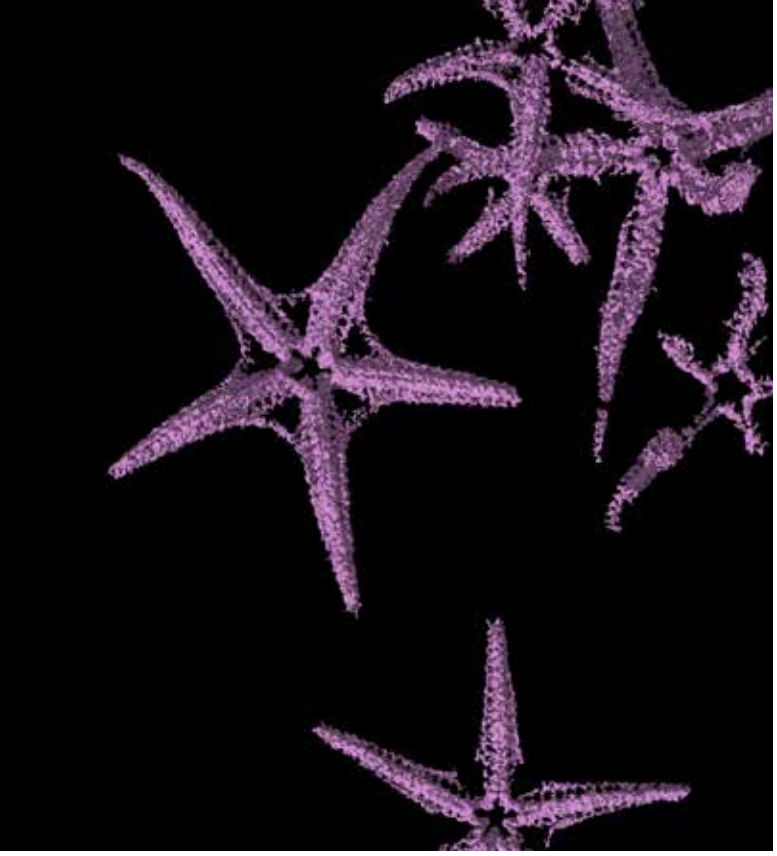


Brittle stars in the Bokkeveld

The next time you travel along the N1 national road from Johannesburg to Cape Town, look around at the arid landscape before you descend the pass into the Hex River Valley. Consider the fact that you are 125 km from the nearest coastline, and some 950 m above present-day sea level – and then picture the marine brittle stars that were found here, as ancient fossils!

In the Devonian Period some 400 million years ago, when the land that is now the African continent was part of the giant supercontinent Gondwana, the southern Cape was underwater, part of a basin covered by the Agulhas Sea. It was during this time that the fine-grained sediments of the Bokkeveld Group were deposited on the seafloor, which was home to a thriving community of bottom-dwelling invertebrates.

The Bokkeveld Group was laid down on top of the Table Mountain Group, and was subsequently overlain by the Witteberg Group. These three groups make up the Cape Supergroup, which was later buckled and thrust up by tectonic activity to form the Cape Fold Belt mountains. The Bokkeveld is known to be rich in fossils, as the marine organisms of the time were better preserved in the fine sediments that ultimately hardened to mudstone and shale, compared to the coarser sandstones of the other two groups. Two of the oldest Bokkeveld layers, the Voorstehoek and deeper Gydo formations, have particularly well-preserved 'shelly' fossils such as trilobites (now extinct), brachiopods (lamp shells), bivalves (mussels and clams), gastropods (sea snails) and even echinoderms (including starfish, feather stars and brittle stars).

With this in mind, Mhairi Reid – then a BSc Honours student in the University of Cape Town's geology department – went on a fossil-finding road trip in 2014 with Honorary Research Associate Dr Wendy Taylor, an expert on echinoderm fossils. Mhairi was searching for a suitable subject for her Honours project, which she specifically wanted to do on fossils.

"We went out for a week, driving around and looking at outcrops, and we stumbled across it by pure chance," says Mhairi.

What they discovered, at a road-cutting next to the N1, was an entire bed of fossil brittle stars – or ophiuroids. The bed was lying about 120 cm below the surface of the 2 m high rocky embankment, which had a sedimentary profile representative of the Voorstehoek formation.

"It's quite rare to find echinoderms, just because they're so delicate," says Mhairi. "They need exceptional events to be preserved."

