6(c). Inherent problems of terminology: definition of terms frequently used in connection with microbial mats

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Introduction

Like all branches of the earth sciences, the study of microbial mats and the features they leave behind preserved within clastic sediments of various calibers, is rife with terminology. As terms are used over several decades, the original meanings often become more imprecise as shades of meaning are added to an initial definition. One example examined briefly here is the term 'wrinkle mark', discussed in greater detail in section (a) of this chapter.

Another example of changing uses of a single term over time is provided by 'petee'/'petee ridge' (Fig. 6(c)-1B, -1C, -1D, -1G). Gavish et al. (1985) introduced the term in relation to modern mats, defining it as undulation and wrinkling of microbial mats due to either wind or gravity. Reineck et al. (1990) classified these forms into alpha-, beta- and gamma-petees, and considered the term in general to refer to biologically modified overthrust structures such as single domes, multitudes of buckles and transitions of the latter into domes. In both of these original definitions the petee forms were rounded, resulting from cohesiveness of the observed modern microbial mats. Reineck et al. (1990) interpreted the deformation of the mat inherent in petee formation as being due to sub-mat concentration of gas, to wind or water friction, or resulting from gravity. Neither of these earlier works really considered sediment filling in the positive deformation features of the mats growing above sandy substrates (see also, Chapter 4(c)). An association of petees with cracks in the mats (e.g., Gehling, 1999, 2000) expanded the original definition, with Gehling (1999) defining petees *sensu stricto* as related to genesis through mat growth expansion and underlying gas pressure. Schieber (2004; see also, Chapter 3)) embraced this broader concept of the meaning of the term, and linked 'petee ridges' to positive features related to rupturing of mat surfaces; a relationship between the geometry of desiccation patterns and concomitant petee ridges (e.g., Fig. 6(c)-1G) thus became implicit in this further expansion of the meaning of the term. Noffke et al. (2001a) espoused this broader, looser usage of petee/petee ridge to denote positive epirelief on a mat surface. This loose definition was also applied in this book in Chapter 4(c), and can perhaps be viewed as denoting petees *sensu lato*.

Although evolution in the meaning and usage of scientific terminology is almost inevitable, it is important to try and minimize the resulting confusion, particularly in an atlas-type publication such as this book. For this reason, this section attempts to clearly define certain critical terminology related to microbial mats and their preserved features in the clastic sedimentary record; in general, recourse is had to original definitions and usages rather than to those developed later, which often led to confusion. This endemic difficulty with scientific nomenclature is thus highlighted in this chapter as amongst the problems inherent in research on microbial mat-related features, and this section should thus not be viewed as a comprehensive glossary of relevant terminology, which would more logically appear either at the beginning or end of a book. Obviously, many mat-related structures are complex features, reflecting a multiple-structure genesis, as is illustrated in Fig. 6(c)-1.

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Some critical terms defined

Blister

A descriptive term; in relation to microbial mats, blisters are photosynthetic gas bubbles, stabilized and overgrown by microbes; according to Stolz (2000), they are “pockets of trapped gas bubbles”. Genetic relation to ‘photosynthetic (PS) dome’. Blisters should not be confused with ‘pustular’ or ‘nodular’ patterns which evolve from localised growth and cell division of coccoids, e.g., *Entophysalis* sp.

Bulge

An elongated round-crested positive form on microbial mat surfaces, initiated by growth and confined biomass accretion; may be filled by sediment uprising from below; frequently related to mat polygons. ‘Upturned’ or ‘curled’ margins of cracks often are overgrown by new mat layers and become preserved as bulges (see Chapter 8(d), Fig. 8(d)-2F). Bulges are members of a group of microbial mat-induced positive structures (see also ‘petees’, ‘growth domes’).

Complex structure (e.g., Fig. 6(c)-1E, -1F, -1G, -1H)

A structure in which physical and ecophysiological processes are intimately interrelated, e.g.: an overgrown crack margin (bulge) is the product of induced polarity change and growth response of mat-forming microorganisms to physical deformation or destruction of a mat, which in turn means change of the habitat (e.g., polygonal cracking provides not only fissures and margins but aids also the emergence of groundwater as a trigger for growth). Most terms discussed here denote complex structures due to ‘parahistological’ behaviour of mat-forming biota (like living tissues).

Curled margin

Crack margin that has developed an involute structure, due to shrinkage-related contraction being strongest in the still flexible surface layer of a subaerially exposed mat. May be overgrown and remain as a bulge-like feature (cf. ‘overgrown curled margin’, see also complex structure, bulge).

