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TAPHONOMY OF THE EDIACARAN FOSSIL PTERIDINIUM SIMPLEX PRESERVED THREE-DIMENSIONALLY IN MASS FLOW DEPOSITS, NAMA GROUP, NAMIBIA

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ABSTRACT—Ediacara-type fossils are found in a diverse array of preservational styles, implying that multiple taphonomic mechanisms might have been responsible for their preservational expression. For many Ediacara fossils, the “death mask” model has been invoked as the primary taphonomic pathway. The key to this preservational regime is the replication or sealing of sediments around the degrading organisms by microbially induced precipitation of authigenic pyrite, leading toward fossil preservation along bedding planes. Nama-style preservation, on the other hand, captures Ediacaran organisms as molds and three-dimensional casts within coarse-grained mass flow beds, and has been previously regarded as showing little or no evidence of a microbial preservational influence. To further understand these two seemingly distinct taphonomic pathways, we investigated the three-dimensionally preserved Ediacaran fossil Pteridinium simplex from mass flow deposits of the upper Kliphoek Member, Dabis Formation, Kuibis Subgroup, southern Namibia. Our analysis, using a combination of petrographic and micro-analytical methods, shows that Pteridinium simplex vanes are replicated with minor pyrite, but are most often represented by open voids that can be filled with secondary carbonate material; clay minerals are also found in association with the vanes, but their origin remains unresolved. The scarcity of pyrite and the development of voids are likely related to oxidative weathering and it is possible that microbial activities and authigenic pyrite may have contributed to the preservation of Pteridinium simplex; however, any microbes growing on P. simplex vanes within mass flow deposits were unlikely to have formed thick mats as envisioned in the death mask model. Differential weathering of replicating minerals and precipitation of secondary minerals greatly facilitate fossil collection and morphological characterization by allowing Pteridinium simplex vanes to be parted from the massive hosting sandstone.

INTRODUCTION

EDIACARA FOSSILS (580–542 Ma) are some of the earliest known complex multicellular life forms but have enigmatic taphonomic histories and phylogenies. Four preservational styles falling under the Ediacara-type preservation umbrella have been described as the classic taphonomic modes of the Ediacaran Period (Fig. 1). Flinders-style death-mask preservation (Fig. 1.1), characteristic of most Ediacara fossiliferous beds in the Flinders Ranges of South Australia (and some facies in the White Sea Region of Russia), captures epibenthic organisms that lived in shallow, photic zone environments between normal and storm wave-base (Gehling and Droser, 2013). This preservational regime was dependent on event deposition of storm beds and lithification aided by microbial communities (Gehling, 1999; Narbonne, 2005). Three-dimensional Nama-style preservation (Fig. 1.2), characteristic of the Kuibis and Schwarzrand subgroups of Namibia, entombs organisms within mass-flows or storm event sediments as opposed to preservation under event sediments at the base of the event bed (Jenkins, 1992; Narbonne, 2005; Vickers-Rich, 2007; Vickers-Rich et al., 2013). Fermeuse-style preservation (Fig. 1.3) represents deeper water assemblages found in outer shelf, slope, or basinal paleoenvironments, and is known from the Fermeuse Formation of Newfoundland, the Windermere Supergroup of northwestern Canada, and the Innerley Member of northern Norway (Narbonne and Hofmann, 1987; Farmer et al., 1992; Gehling et al., 2000). While Fermeuse-style preservation was previously suggested to have less influence from microbial mats due to its deeper water paleoenvironmental setting (e.g., Narbonne, 2005), recent investigations have shown that three-dimensionally preserved Aspidella in the Fermeuse Formation is surrounded by fine-grained clay material representing biofilm envelopes (Laflamme et al., 2011b). Finally, Conception-style preservation (“Ediacaran Pompeii”; Fig. 1.4) results from the burial of benthic organisms beneath volcanic ashes, as is observed in the Conception Group of Newfoundland and the Charnwood succession of England (Seilacher, 1992; Narbonne, 2005).

