Microbialites: an untapped resource

by

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Microbialites are defined as 'organosedimentary deposits that have accreted as a result of a benthic microbial community trapping and binding detrital sediment and/or forming the locus of mineral precipitation' (Burne and Moore, 1987). These include stromatolites and thrombolites, as well as the lesser known leolites, dendrolites and microbially induced sedimentary structures (MISS) (Fig. 1), and composites of the various types. Western Australia is renowned for its wealth of microbialites, with living and fossil examples in relatively close proximity allowing comparative study. Living microbialites are best known from the World Heritage Area of Shark Bay and also from saline lakes such as the Yalgorup Lakes including Lake Clifton, and Lakes Thetis, Richmond, Walyungup, Pink and those on Rottnest Island (Grey and Planavsky, 2009). Western Australian fossil microbialites span the geological timescale from Paleoarchean to Recent, with the c. 3.43 Ga Strelley Pool Formation stromatolites perhaps the most notable of these early records (Allwood et al., 2007).

A changing focus

Many early Australian microbialite studies focused on the systematic description and biostratigraphic potential of different forms (Preiss, 1972, 1973, 1974, 1977; Walter, 1972a,b), particularly in Precambrian strata due to the lack of other macroscopic fossils suitable for correlation. Over time, systematic description of microbialites diminished as studies focused on other aspects of ancient microbialites, for instance considering biogenicity of older structures (Nutman et al., 2016; Allwood et al., 2018). Research on both living and fossil stromatolites saw a shift away from comparative analogues (such as Grey and Thorne, 1984) to environmental studies with a biological (such as Suosaari et al., 2016; Johnson et al., 2018), rather than a morphologic, temporal and spatial focus. As a result of this change in emphasis, biostratigraphic applications have been neglected.

Compounding this diversification in focus of studies, the naming of microbialites and their biostratigraphic use has been contentious (Grotzinger and Knoll, 1999; Turner et al., 2000; Altermann, 2004). Preiss (1977) recognized that the biostratigraphic potential of Precambrian stromatolites could only be tested empirically by determining the time ranges of defined taxa, relying on other means of dating and correlation. Collecting such empirical data has been hampered by difficulties with terminology, naming and adequate locational and temporal data. A more balanced and consistent approach in how microbialites are described and named is needed to address problems that have historically prevented microbialite comparative studies.

A new resource

Geological Survey of Western Australia (GSWA) Bulletin 147 Handbook for the study and description of Microbialites (Grey and Awramik, 2019 in prep.), consolidates definitions and terminology from the global literature into a rational and systematic manual. This microbialite handbook presents a practical guide, extensively illustrated with actual examples. It sanctions microbialite description from the regional and outcrop scale down to the macroscopic and microscopic scale, and aims to foster more effective communication by presenting a set of procedures and terminology that should rationalize international standards for microbialite studies.

Application

GSWA continues to include microbialite studies as part of its targeted regional mapping projects and stratigraphic revisions. Recent projects to utilize microbialites for correlation include reviews of Neoproterozoic units of the Officer and Amadeus Basins, and Paleoproterozoic successions in the Hamersley province. Using stromatolites as a mapping tool is well established in Australian Neoproterozoic sections (see Allen and Haines, 2018; Allen et al., 2012, 2018; Grey et al., 2012 and references therein). The most recent stratigraphic revision of components of the Centralian Superbasin has been robustly supported by stromatolite studies (see Haines et al., 2012; Haines and Allen, 2014 and references therein). The Ediacaran *Tungussia julia* and Tonian *Baicalia burra* and *Acaciella australica* Assemblages are now well documented and extend across Australia.

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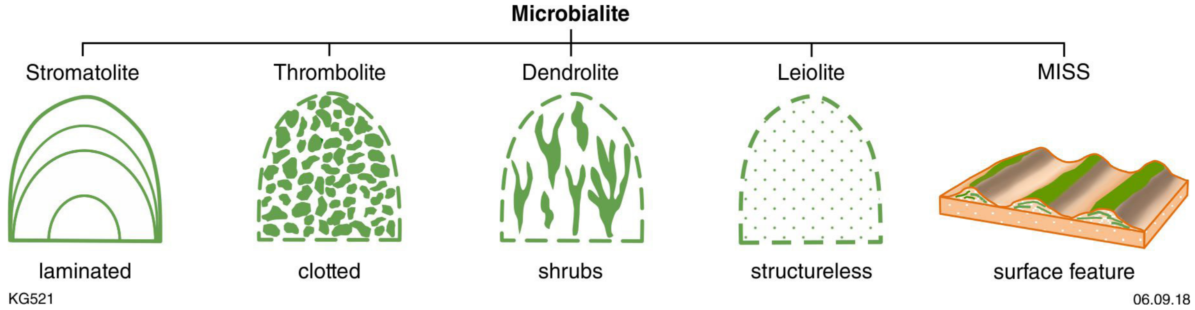

