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Pleistocene ichnological geoheritage in national parks on the Cape coast

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Aeolianites and cemented beach deposits on South Africa's Cape coast preserve evidence of events that transpired on them when they were composed of unconsolidated sand. Over the past decades, numerous Pleistocene vertebrate tracksites have been identified on aeolianite palaeosurfaces in the Garden Route National Park, West Coast National Park, and Addo Elephant National Park. In the Garden Route National Park alone, 57 Pleistocene vertebrate tracksites have been discovered. An equilibrium exists, whereby new sites become exposed through cliff-collapse events, while known sites slump into the ocean, are eroded through the action of wind and water, or are destroyed through wave action. Engraved graffiti poses a further threat. These sites complement the traditional body fossil record, and have significant palaeoenvironmental and palaeoanthropological implications. Hominin sites are of global importance: one contains the oldest tracks attributed to Homo sapiens, others contain patterns made in sand by ancestral humans and constitutes a form of early palaeoart. Collectively, these sites have substantial geoheritage value. The discoveries create management questions: which sites require active management, and how should they be ranked in importance? Factors which need to be considered in developing a management strategy include the scientific and heritage value of the sites, whether recovery or replication is preferable, the presence or absence of suitable repositories, the level of the threat to site integrity, the accessibility of the site, and the feasibility of recovery. Checklists containing appropriate criteria and questions can form tools in assessing the importance of these ichnosites.

Keywords: aeolianite; vertebrate tracksite; graffiti; hominin; palaeoenvironment; palaeoanthropology; ranking.

Introduction

Aeolianites (cemented dunes) and cemented beach deposits are well preserved on the Cape coast of South Africa, and have the capacity to preserve evidence of track- and trace-making activity that was registered on them when they were composed of unconsolidated sand (Helm 2023). Through the Cape South Coast Ichnology Project, our research group has identified more than 350 vertebrate ichnosites (trace fossil sites) in these Pleistocene deposits, spanning the coastline from Arniston in the west to the Robberg Peninsula in the east (Figure 1). The coastal section of the Garden Route National Park, under the jurisdiction of the South African National Parks (SANParks), forms part of this coastline, along with other protected areas that fall under the jurisdiction of CapeNature (De Hoop Nature Reserve, Geelkrans Nature Reserve, Goukamma Nature Reserve and Robberg Nature Reserve) as well as private nature reserves. In the coastal section of the Garden Route National Park alone, 57 vertebrate ichnosites have been identified. We have begun to explore the coastline further east and west, including the area in and adjacent to the West Coast National Park, Walker Bay Nature Reserve and the Addo Elephant National Park. In all these geographical localities, Pleistocene ichnosites were found in significant numbers (Figure 1).

The age range of these rocks on the Cape south coast extends from ~400 ka at Dana Bay (Roberts et al. 2012) to ~35 ka at Robberg (Carr et al. 2019). The Cape coastline is subjected to varying amounts of erosion, through high tides, storm surges, and forces of wind and rain. Ichnosites are best

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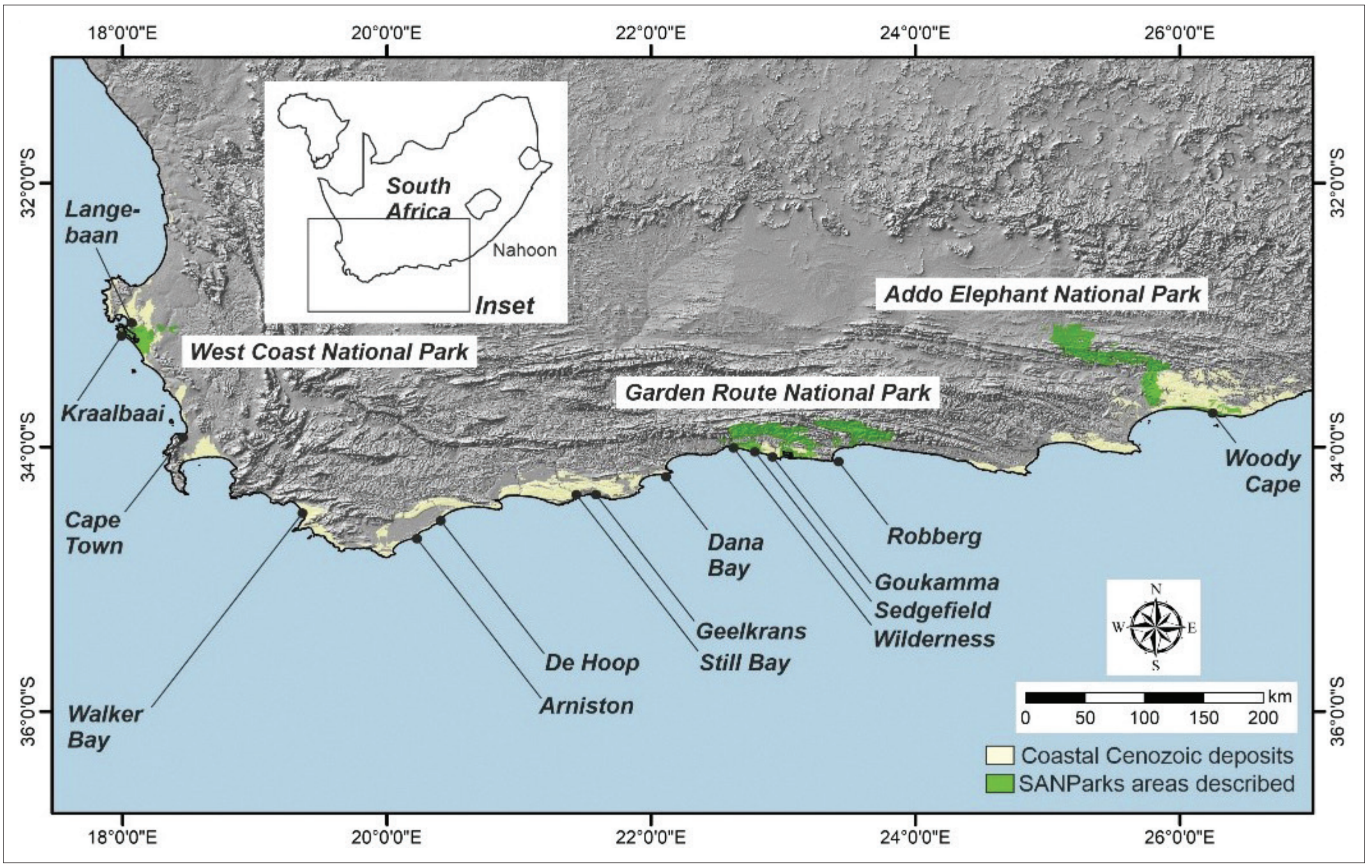


Source: Image by Hayley C. Cawthra

FIGURE 1: The Cape coast of South Africa, indicating national parks, sites mentioned in the text, and the distribution of Cenozoic deposits.

studied and interpreted within a short time window after their exposure (typically after cliff-collapse events and rockfalls). The 'half-life' of such sites may be as short as weeks, before fine detail becomes obscured or loose, track-bearing blocks and slabs slump into the sea. Unfortunately, graffiti in the form of engravings is emerging as an increasing threat to ichnosites, as aeolianite surfaces form an attractive canvas for such activity (Helm et al. 2021a). A dynamic equilibrium thus exists, whereby new sites are exposed and known sites deteriorate in quality or disappear. Furthermore, prodigious movements of sand along the shoreline result in some important sites being covered by metres of sand for years, and then occasionally exposed for only a few days (Helm 2023).

