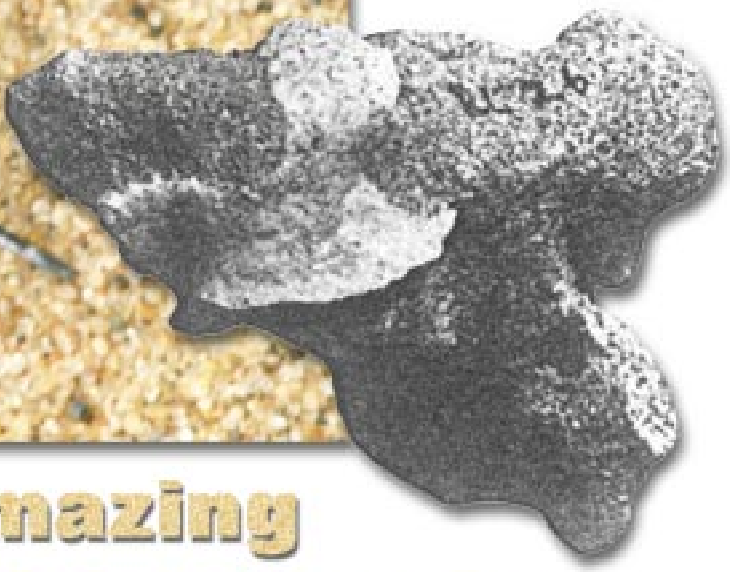


The Namib's amazing fossil spider webs

Spider webs are normally too fragile to be fossilized and they are constructed in the wrong places. Yet there are spider webs in the fossil record, writes Martin Pickford, some of them tens of millions of years old. How can such ephemeral structures become fossils and what can such fossils tell us about the past?

Above left: A present-day male Seothyra.

Photograph: Les Oates (Picture reproduced courtesy of the ARC-Plant Protection Research Institute)

Above right: Half of a fossilized roof web cemented onto a burrow-shaped nodule of indurated dune sand was found at Rooilepel, near Oranjemund. Wind-blown sand had probably destroyed the missing half of the web.

Picture: Courtesy of Martin Pickford

Over the last century, palaeontologists have found many fragments of spider webs in amber, which is fossilized tree gum. The webs (or small fragments of them) get incorporated into exuding tree gum, which flows over them and preserves them so perfectly that arachnologists (people who study spiders) can often tell what family of spiders made the web and even what part of the web is preserved – for example, signal threads or web fibres with sticky globules of silk for trapping insects. Amber containing fossil spider web is known from Europe, the Middle East, and the Caribbean, the oldest specimens being from the Cretaceous period, some 100 million years old.

Until recently, amber was the only known source of information about fossil spider webs, and it was generally thought to be the only means for preserving such fragile structures. But discoveries in the Namib Desert have radically changed our thinking and opened up a new field of research.

A mystery solved

The Namibia Palaeontology Expedition started surveying the fossil sand dunes (aeolianites) of the Namib Desert in 1992 and discovered many fossil bird eggs and reptile and mammal bones and teeth, as well as a bewildering variety of trace fossils made by small animals, such as beetles and rodents, that burrowed through the sand when it was loose. The expedition also found fossilized termite mounds, petrified beetle cocoons, and even some mineralised wood lice, preserved in calcite ($CaCO_3$). But most extraordinary of all was finding small white dome-shaped structures with lobed margins about 2 cm across, similar in shape to clover leaves. Each of these structures is preserved as a layer of calcite about 2 mm thick cemented onto a nodule of hardened sand*.

For several years we didn't know what these structures were, till I observed some peculiar traces in the sand near the Tsondab River in the Namib-Naukluft Park. These looked superfically like antelope spoor but did not occur in trails; they were scattered randomly over the surface of the sand. Excavation of one of them revealed a mat of thick spider web with a vertical tube-shaped burrow beneath, and the literature soon revealed that it was made by the buck spoor spider (*Seothyra*). The similarity of these *Seothyra* roof mats and the calcite domes was immediately apparent.

