Squaring up over ancient life

The textbooks say that oxygen-producing microorganisms evolved some 3.5 billion years ago. But as that claim and its author come under attack, the history of life on Earth may have to be rewritten. Rex Dalton investigates.

It was the academic equivalent of a heavyweight prizefight. In the red corner, defending his title as discoverer of the Earth's oldest fossils, was Bill Schopf of the University of California, Los Angeles (UCLA). In the blue corner, Martin Brasier of the University of Oxford, UK, who contends that Schopf's 'microfossils' are merely carbonaceous blobs, probably formed by the action of scalding water on minerals in the surrounding sediments.

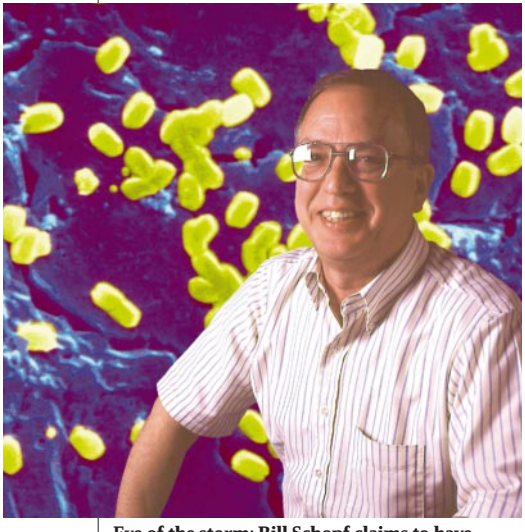
The bout took place on 9 April at the second Astrobiology Science Conference, held at NASA's Ames Research Center in Moffett Field, California. It was the first time that Schopf and Brasier had faced each other since their publication, in the 7 March issue of *Nature*, of conflicting papers[1,2] re-examining Schopf's claim to have discovered cyanobacteria in Australian rocks 3.5 billion years old.

Most judges gave a clear points victory to Brasier. But as Schopf licks his wounds, one of his former graduate students has come out of the woodwork to deliver what may prove to be a knockout blow. She argues that her supervisor was aware from the start of evidence that cast doubt on his conclusions — a charge Schopf vigorously denies.

The samples in question are Schopf's claim to scientific fame — they are even listed in *Guinness World Records* as the world's oldest fossils. But more significant than their sheer antiquity is Schopf's interpretation that they are most likely to be fossilized cyanobacteria — organisms that can use the energy of sunlight to make sugars from carbon dioxide. Although other researchers have found microorganisms in rocks of similar age[3,4], these are not thought to have been capable of this trick. The existence of cyanobacteria 3.5 billion years ago, which would have pumped oxygen into the atmosphere as a by-product of photosynthesis, has long been a puzzle — the geochemical evidence suggests that the atmosphere contained very low levels of oxygen until about a billion years later[5,6].

OWEN GREEN

Trading blows: Martin Brasier (left) puts his case at the NASA meeting as Bill Schopf (right) listens.



C. MUNOZ-YAGUE/EURELIOS/SPL

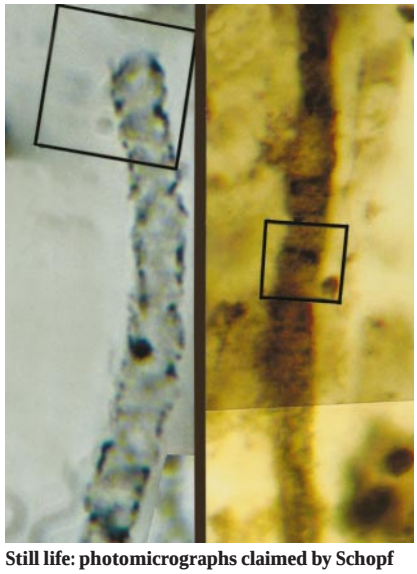
Eye of the storm: Bill Schopf claims to have discovered the oldest fossils of life on Earth.

Slice of life

The specimens described by Schopf were collected from chert — a flint-like sedimentary rock — near the Western Australian town of Marble Bar (see map, opposite). Together with sites in Greenland and South Africa, this region boasts the world's oldest surface rocks.