Ichnology (the study of tracks and traces) provides a census of the creatures (including our hominin ancestors) that once walked on, ran on, burrowed in or left other traces of their activities on these ancient dunes and beaches. We have repeatedly demonstrated the capacity of the trace fossil record to complement and enhance the body fossil record. For example, the Pleistocene presence of giraffe (Helm et al. 2018), sand-swimming golden moles (Lockley et al. 2021), large birds (Helm et al. 2020a), crocodiles (Helm et al. 2020b), breeding sea turtles (Lockley et al. 2019) and giant tortoises (Helm et al. 2022a) on the Cape south coast is known only through their fossilised tracks. Indeed, the body fossil record and trace fossil record exhibit different biases: the more easily transported bones of smaller animals tend to predominate at archaeological rock shelters and scavenger dens, whereas the deeper tracks of larger animals are often better preserved and are easier to recognise and interpret (Helm 2023).

The two types of fossil record (body and trace) therefore have the synergistic potential to complement and corroborate each other. Ichnology had a relatively late start on the Cape south coast (Roberts et al. 2008), although the first reported discovery from southern Africa was from Nahoon near East London in the Eastern Cape province in 1964 (Mountain 1966): three hominin tracks were identified in a coastal aeolianite deposit, and two were recovered and housed in the East London Museum. They were subsequently dated through Optically Stimulated Luminescence (OSL) to ~126 ka (Jacobs & Roberts 2009).

The geoheritage value of the Pleistocene Cape coastal deposits forms part of an increasing global appreciation of such sites. Geoheritage is the abbreviated version of the term 'geological heritage'. It can include, *inter alia*, *in situ* elements (geosites) and *ex situ* elements (collections of specimens in museums or other suitable repositories) with paleontological significance. At a national level, the Geological Society of South Africa states that 'Geoheritage is a descriptive term applied to sites (geosites) or areas of geologic features with significant scientific, educational, cultural or aesthetic value' (https://www.gssa.org.za/?page_id=6289). International bodies such as the International Union for the Conservation of Nature

(IUCN) have addressed the concept of geoheritage and made it relevant to the United Nations 2030 Agenda for Sustainable Development goals (https://www.iucn.org/sites/default/files/2022-09/progeo_leaflet_en_2017.pdf). The United Nations Educational, Scientific and Cultural Organization (UNESCO) Global Geoparks protect sites with particular geological value that are hence worthy of safeguarding for the benefit of present and future generations (https://www.unesco.org/en/iggp/geoparks/about).

The portions of the Cape coastline described here are of substantial global geoheritage importance, in part because of the wealth of palaeontological and palaeoenvironmental data that have been accumulated, but in particular, because this is an area where modern humans survived in the Middle Stone Age during the relatively harsh conditions of Marine Isotope Stage 6, and then appear to have thrived during Marine Isotope Stage 5 and subsequently (e.g. Brown et al. 2009, 2012; d'Errico et al. 2005; Henshilwood et al. 2001, 2002, 2018; Marean 2010; Marean et al. 2007). This occurred in association with remarkable shifts in the location of the coastline as a result of Pleistocene sea-level oscillations (Fisher et al. 2010). It is remarkably serendipitous that, in this area where our distant ancestors 'found their feet', the coastal zone geology from the same time period is characterised by some of the best-preserved and most widely accessible aeolianites in the world (e.g. Bateman et al. 2011; Brooke 2001), and that these surfaces are amenable to our interpretation. The region is thus of critical importance in hominin ichnology, and the palaeoanthropological inferences and implications of new discoveries may be unprecedented and profound. Each can be celebrated as a miracle of preservation (Helm 2023).

Aeolianite track-bearing surfaces on the Cape coastline are of scientific, cultural, palaeoenvironmental, heritage and aesthetic importance. The exposure of such sites is not new – they have likely come and gone through the ages. What is indeed new is our capacity to recognise and document them, and to appreciate their geoheritage value. This raises the issue of how best to manage the integrity of such sites. Is there a means of ranking their importance? Are repeated searches, identification, documentation, reporting and publishing of findings sufficient, or is there a desire, responsibility or obligation to manage identified sites more actively, in fields such as preservation, replication, recovery, exhibition and education? Recovery initiatives from the Garden Route National Park (by truck), West Coast National Park (by helicopter) and east of Still Bay (by helicopter) provide examples of such successful endeavours.

