Chapter

San Master Trackers: Deploying Ancient Skills to Enhance Palaeo-Ichnological Interpretation on South Africa's Cape South Coast

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Abstract

Since 2023, Ju/'hoansi Master Trackers from the Nyae Nyae Conservancy in northeastern Namibia have assisted the Western-trained palaeo-ichnology team (based out of Nelson Mandela University) in the analysis and interpretation of Pleistocene vertebrate tracks. The resulting insights, gleaned from a fusion of two scientific perspectives, through which traditional scientific knowledge and modern scientific approaches are blended, have been profound and compelling. These include novel interpretations for nine vertebrate trackmaker groups, resulting in the publication of several peer-reviewed scientific papers, with more to follow. The results have helped to create an extra dimension to the discipline of palaeo-ichnology, while the partnership that has been forged is mutually beneficial.

Keywords: Ju/'Hoansi, San, Indigenous Master Trackers, palaeo-ichnology, Pleistocene, aeolianite

1. Introduction

The San ('Bushmen') of modern southern Africa possess one of the oldest distinct lineages of *Homo sapiens*, with genome sequencing signalling a history of more than 200,000 years [1–3]. They were hunter-gatherers then; pockets within their remaining clans are hunter-gatherers now. A range of physiological, cognitive, and cultural attributes would have contributed to their survival and adaptability over many millennia. We focus here on one of these attributes: their tracking ability, now gainfully repurposed to enhance the discipline of palaeo-ichnology. An ancient science has brought new resources to a modern one.

The skills of San trackers have developed a legendary mystique. Palaeo-ichnologist Martin Lockley noted that:

'. . . the Bushmen were masters at observing the subtle differences that distinguish (the) species of antelope, whose tracks would all seem the same or very similar to the footprint-illiterate western eye. . . the skeptical office-bound researcher may want measurements and statistical proofs that two or more tracks are different before accepting that they are distinct or applying scientific names to them. Such an approach would seem incomprehensible to the Bushman, whose ability to differentiate tracks, know the trackmaker with certainty and discern the subtlest nuances of behaviour they betray was second nature, and moreover proven by empirical experience: i.e., the species recognized from the track was always found at the end of the trail', [4], p. 14 and referred to '[the] Bushmen, who somehow possessed a form of holistic consciousness that allowed them to correlate tracks with animals with such consistency that observers claim they were never wrong'.

Van der Post [5] and Thomas [6] provided similar commentary, alluding to the remarkable tracking skills that astonished and bewildered early Western observers. Suzman [7] (p. 163) expanded on this skill:

'To be a good tracker requires engaging in a constant physical dialogue with the environment and ultimately an ability to project oneself into the animals that left the tracks. Like poetry, tracks have a grammar, a meter, and a vocabulary. But also like poetry, interpreting them is far more complex than simply reading sequences of letters and following them where they go'.

Liebenberg [[8] – p. 17] approached this from a scientific perspective:

'The apparent paradox [of how the human brain seems to have possessed capacities far in excess of their early evolutionary function] may be resolved if it is assumed that at least some of the first fully modern hunter-gatherers were capable of scientific reasoning, and that the intellectual requirements of modern science were, at least among the most intelligent members of hunter-gatherer bands, a necessity for the survival of modern hunter-gatherer societies'.

Since the inception of the Cape South Coast Ichnology Project in 2008, almost 400 Pleistocene vertebrate tracksites have been identified along a 350-km stretch of coastline on South Africa's Cape coast [9], and more than 50 peer-reviewed scientific articles have resulted to date. The project has been based out of the African Centre for Coastal Palaeoscience at Nelson Mandela University. Consequently, the global understanding of Quaternary ichnology (the study of tracks and traces) has been enhanced [10, 11].

The work of identifying these tracksites involves methodically walking the coastline, usually around spring low tide, searching for evidence left by Pleistocene trackmakers in unconsolidated dune and beach sand, now cemented into rock (aeolianites and cemented foreshore deposits). These outcrops occur in clusters, and their level of lithification and depositional style impacts whether tracks and traces are well-preserved or not. Re-examination of previously well-explored track-bearing areas is required after storm surges and particularly high tides, as coastal erosion is ongoing. These rocks are liable to be eroded by wave action, and many tracksites are ephemeral. An indent or protrusion may qualify as a track candidate, but the 'Holy Grail' is a sequence of tracks – a trackway, a repeating pattern that dispels all doubts about a biological provenance [12].