In addition to these “classic” styles, other preservational modes have also added important details to Ediacaran taphonomic descriptions. These include three-dimensional pyritization of the Gaojiashan biota (Cai et al., 2010, 2012), aluminosilicification and kerogenization of the Doushantuo and Dengying formations (Anderson et al., 2011; Cai et al., 2012; Meyer et al., 2012), three-dimensional phosphatization of cellularly preserved microfossils in the Doushantuo Formation (Xiao and Knoll, 2000; Xiao and Schiffbauer, 2009; Schiffbauer et al., 2012), carbonaceous compression of macroalgae in the Doushantuo Formation (Xiao et al., 2002; Yuan et al., 2011), as well as silicification of microfossils in Doushantuo chert nodules of South China (Xiao et al., 2010). While this diversity of preservational modes has greatly increased our understanding
of Ediacaran biodiversity and ecology, the taphonomic processes of many Ediacaran fossil localities remain enigmatic. One of the most important findings in recent taphonomic investigations is the association of clay minerals in Ediacaran fossil preservation (Anderson et al., 2011; Laflamme et al., 2011b; Cai et al., 2012; Meyer et al., 2012), an association that has also been known from Phanerzoic Burgess Shale-type (BST) preservational windows. For example, the association of clays with exceptionally preserved Ediacaran fossils have been previously documented in carbonaceous compressions in the Ediacaran successions of South China (Anderson et al., 2011; Cai et al., 2012) and in Aspidella from the Fermeuse Formation in Newfoundland (Laflamme et al., 2011b). However, debates surround the origin of the clays and their possible constructive roles in exceptional preservation, particularly the preservation of BST fossils (Butterfield, 1990, 1995; Orr et al., 1998; Petrovich, 2001; Gaines et al., 2005; Butterfield et al., 2007; Gaines et al., 2008; Page et al., 2008). BST fossils are consistently found in a narrow range of conditions (fine-grained sediments, deeper water, anoxic settings) and it is important to know whether a clay association is also present in other taphonomic pathways, for example in coarser grained sediments deposited in shallow-water environments where Ediacara fossils are preserved, and whether such clays are of detrital, authigenic, metamorphic, or weathering origin.

For many Ediacara fossils found in coarse- and fine-grained siliciclastic rocks, some variation of the death mask hypothesis (Gehling, 1999; Narbonne, 2005) has been invoked as the primary taphonomic pathway. This hypothesis proposes that authigenic pyrite precipitation just beneath microbial mats that colonized bedding surfaces can preserve both microbial mats and organisms associated with the mats (Gehling, 1999). The death mask taphonomic process relies on storm events to smother and seal mat-associated benthos along a bedding surface, where bacterial sulfate reduction and reactive iron drive pyrite precipitation and hence fossil preservation. However, this model does not address how some Ediacara fossils, such as those in the Nama Group, are preserved in full three-dimensionality within mass flow sediments (Crimes and Fedonkin, 1996; Grazhdankin and Seilacher, 2002; Elliott et al., 2011) and how they can be easily separated from the matrix to facilitate fossil collection.

To further explore how Ediacara fossils are preserved within mass flow sediments and how these three dimensionally
preserved fossils can be removed from their matrix, we investigated the enigmatic Nama fossil *Pteridinium simplex* (Gürich, 1930) from the upper Kliphoek Member (equivalent to the Aar Member of Hall et al., 2013) of the Dabis Formation, Kuibis Subgroup, at Farm Aar of southern Namibia (Fig. 2.1). The genus *Pteridinium* has been found globally from numerous late Ediacaran sites (Glaessner, 1966; St. Jean, 1973; Keller et al., 1974; Gibson et al., 1984; Xiao and Laflamme, 2009; Laflamme et al., 2013). It is characterized by three vanes that are joined along a seam, with a medial vane surrounded by two lateral vanes. In *P. simplex* these lateral vanes are often bent to form a boat-like structure (Fig. 2.2). Each of the three vanes consists of numerous segments (‘quilts’ and ‘furrows’ in Grazhdankin and Seilacher, 2002) that are interpreted as tubular structures (Seilacher, 1992). At Farm Aar, *P. simplex* fossils are preserved as three-dimensional casts or molds within coarse-grained sandstone beds, interpreted as storm-induced density flow deposits that fill gutters and channels (Vickers-Rich et al., 2013; Hall et al., 2013). There is very little organic matter associated with *P. simplex* fossils, possibly due to chemical weathering (Grazhdankin and Seilacher, 2002; Elliott et al., 2011). While *P. simplex* fossils are sometimes preserved on bedding surfaces and presumably as death masks (Fedonkin et al., 2007), they are primarily preserved within massive sandstone beds (Jenkins et al., 1983; Hall et al., 2013). The unusual preservation of *P. simplex* and other Nama fossils establishes their suitability as candidates to investigate mass flow taphonomy in comparison with other prevailing Ediacaran preservational modes.