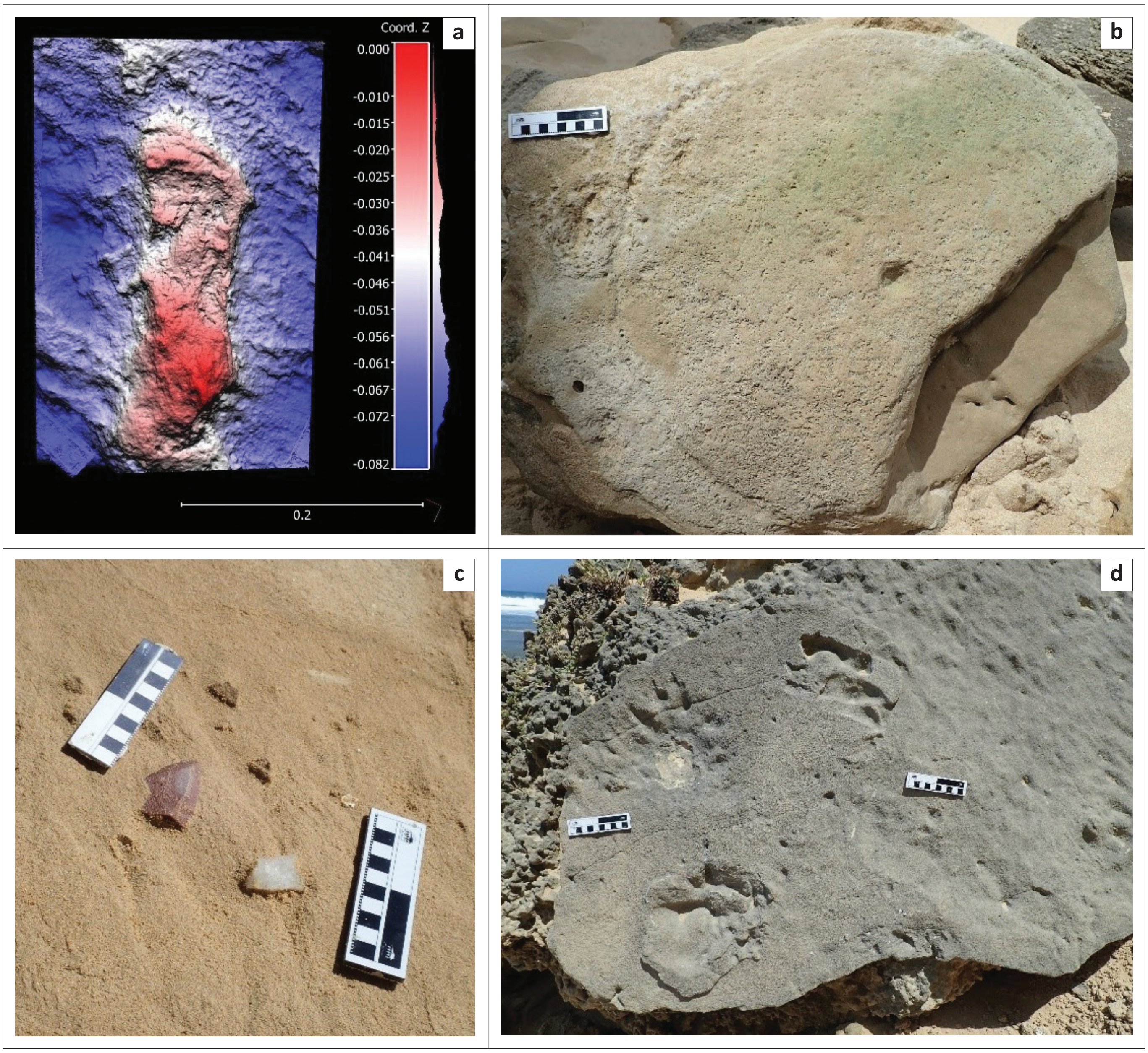
The purposes of this article are to: (1) briefly review the contrasting ichnological attributes of three Cape coastal national parks: Garden Route National Park, West Coast National Park and Addo Elephant National Park, (2) consider examples from other continents that document how palaeoichnological heritage has been approached and managed, (3) suggest an approach that may be regionally effective in South Africa and (4) consider examples of recovery, replication and preservation from the Cape coast.

Garden Route National Park

The 1210 km^2 Garden Route National Park encompasses mountain catchments, indigenous forests, fynbos and coastline. One stretch of coastline is of relevance here, extending for 25 km from near Wilderness in the west, past Kleinkrantz and Gericke's Point, to Platbank (east of Sedgefield) in the east. Fifty-seven vertebrate ichnosites have been identified within this coastal area of beaches and aeolianite cliffs. The eastern boundary at Platbank is contiguous with the Goukamma Nature Reserve, administered by CapeNature, in which a further 65 vertebrate ichnosites have been identified. Track-bearing surfaces are encountered in two formations: aeolianites of the Waenhuiskrans Formation (Malan 1989) and cemented beach and lagoonal deposits of the Klein Brak Formation (Malan 1991). Our OSL dating studies, performed at the University of Leicester in the U.K., confirm that the basal stratigraphic sites in the Gericke's Point area are the oldest sampled thus far – dating to ~150 ka – and those to the east (just east of the eastern park boundary) are younger at ~75 ka – 71 ka (Helm et al. 2023a). Sites in the Wilderness-Kleinkrantz area have previously been dated to ~133 ka – 131 ka (Bateman et al. 2011). While many portions of this coastline remain relatively pristine, the presence of many coastal communities and easy access points, combined with a burgeoning regional population, has led to some areas being more heavily visited. While graffiti was not a significant problem in the past, its unwelcome presence has been increasingly noted in recent years, although not to the extent seen in the West Coast National Park. Cliffs along parts of the coast are undergoing rapid erosion; some important documented sites have been buried in landslides or have slumped into the sea, while new sites are frequently exposed.

From the cornucopia of 57 sites, the following are selected for mention here as being novel, unusual or of particular significance:

- Hominin tracks dated to 153 ka ± 10 ka (Figure 2a) are the oldest thus far identified for *Homo sapiens* (Helm et al. 2020c, 2023a).
- A suite of ammoglyphs (patterns made by ancestral hominins in unconsolidated sand, now evident in cemented rock) includes a large circular groove with a central depression that suggests how it was made (Figure 2b – Helm et al. 2019). Our OSL studies indicate a date of 136 ka ± 8 ka, and thus these ammoglyphs can be regarded as among the oldest examples of 'palaeoart' thus far identified (Helm et al. 2023a). Beside them, two rocks containing features suggestive of human foraging with a long stick were present (Figure 3a–c, Helm et al. 2019). Three of these rocks, including the circular groove feature, were recovered by SANParks staff, as described below. A 2022 landslide has obliterated the site.
- One site, identified in 2018, contained both probable hominin tracks and associated ammoglyphs, but within