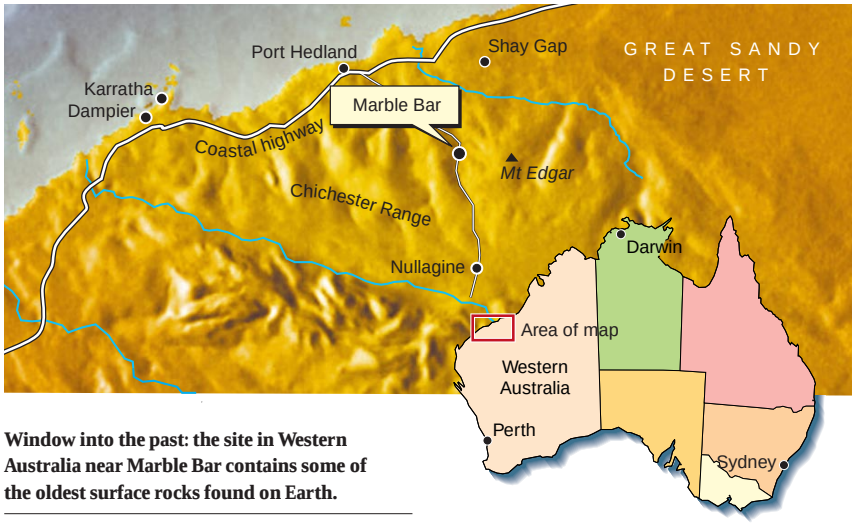
Looking for fossil microbes in such samples involves cutting slices thin enough to shine a light through, and then examining them under the microscope for countless hours, micrometre by micrometre. Schopf and his graduate student Bonnie Packer first suggested that the samples may contain cyanobacteria in 1987 (ref. 7). In 1992, Schopf advanced his description[8] in a book, *The Proterozoic Biosphere*, which he co-edited. Then in a *Science* paper[9] the following year, Schopf described a total of 11 taxa of microorganisms from the samples, arguing that most were filamentous colonies of "probable cyanobacteria" dating from 3.465 billion years ago.

At the time, some researchers thought it



J. W. SCHOPF *ET AL. NATURE*

Still life: photomicrographs claimed by Schopf to show 3.5-billion-year-old microbial fossils.



Window into the past: the site in Western Australia near Marble Bar contains some of the oldest surface rocks found on Earth.

was a stretch to conclude that the specimens were cyanobacteria based on morphology alone. But over the years, Schopf's description became textbook orthodoxy. However, when Brasier updated his microfossil textbook[10] in 1999, he re-examined Schopf's specimens, which are now stored at the Natural History Museum in London (see 'The London connection', overleaf). As Brasier searched through the thin sections, he found that the some of the 'fossils' were branched in ways never depicted in Schopf's papers. Others took on weird shapes that looked quite unlike filamentous cyanobacteria. "You scratch your head and wonder if maybe there was some terrible mistake," says Brasier, recalling his thoughts at the time.

His suspicions raised, Brasier pored over the specimens, giving some nicknames such as 'Loch Ness monster' and 'wrong trousers'. What he saw under the microscope was buttressed by a 1999 trip to Marble Bar, which revealed that the site from which the specimens came was riven with lava flows, rather than being a continuous sedimentary formation.

From their geological mapping and chemical analyses, Brasier and his colleagues concluded that Schopf's samples had not originally been laid down on the floor of a shallow sea, as his papers suggested. Instead, the site seemed to have been a hot spring pouring volcanically heated water from the seabed. Schopf's 'microfossils', Brasier argued, were merely artefacts formed from amorphous graphite in this hostile environment.

Rocks revisited

Having submitted his paper[2] to *Nature* in February 2001, Brasier began lecturing about his findings on the conference circuit, including a talk at the Earth System Processes conference in Edinburgh in June 2001, organized by the Geological Society of London and the Geological Society of America.

Early last year, as he became aware of Brasier's results, Schopf began his own reanalysis. He had earlier teamed up with researchers from the University of Alabama at Birmingham who were experimenting with laser–Raman imagery. This is a technique for characterizing molecular structure, in which a laser is focused on a point within the sample and optical sensors record the spectrum of the backscattered light. In January 2001, Schopf and his Alabama colleagues reported that these spectra can distinguish between microfossils and inorganic carbonaceous deposits[11]. They then applied the same technique to Schopf's 'microfossil' samples, reporting in their *Nature* paper[1] that the results substantiated the original claim that the specimens were fossilized microorganisms.

Given that the search for extraterrestrial microbial life is likely to involve similar techniques to those used to look for microfossils, it was natural that NASA's April astrobiology conference would be the venue for Schopf and Brasier's first public duel since their papers were published. In front of a packed audience in a huge white tent, the pair gave back-to-back 15-minute lectures. It amounted to an intellectual brawl, with the protagonists exchanging several low blows.

