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Research paper

The modern calcifying sponge *Spheciospongia vesparium* (Lamarck, 1815), Great Bahama Bank: Implications for ancient sponge mud-mounds

Fritz Neuweiler[a,*], David J. Burdige[b]

[a]Institute for Paleontology, University Erlangen, Loewenichstrasse 28, D-91054 Erlangen, Germany
[b]Department of Ocean, Earth and Atmospheric Sciences, Old Dominion University, Norfolk, VA 23529, USA

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Abstract

Modern calcified siliceous sponges from the Great Bahama Bank, living at water depth ranges of 2 to 5 m, have been proposed as likely analogues for calcified sponges in Upper Jurassic sponge "reefs" (e.g., southern Germany), or Lower Jurassic bioherms that consist of reddish, spiculiferous limestones (e.g., Broccatello Formation of the Southern Alps). Indeed, sponge-related calcification or siliceous sponge diagenesis, in general, is widely considered a key feature for the mechanisms of accretion and textural maturation in Phanerozoic sponge mounds or spiculiferous carbonate mud-mounds. Based on a revisit of the original sites on the Great Bahama Bank (NW of Andros Island) the biostratonomy of the calcifying sponge *Spheciospongia vesparium* (Lamarck, 1815) was explored using the patterns of fluorescent dissolved organic matter (FDOM) as revealed by the application of three-dimensional excitation–emission matrix (EEM) fluorescence spectroscopy. Geochemical sampling distinguished between FDOM that was extracted from sponge tissue and FDOM that was intimately associated with $CaCO_3$ (from particles due to sediment agglutination and authigenic $CaCO_3$), both obtained from the living sponge at the sediment surface and from the calcified sponge at the shallow subsurface (from 5 to 10 cm of depth). As expected, the sponge tissue shows highest intensities for protein-like fluorescence. However, from the surface to the subsurface, there is a loss of such relatively pristine fluorescent material in the range of 70%. Humic-like fluorescence that occurs associated with sponge tissue is relatively mature or aged, thus it most probably represents seawater FDOM taken up through active filter feeding. Relative to the sponge tissue material, the FDOM patterns associated with Ca-carbonates show much lower total fluorescence intensities, by up to two orders of magnitude. The agglutinated sedimentary carbonate particles from the surface (pellets, ooids, grapestones) exclusively show a relatively mature, humic-like fluorescence. The deeper, calcified parts of *Spheciospongia*, which represent a mixture of particles and authigenic $CaCO_3$, provided a FDOM pattern that obviously combines the mature FDOM pattern of particles with diagenetically fresh, protein-like and fulvic acid-like fluorescence. We conclude that shallow subsurface calcification of *S. vesparium* correlates with the

* Corresponding author. Permanent address: Département de géologie et génie géologique, Université Laval, Québec (Québec), Canada G1K 7P4.
E-mail address: fritz.neuweiler@ggl.ulaval.ca (F. Neuweiler).

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initial stage of sponge biomass humification. Such a mechanism of biomass transformation, i.e., from biopolymers to geopolymers via degradation and condensation, has also been suggested for the large-scale development of carbonate (sponge) mud-mounds. Therefore, we consider the modern calcifying siliceous sponge *S. vesparium* (Lamarck, 1815) a potential pardigm to decipher in more detail the geologically important process of biomass-induced calcification or organomineralisation with its subsequent effect of pore water FDOM preservation and sediment lithification.

Keywords: Sponges; *Spheciospongia vesparium*; Lithification; Fluorescence spectroscopy; Fluorescent dissolved organic matter (FDOM); Great Bahama Bank

1. Introduction

Modern bioherms displaying a community that is essentially composed of siliceous sponges (Hexactinellida, Demospongiae) have been reported from a wide range of oceanographic and bathymetric settings: from polar, subphotic continental margins (e.g., along the Canadian and Russian polar margin), to shallow-water tropical carbonate platforms of the Caribbean (Zenkevitch, 1963; Wiedenmayer, 1978; Van Wagoner et al., 1989; Henrich et al., 1992; Conway et al., 1991, 2001; Krautter et al., 2001). In most studies the authors emphasize the importance of their individual case for the understanding of ancient siliceous sponge mounds. Indeed, Wiedenmayer (1978, 1980) regarded modern Bahamian sponge bioherms as likely analogues to the Upper Jurassic sponge "reefs" of southern Germany (Flügel and Steiger, 1981) or to the Lower Jurassic Hierlatz or Broccatello facies of the Alps (Wiedenmayer, 1963, 1980; Neuweiler and Bernoulli, 2005). Van Wagoner et al. (1989) made reference to late Palaeozoic demosponge bioherms, in particular to Silurian lithistid sponge reefs as described by Narbonne and Dixon (1984). Conway et al. (1991, 2001) and Krautter et al. (2001) considered the modern communities they studied an analogue of Upper Jurassic hexactinellid mounds or carbonate sponge mud-mounds on a whole.

However, with the exception of Wiedenmayer (1978, 1980), all other studies missed the key geological feature of ancient sponge mounds or spiculiferous carbonate mud-mounds, namely their "carbonate island" character that requires in-place production of fine-grained calcium carbonate within a commonly carbonate-depleted surrounding facies (cf. Bourque, 2003). Reports on such calcifying siliceous sponge communities, including Wiedenmayer's papers, only exist in small number, e.g., by Froget (1976) from the Mediterranean Sea and by Reitner (1993) and Reitner et al. (1995) from cryptic sponges of the Great Barrier Reef (Australia).

The aim of this paper is to re-examine Wiedenmayer's descriptions and observations in order to reassess the potential of Bahamian calcifying siliceous sponges to further our understanding of ancient sponge mounds. We revisited Wiedenmayer's original sites and made several dives to collect fresh sampling material for fluorescence studies similar to those we have carried out with samples collected from Cretaceous sponge mounds of Spain (Neuweiler et al., 2000, 2003) and Quaternary lithoherms of the Florida Straits (Neuweiler et al., in preparation). The approach we have taken here is process-oriented on a hand specimen scale. It argues for some type of correlation between sponge soft tissue degradation and calcification, irrespective of the regional setting, bathymetry, local community structure and the scale of the resulting geological feature (cf. footnote in Lees, 1964 or Bourque and Gignac, 1983 for early suggestions on the role of sponges to explain some key features of Palaeozoic spiculiferous carbonate mud-mounds).

2. Materials and methods

The sampling sites are located NW of Joulters Cay, about 15 km off the northern tip of Andros Island, Bahamas (Fig. 1). We sampled at two stations with water depths of 3.2 m and 2.0 m, salinity of 36.9‰, and water temperature of 23° C and 24 °C, respectively. The sampling sites are well within the strip of "sponge bioherms" indicated in Wiedenmayer