How a web becomes fossilized

The structure of the *Seothyra* tube and roof web is extremely fragile. A strong wind, for example, can easily destroy it by blowing away the sand, or a passing gemsbok or hyena could step on it and ruin it. After hatching, baby *Seothyra* eat

* The expedition collected several of these structures near Sossus Vlei, Namibia, and at Rooilepel, not far from Oranjemund in the Sperrgebiet. Specimens found *in situ* revealed that the domes were originally orientated with the convex part upwards and the nodular part downwards. A specimen from Rooilepel preserved part of a burrow-shaped nodule beneath the calcite layer.

their mother, and they consume the roof web as well because it is a rich source of protein. So physical destruction is probably the fate of more than 99.9% of the webs ever built.

Now and then, one will be buried by wind-blown sand and protected from such damage. Even then, its chances of survival are infinitesimally small – the web can rot and fossorial insects, of which there are many in the Namib, can eat it or damage it by their burrowing activities.

Very occasionally, however, the sand surrounding the web becomes moist (perhaps after rain, or due to fog precipitation or to a rise in groundwater level), which improves its chances of being preserved. The moisture can dissolve calcium carbonate from surrounding sand, which can then diffuse into the spider web. The pore spaces in the surrounding sand are too large for them to act as diffusion traps, but the pore spaces in spider webs are of suitable dimensions for such chemical processes to occur. With sufficient diffusion of molecules of calcium carbonate into the web structure, the entire web can be replaced by calcite – the web is fossilized.

Millions of years later, wind may erode the surrounding sand to uncover such fossils, exposing them to physical damage. But once in a while a passing palaeontologist may notice a small white gleaming dome-shaped structure with lobed margins, may bend down to pick it up, and may even wonder what it is before throwing it away. Or he may keep it, and embark on a lengthy search to interpret how it formed, how old it is, and what it means.

What the fossils reveal

Seothyra currently occurs widely in southern Africa in areas where there is loose sand or gravelly soil that is dry most of the year. In the Namib Desert, the spiders survive at the thermal limit. Exposed to the heat of the desert day for a few minutes they die, but waiting safely in the bottom of their burrows, where the temperature is much lower than at the surface, they are safe. If a passing ant gets caught in the trap on the surface, the spider dashes up its tunnel, lifts the appropriate marginal lobe, captures its prey, carries it down to the bottom of its tunnel, and eats it at leisure. The discovery at Rooilepel of 16-million-year-old fossil webs that look extremely similar to those of extant *Seothyra* reveals that buck spoor spiders quickly adapted to the sandy desert conditions that became established in the Namib at that time.

Many plants and animals were affected by the climatic changes from savanna to desert. Savanna species went extinct locally or they adapted, evolving into new forms. The burrowing spiders, because of their subterranean behaviour, were partially buffered from the full harshness of the desert environment and had a head start on many inhabitants of the region. The fossilized *Seothyra* roof webs preserved in the fossil dunes of the Namib elegantly attest to the rapid adaptation of this family of spiders to the extreme conditions in the region for the past 17 million years. They also provide the only known evidence of the existence of these spiders in the fossil record: no body fossils of *Seothyra* have ever been found.

Other trace fossils that occur in dizzying quantities and innumerable varieties in the Namib aeolianites will yield precious information about the evolution of the Namib fauna and flora and the climatic conditions at various stages in the desert's history. Fossilized ▹▹

Surface view of two buck spoor spider burrow complexes. The crescent-shaped depressions in the sand, which give the structure its name, occur at the edges of the flexible lobes in the roof mat. They are lifted by the spider to catch a passing insect and lowered when it carries the prey down into its burrow, located beneath the roof web.

Photograph: Martin Pickford

How the *Seothyra* catches its prey

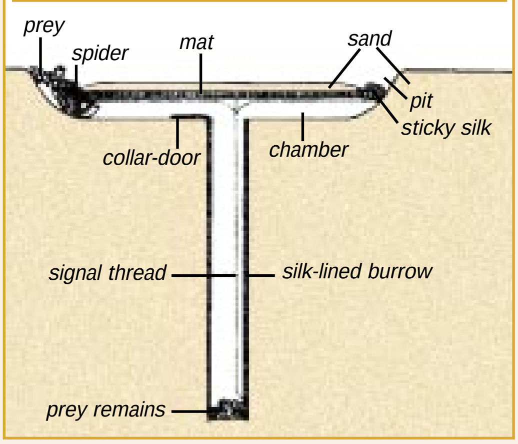
Seothyra is a small spider that burrows into loose soil and sand, where it excavates a short vertical tube that it lines with strands of web to prevent the sides from collapsing inwards.

