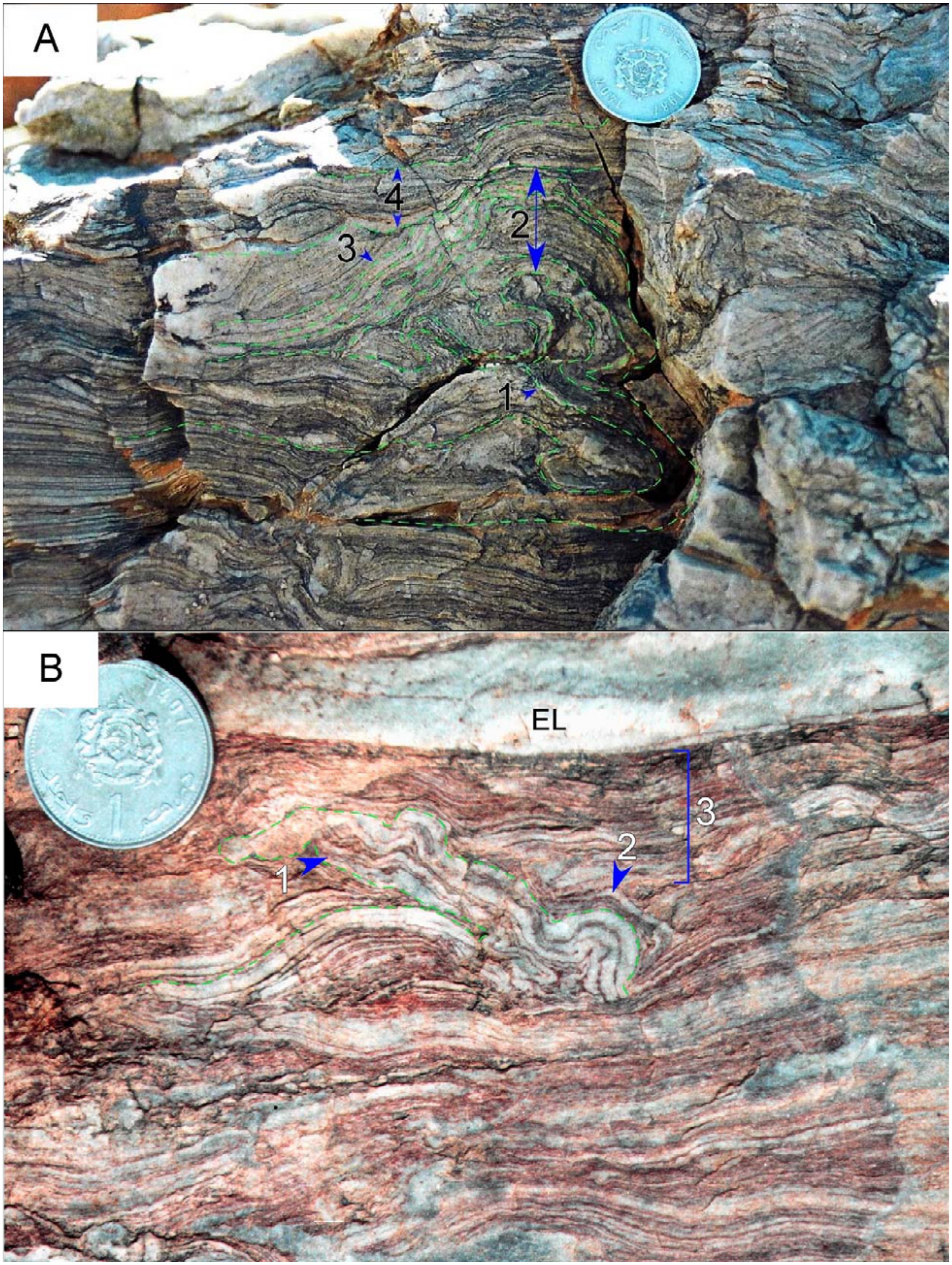

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Figure 4(f)-2: Complex features in biolaminites resulting from shrinkage, upturning of crack margins, concomitant mat growth and deformation during burial; ancient example from the Neoproterozoic of the Anti-Atlas.

(A) Internal organisation of structure resulting from shrinkage and overgrowth within biolaminite deposits. The geometry and organisation of the laminae record multiple stages of overgrowth and crack-margin upturning. Thus, the structure comprises: (1) an upturned crack margin resulting from shrinkage of the biolaminite layer; (2) a first interval of microbial layers overgrowing the margin, and in which the first overgrowth laminae are deformed behind the margin due to a high rate of overturning (and later compaction?), while the laminae above are continuous; (3) discontinuous laminae not continuing past the crack-edge which is again upturned, thus creating a depression behind; (4) continuous overgrowth laminae covering the whole structure. (B) Laminated siltstone/argillite (biolaminite) with interbeds of fine-grained quartzite (event layers: EL) showing internal fold structure (green dashed line) which records a high degree of flattening under burial and compaction. The structure is interpreted as resulting from shrinkage, cracking and overgrowth of the upturned crack margin, undergoing the following sequence of events: (a) shrinkage of biolaminite layers and formation of an upturned crack-margin developing an asymmetric S-like shape (1); (b) the margin is overgrown by new laminae with progressive onlap towards the stabilised overgrowth edge (2); (c) the whole structure is progressively sealed by growth of new biolaminite layers (3); (d) burial and compaction cause gliding between internal and surrounding (overgrowth) laminae; overgrowth layers are torn and the margin is strongly compacted; biolaminite layers below are disrupted forming a 'convex-up' structure in the left-hand part of the feature. Locality: Tirsal section, Tamgarda Formation, Tizi n-Taghatine Group, Anti-Atlas, Morocco. Scale (coin) is 24 mm. Palaeoenvironment: intertidal zone. Photos: E. Bouougri and H. Porada.

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