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Microbial remains and other carbonaceous forms from the 3.24 Ga Sulphur Springs black smoker deposit, Western Australia

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Abstract

Well-preserved carbonaceous materials including filamentous microbial remains have been isolated from an Archaean sedimentary package overlying the Sulphur Springs volcanic hosted massive sulphide (VHMS) deposit in the Pilbara of Western Australia, one of the oldest, best-preserved VHMS deposits on Earth. The isotopically light carbonaceous material ($\delta^{13}C$ values of −26.8 to −34.0‰ V-PDB) occurs as finely striated, lenticular to banded organic matter (OM) within fine-grained epiclastic sediments and silicified materials that overlie the deposit. The predominant banded/lenticular carbonaceous material occurs parallel to original sedimentary bedding planes and is distinctly visible in light microscopy. Transmission electron microscopy (TEM) reveals this OM as bundles of filamentous and tubular structure, closely resembling both modern-day and more ancient microbial forms documented from sea floor hydrothermal environments. Total organic carbon (TOC) has a range of <1.0 to 2.3%, while the thermal maturity of the filamentous microbial bundles indicated by reflectance ($\%R_o$), points to maximum temperatures since deposition ca. 3.24 Ga of around 90–100 °C, a factor that has enabled the preservation of their morphology. These results, and the intimate association of sulphides with the OM, are suggestive of a well-developed Archaean sediment-hosted microbial community, situated within a basinal environment associated with an active centre of seafloor hydrothermal activity.

Keywords: Archaean; Carbonaceous matter; Organic petrology; Transmission electron microscopy (TEM); Carbon isotopes

1. Introduction

Modern sea-floor hydrothermal vent environments host a wide-ranging variety of microbial life that exploits the chemical and physical energy available in these systems (e.g. Jannasch and Mottl, 1985; Teske et al., 2002). Typically, in the transition from seafloor depositional environment to land-locked deposit, such environments rarely survive the associated effects of tectonic displacement and metamorphic alteration intact. This has resulted in limited examples of well-preserved, unaltered early-Earth deposits that can be studied for evidence of microbial life. The very low strain, very low to low metamorphic grade (Vearncombe, 1995; Vearncombe et al., 1995) rock packages associated with the Archaean Sulphur Springs VHMS deposit in the Pilbara Craton of Western Australia, present a potentially favourable early-Earth analogue in this respect. Indeed, Rasmussen (2000) has previously interpreted pyritic filaments isolated from silicified units of the Sulphur Springs prospect as the remains of thermophilic microbes "inhabiting low-temperature (<110 °C) sub-sea-floor niches adjacent to discharging hydrothermal fluids."

In this paper, we report the isolation of well preserved, filamentous, isotopically light (bulk $\delta^{13}C_{PDB}$

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values between −26.8 and −34.0‰) OM from the black shale-dominated, epiclastic/volcaniclastic hanging wall sedimentary sequence of the ca. 3.24 Ga Sulphur Springs deposit. Samples sourced from diamond drill core contain carbonaceous material exhibiting a high level of morphological preservation outstanding for their age. Light microscopy reveals the OM as finely striated, lenticular to banded occurrences aligned parallel to bedding planes, reminiscent of both modern-day and more ancient microbial colonies (Jannasch and Wirsen, 1981; Noffke et al., 2003). The degree of preservation is a result of low thermal maturity (0.6% Vitrinite R_o equivalent), which suggest these sediments have experienced maximum temperatures of not greater than 100 °C since deposition.

2. Geologic setting

The 3.24 Ga Sulphur Springs VHMS deposit is situated in the north-eastern Panorama District of the Pilbara Craton, Western Australia approximately 100 km south-east of Port Hedland and 50 km west of the township of Marble Bar (Fig. 1). The deposit was discovered in 1984 (Morant, 1995) and has since been described as Earth's oldest black smoker (Vearncombe et al., 1995; Morant, 1998). It is interpreted to have formed at a water depth of around 1000 m in elevated grabens in an Archaean setting equivalent to a modern back-arc basin (Vearncombe et al., 1995, 1998). A lack of any major tectonic overprint has resulted in an exceptional level of structural and textural preservation (Morant, 1995; Vearncombe et al., 1995).