**GEOLOGICAL AND STRATIGRAPHIC BACKGROUND**

The Kuibis Subgroup was deposited in a foreland basin on the northern edge of the Kalahari Craton (Fig. 2.1) (Germs, 1973). Available radiometric dates constrain the Kuibis Subgroup to be older than 548.8 ± 1 Ma (revised as 547.32 ± 0.65 Ma) (Grotzinger et al., 1995; Schmitz, 2012). This foreland basin includes two subbasins, the northern Zaris and the southern Witputs subbasins, separated by the Osis arch (Gresse and Germs, 1993; Saylor et al., 1995). Our specimens were collected from the Witputs subbasin where the Kuibis Subgroup contains
**FIGURE 3—** Thin section photomicrographs of *Pteridinium simplex* fossil and matrix. 1, 2, cross-polarized and plane-polarized light photomicrographs of fossil and matrix, with dashed line and arrows denoting the vane of a fossil; 3, 4, cross-polarized and plan-polarized light photomicrographs of matrix, with dashed line and arrows pointing to mica crystals; arrows in 3 point to mica crystals cutting across quartz grains; 5, BSE-Z image of two mica crystals in the quartz sandstone matrix. Scale bar in 1–4 = 300 µm and in 5 = 400 µm.
FIGURE 4—Light photographs (1–3) and BSE-Z image (4) of specimen V-8-2009 containing several *Pteridinium simplex* specimens. 1, hand sample with *P. simplex* specimens; white arrow points to main specimen in this study, while black arrows denote additional specimens; letters A–C identify blocks between cuts represented by lines i and ii; line i is solid where main specimen was cut, and this cut surface on Block A can be seen in 3 and 4; 2, side view of block showing main specimen folded over (white arrows); perspective is from white arrow in 1 looking toward the hand specimen; 3, 4, light photography and BSE-Z image mosaics of cut surface i Block A; arrows in 3 mark the medial vane (m) and lateral vanes (l); labeled boxes in 4 represent mapped areas shown in Figure 6. Asterisks in 1–4 mark the same location to assist orientation. All scale bars=1 cm.
two formations: the Dabis and Zaris. Here, the Kuibis Subgroup is characterized by feldspathic sandstone-orthoquartzite-limestone cycles, with limestones becoming more common upsection.

Our specimens come from the Kliphoek Member (equivalent to the Aarhauser Member of Hall et al., 2013) of the Dabis Formation. The lower Kliphoek Member is the last major sandstone unit of the aforementioned sandstone-limestone cycles before the beginning of the Schwarzwand Subgroup (Gresse and Germs, 1993; Saylor et al., 1995). The lower Kliphoek Member (Fig. 2.1) consists of fine- to coarse-grained orthoquartzite, with coarser material found within mass flow deposits (Elliott et al., 2011), whereas the upper Kliphoek Member (Hall et al., 2013) consists mainly of interbedded sandstones (1–2 m thick) and shales with a few limestone beds. The base of many Kliphoek Member sandstone beds are often characterized with scouring and tool marks, representing channel and gutter fills in shallower water high-energy environments (Saylor et al., 1995; Hall et al., 2013). The Kliphoek Member is directly overlain by bedded limestones of the Mooifontein Member, indicating a major marine transgression (Gresse and Germs, 1993).