Noticing the traces is the initial step; reliably interpreting them and identifying the trackmaker are usually more challenging. Sometimes, subtle details may go unnoticed, while other observed phenomena remain perplexingly enigmatic.

This provides the context for the involvement of Ju/'hoansi Indigenous Master Trackers in our palaeo-ichnology work on the Cape south coast. We knew that discontinuous pockets of traditional hunter-gatherers and trackers remain globally, despite the fact that much of the knowledge that Indigenous peoples possessed has been lost over only a few millennia [13]. In southern Africa, there is growing concern about a vanishing body of wisdom [14]. The Cape South Coast Ichnology Project recognised an opportunity to collaborate with San trackers in order to apply aspects of their knowledge in a scientific space and to interpret ichnological features from a broader perspective.

The background to this collaboration arose from partnering with the trackers in more established terrain. One of us (CT) is involved in running wilderness trails in remote areas of the Greater Kruger National Park. Being a trail guide necessarily involves being able to interpret not just tracks but also all the surrounding signs. However, in contrast to those whose exposure begins at the toddler stage, late learners struggle to interpret these traces with proficiency.

The San once populated all of southern Africa, including what is now the Kruger National Park. Their artwork adorns rock surfaces throughout the subcontinent. However, their presence as a distinct people was often erased with the arrival of others in recent centuries – through eviction, assimilation, and outright extermination.

Amongst the last of the San still exercising their hunter-gatherer skills are the Ju/'hoansi of the Nyae Nyae Conservancy in north-eastern Namibia. The most accomplished among them have been recognised as 'Indigenous Master Trackers' through an accreditation program developed by CyberTracker (https://cybertracker.org/track/master-trackers/).

Leading trackers were enthusiastic about the prospect of demonstrating their tracking and interpretation skills on Kruger National Park walking trails, and in 2017, the first such initiatives began. Their impressive contributions to the trail experience led to lateral speculation: could their skills be re-deployed and applied to the field of palaeo-ichnology? The result was a connection between our Cape South Coast scientific team and Indigenous trackers from the distant Kalahari.

Our interest in this field coincided with an increasing global awareness of ancient Indigenous knowledge of palaeontology [15, 16]. We knew that our initiative followed other similar projects. For example, the 'Tracking in Caves' project involved Indigenous Master Trackers from Nyae Nyae collaborating with Western-trained scientists in western Europe in interpreting hominin tracksites [17–19]. Furthermore, those same trackers provided highly instructive assistance in the interpretation of prehistoric track depictions in Namibia's rich archive of rock art [20]. In both cases, the illuminating outcomes of these initiatives augured well for collaboration on Cape south coast Pleistocene ichnology.

Beginning in 2023, the expertise of trackers from the Nyae Nyae Conservancy in northeastern Namibia was sought in trackway interpretation. In 2023, #Oma Daqm and /Uce N‡amce, Indigenous Master Trackers from the Conservancy, explored the coast with Western-trained scientists and provided their input. In 2024 and 2025, they were joined by Steve Kunta, also from Nyae Nyae, and further discoveries, trackway interpretations, and identifications ensued (**Figure 1**). The

Figure 1.
The three team members from the Nyae Nyae Conservancy in northeastern Namibia take a break to examine the Indian Ocean.

resulting Western/Indigenous collaboration has led to several publications, with further publications currently in press or in preparation. An article on the mutual benefits of the newly-developed relationship was published in Namibia [21].

The Pleistocene vertebrate tracksites are located within two formations of the Cenozoic Bredasdorp Group (**Figure 2**) [22]. The majority occur in aeolianites (cemented dunes) of the Waenhuiskrans Formation [23]. A minority occur in cemented foreshore deposits of the Klein Brak Formation [24]. The tracks were registered on these dune and beach surfaces, respectively, when they were composed of unconsolidated sand, which has now been consolidated into rock. While the relatively coarse grain size largely precludes the preservation of fine detail and exceptional anatomical fidelity, identification of the trackmaker group or species is frequently feasible [10]. The majority of tracksites are dated through optically stimulated luminescence (OSL) to marine isotope stage (MIS) 5, often around the time of the MIS 5e sea-level high-stand (~125 ka) [25–29]. The oldest Pleistocene tracksites are dated through OSL to MIS 11 (~400 ka) [25], and the youngest are dated through OSL to MIS 3 (~50 ka) [30].