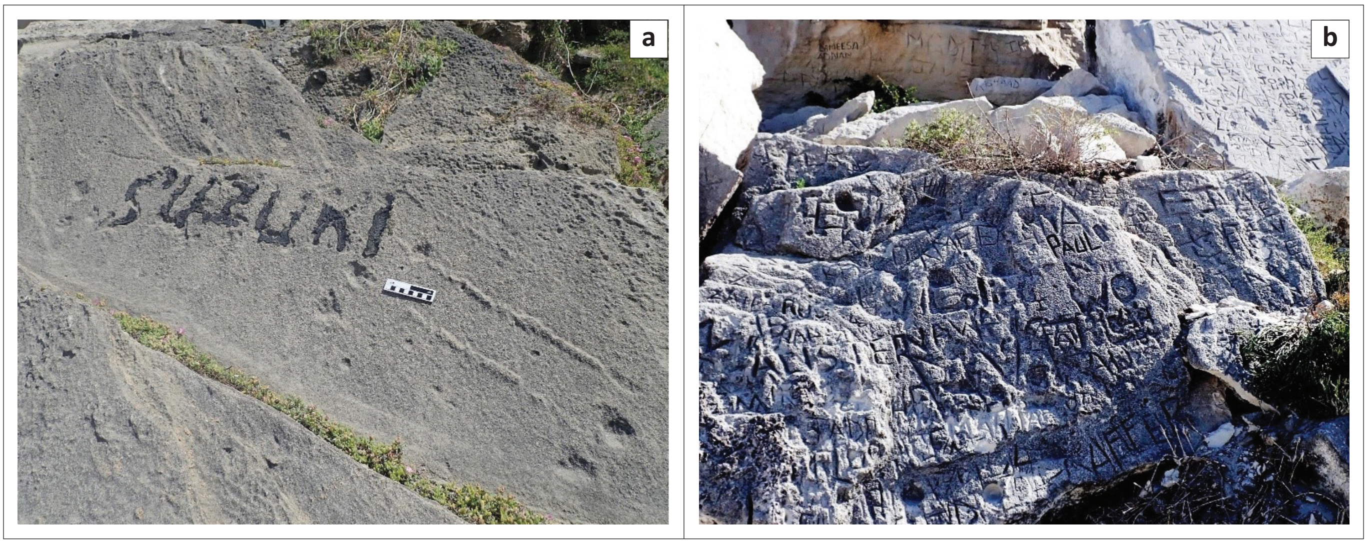


Source: (a) Photogrammetry and photographs taken by Charles W. Helm, on (b) 30 Nov. 2018; (c) 28 Nov. 2018; (d) 19 Nov. 2018

FIGURE 2: (a) 3D photogrammetry image of hominin track, Garden Route National Park – vertical and horizontal scales are in metres; (b) circular ammoglyph with a central depression, Garden Route National Park; (c) Middle Stone Age lithics embedded in a track-bearing aeolianite surface, Garden Route National Park and (d) crocodylian racks, Garden Route National Park. Scale bars in (b), (c) and (d) are all 10 cm long.

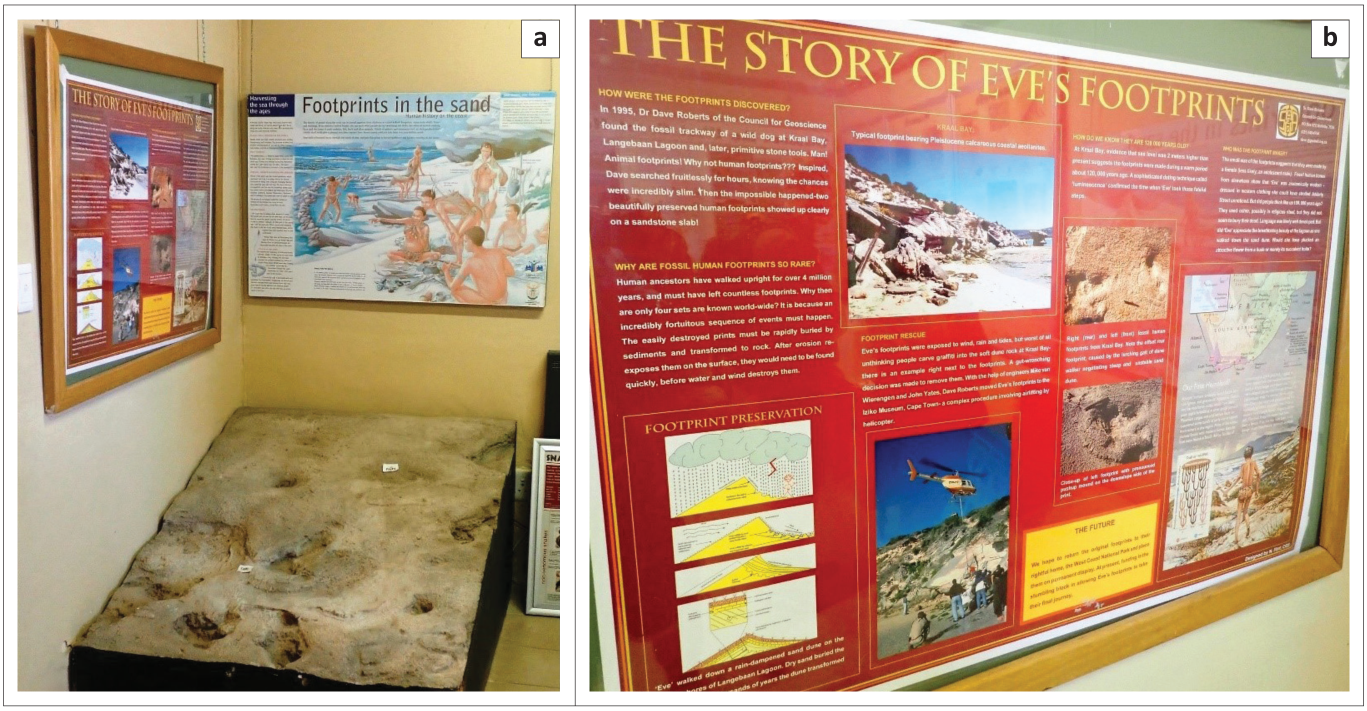
weeks the surface deteriorated rapidly in quality before it could be adequately documented (Figure 4, Helm et al. 2019). Within months it had slid into the sea.

- Middle Stone Age lithics (Figure 2c) were found embedded in a surface that contained crocodile, monitor lizard, hyena and small bird trackways (Helm et al. 2020b). The track-bearing block was buried in a subsequent landslide, but much of it was re-exposed in a storm surge event.
- Crocodile tracks (Figure 2d) provided unexpected evidence of an expanded range during a warmer phase in the Pleistocene (Helm et al. 2020b), and crocodile swim traces were the first reported from Africa (Helm & Lockley 2021).
- Tracks of the giant Cape zebra (*Equus capensis*) and long-horned buffalo (*Syncerus antiquus*) have contributed to the understanding of the distribution ranges of these extinct species (Helm et al. 2023b).
- Numerous elephant tracks have been identified, much more than would be expected from the body fossil record (Helm et al. 2021b). We have demonstrated that elephant tracks were precursors to some potholes, in a palaeobeach deposit on the coastline (Helm et al. 2021c).
- The only example we have observed thus far of a lagomorph (hare) trackway was unfortunately defaced by engraved graffiti (Figure 3a) and daubed with an erosion-resistant black substance (Helm et al. 2021a).



Source: Photographs taken by Charles W. Helm, on (a) 25 Nov. 2019; (b) 17 Nov. 2019

FIGURE 3: (a) Graffiti defacing a hare trackway, Garden Route National Park – scale bar = 10 cm; (b) a concentration of graffiti on aeolianite surfaces, West Coast National Park.



Source: Photographs (a) and (b) taken by Charles W. Helm, on 17 Nov. 2019

FIGURE 4: (a) and (b) Interpretive signage above a replica of 'Eve's Footprints', Geelbek Visitor Centre, West Coast National Park.

Subsequently, most of the surface was buried by a landslide in 2022.