It covers the top of the burrow with a thick 'mat' or 'roof web' about twice the width of the tube and camouflages its upper surface with sand. Wind-blown sand also covers the structure until it becomes invisible from above. The roof web is built with marginal lobes (normally four) that are flexible enough for the spider to lift up without dislodging the entire web.

The spider then spins a mass of sticky web, called a cribellar tangle, almost like a miniature ball of tangled wool, which it leaves near the edge of each of the lobes. These cribellar tangles are connected to signal threads which lead to the centre of the roof web, and from there go vertically downwards into the tube, at the bottom of which waits the spider, away from the heat of the desert surface.

Any unwary insect, such as an ant or a small beetle, that touches the cribellar tangle is temporarily stuck to it and, as it wriggles to free itself, it vibrates the signal thread alerting the spider at the bottom of the burrow that its next meal is trying to get away. By analysing the vibrations in the signal threads, the spider can tell which of the lobes to lift so as to capture its prey. Each time it lifts a lobe, it disturbs the sand that covers it, and when it lowers the lobe back into position it leaves a small crescentic depression in the surface of the sand. With repeated lifting and lowering of each lobe, it produces the characteristic 'buck spoor' pattern in the sand.

Seothyra burrow and roof web



Two views of a Late Miocene Seothyra *fossilized roof web. The dome-shaped structure and its lobed margin are typical of this kind of fossil, which is generally about 2 cm in diameter.*

Picture: Courtesy of Martin Pickford

Climate change in the Namib

Before the Middle Miocene period (some 16–17 million years ago): the Namib was a savanna area, with grassland, trees, and various vertebrates (e.g. primitive antelopes, ostriches, crocodiles, and dassies).

At the end of the Early Miocene: the Antarctic Ice Cap expanded to continental scale, causing global climatic changes. The cold climatic belts increased in area, and the subtropical and tropical ones were squeezed northwards towards the equator. The Southern Namib changed from savanna to steppe, and winter rainfall replaced the summer rainfall of the Early Miocene.

From steppe to hyper-arid desert: The new configuration of the world's climatic belts led to the formation of the South Atlantic anticyclone as we know it today; the dune bedding in the indurated sands of the Namib show consistent southerly wind directions from 17 million years ago to today and, in that time, vast volumes of glacial melt water have been shed into the oceans surrounding the Antarctic continent.

Being fresh and cold (therefore denser than seawater), melt water sinks to the ocean depths and flows away from the continent. The rotation of the globe ensures that the cold bottom water drifts northeastwards, where it eventually encounters the continental shelves on the west side of continents (South America, southwest Africa, and western Australia). Here the water is forced upwards by a combination of two factors: the upward slope of the continental shelf and the offshore winds related to the South Atlantic anticyclone that blow surface waters away from the shore towards the open ocean. Water wells upwards from the depths to fill the place left by the departing surface water: these upwelling cells of cold water intensify the arid conditions along the southwestern coast of Africa, turning the Namib from semi-arid steppe into hyper-arid desert.

▷ termite nests and hives abound in the fossil dunes and reveal that the climate of the southern Namib has fluctuated between summer and winter rainfall several times in the last 17 million years.

Some trace fossils (called ichnofossils by palaeontologists) are so well preserved that we can identify the organisms that made them. This is particularly so for fossilized 'bioconstructions', a class of ichnofossils manufactured from body contents of the makers rather than from sediment. Most trace fossils, such as footprints and back-filled burrows, result from the passage of organisms over or through sediment and their makers are therefore difficult to identify. Being constructed of organic matter, bioconstructions are more readily attributed to their makers. Fossilized bioconstructions, such as the petrified hives of harvester termites (*Hodotermes*), are large and spectacular.

Till now, however, because of their fragility, the most surprising ichnofossils to come out of the Namib Desert are the roof webs of *Seothyra*. Their preservation gives scientists intriguing glimpses into the Miocene palaeoecology of burrowing spiders in desert environments and provides a precious piece of the puzzle which is the history of the Namib Desert. □

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