These events, known as obrution events, involve rapid burial or smothering by an underwater 'landslide' or a storm-induced current that sweeps sediment down a slope. Sedentary bottom-dwelling (benthic) invertebrates that cannot move fast enough to escape are particularly prone to being entombed in this way. Over time their soft tissues and eventually their calcareous shells – or ossicles in the case of echinoderms – dissolve away, but by then

The presence of the brittle star bed was given away by orange, star-shaped patterns on the surface of the rock, caused by oxidation of iron in the mould fossils.

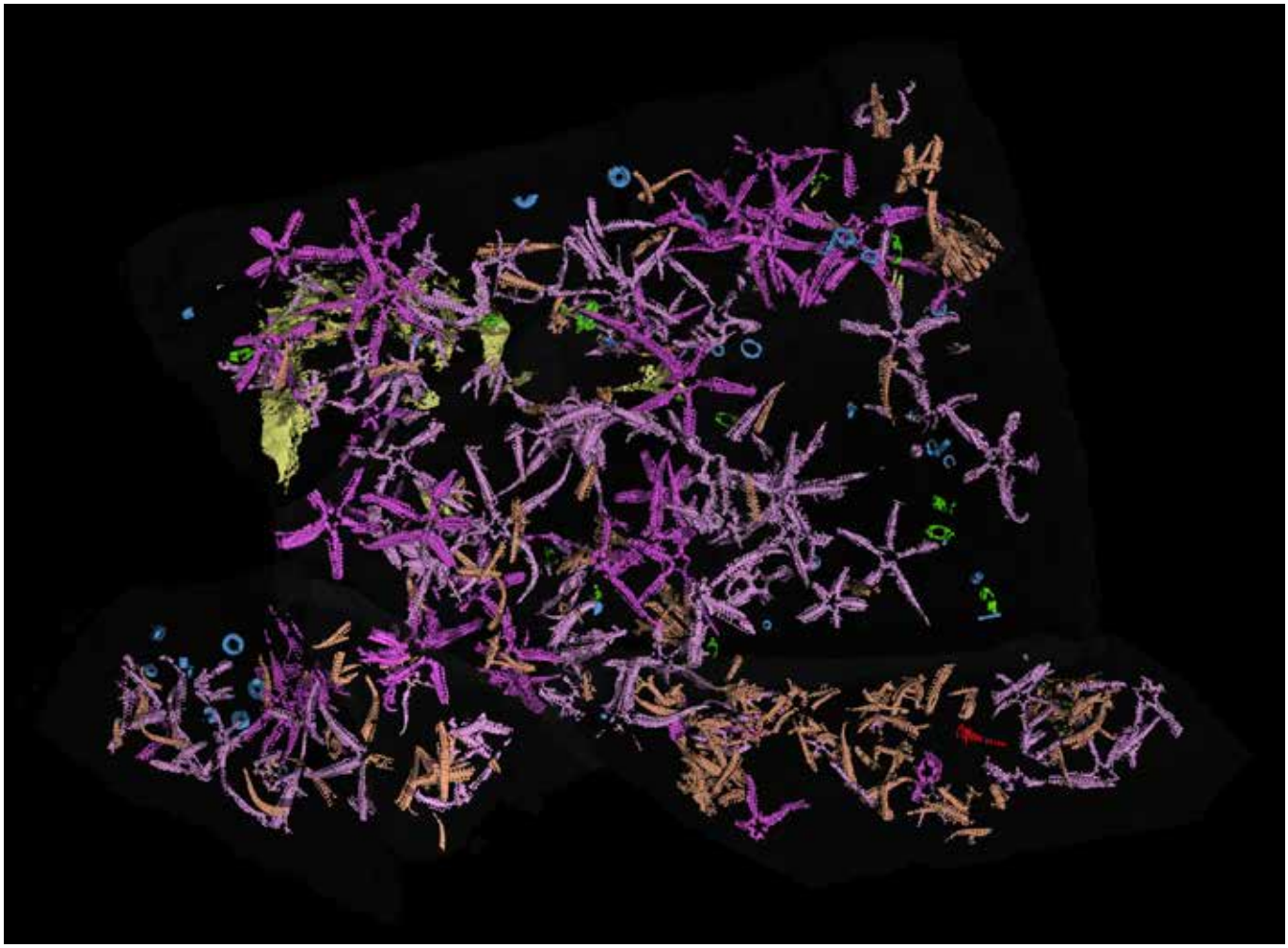
their bodies have left impressions in the rock. The fossil brittle stars were examples of these mould fossils, rather than a mummified version of the animal itself.