- Tortoise and terrapin tracks were among the first of their kind to be described (Helm et al. 2022a).
- A hatchling turtle trackway consistent with that of a loggerhead turtle (*Caretta caretta*) contributed to the inference that sea turtles successfully bred on the Cape south coast during the Pleistocene (Lockley et al. 2019).
- Tracks and traces of large birds contributed to the understanding of extinct large Pleistocene birds in the region, and/or larger subspecies of extant birds (Helm et al. 2020a). The first examples of avian tracks evident in cross section and flamingo feeding traces were also reported (Helm et al. 2020a). This is one of the fragile sites that was destroyed in a single storm surge event.
- Coprolites embedded in Pleistocene palaeosurfaces have helped us realise that such fossilised scat is quite readily preserved as raised features in and adjacent to tracks (Helm et al. 2022b). We continue to collaborate with colleagues who perform special tests on such samples, in the hope of determining palaeoenvironmental implications.

An excellent relationship has been established between our research team, SANParks management and staff, and

Heritage Western Cape. This was epitomised by the recovery of the circle ammoglyph (and the two rocks suggesting foraging activity) from the beach near Gericke's Point, with the deployment of a strong work crew and a truck in 2019. Given the lack of suitable storage space or exhibit space in the Garden Route National Park, a long-term loan agreement was concluded with the Blombos Museum of Archaeology in Still Bay. The specimens were transported to Still Bay, where they were accessioned in the museum and are currently on exhibit. In another example of collaboration, Lizette Moolman, a SANParks researcher, provided extremely valuable input as a co-author in our published study on elephant tracks and traces (Helm et al. 2021b).

In summary, of the three parks considered here, the Garden Route National Park has been home to our most intensive and repeated study, as evidenced by the large number of ichnosites identified, and the many resulting publications in peer-reviewed southern African and international journals. The area appears to be particularly vulnerable to erosion, landslides and storm surges, with a resulting high turnover rate of ichnosites. Graffiti has not reached epidemic proportions, but its increasing presence is worrisome. The excellent relationship between our research team and SANParks has been fundamental to our success, while the lack of suitable storage and exhibit space is acknowledged.

West Coast National Park

Modern graffiti occurs in abundance on aeolianite surfaces in the Langebaan area, including the national park (Figure 3b). Undoubtedly, from an ichnological perspective, the West Coast National Park is best known for the three hominin tracks that were identified on an aeolianite surface at Kraalbaai and attributed to *Homo sapiens* in 1995 by David Roberts (Roberts 1996; Roberts & Berger 1997). Roberts (2008) provided a more detailed summary of the tracks (which were dated to ~117 ka) and also reported fossilised hyena tracks. The discovery of hominin tracks created intense interest, and they became popularly known as 'Eve's footprints', even becoming the subject of a book (Berger & Hilton-Barber 2000).

The tracks were airlifted by helicopter to the Iziko South African Museum in Cape Town, where they are on display. A replica of the tracks is on exhibit at the Geelbek Visitor Centre, along with interpretive text (Figure 4), which also appears on signage near the discovery site.

A graffiti artist had reached the surface containing the hominin tracks before Roberts did. Fortunately, the graffiti narrowly missed defacing the tracks. The threat of further graffiti on the surface probably played a role in the decision to recover the tracks by helicopter and to have them accessioned in a recognised facility. Other tracks are detectable in the vicinity, but have either not been formally studied or are not identifiable because of the presence of graffiti.

Almost two decades earlier, in what was the first documentation of fossilised tracks from the west coast, Tankard (1976) had reported on a large carnivoran trackway on an aeolianite surface at Kraalbaai, also attributed to a hyena. All the tracks were found in the Langebaan Formation of the Sandveld Group (Roberts et al. 2006).

After a hiatus of more than a quarter century, two probable hominin tracks were reported just outside the national park boundary by our research team (Helm et al. 2022c). The tracks occurred as natural casts on the ceiling of a small cave.

In summary, the ichnological attributes of the West Coast National Park provide an intriguing mix. Graffiti is rampant and will need to be addressed to protect the palaeontological heritage of the park. It is pleasing, though, that the tracks were rescued in the nick of time and are curated at a museum. They were appropriately replaced by an impressive exhibition and interpretation of the tracks.

Addo Elephant National Park

Since 2020, members of our research team have explored the remote Woody Cape coastal portion of the park, an area which forms part of the Alexandria hiking trail. Other than by registered hikers and park staff, human presence in this remote area is minimal, and graffiti does not appear to be a significant issue.

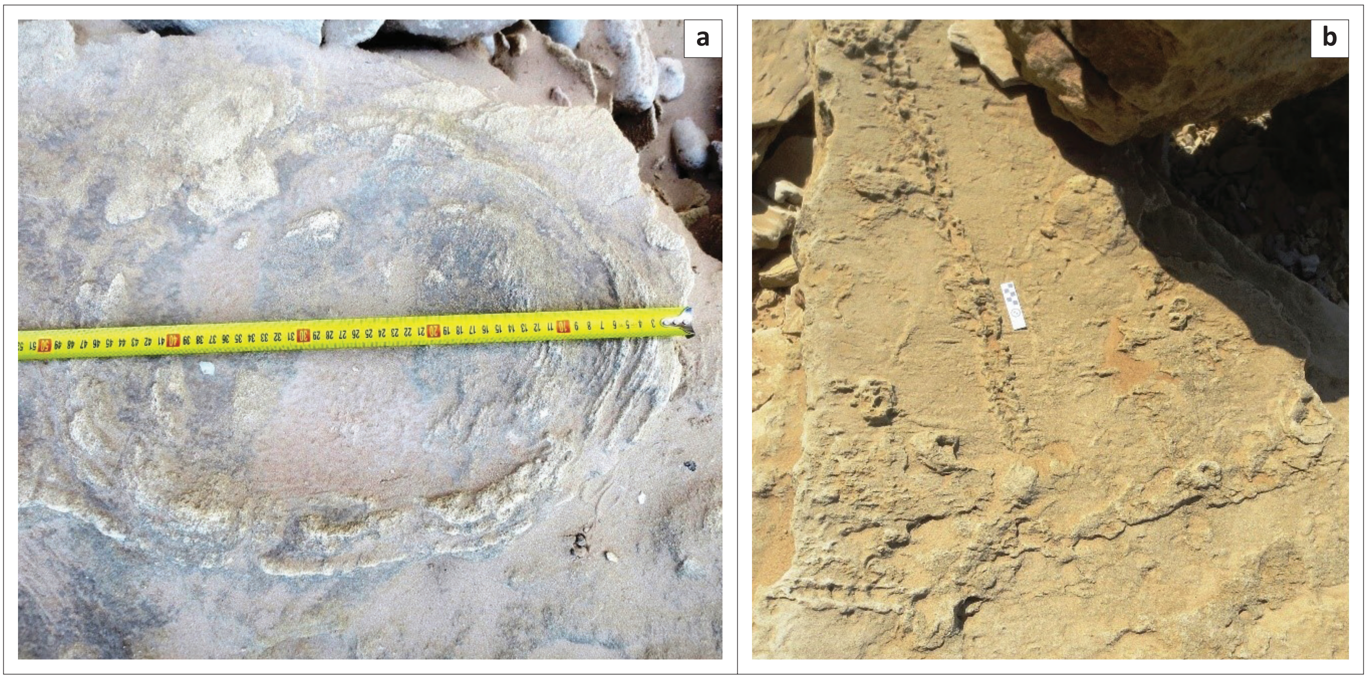
Brief surveys in 2020 of aeolianite surfaces resulted in, *inter alia*, the identification of fossilised elephant tracks (Figure 5a) and a probable hominin trackway. The tracks occur in the Nahoon Formation of the Algoa Group (Le Roux 1989). Sand-swimming golden mole traces (Figure 5b) formed the holotype for the new ichnogenus and ichnospecies *Natatorichnus sulcatus* (Lockley et al. 2021). The presence of large dune fields in the Pleistocene was inferred.