Deformation (Fig. 6(c)-1A)

Contortion or distortion of surface mats due to external physical impacts, e.g., ‘folding’, ‘flip-over’, ‘roll-up’ due to tractional forces acting upon the mat. The term should not be confused with “destruction”.

Destruction

Deterioration of a mat, e.g., shrinkage cracking due to desiccation; also including erosion by strong currents and formation of mat fragments (‘mat chips’, ‘sand chips’).

Dome

A descriptive term; several causes: see photosynthetic (PS) dome, gas dome, mat expansion structure, petee.

Gas dome (Fig. 6(c)-1H)

Domal feature on mat surface resulting from gas accumulation below mat; gas production due to decay of buried mats.

Growth dome (Fig. 6(c)-1E, -1F, -1H)

Domal mat expansion structure resulting from localised microbial growth; in the supratidal zone accompanied by crystallization of evaporite minerals similar to tepees.

Induced growth

Locally restricted microbial growth may be induced by ascending groundwater in shrinkage cracks, even in dry seasons; induced growth also applies to microtopographically-controlled, selective growth on ripple crests or in shallow depressions after rainfall or minor inundation (see also polarity).

Mat expansion structure

Collective term including several positive structures resulting from 'microbial growth' and localised biomass accretion; see petees, growth domes, overgrown crack margins. Genetic relation to growth and to polarity.

Microbial growth

Increase in the number of cells in a population due to binary fission, usually measured as an increase in microbial mass (see also polarity).

Nodular pattern

Localised growth and cell division of coccoid cyanobacteria, e.g., *Entophysalis* sp., may lead to 'pustular' or 'cauliflower-like' surface structures.

Petee (Fig. 6(c)-1B, -1G)

Arched-up, sometimes undulated and wrinkled surface form. Petees owe their form primarily to the growth and expansion of coherent microbial surface mats. Original definition (Gavish et al., 1985) stresses the interactive role between mat growth/expansion (see mat expansion structures**)** and physical processes. The latter can include (i) wetting and drying ("wetting enables microbial mat to form new surface layers, drying desiccates and cracks the new crusts"; Gavish et al., 1985); (ii) rise in water level (see as well the important role of upwards-directed groundwater in the tepee definition); (iii) wind and slope gravity (may lead to undulated, wrinkled petee forms according to Gavish et al., 1985). In analogy to tepees (see below) in salt crusts resulting from surface crust expansion due to crystallisation of evaporite minerals, petees originate from mat expansion due to localised microbial growth and biomass accretion.

Petee ridge (Fig. 6(c)-1C, -1D)

According to Gehling (1999): “rounded and ruptured ridges in sinuous and polygonal patterns” ...”Growth expansion and the gas pressure from buried decaying mats produces buckling....”; ... ”desiccation, wind and wave action causes disruption and overturning of the mats..”. While physical factors involved may be ambiguous, the unifying factor seems to be mat expansion due to growth which may allow one to subsume the term ‘petee’/‘petee ridge’ under the collective term ‘mat expansion structure’.

Photosynthetic (PS) dome

Domal feature on mat surface, 0.5 to rarely 10 cm in diameter, resulting from photosynthetic gas production; domes may merge into each other and form also oval bodies. The structures form in highly elastic surficial EPS film and are stabilised by overgrowing microbes.

Pinnacle, tuft

Growth structures, products of polarity changes of filamentous cyanobacteria originally contributing to condensed fibrillar meshworks. Tufts represent erected filament bundles rising some millimetres above mat base. Pinnacles are more rigid, stabilised forms due to amounts of EPS produced by associated community types, e.g., coccoids and diatoms that follow the slight microtopographic elevations.

Polarity

The spatial orientation of mat-forming benthic cyanobacteria is of importance for the type of mat produced. Basically, the preferential spatial orientation of filamentous cyanobacteria (and others) is due to their polar attributes. Two possible pathways exist: a growth direction that is causal to the cell (cytoplasma) organisation and taxon-specific division planes, which is termed ‘structural polarity’; growth directions induced by ecological factors (e.g., light, gravitation) are termed ‘induced polarity’.

Reticulate growth pattern

Surface ornamentation on microbial mats in which pinnacles/tufts and ridges (small-scale bulges) are the main constructive elements. The ridges in many modern examples are growth patterns of *Lyngbya* sp. Pinnacles often represent the focus of radially arranged ridges. Intersecting ridges and pinnacles form reticulate growth patterns that macroscopically resemble ‘elephant skin’.