Initially, for Mhairi's Honours project, some rock samples containing the fossils were collected, but for her MSc project an entire section – about 2 m long, 1 m wide and 4 cm thick – was excavated using a pickaxe, flat brick chisel and geological hammer. The weathered nature of the rock meant that it was impossible to remove the section as a single slab though. It broke up into 55 pieces, which were carefully labelled and then put back together again in the laboratory to be photographed.

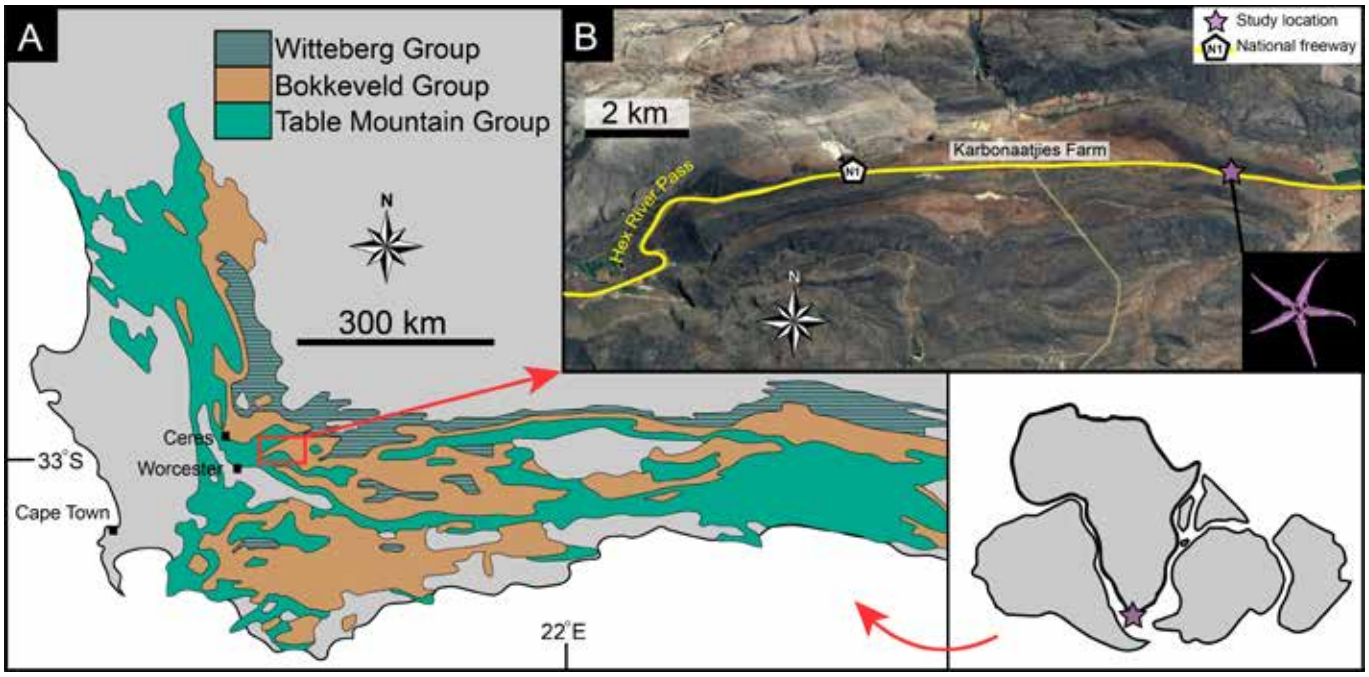
While photos were fine for capturing the fossils on the surface of the rock pieces, they were hopelessly inadequate for showing what lay inside, so the pieces were taken to Stellenbosch University's microCT facility for scanning. This allowed the internal contents of the rocks to be 'exposed' as cross-sectional images from all angles, without any risk of damaging the fossils. All the images were then digitally stitched together to create a virtual 3D model, which revealed that there were more than 700 brittle stars in the excavated section, along with trilobites, brachiopods, bivalves, gastropods and other echinoderms. The microCT images essentially represented a snapshot of a benthic marine community that lived together 400 million years ago.

What was even more special about the Karbonaatjies obrution bed, named after the local farm, is that more than half of the brittle star fossils were 'intact' – in other words, all five arms remained joined to the central disk. Brittle stars have arms that easily detach, which is an adaptation to escape predators. When grabbed by an arm, they can simply shed it and grow a new one later, but they also tend to fall apart quickly after death, as the soft tissue and ligaments attaching the arms to the disc soon decay. The number of intact specimens lend proof to the theory that the animals were buried alive.