Given the obvious relevance of the discovery of elephant tracks in a national park that is globally renowned for its elephant population, communication ensued with park management and staff. Discussions have begun on the possibility of recovering specimens and exhibiting them in the interpretive centre in the Addo Main Camp, or otherwise interpreting this resource through replicas, photographs and text panels. A thorough coastal survey aimed at documenting all ichnosites will form an appropriate starting point.

In summary, research in Addo Elephant National Park is at an early stage. Tracksites are located in a remote area, which is likely the reason why graffiti is minimal. There is substantial potential for collaboration with SANParks management and staff on the exhibition and interpretation of the known fossil elephant tracks in a park themed around this mammal species.

Initiatives from other continents

Addressing the heritage value of such a resource begins with understanding it. It is incumbent upon researchers to



Source: Photographs (a) and (b) taken by Jan C. De Vynck, on 07 Mar. 2020

FIGURE 5: (a) Elephant track, Addo Elephant National Park – tape measure in cm.; (b) sand swimming golden mole traces, Addo Elephant National Park – scale bar = 10 cm.

inform jurisdictional authorities such as the South African Heritage Resources Agency (SAHRA), Provincial Heritage Resource Authorities (e.g. Heritage Western Cape), SANParks, CapeNature, local municipalities and private landowners, of discoveries. In fact, SAHRA sets minimum standards with regard to the palaeontological component of heritage impact assessment reports (https://sahris.sahra.org.za/sites/default/files/website/articledocs/PIA%20Min%20Stds.pdf).

While annual reports are a necessary requirement, given the potential rapid turnover or brief exposure of ichnosites, a collaborative relationship in which newly identified sites deemed to be of critical importance can be rapidly reported, and their significance assessed (ideally within days), is clearly advantageous. A haphazard approach in which such sites are assessed on an urgent case-by-case basis is obviously suboptimal, and an approach that has been agreed upon in advance can help to address the management challenges that come with such discoveries. Using objective criteria and minimising subjective elements will allow informed decisions on which sites require more active management, and how they should be ranked in importance.

As there do not appear to be similar initiatives in Africa, it is instructive to consider examples from other continents, which include criteria for the ranking of fossil ichnosites in terms of their international, national or regional importance. Lockley and Schumacher (2021) developed a ranking system for dinosaur tracksites in the United States of America (USA), following earlier work on sites in the Iberian Peninsula by Alcalá et al. (2016). Such initiatives might not be fully applicable to Cape coastal ichnosites, but 'pearls of wisdom' can potentially be gleaned and applied to the region. For example, the above-mentioned initiatives were broad in their scope and included criteria that considered sites' educational, scientific and cultural value via links to UNESCO criteria. These ultimately allow for the inscription of sites as being of 'Outstanding Universal Value'.

Criteria included:

- site size
- accessibility
- potential visitor traffic
- number of trackways
- number of holotypes
- preservation quality
- number of peer-reviewed published works
- other significant documentation such as guidebooks.

It was recognised that the process was dynamic, with new sites being discovered and others becoming eroded or degraded. Decisions based on isolated criteria, for example, the 'longest, oldest or largest', were not viewed alone as comprehensive criteria for ranking sites. As many as 24 criteria were employed in these studies, each with a point score of 1–5.

Applying such considerations to the Cape south coast ichnosites leads to practical questions, particularly in terms of which sites require active management, replication (e.g. through photogrammetry and 3D printing), or recovery (Helm 2023). Some of the above criteria may not be applicable to national parks on the Cape coastline. For example, site size was regarded as an important factor in the USA, which is known for its 'megatracksites' (often preserved as resistant, indurated surfaces) whereas large track-bearing surfaces are rare on the Cape coast. Moreover, the potential risk of vandalism may vary from region to region, and while educational initiatives through guided site visits are laudable, the resulting increase in awareness brings a risk of increased site vandalism unless adequate protection can be ensured. The latter is a challenging, almost insurmountable task, aggravated by the effects of unstable slopes and storm surges on any attempts to install gates or other protective devices.

Recovery or replication?

Until relatively recently, replication involved applying latex or silicone to tracks or track-bearing surfaces, and using the resulting peels to generate accurate replicas. These methods are not without risk of damaging the tracks. Additionally, leaving layers of latex applied to such surfaces for a day or two can draw unwanted attention. Furthermore, latex peels shrink slightly over time. Such concerns have become obsolete with the advent of 3D photogrammetry (Falkingham 2012; Matthews, Noble & Breithaupt 2016). This non-invasive technique has the advantage of contributing to the 'open data' movement within science in allowing researchers anywhere to confidently download and evaluate track images. It can also allow the generation of 1:1 replicas using evolving 3D printer technology. Disadvantages include the size and cost limitations currently inherent in making such replicas, but the technology has already been applied through the creation in 2019 of a 1:1 replica of a Cape south coast fossil hatchling turtle trackway. Indeed, a comprehensive photogrammetry database has been created for long-term documentation of the most important Cape coastal ichnosites, including those in the national parks, and we have never had to resort to the antiquated techniques of using latex or silicone.

Related to this is the topic of the physical recovery of specimens, for which an argument can be made for a ranking system. This represents a substantial undertaking, with financial and manpower considerations. In addition, there is a small but non-negligible risk of damaging or destroying specimens through such efforts, be they by helicopter or ground transport. Regulatory bodies (e.g. Heritage Western Cape) and management bodies (e.g. SANParks, CapeNature, local municipalities) or the owners of private nature reserves may be interested in the 'value' of ichnofossil sites in the areas under their jurisdiction before undertaking such efforts. The goal would be well-informed decision making on the appropriateness and feasibility of recovering specimens. The presence or absence of suitable museums or repositories would also guide this process and the associated permitting (Helm 2023).

