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Research papers

Amorphous organic matter — Experimental data on formation and the role of microbes

Muriel Pacton [a,*], Georges E. Gorin [b], Crisogono Vasconcelos [a]

[a] Geological Institute, ETH Zurich, Switzerland
[b] Department of Geology and Paleontology, University of Geneva, Switzerland

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ABSTRACT

The origin of microscopically-amorphous organic matter (AOM) is problematic. It has been extensively studied because it is the dominant kerogen constituent in petroleum source rocks. Although microbes are widespread in natural environments, they are commonly associated only with marine AOM derived from phytoplankton. In this study, we have selected terrestrial and marine samples with various microbial inputs in order to decipher the role of microbes in AOM composition. A specially-tailored laboratory device has been used for determining the effect of oxygen- and light-depleted conditions on recent microbial mats for a duration of three years. This experiment aimed at reproducing conditions existing in nature at the water–sediment interface.

This research has permitted the characterization of AOM according to its biological origin. Two different types of AOM have been observed, i.e., gelified and granular types. They are related respectively to microbial reworking of terrestrial fragments and primary microbial populations. Moreover, bacterial bodies constitute the ubiquitous, strongly fluorescent material, whereas extracellular polymeric substances (EPS) surround bacteria and show a weaker fluorescence. Consequently, this study on modern OM has unravelled the amorphization process of specific organic particles leading to AOM classically encountered in fossil sediments. This has considerable implications for palaeoenvironmental reconstructions associated with the origin and preservation of OM.

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1. Introduction

Microscopical investigation of organic matter (OM) is commonly used as a complementary tool to sedimentology for depositional and palaeoenvironmental reconstructions. Moreover, it provides a quick evaluation of the source rock potential when OM occurs as amorphous kerogen, formerly called amorphinite (Tyson, 1995). Amorphous organic matter (AOM) is the standard name used for all particulate organic components which appear structureless at the scale of light microscopy. It corresponds to degraded phytoplankton or bacterially-derived AOM, higher plant resins, and amorphous products resulting from the diagenesis of macrophyte tissues (Tyson, 1995). The syn-sedimentary processes of "amorphization" take place in the photic zone, where most of the biomass consumption and remineralization occurs at or near the sediment–water interface. Among all constituents of sedimentary OM, AOM is so far the most problematic in terms of palaeogeographical interpretation, particularly when trying to determine its origin. The amorphous material commonly acts as a matrix for various structured inclusions. According to Tyson (1995), AOM is the dominant organic component in dysoxic to anoxic depositional environment and increases with increasing nutrient availability and decreasing oxygen in the waters. Palynologists use the term "amorphous" in a purely descriptive way which does not imply specific environmental conditions. The existing classifications of AOM (palynofacies) are based on specific features under natural light and blue-light fluorescence, without any relation to its origin (Batten 1983, Combaz 1980, Ercegovac and Kostic, 2006; Masran and Pocock 1981, Misra 1991, Pocock 1982, Valdés et al., 2004; Venkatachala, 1981, 1984). They are purely descriptive or refer to OM origin and depositional conditions. Venkatachala (1981) defined AOM *sensu stricto* as having a yellowish brown or orange colour. This type can be further subdivided into flaky, granular, spongy and granular types (see references above). The semi-structureless AOM material is described as an intermediate stage between structured OM and completely biodegraded OM (Pocock, 1982). Commonly assumed to be a degradation product of terrestrial or marine components, its decrease in fluorescence is usually correlated with increasing oxidation, especially for plankton- or bacterially-derived AOM.

According to some authors, the differences in colours of AOM correspond to the degree of agglomeration (Valdés et al., 2004) and are related to its preservation state (Boussafir et al., 1995; Ercegovac and Kostic, 2006; Tyson, 1989, 1995; Valdés et al., 2004).

* Corresponding author at: ETH Zurich, Geological Institute NO F 55.1, Sonneggstrasse 5, 8092 Zurich, Switzerland. Tel.: +41 44 632 56 14.
E-mail address: muriel.pacton@erdw.ethz.ch (M. Pacton).

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Although observations in transmitted light may be sufficient to recognize plankton- or bacterially-derived AOM, fluorescence observations are essential for establishing the degree of chemical preservation of its originally oil-prone composition. Published data are mostly concentrated on fossil OM, which has already undergone some degree of diagenesis. However, there is a significant gap between the preservation state of OM already accumulated in the sediment and the amorphization of different biological components caused by microbial reworking. Therefore, in this research, various recent samples have been selected, in which microbes play a minor to major role in OM composition. The aim is to re-evaluate their influence in AOM formation. Moreover, an experiment has been conducted for a duration of three years on microbial mats in order to test the effects of oxygen- and light-depleted conditions. Finally, this study aims at proposing new perspectives for AOM classification highlighting microbial influence on degradable particles.

2. Materials and methods

Samples were selected according to diagenesis and biological origin. They were recovered from a marginal marine setting in Brazil, hypersaline microbial mats in Tunisia, and terrestrial OM in Tanzania.