Schopf hit out at Brasier for "errors" in interpretation — the specimens were not branched, but "folded". Brasier, every inch the haughty Oxford don, was brutally dismissive of his opponent's arguments: "A truly hydrothermal performance, with more heat than light," he announced, after taking over from Schopf at the podium.

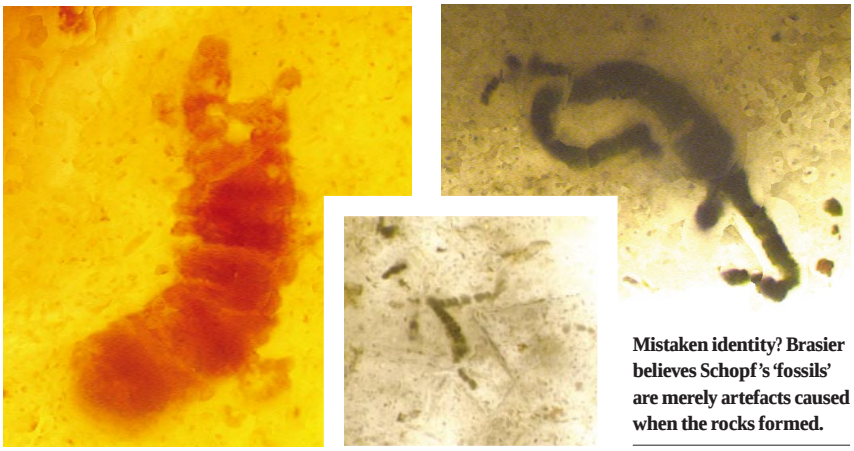
Seeking to convince the gathering of some 300 scientists that the specimens were, indeed, microfossils, Schopf had adopted the tone of a revivalist preacher, shouting at times. "Hallelujah! I believe!" responded one palaeontologist mockingly, after Schopf brought his talk to a close. But when both men had finished their presentations, it was clear that Schopf had won few converts to his cause.

Elements of doubt

Those present also thought Schopf had made a major concession, accepting that the specimens were not oxygen-producing cyanobacteria after all. In his talk, he stressed that none of his papers claim that the specimens are definitely cyanobacteria. "I was absolutely struck by that," says geochemist John Hayes of the Woods Hole Oceanographic Institution in Massachusetts. The original suggestion that the specimens were cyanobacteria was the key point of interest, and if that is gone, many in the field are unmoved by the issue of whether they are fossils or not. "That makes his whole argument irrelevant," says Australian geologist Roger Buick, now at the University of Washington in Seattle.

Other presentations in the same session also had a bearing on the issue of Schopf's specimens. Physicist Stephen Hyde of the Australian National University in Canberra showed that, using techniques pioneered by Juan Garcia-Ruiz of the University of Granada in Spain, his team has created at room temperature mineral deposits that under the microscope look exactly like Schopf's purported microfossils. "That was remarkable material," says Hayes.

And although the laser–Raman evidence was not seriously challenged at the Ames meeting, experts in the field are now questioning Schopf's claim that the technique



M. D. BRASIER *ET AL.*, *NATURE*

Mistaken identity? Brasier believes Schopf's 'fossils' are merely artefacts caused when the rocks formed.

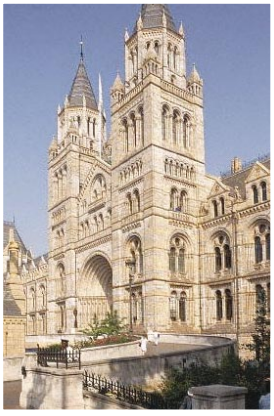
The London connection

As micropalaeontologists debate whether Bill Schopf's Australian specimens really are fossils, some experts are also questioning why they haven't been returned to their country of origin. After studying the thin slices of rock for several years, Schopf deposited them in 1992 at the Natural History Museum in London (below). In 1988, Australian law was changed to require the return of fossils collected from its territory and used to describe new species. It does not apply to specimens collected before this date, but Bruce Runnegar, an Australian who now directs the Center for Astrobiology at the University of California, Los Angeles, says he cautioned Schopf against sending the samples to London: "I advised him not to do it."

The Geological Survey of Western Australia in Perth wrote to Schopf seeking the return of the specimens. And in 1999, when Schopf published an acclaimed account of his work[16], he wrote that "backup specimens" had been sent to Australia. But Kath Grey, the survey's palaeontologist, says that the specimens sent to Perth appear to be rejects in which no identifiable 'microfossils' have yet been found.

A spokeswoman for the Natural History Museum says that officials there would be glad to discuss the issue of repatriating the samples. But Grey remains concerned about the condition of the much-travelled specimens. In an unusual move, the London museum last year permitted all of the specimens — not the normal allotment of three — to be shipped to Schopf for fresh analysis.