Subcircular crack

Starting from a circular, subcircular or irregularly sinuous opening, and resulting from accelerated shrinkage and initial cracking at the top of a domal feature in a thin mat, the usually curled margin of the opening (see ‘curled margin’) may be preserved as a subcircular positive feature on the mat surface, particularly if subsequently overgrown by new mat layers.

Tepee (peritidal)

“Arched-up antiform margins of expansion megapolygons...; ..when the surface area... increases; .. when repeated incremental fracturing and fracture fill by sediment and/or cement.. causes the area of the hardgrounds to expand; ..where the marine phreatic lens is close to the sediment surface and the climate is tropical... where crusts experience alternating phreatic and vadose conditions, in time intervals of days to years...” (Kendall and Warren, 1987).

Upturned margin (see Fig. 4(f)-1)

A structure resulting from successive upturning of a crack margin due to desiccation and shrinkage advancing from the crack edge into the mat polygon; usually involving a stack of alternating sedimentary and organic-rich layers below the mat surface; typically occurring in mats overlying biolaminite successions. Antiformal, inverted ‘V’ structures (similar in shape to ‘tepees’) may result and be preserved in the ancient record, when opposite crack margins are upturned (see for comparison, Gehling, 1999, his Fig. 4B).

Wrinkle structure

Member in a group of small-scale structures genetically related to microbial mats; characterised by alternating mm-scale crests and troughs of various length and more or less irregular trend (see Hagadorn and Bottjer, 1997, 1999). Various origins are discussed: (a) mat surface structure reflecting (exceptional) linear growth patterns; (b) mat deformation structure due to tractional or gravitational forces acting upon a thin mat; (c) mat subsurface structure formed beneath a cohesive microbial mat, e.g., ‘*Kinneyia’* structure (known from the ancient record only). Typical reticulate growth patterns and their ancient analogue ‘elephant skin’ texture (Runnegar and Fedonkin, 1992) should not be subsumed under the term ‘wrinkle structures’ (see section 6(a)).