Figure 1. **Subsets of microbialites (after Grey and Planavsky, 2009, fig. 13). Stromatolites, with a laminated internal structure, are the most common in the geological record. Thrombolites have an internal clotted fabric. Dendrolites and leiolites are relatively rare in the rock record, and have a branching or structureless internal fabric, respectively. Microbially induced sedimentary structures (MISS), are included in the current broader definition of microbialites**

Most recently, correlation of Cryogenian units has also effectively utilized stromatolites, namely *Atilanya fennensis* and *Tungussia inna* (see Allen et al., 2018; Fig. 2a–e).

Previous studies indicated the applicability of microbialites to other ages and stratigraphic successions. More recently, GSWA work in the Hamersley province has successfully used microbialites as temporal markers for the Woolly Dolomite, Duck Creek Dolomite and Turee Creek Group. In particular, three microbialite assemblages of the lower and upper Kazput Formation (Fig. 2f–h) are distinct and regionally persistent (Allen and Martin, 2018). These assemblages include new microbialite Forms that have proven valuable as temporal markers during a targeted regional mapping program.

Detailed documentation of stratigraphic distributions of microbialites, particularly in Russia, India, China and Australia (Raaben et al., 2001; Cao and Yuan, 2003; Grey et al., 2012 and references therein) that demonstrated the applicability of microbialites to correlation has been expanded upon. Considerable progress has been made in documenting provenance data of Australian microbialites; a GSWA database containing more than 4000 Australia-wide entries demonstrates that microbialites are reliable temporal and stratigraphic markers. Microbialites continue to produce correlations consistent with results from other methods, such as lithostratigraphy, isotope chemostratigraphy, sequence and seismic stratigraphy, palynology and downhole geophysical correlations.

Summary

Despite being regarded as outmoded, correlation based on the systematic description of microbialites remains a viable stratigraphic tool. Bulletin 147 Handbook for the study and description of Microbialites should prove a valuable resource in furthering the application of microbialite studies. A more consistent approach to systematic description of microbialites will allow greater resolution to already established and working biostratigraphic schemes — accessing a largely untapped resource.

References

Allen, HJ and Haines, PW 2018, A stromatolite assemblage, including *Eleonora boondawarica* Grey and Walter, 1994 and *Acaciella savoryensis* Grey and Walter, 1994, from mineral drillhole AusQuest Table Hill 07THD003: Geological Survey of Western Australia, Paleontology Report 2018/1, 4p.

Allen, HJ, Grey, K, Haines, PW, Edgoose, CJ and Normington, VJ 2018, The Cryogenian Aralka Formation, Amadeus Basin: a basinwide biostratigraphic correlation: Geological Survey of Western Australia, Record 2018/11, 32p.

Allen, HJ, Grey, K and Haines, PW 2012, Neoproterozoic stromatolite biostratigraphy in the western Amadeus Basin, *in* Proceedings of the Petroleum Exploration Society of Australia (PESA); Central Australian Basins Symposium III, Alice Springs, Northern Territory, 16–17 July 2012 *edited by* GJ Ambrose and J Scott: PESA, Special Publication, 11p.

Allen, H and Martin D 2018, Chicken or egg? A diverse microbialite assemblage coeval with the Great Oxidation Event, *in* Australian Geoscience Council Convention Abstract Volume: Adelaide, South Australia, 2018, 14–18 October, p. 749.

Allwood, AC, Walter, MR, Burch, IW and Kamber, BS 2007, 3.43 billion-year-old stromatolite reef from the Pilbara Craton of Western Australia: ecosystem-scale insights to early life on Earth: Precambrian Research, v. 158, p. 198–227.

Allwood, AC, Minik, TR, Flannery, DT, Hurowitz, JA, Heirwegh, CM 2018, Reassessing evidence of life in 3,700 million year old rocks of Greenland: Nature, v. 563, p. 241–244.