Two of the thin sections were broken while on loan or in transit. "I'm amazed they sent them to Los Angeles," says Grey. "We wouldn't have allowed typed material to have been sent overseas. We like people to come to the museum; it lessens the risk of breaking."



can provide a signature of once-living material. "I don't know of any work that definitively shows the difference between the Raman spectra of organically precipitated material and inorganically precipitated carbon," says Jill Pasteris, a geologist at Washington University in St Louis, Missouri, who has worked on laser–Raman for 15 years. "Laser–Raman is a wonderful technique, but they pushed it too far. Schopf's *Nature* article is a misstatement of what the technique can do." Pasteris also notes that Brasier's own laser–Raman analysis[2] found no differences between the spectra of the purported fossils and those of neighbouring inclusions in the rocks.

But Schopf, responding to *Nature*'s written questions, stands by his paper. "The claim of our article is that morphology and chemistry together provide a powerful means to address the problem of biogenicity," he wrote.

As the dust settled after the meeting session, Brasier remained aghast at Schopf's claim that the fossils were folded, rather than branched. If so, why had Schopf not pointed this out in his earlier publications? "He was arguably misleading the scientific community and the public about their true nature," says Brasier. Schopf rejects that accusation, adding that the folding conveys "no useful scientific information".

But now Packer, who has not previously spoken out, claims that Schopf was, indeed, highly selective with the evidence he presented in his original papers. Backing up her account with pages from her lab notes, Packer claims that Schopf withheld from publication images of the purported cyanobacteria that indicated branching structures.

Although named as co-author on the initial paper[7], Packer says that she became increasingly concerned about Schopf's presentation of the data. She claims that her attempts to challenge him met with stubborn resistance. "There wasn't a bloody thing I could do," she says. Packer parted company with Schopf in 1987, and eventually completed her PhD in another UCLA laboratory. She now works at the US Army Environmental Center at the Aberdeen Proving Ground in Maryland, studying the environmental impacts of unexploded and detonated ordnance.

Photographic memories

Again responding to written questions, Schopf initially contested Packer's account of events: "Never, not at any time, did she mention to me (or show me photos of) branched filaments … Dr Packer's memory is simply in error." But shortly before this article went to press, he sent a second e-mail, saying that he had found records of Packer's observations of "branching". In this note, Schopf added that he could not recall whether he saw the photos at the time, which he argued depict "mineralic fossil-like artifacts" or "clumps of unbranched overlapping poorly preserved filaments". But Packer says that Schopf's handwriting is on the photos she retains.

Supporters and critics of Schopf alike describe him as a driven and tenacious character — nicknamed 'Bull' Schopf by some — whose energy and enthusiasm has done much to raise the profile of micropalaeontology, and to draw funding into the field. "He has a driving ambition to be in the limelight, and he doesn't like to admit he's wrong," says one former colleague. But these traits have led Schopf into conflict with his collaborators on at least one previous occasion.

In 1980, Schopf was working with Stan Awramik, now an associate vice-chancellor at the University of California, Santa Barbara; Malcolm Walter, now director of the Australian Centre for Astrobiology at Macquarie University in Sydney; and Buick, then a graduate student at the University of Western Australia in Perth. Schopf prepared a manuscript claiming the discovery of 3.5-billion-year-old bacterial fossils, after analysing rocks collected in 1977 by Awramik in the same general region as the specimens in the Brasier dispute. They came from sites, one of which had been identified by Buick, near a structure called the North Pole Dome, named for its desolate appearance. Buick says he returned from the field one day to learn that the manuscript had been accepted for publication by *Science* — and that he was listed as an author. "I wrote to *Science* saying I strongly disagreed, and withdrew my name as co-author," Buick says.

Science subsequently declined to publish the paper. Undeterred, Schopf, Awramik and Walter eventually published their findings in *Precambrian Research*[12]. But before the paper appeared, Awramik and Schopf had become embroiled in a dispute over credit for the specimens' discovery. Although Awramik was, in the end, satisfied with the credit given for his contribution, he never collaborated with Schopf again. Buick, meanwhile, published a rebuttal to the paper a few months later[13], and the debate continued in print for some time[14,15].

Although that disagreement has since subsided, Schopf and Brasier are not calling it quits, and are set for a rematch. Their next bout is scheduled for the International Conference on the Origin of Life, to be held in Oaxaca, Mexico, from 30 June to 5 July. Don't expect either man to pull his punches. ■

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