Figures

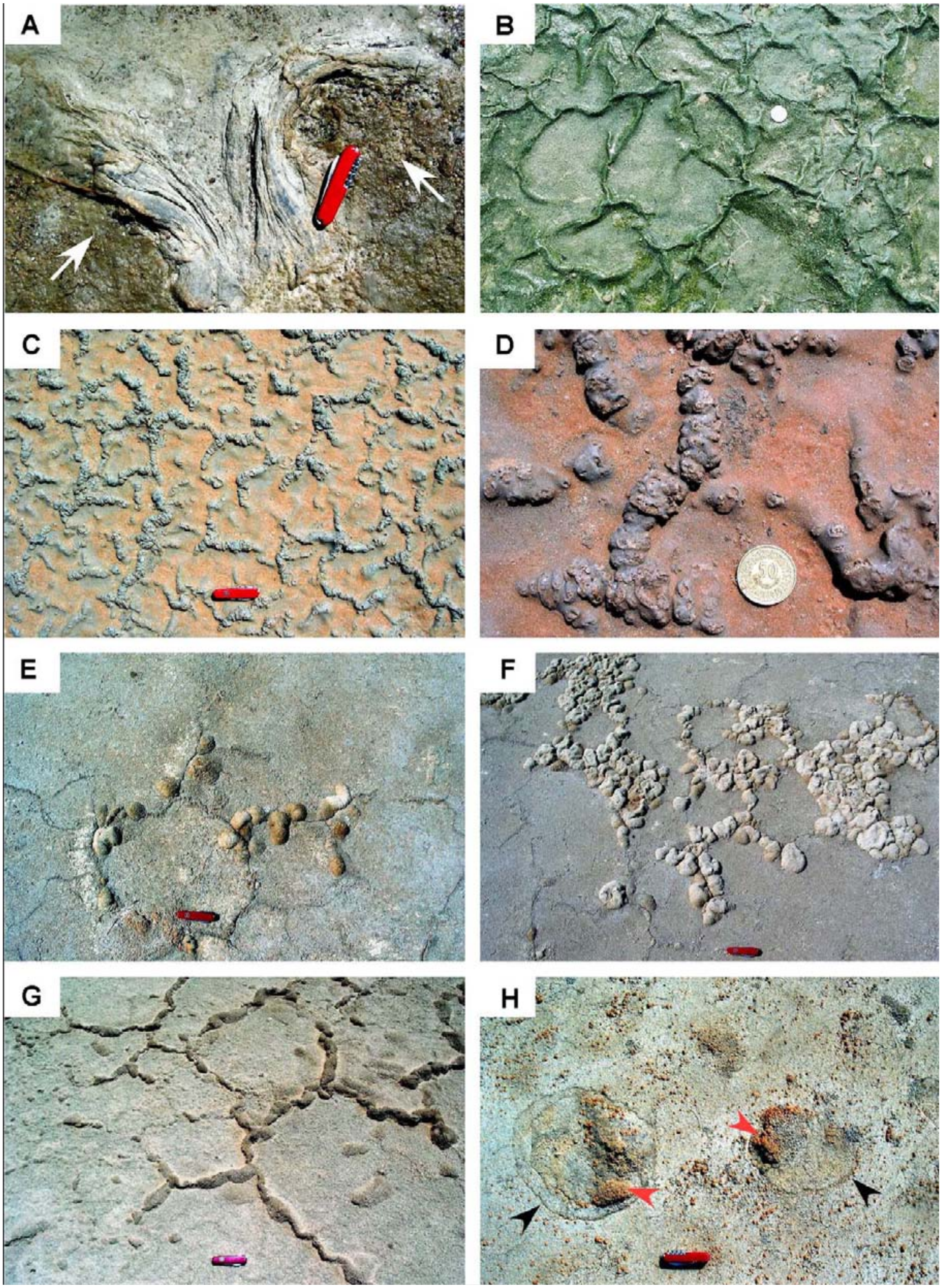

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Figure 6(c)-1: Structures illustrating mat deformation, petees resulting from mat growth and expansion, gas domes and induced growth structures (domes and petees).

(A) Deformation along the margin of a leathery microbial mat. The deformation is due to water oscillation and friction along the mat margin, inducing formation of belts of irregular to curved ridges. The whole structure appears biostabilised by growth of new mat.White arrows indicate the direction of water movement. Preconcentration basin of 'Salins du Midi' saltern, Réserve Nationale Camargue, Southern France. Scale (knife) is 8 cm. (B) Petees with round crests arranged into polygonal network. The petees start commonly as triradiate or isolated lenticular ridges evolving to a polygonal network during progressive and continuous mat growth and expansion. Supratidal pond, Djerba island, southern Tunisia. Scale (coin) is 25 mm. (C–D) Petees arranged into polygonal network and with pustular crest, these may due to other dominant taxa (coccoid possibly) increasing at the elevated part of the mat surface (crests), as well as photosynthetic activity that has produced blisters on/in slime which finally desiccated on the crests (pustular petees). The close-up view (D) shows that petee ridges may exhibit a nodular pattern and are filled from below by uprising of underlying sediment. Desiccation at peaks of petees frequently leads to circular/ subcircular curled margin which subsequently may be overgrown. Lower supratidal zone, Bhar Alouane, southern Tunisia. Scales (knife) is 8 cm and (coin) is 25 mm. (E–F) Complex structures associating shrinkage cracks and growth domes aligned along the cracks. Crack formation starts with faint fissures in the mat which may create an immediate decrease of tension of the surface mat and ascent of water or moisture to which organisms respond in a very localised way. The biotic response encompasses active mat growth and expansion along the cracks with a development of incipient growth domes along one side or both sides (E). The resulting incipient growth domes exhibit round to slightly elongate shapes with diameters up to 5 cm. The continuous growth of domes may encompass the whole polygon surface and form coalesced structures (F). Supratidal zone, Sabkhat Boujmel, southern Tunisia. Scale (knife) is 8 cm. (G) Petees resulting from selective induced growth along faint polygonal shrinkage cracks. The process invoked is similar to that in photos (E–F). The petees ridges have rounded-crests and exhibit a polygonal network. Supratidal zone, Sabkhat Boujmel, Tunisia. Scale (knife) is 8 cm. (H) Complex structures associating collapsed gas domes and induced growth domes. The collapsed gas domes with diameter up to 20 cm are indicated by concentric flat pattern and remaining margins (black arrows). In between the collapsed domes, there are smaller growth domes more or less stippled by beetle pocks (red arrows). The growth of domes starts from the margins of collapsed gas domes which were not completely sealed. This as well as vertical to diagonal burrows induced by beetles below, may enhance localised seepage of groundwater which gives the microbes the growth impulse. Supratidal zone, Sabkhat Boujmel, Tunisia. Scale (knife) is 8 cm. All photos: El Hafid Bouougri and Hubertus Porada.

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