The focus of this paper is on the upper Kliphoek Member, which was likely deposited in an extensive, sandy, braided fluvial to shallow marine system (Elliott et al., 2011; Hall et al., 2013), partly reworked into vast inter-tidal sand flats along a low gradient coastal plain. The upper Kliphoek Member consists mainly of cross-bedded sandstones (1–2 m thick) interbedded with shale units. Shale interbeds found between the sandstones are interpreted as intertidal to shallow subtidal muds deposited during regional transgression. Individual sandstone beds range up to 35 cm in thickness, commonly showing thin laminations and seldom with symmetric ripples and peloidal structures resembling rip-up clasts (Elliott et al., 2011). Sandstone beds in the upper Kliphoek Member typically have sharp bases and tops, and sometimes exhibit very low angle scouring of the underlying shale (Elliott et al., 2011; Hall et al., 2013). Individual sandstone beds were likely deposited during sheet flow events which brought sandy sediments over mud-dominated inter-tidal to sub-tidal sediments. Pteridinium simplex fossils are found in these sandstone beds, particularly in the Aarhauser sandstone of the upper Kliphoek Member (Hall et al., 2013).

MATERIALS AND METHODS

Specimens examined here were collected from the upper Kliphoek Member at Farm Aar of the Aus region in southern Namibia (Fig. 2.1). Rock specimens were analyzed using standard petrographic techniques (Fig. 3). Fossil specimens are reposited the Namibian Geological Survey, Windhoek. Our paleontological analysis focused on a hand sample (V-8-2009) that contains several Pteridinium simplex specimens. This sample was cut into three slabs (labeled A–C in Fig. 4.1) perpendicular to the main axis/seam of the largest P. simplex specimen, which constitutes the main focus of this investigation. The lateral vanes and seam of the main specimen are exposed, but the medial vane is not exposed and visible only on cut surfaces (Fig. 4.3, 4.4). As such, the medial vane provides an opportunity to analyze minimally weathered anatomical structures of P. simplex.

The cut slabs were polished and then analyzed using light microscopy (Fig. 5), scanning electron microscopy (SEM; Figs. 6, 7), and laser Raman microspectroscopy (Fig. 8). SEM was conducted using an FEI Quanta 600 field emission environmental scanning electron microscope (ESEM) in both high- and low-vacuum modes. The choice of vacuum mode was directly related to specimen size, i.e., larger specimens were analyzed in low-vacuum mode as their profuse void space would have outgassed excessively in high-vacuum mode. Both secondary (topographic; SE) and backscattered (atomic number, or Z, contrast; BSE-Z) electron detectors were used in SEM analysis. Specimens analyzed in high-vacuum mode were sputter-coated with Au-Pd (approximately 5–7.5 nm thickness) using a Cressington 208HR high-resolution sputter-coater. Energy dispersive X-ray spectroscopic (EDS) point spectra (Table 1, online Supplemental Data file 1) and elemental maps (Figs. 6, 7) of fossils in polished cross-section were collected using an integrated Bruker AXS QUANTAX 400 with a high-speed silicon drift detector. Regardless of vacuum mode, identical operating conditions were maintained for all EDS analyses: 20 keV accelerating voltage, 5.0 spot size (unitless categorization of beam current and probe diameter), 11.5 mm working distance, and X-ray signal count-rate of 25–35 kilo-counts per second (the upper end of the range was captured in high-vacuum mode and the lower end in low-vacuum mode). All elemental maps were acquired for 600 seconds live-time, and individual point spectra were collected for 100 seconds live-time. Elemental peaks from point spectra were identified and quantified (with zaf and Au-Pd coating corrections applied if applicable) using the Bruker Esprit 1.9.2 software.

Initial X-ray point spectra were collected from the vanes of P. simplex and surrounding matrix (both within and outside the space defined by the two lateral vanes). Elemental maps were subsequently generated for all elements found at >1% (normalized weight percentage; nvp) in point analyses (Table 1). While the topography of unpolished specimens can significantly affect EDS analysis and particularly elemental mapping, all of the analyzed slabs were finely polished, with the only topography resulting from interstitial pore spaces between quartz grains of the host rock.