Altermann, W 2004, Precambrian stromatolites: problems in definition, classification, morphology and stratigraphy, *in* The Precambrian Earth: tempos and events *edited by* PG Eriksson, W Altermann, DR Nelson, WU Mueller and O Catuneau: Elsevier Developments in Precambrian Geology, v. 12, p. 564–574.

Burne, RV and Moore, LS 1987, Microbialites: organosedimentary deposits of benthic microbial communities: Palaios, v. 2, p. 241–245.

Cao, RJ and Yuan, XL 2003, Brief history and current status of stromatolite study in China: Acta Micropalaeontologica Sinica, v. 20, p. 1–5.

Grey, K, Allen, H-J, Hill, A and Haines, PW 2012, Neoproterozoic biostratigraphy of the Amadeus Basin, *in* Proceedings of the Petroleum Exploration Society of Australia (PESA); Central Australian Basins Symposium III, Alice Springs, Northern Territory, 16–17 July 2012 *edited by* GJ Ambrose and J Scott: PESA, Special Publication, 18p.

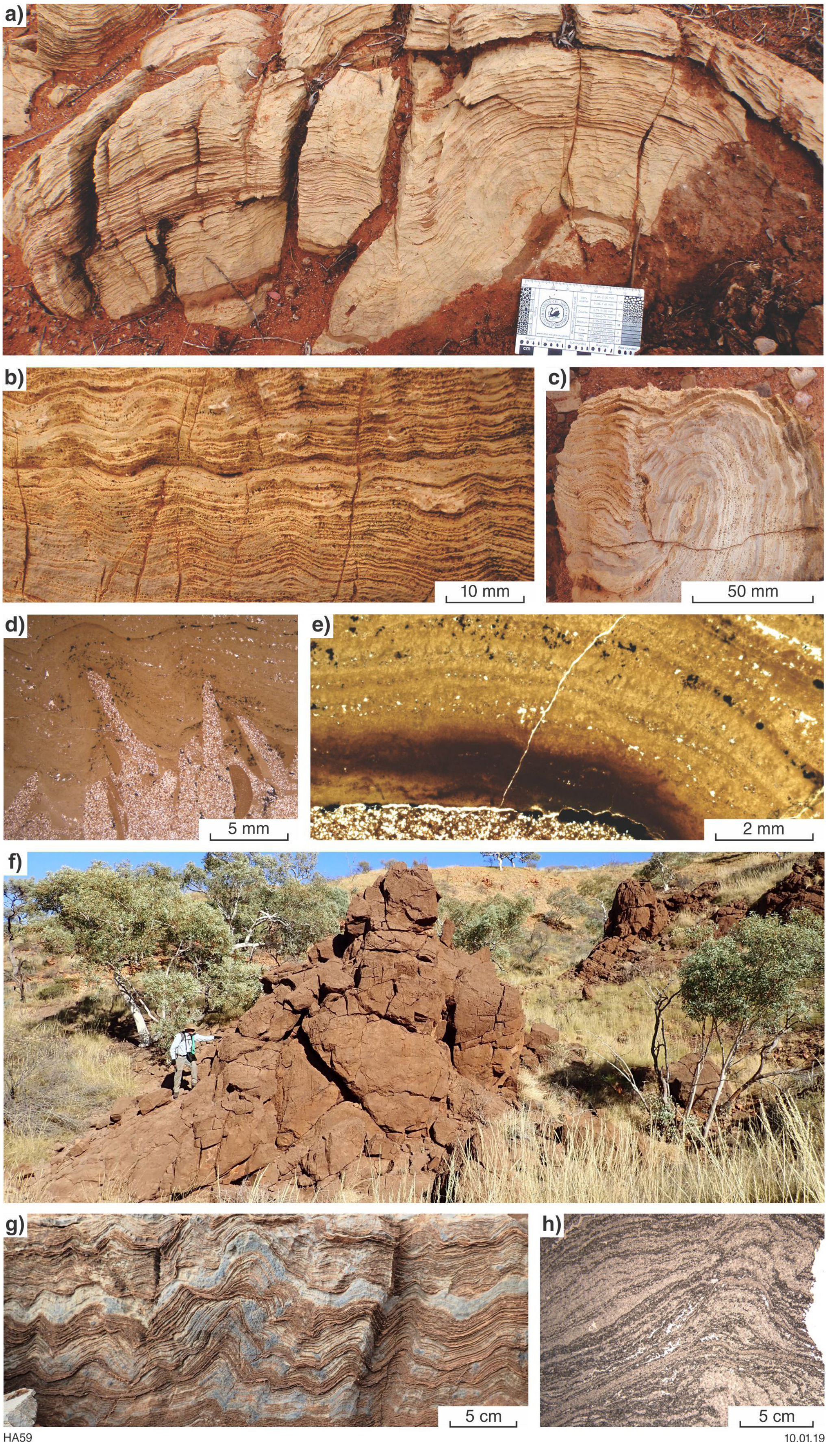

Figure 2. **a–e) Stromatolite *Atilanya fennensis* used for correlating Cryogenian units in the Amadeus Basin (Allen et al., 2018). Diagnostic features of *Atilanya fennensis* (a) include its common growth mode of encrusting intraclasts (c,d) and a pillared microstructure (d,e) that is manifested as wrinkles (b) in the hand specimen scale; f–h) stromatolites from the Kazput Formation, Turee Creek Group, used as temporal markers during a regional mapping project (Allen and Martin, 2018)**

Grey, K and Awramik, SM 2019, Handbook for the study and description of Microbialites: Geological Survey of Western Australia, Bulletin 147 (in prep.).

Grey, K and Planavsky, NJ 2009, Microbialites of Lake Thetis, Cervantes, Western Australia — a field guide: Geological Survey of Western Australia, Record 2009/11, 21p.

Grey, K and Thorne, AM 1984, Biostratigraphic significance of stromatolites in upward shallowing sequences of the early Proterozoic Duck Creek Dolomite, Western Australia: Precambrian Research, v. 29, p. 183–206.

Grotzinger, JP and Knoll, AH 1999, Stromatolites in Precambrian carbonates: evolutionary mileposts or environmental dipsticks?: Annual Review of Earth and Planetary Sciences, v. 27, p. 313–358.