Developing a ranking checklist

Ranking considerations include the ease of removal, the scientific value and uniqueness of the specimen, whether further research might become feasible on accessioned specimens and whether recovery might enhance educational potential. With such considerations in mind, the following criteria are presented as a checklist of 17 questions in five categories (modified from Helm 2023) as a starting point in developing an approach to fossil ichnosites on the Cape coast:

- Uniqueness and scientific value:
  - Are globally unique track types present?
  - Is there palaeoanthropological heritage value?
  - Are nationally or regionally unique track types present?
  - Is the quality of preservation of a suitably high standard?
  - Are holotypes present?
- Threats in current location:
  - Is there a high likelihood of vandalism if not recovered?
  - Is there a high threat of damage through erosion if not recovered?
  - Is there a threat of slumping into the sea if not recovered?
- Accessibility and feasibility:
  - Is there ready accessibility?
  - Are means of recovery available and feasible (e.g. 4WD vehicle, ATV, helicopter)?
  - Is the specimen *in situ* or *ex situ*; if *in situ*, can it easily be removed?
  - Is it portable?
- Research and education value:
  - Have peer-reviewed articles been published or are they planned?
  - Will further research be enabled if recovery is successful?
  - Is there high education value if an exhibit featuring the recovered specimen is developed?
- Post-removal care:
  - Is there a management body interested in protection and recovery?
  - Is there a suitable repository?

The following potential categories were considered but not included:

- Site size
- Number of tracks and trackways
- Number of track levels
- Historic value
- Visitation potential if not recovered
- Presence of other nearby sites

The above list of questions thus builds upon the criteria of Lockley and Schumacher (2021) and Alcalá et al. (2016). It relates to the specific characteristics of Pleistocene deposits on the Cape coast and their vulnerability to erosion and burial. It addresses the practical issues of protection from vandalism, geoheritage value and recovery. It is presented primarily for initial guidance, acknowledging the possibility of future amendment as required. It aims to provide practical methods that are specific to the region to protect the Cape coast; in this context, a lengthy list might be unnecessarily cumbersome.

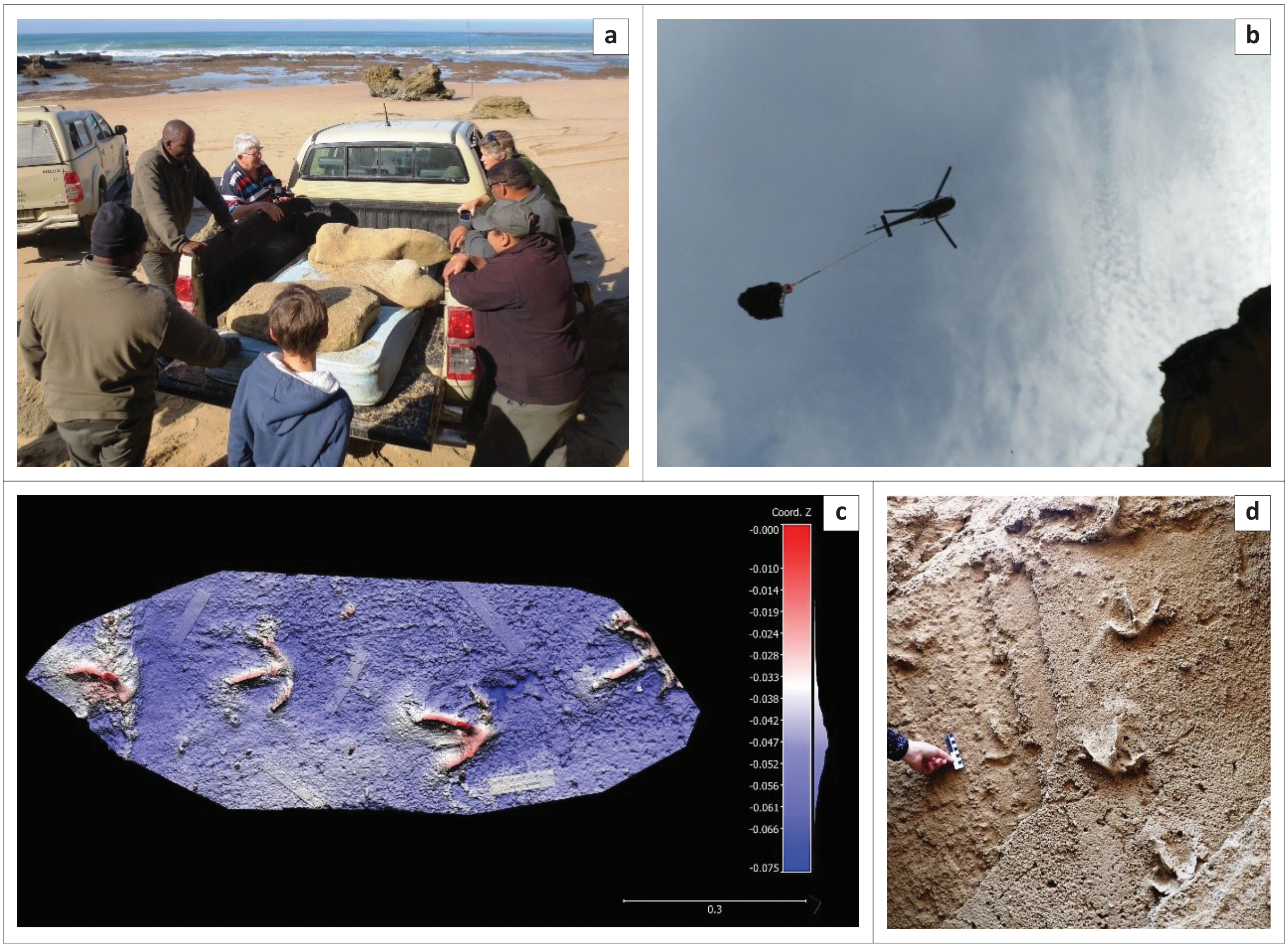
Collaboration between researchers as well as regulatory and management authorities could allow the weighting of criteria and the assignment of scores, with joint decision-making on what score might qualify for action to be initiated. In addition, a decision could be taken on whether certain criteria might be 'deal-makers'. While considering these possibilities is important, the starting point is simply to begin such discussion, with the understanding that a rapid process is optimal once a site is identified and reported, in order to minimise any risks of deterioration or destruction.

On a final note, we have heard the opinion expressed that the most appropriate approach to this heritage resource is to do nothing. According to this argument, these ichnosites have come and gone over millennia in cycles of exposure and erosion; this needs to be respected as part of 'time's arrow', and there is no need to interfere with this process. While we acknowledge this argument, we do not share the same view as its proponents. From our perspective, these are among the most important rocks in the world. It is true that in previous times they have come and gone, but once we know that we can recognise their patterns and can appreciate their geoheritage and other values, we accept an obligation to do our best to manage this resource for the benefit of all. In short, unlike the past when sites were not studied and were left to the vagaries of erosion, scientific intervention and resource management now form essential ichnological facets of understanding the geosphere and palaeobiosphere.