To assist in mineral identification, fossil and matrix material were also analyzed using Raman microspectroscopy (Fig. 8), using a JY Horiba HR 800 UV spectrometer with a 244 nm laser (15 mW), a 2,400 gr/mm grating, and a Symphony CCD detector system (LN2 cooled, 2048 × 512 pixel). Spectra were collected at 300 seconds/scan using a 40× UV objective (4 μm laser spot size), and were baseline corrected using Labspec software.

RESULTS

Examination of petrographic thin sections reveals a high degree of syntactical quartz overgrowth on rounded quartz grains (Fig. 3.1–3.4), as well as the presence of micas which may cut through quartz crystals (Figs. 3.3, 3.4, 7.2). In thin section, the vanes of P. simplex appear stylolitic (Fig. 3.1, 3.2). The vanes are opaque in transmitted light and appear to consist of a mixture of pyrite and organic matter.

Pteridinium simplex fossils in sample V-8-2009 are preserved as casts or molds in massive sandstone with vanes consisting of segments (represented by parallel lines or ridges) emanating perpendicularly from the central seam (Figs. 2.2, 4.1, 4.2). These ridges become less prominent and eventually grade into a mixture of pyrite and organic matter. Pteridinium simplex fossils are often found jumbled and twisted over each other, yet there is no evidence of torn, broken, or split specimens from visual inspection of the specimens.

Cross sections of the main specimen (Figs. 4.3, 4.4, 5) reveal that both the lateral and medial vanes are easily visible in light and BSE-Z electron microscopy. While separated by only a few laser
Figure 5—Light photograph (1) and photomicrograph (2) of cut surface ii on Block B (see Fig. 4.1). Dashed line in 1 marks the main P. simplex specimen, and arrows in 1 denote additional specimens. Boxed area in 1 is magnified in 2, with 135° counter-clockwise rotation. Dashed lines in 2 mark the medial vane (m) and lateral vanes (l) of the main specimen. Labeled box in 2 represents mapped area shown in Figure 7.1. Scale bar in 1=1 cm and in 2=500 μm.
centimeters and part of the same specimen, cross sections show dramatically different vane morphology (compare Fig. 5 with Fig. 4.3 and 4.4). For example, the medial vane in Figure 5.2 is much shorter than that in Figure 4.3 and 4.4, and it splits into a Y-shape structure ~1 mm from the central seam.

The vanes are represented by voids, although sometimes rusty staining is present along the vanes (Fig. 5.2), presumably resulting from oxidative weathering of pyrite (Vickers-Rich et al., 2013). Elemental mapping shows that these voids are often at least partially filled with carbonates (Figs. 6.3, 6.4, 7.1, 7.3) and minor amount of flaky clay minerals (Fig. 7.2, 7.4). The carbonate precipitates can range from ~3 mm thick on exposed lateral vanes (Fig. 6.1, 6.3) to barely visible on unexposed medial vanes (Fig. 6.2, 6.4). Although they predominately follow the vanes, they can also be found in cracks and pore spaces within the host-rock matrix (Fig. 7.4). Our examination
FIGURE 7—BSE-Z images and EDS elemental maps of *P. simplex* vanes. 1, 3, BSE-Z image and EDS elemental maps of boxed area in Fig. 5.2, rotated 135° degrees counter-clockwise; 2, 4, BSE-Z image and EDS elemental maps of boxed area in 1. Scale bars in 1 and 3=1 mm; in 2 and 4=100 μm.
Figure 5.2 located approximately at 465, 700, 1,085, 1,580, 3,620, and 3,690 cm