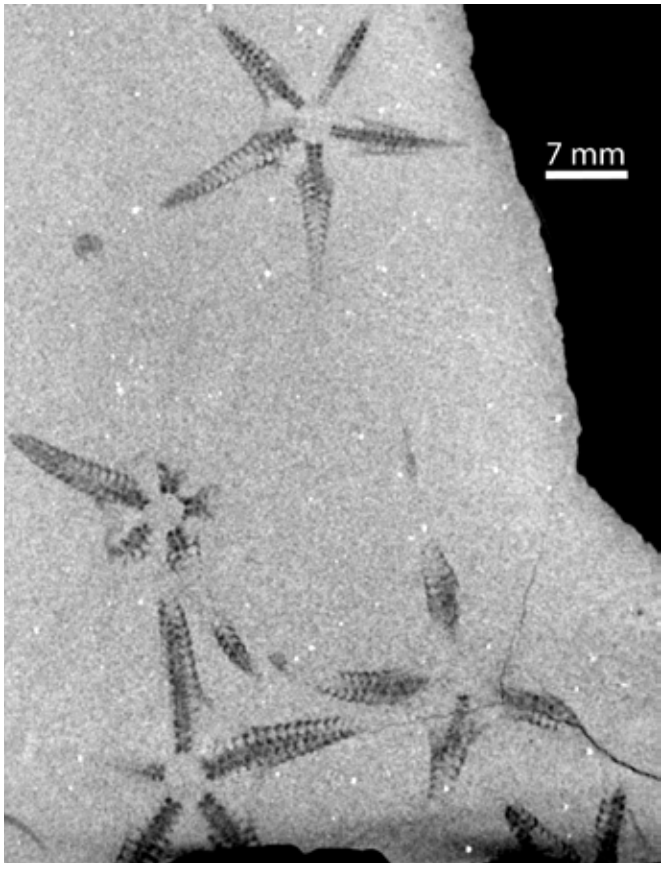
Mhairi also counted more than 600 detached arms in the microCT scans, and noted that many of the brittle stars were lying upside down. Since there are a number of records of mass amputation in modern-day brittle stars after storms and hurricanes, she interprets her observations as being consistent with a strong, storm-induced current that tumbled the ancient brittle stars over as they were covered in sediment. Some even had one or more arms raised, which is exactly the posture modern brittle stars adopt when crawling up out of a thin layer of sediment, but the ancient brittle stars were clearly buried too fast and too deep to escape. Their muddy grave was beyond the reach of scavenging or burrowing animals, which would either have eaten their remains or facilitated aerobic decomposition through bioturbation.



A virtual reconstruction of a portion of the fossil bed showing about 80 complete brittle stars (light pink = right side up, dark pink = upside down), as well as fragmented arms (pale orange) and parts of other animals.



A simplified geological map of the Cape Supergroup showing the fossil bed's location beside the N1 national road, near the Hex River Pass. The small inset depicts Africa's position within Gondwana.



A 2D microCT scan representing a cross-section of rock with brittle star fossils.

The fossil brittle stars were recognised as members of the Family Protasteridae, but were a genus and species new to science – although long extinct and only distantly related to modern-day brittle stars. Mhairi has recently co-authored a paper with British fossil echinoderm expert Dr Aaron Hunter, Dr Taylor and her MSc supervisor Dr Emese Bordy, formally describing the new species. She named it *Gamiroaster tempestatis*.

"For the genus name, it had to end in *'aster'* [Greek for star], but I wanted to name it something African, so I went with *'Gamiro'*, which is the Khoikhoi word for a star in the sky – although I had to take out the click syllable!" explains Mhairi. "The species name, *'tempestatis'*, refers to the storm that smothered the animals."

The fossil-bearing rocks have now been curated in the Iziko South African Museum, and it is hoped that the 3D microCT images will form part of a future display.

- Fossils are protected by the National Heritage Resources Act (*No. 25 of 1999*) and may not be destroyed, damaged, altered, excavated or removed from their original site, without a permit from the relevant heritage resources authority. The necessary permits were obtained in order to conduct this research.

Article by Sue Matthews, images courtesy of Mhairi Reid.
For more detail, and access to the 3D model of the fossil bed, refer to the open-access paper: Reid et al. (2019) in GigaScience, Vol. 8 (3). https://doi.org/10.1093/gigascience/giy156
A short animation entitled 'A 3D visualisation of a microCT dataset of fossil starfish in an ancient sea bed' is available on the GigaScience Journal's YouTube channel.

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