VHMS mineralisation at Sulphur Springs is hosted mostly within extensive dacite sills synchronous with intrusion of the 3238 Ma Strelley granite (Morant, 1995; Vearncombe et al., 1995; Buick et al., 2002), combined with or immediately below a marker chert consisting of a regionally extensive silicified siltstone unit (Brauhart et al., 1998). The marker chert occurs at the top of the Kangaroo Caves Formation, an upper member of the Sulphur Springs Group (SSG) (Fig. 2), and is typically 2–20 m thick (Morant, 1995; Vearncombe et al., 1995; Brauhart, 1999; Buick et al., 2002), but may be up to 80 m thick proximal to mineralised zones (Brauhart, 1999; Brauhart et al., 2000; Van Kranendonk, 2000). This regionally extensive unit is composed of centimetre-layered, grey-blue and white, silicified, fine-grained volcaniclastic shard-rich sandstone interbedded with epiclastic sandstone, breccia and black mudstones (Morant, 1995; Van Kranendonk and Morant, 1998; Van Kranendonk, 2000). Similarities between the black mudstones of this unit and the overlying Gorge Creek Group

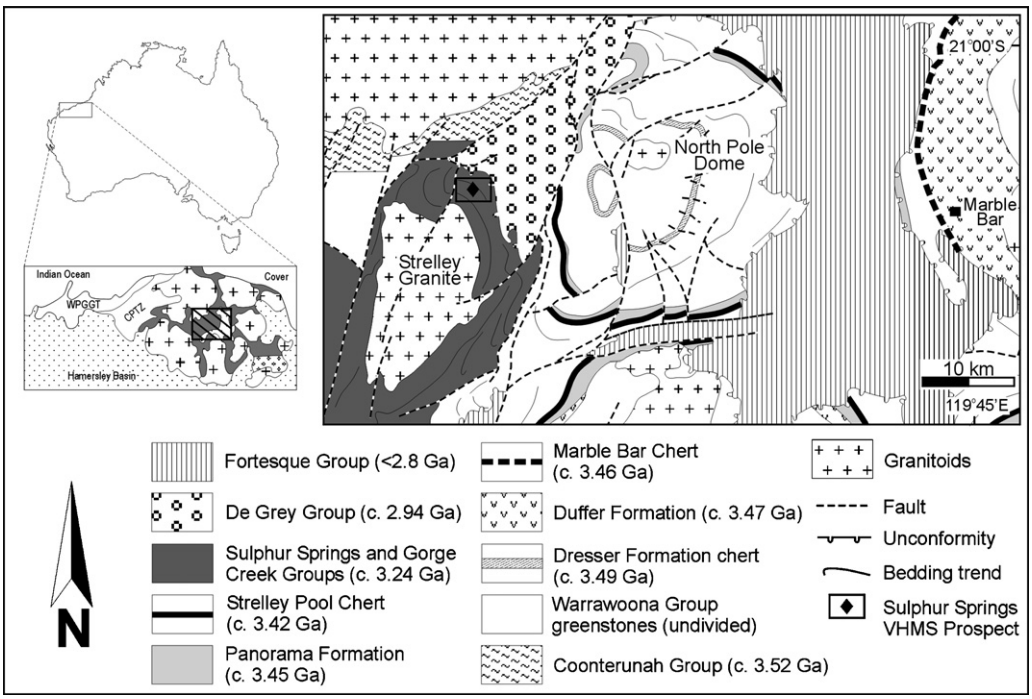

Fig. 1. Locality map and regional geology of the Sulphur Springs VHMS deposit, Panorama District, Pilbara Craton, Western Australia (adapted from Van Kranendonk and Pirajno, 2004).