data also show that material associated with vanes have a
amounts of C, Ca, and Ti than any of the clay material. EDS
analysis of the secondary carbonate material reveals higher
are the most abundant components of the rock matrix. EDS
and titanium. As expected for siliciclastic sediments, Si and O
(mean normalized weight percent) and include iron, magnesium,
cations, including aluminum and potassium (Table 1). Minor
constituents, accounting for a combined total of less than 2%
(mean normalized weight percent) and include iron, magnesium,
and titanium. As expected for siliciclastic sediments, Si and O
are the most abundant components of the rock matrix. EDS
analysis of the secondary carbonate material reveals higher
amounts of C, Ca, and Ti than any of the clay material. EDS
data also show that material associated with vanes have a
compositional departure from the micas in the matrix. Specifically, vane material exhibits higher levels of Fe and S, but lower levels of Al, Si, and K, than mica minerals in the matrix. The EDS data are consistent with evidence indicative of
oxidative weathering of pyrite (Fig. 5.2) and the presence of
carbonate and clay minerals associated with the vanes.

Raman spectral analysis shows differences between P. simplex vane material and surrounding matrix (Fig. 8). Both
the matrix and vane material show a strong peak at ~465 cm
reiterating the obvious presence of quartz, and minor peaks at
~700 cm
and 3,620 cm
, which match the signals of many
phylosilicate minerals and related hydroxyl groups (Wada and
Kamitakahara, 1991; McKeown et al., 1999; Wang et al., 2002).
Some spectra of vane material also show strong peaks at ~1,085
cm
and ~1,580 cm
, characteristic of calcite and carbona-
ceous material, respectively (Nicola et al., 1976; Wopenka and
Pasteris, 1993; Awonusi et al., 2007).

DISCUSSION

A unique feature of the Nama fossils is their preservation as
casts and molds within massive sandstone beds, which are
interpreted as mass flow deposits. As such, their extraction from
the rock matrix depends on subtle differences between the
matrix and material replicating the fossils. Our analysis of
Pteridinium simplex shows that its vanes are often represented
by voids, which greatly facilitate the separation of P. simplex
fossils from the matrix. Such voids are the result of differential
chemical weathering which lead to the preferential dissolution
of primary minerals that replicated the vanes and the
precipitation of secondary minerals following the vanes.

We interpret that the vanes of Pteridinium simplex were
originally replicated or pseudomorphed by pyrite minerals. This
inference is based on the presence of opaque material (likely
pyrite and organic matter) following the stylolitic vanes in thin
sections (Fig. 3.1, 3.2), as well as the presence of iron staining in
some vanes (Fig. 5.2). The former presence of pyrite is also
supported by the discovery of its oxidative weathering product,
jarosite, in association with other Nama fossils such as Rangea
(Vickers-Rich et al., 2013; Hall et al., 2013). Thus, the death
mask model of Gehling (1999) can be applied to explain the
three-dimensional preservation of P. simplex, to the extent that
bacterial sulfate reduction likely drove the precipitation of
pyrite along degrading vanes. On the other hand, given the
rapidity of mass flow deposition and the fossil preservation
within sediments, it is unlikely that thick microbial mats could
have developed along P. simplex vanes, as implied by the death
mask model. As such, organic substrates for bacterial sulfate
reduction (and hence pyrite precipitation on P. simplex vanes)
mostly came from the vanes themselves, rather than thick
microbial mats. A prediction of this interpretation is that the
amount of pyrite produced would be limited, leading to only a
thin pyrite coating on degrading P. simplex vanes. This
prediction, along with the weathered nature of Nama fossils,
can explain the rare occurrence of pyrite in association with P. simplex.

Calcite minerals found along P. simplex vanes are interpreted
as secondary precipitates in voids, following the oxidation of
pyrite. They likely represent precipitates from chemical
weathering in an arid environment, similar to caliches. This
interpretation is based on several observations. First, the
Kliphoek sandstone is originally cemented by quartz rather
than calcite (Fig. 3.1–3.4). Therefore, void-filling calcite
cements are most likely secondary. Second, the prominent
presence of calcite on exposed lateral vanes and exposed rock
surfaces is also consistent with secondary precipitation driven
by evaporation in an arid environment.