Recent examples

The following five examples serve to illustrate a number of successful recovery or replication initiatives. Three of them are from within national parks:

- The recovery of 'Eve's footprints' in the West Coast National Park has been alluded to above. The fact that graffiti had not impinged on the tracks was fortuitous. Although consideration may have been given to preserving and interpreting them *in situ*, their global heritage importance, the imminent threat of more graffiti and the logistical challenges of continuously policing such a site led, in our opinion, to a correct (if reluctant) decision to airlift them to a safe repository. The subsequent exhibition of the original tracks in the Iziko South African Museum, and track replicas in the West Coast National Park, can be viewed as a success story which has brought information, pride and joy to many residents and visitors.
- The recovery, from the Gericke's Point area in the Garden Route National Park, of the circle ammoglyph and associated rocks provides evidence of the kind of collaboration that can be achieved through our research team and SANParks (Figure 6a). Hurdles such as the absence of a suitable repository, storage and exhibition space were overcome through the loan agreement with the Blombos Museum of Archaeology, with support from Heritage Western Cape. Spring low tide, a strong and willing workforce and 4WD vehicles combined to result in a flawless operation that led to the creation of an engaging display in the museum, where the rocks have already been appreciated by thousands of visitors. The timely wisdom of this 'intervention' in 2019 is evidenced by the subsequent landslides in 2022, debris from which now covers the site. Without these efforts, what may be among the oldest palaeoart ever identified might have been lost forever.
- Compared with the Garden Route National Park site, an ammoglyph site east of Still Bay (Helm et al. 2021) involved additional challenges. It was dated to 139 ka ± 10 ka (Helm et al. 2023a). It initially comprised two adjacent rocks with large triangular patterns; one angle exhibited a bisecting groove, resembling a purported female fertility motif (Gimbutas 1989; Leroi-Gourhan 1982). The significance of the site was apparent. However, over time, the smaller rock was destroyed by tidal forces, and we knew that without intervention, the larger rock would likewise be destroyed. It lay at the foot of 30 m-high cliffs in a remote location, and weighed an estimated 500 kg. Members of our research team received funds through the Knysna Basin Project, an initiative focusing on coastal system research. The funds raised were used in a rescue initiative by helicopter. A permit was obtained from Heritage Western Cape to proceed, along with the approval of the landowner. This enabled the rescue of the rock by helicopter (Figure 6b), and the development of an exhibit in the Blombos Museum of Archaeology, which now contains all the ammoglyphs recovered thus far. There was considerable media attention (e.g. https://theconversation.com/rock-stars-how-a-group-of-scientists-in-south-africa-rescued-a-rare-500kg-chunk-of-human-history-192508). This example illustrates the successful collaboration that can be achieved between researchers, a supportive landowner, an accomplished helicopter pilot, a reliable local museum and a dedicated team of volunteers. The operation was filmed by our colleague Richard Webb: https://www.youtube.com/watch?v=L9kvwi_B4TI.
- Just west of Platbank, in the Garden Route National Park, an avian ichnosite was identified in 2018. It contained flamingo tracks and traces, larger than those of the extant greater flamingo (*Phoenicopterus roseus*). The features were preserved as natural casts on the ceiling of a small cave. In 2019, the site was fully documented, including through photogrammetry (Figure 6c), and the results with associated inferences were published (Helm et al. 2020a). The fragile, crumbling nature of the surface and its trace fossils was noted, and the short window of opportunity in which to enjoy and document it was appreciated (Figure 6d). It came as no surprise when the tracks and traces were destroyed during a storm surge in 2021. While the site may have disappeared, the 3D photogrammetric record is of lasting value, and is available should there ever be a desire to create a replica and exhibit these globally unique trace fossils.
- As noted above, one hominin tracksite in the Garden Route National Park, dated to 153 ka ± 10 ka, contains the oldest footprints that have thus far been attributed to *Homo sapiens* (Helm et al. 2023a). Since the identification of these tracks in 2019, their quality in some cases has deteriorated through erosion as a result of storm surges, especially in 2022. Again, 3D photogrammetric documentation (Figure 2a) provides a durable record. Without divulging



Source: Photographs (a) and (b) taken by Jan C. De Vynck, on (a) 04 Dec. 2018; (b) 29 Sept. 2022; (c) Photogrammetry and photograph (d), taken on 24 Sept. 2019 by Charles W. Helm

FIGURE 6: (a) The circle ammoglyph and associated rocks are loaded onto a mattress on the back of a truck by South African National Parks staff, Garden Route National Park; (b) recovery of ammoglyph east of Still Bay by helicopter; (c) 3D photogrammetry image of a flamingo trackway, Garden Route National Park – vertical and horizontal scales are in metres and (d) the fragile flamingo trackway prior to its destruction in a storm surge event.

the locality, other than stating that it lies within the Garden Route National Park, this was brought to the attention of the broader public (https://theconversation.com/worlds-oldest-homo-sapiens-footprint-identified-on-south-africas-cape-south-coast-205310). The article received more than 65000 views and was covered around the world, demonstrating considerable interest in the topic of Cape coastal hominin ichnology. Collaboration between our research team and SANParks staff could lead to an exhibit in the Garden Route National Park that celebrates this phenomenon.

Together, these five examples can serve as inspiration for a future approach in which newly identified ichnosites are rapidly evaluated. An informed, logical, collaborative decision-making process (using, for example, the questions and criteria listed above) would ensue and determine the most appropriate management approach to be agreed upon.

Conclusion

The Garden Route National Park, West Coast National Park and Addo Elephant National Park provide three examples with different attributes, strengths and weaknesses in terms of management of ichnological geoheritage. The increasing number of published research articles from the Cape coastline, and the public interest that has been generated, bear testimony to the magnitude and importance of this geoheritage, whether global, national or regional. Fortunately, many of the identified sites lie within the national parks and other protected areas.

We believe that it is incumbent upon researchers and management bodies alike to attempt to do justice to this resource, and to do their utmost to preserve it when this is indicated. The approach suggested here is a collaborative one, through agreement on a process whereby newly identified sites are rapidly ranked in importance, using a checklist of questions and criteria, followed by decisions on optimal management.

The collaborative relationships that have already been established augur well for the future implementation of such a process. Successful recent examples of recovery and potential replication can help guide this process forward.

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Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Authors' contributions

C.W.H., A.S.C., H.C.C., J.C.D.V., M.G.L., M.G.D., R.R., W.S., G.H.H.T., F.V.B. and J.A.V. contributed equally to this study and agreed upon the contents of the article for publication.

Ethical considerations

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Data availability

The authors confirm that the data supporting the findings of this article are available to researchers through the African Centre for Coastal Palaeoscience, Nelson Mandela University.

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