2.1. Brazil samples

Samples corresponding to the primary productivity stage consist of a living microbial mat from the Lagoa Vermelha lagoon in Brazil (Vasconcelos and McKenzie, 1997) and a cultured photosynthetic biofilm developed from the latter (Pacton et al., 2006). This several μ-thick biofilm is composed of photosynthetic microbes associated with calcite crystals (Fig. 1.1). The microbial mat in Lagoa Vermelha is on average 3 cm thick and composed of alternating carbonate and non-lithified organic layers (Fig. 1.2). It is composed of different microbial communities (Fig. 1.2), i.e., from top to bottom, green layers of photosynthetic bacteria, brownish layers containing heterotrophic bacteria, red layers with purple sulfur bacteria and a grey layer with sulfate reducers (Vasconcelos et al., 2006). Minerals are concentrated in white layers made of evaporites and carbonates, typical of hypersaline conditions.

2.2. Tunisia sample

The transformation of all organic particles through microbial activity takes place in the water column down to the water–sediment interface, i.e., from oxic to anoxic conditions. In our study, marine OM undergoing increasing degradation processes is represented by a microbial mat mixed with sediments from Hassi Jerbi in Tunisia (Pacton et al., 2009). This mat is characterized by a dark-coloured, several mm thick anoxic zone in the upper part (Fig. 1.3). At depth, it appears as a light-coloured, laminated and non-cohesive sediment. There is an important detrital contribution (60% quartz). It contains more advanced organic diagenetic products than in the Lagoa Vermelha microbial mat.

2.3. Tanzania samples

Terrestrial OM is represented by that accumulated both in a peat bog from the Kyambangunguru lake and in the Masoko caldera lake in

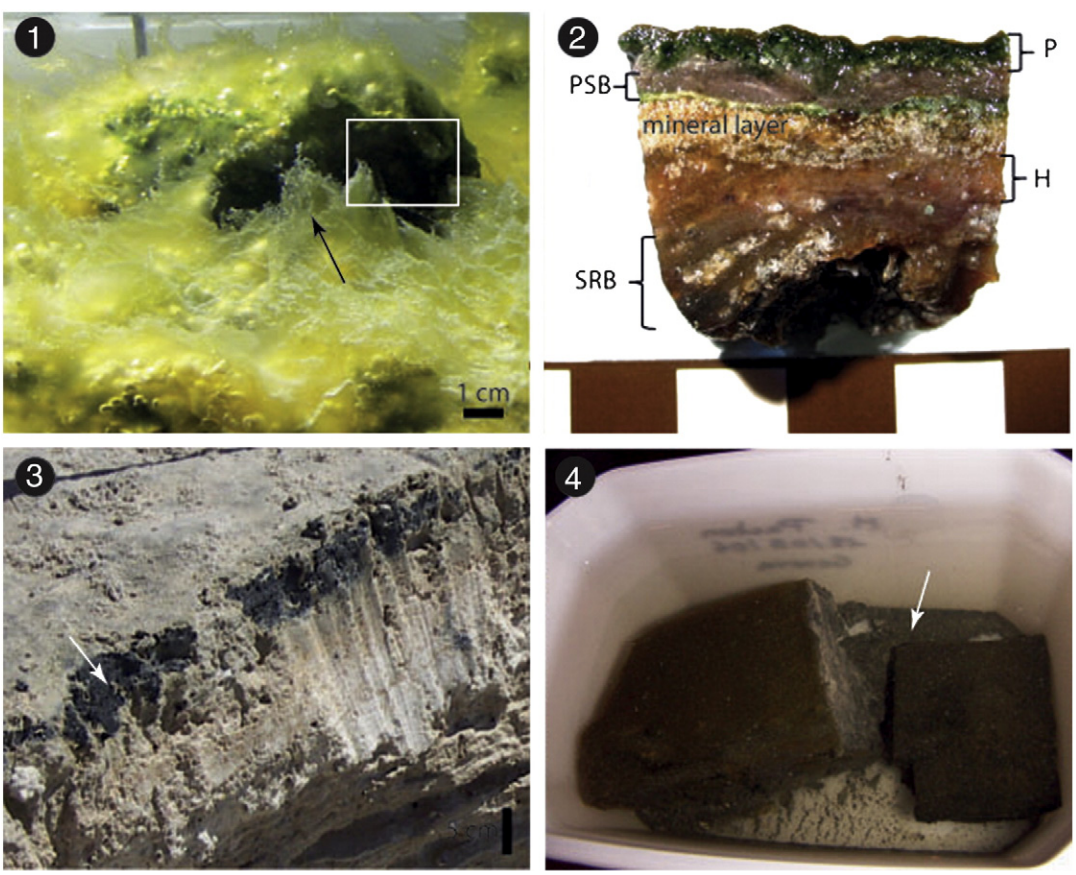

Fig. 1. Microbial samples: 1) green biofilm developed from the Lagoa Vermelha microbial mat in Brazil (square); 2) vertical section in microbial mat from Lagoa Vermelha showing from top to bottom: phototrophs (P), a red layer of photosynthetic purple sulfur bacteria (PSB), a mineral layer, a brownish layer made of heterotrophs (H) and a grey horizon dominated by sulfate-reducing bacteria (SRB); 3) microbial mat from Hassi Jerbi (Tunisia, arrow); 4) microbial mats placed in a box after being exposed to light- and oxygen depleted conditions for a duration of 6 months (arrow points to mud resulting from mat decomposition .

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