Haines, PW, Allen, H-J, Grey, K and Edgoose, C 2012, The western Amadeus Basin: revised stratigraphy and correlations, *in* Proceedings of the Petroleum Exploration Society of Australia (PESA); Central Australian Basins Symposium III, Alice Springs, Northern Territory, 16–17 July 2012 *edited by* GJ Ambrose and J Scott: PESA, Special Publication, 6p.

Haines, PW and Allen, HJ 2014, Geology of the Boord Ridges and Gordon Hills: key stratigraphic section in the western Amadeus Basin, Western Australia: Geological Survey of Western Australia, Record 2014/11, 21p.

Johnson, DB, Beddows, PA, Flynn, TM and Osburn, MR 2018, Microbial diversity and biomarker analysis of modern freshwater microbialites from Laguna Bacalar, Mexico: Geobiology, v. 16, p. 319-337.

Nutman, AP, Bennett VC, Friend, CRL, Van Kranendonk, M and Chivas, AR 2016, Rapid emergence of life shown by discovery of 3,700 million year old microbial structures: Nature, v. 537, p. 535–537.

Preiss, WV 1972, The systematics of South Australian Precambrian and Cambrian stromatolites, part I: transactions of the Royal Society of South Australia, v. 96, p. 67–100.

Preiss, WV 1973, The systematics of South Australian Precambrian and Cambrian stromatolites, part II: transactions of the Royal Society of South Australia, v. 97, p. 91–125.

Preiss, WV 1974, The systematics of South Australian Precambrian and Cambrian stromatolites, part III: transactions of the Royal Society of South Australia, v. 98, p. 185–208.

Preiss, WV 1977, The biostratigraphic potential of Precambrian stromatolites: Precambrian Research, v. 5, p. 207–219.

Raaben, ME, Sinha, AK and Sharma, M 2001, Precambrian stromatolites of India and Russia (a catalogue of type-form-genera): Birbal Sahni Institute of Palaeobotany, Lucknow, 125 pp.

Suosaari, EP, Reid, RP, Araujo, TA, Playford, PE, Holley, DK, McNamara, KJ and Eberli, GP 2016, Environmental pressures influencing living stromatolites in Hamelin Pool, Shark Bay, Western Australia: Palaios, v. 31, p. 483–496.

Turner, EC, James, NP and Narbonne GM 2000, Taphonomic control on microstructure in early Neoproterozoic reefal stromatolites and thrombolites: Palaios, v. 15, p. 87–111.

Walter, MR 1972a, Stromatolites and the biostratigraphy of the Australian Precambrian and Cambrian: The Palaeontological Association, Special Papers in Palaeontology 11, 190p.

Walter, MR 1972b, The biostratigraphic potential of Precambrian stromatolites: Precambrian Research, v. 5, p. 207–219.