Given the evidence for oxidative weathering of pyrite and
secondary precipitation of calcite, it is possible the minor clay
minerals found in association with P. simplex vanes (Fig. 7.2,
stones. Weathering and precipitation of secondary minerals that
Pteridinium simplex in mass flow deposits, it is the differential
have been important in the three-dimensional preservation of
stylolite formation. Regardless, although authigenic pyrite may
in association with
P. simplex
2012), and
Aspidella
(Laflamme et al., 2011b),
constructive role in the preservation of Ediacaran fossils such as
origins. Although detrital or authigenic clays may have played a
derminal mica minerals (Fig. 3.3, 3.4, Table 1), indicating different
weathering. Certainly, such clays are different from diagenetic
7.4) may also be secondary precipitates formed during chemical
weathering. Certainly, such clays are different from diagenetic
mica minerals (Fig. 3.3, 3.4, Table 1) and infilling carbonate material. Standard error of the mean was calculated as sigma/sqrt(n). Spot # denotes location marked on online Supplemental Data Figure 1 (e.g., 1.2 in subfigure 1, spot 2).

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</table>

Average ± standard error (1σ) of all samples

Table 1—Elemental concentrations (in normalized weight percentages) from EDS point analyses of clays within Pteridinium simplex vanes, matrix micas, and infilling carbonate material. Standard error of the mean was calculated as sigma/sqrt(n). Spot # denotes location marked on online Supplemental Data Figure 1 (e.g., 1.2 in subfigure 1, spot 2).

7.4) may also be secondary precipitates formed during chemical
weathering. Certainly, such clays are different from diagenetic
mica minerals (Fig. 3.3, 3.4, Table 1), indicating different
origins. Although detrital or authigenic clays may have played a
constructive role in the preservation of Ediacaran fossils such as
Aspidella (Laflamme et al., 2011b), Conotubus (Cai et al.,
2012), and Shaanxilithes (Meyer et al., 2012), the origin of clays
in association with P. simplex vanes cannot be resolved with
available data. They are tentatively interpreted as weathering
products but their preferential occurrence in association with
P. simplex vanes, particularly unexposed medial vanes;
however, the origin of such clays is uncertain, and we
tentatively interpret them as weathering products. Understand-
ing the taphonomy of P. simplex will allow more detailed
morphologic analyses using X-ray microCT techniques which
can take advantage of the secondarily formed voids that define
P. simplex vanes.

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Boehm, for granting access to fossil site. We would like to thank

CONCLUSIONS

The taphonomic style of Pteridinium simplex, three-dimen-
sionally preserved within mass flow deposits of the upper
Kliphoek Member (equivalent to the Aar Member of Hall et al.,
2013) in Farm Aar of southern Namibia, represents a departure
from the classic ‘death mask’ preservation on bedding surfaces.
However, there is evidence for minor pyrite in association with
P. simplex vanes, indicating that bacterial sulfate reduction and
authigenic pyrite precipitation may have played a constructive
role in fossil preservation. On the other hand, it is unlikely that
thick microbial mats developed on P. simplex vanes preserved
within mass flow sediments. Limited precipitation of authigenic
pyrite and subsequent destruction by chemical weathering
explain the dearth of pyrite in association with P. simplex
vanes. Chemical weathering and differential oxidation of pyrite
result in voids delineating P. simplex vanes and the precipitation
of secondary minerals such as calcite. Thus, chemical weather-
ing facilitates fossil recovery and separation from massive
hosting rocks. There are also minor clay minerals in association
with P. simplex vanes, particularly unexposed medial vanes;
however, the origin of such clays is uncertain, and we

Total average ± standard error (1σ) of all samples

4.9 ± 0.8 52.3 ± 0.8 0.2 ± 0 6.6 ± 1 23.2 ± 1.9 4.9 ± 2.1 2.3 ± 0.5 2.9 ± 0.9 1.2 ± 0.7 1.4 ± 0.8 100 ± 0
ACCESSIBILITY OF SUPPLEMENTAL DATA

Supplemental data deposited in Dryad repository: http://dx.doi.org/10.5061/dryad.96k0t.

REFERENCES


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