The purpose of this chapter is

- To illustrate examples of the type of collaboration that have developed,
- To demonstrate the value of Indigenous expertise to palaeo-ichnology, and
- To consider the potential benefits of this collaboration to the Indigenous population of the Nyae Nyae Conservancy.

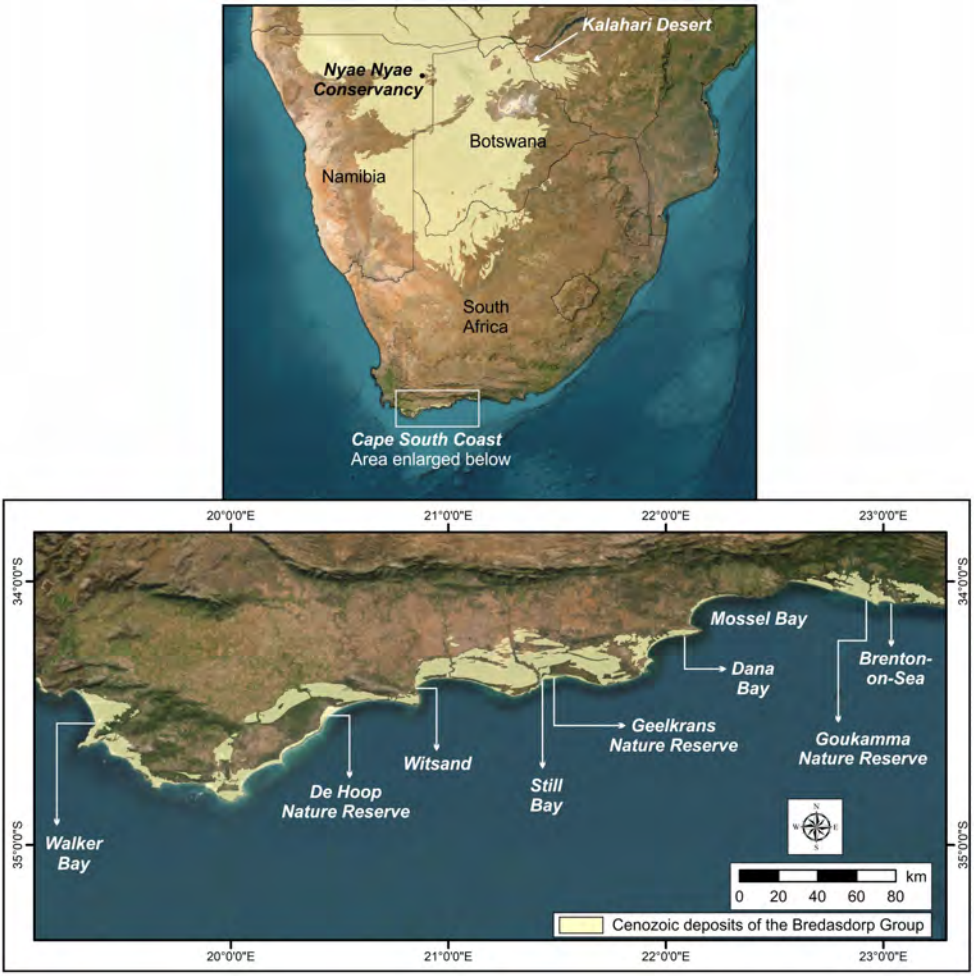

Figure 2.
Map of Southern Africa and the Cape South Coast, showing the extent of Kalahari sand, the extent of Cenozoic coastal deposits, and sites mentioned in the text. Data sources include the University of Koeln Digital Atlas of Namibia (https://www.uni-koeln.de/sfb389/e/e1/download/atlas_namibia/e1_download_physical_geography_e.htm), the Council for Geoscience 1:250,000 geological map series, and Esri, Maxar, Earthstar geographics and the GIS user community.

2. Methods

For the Ju/'hoansi members of our team, what we imagined would be a steep learning curve lay ahead for them as they were given a 'crash-course' in the principles of palaeo-ichnology, focusing in particular on the differences between tracking on Cape South Coast rock surfaces and tracking in the Kalahari sand and bush.

Specifically, the activity of pursuing game in real time offers more clues and involves more senses than the more static exercise of fossil track and trackway identification. When tracking live game, trackers rely not only on their sense of vision but also on their senses of hearing, smell, and touch. An extended set of tracks

Figure 3.
(a) Tracks may occur on the undersides of ceilings, requiring detailed examination in cramped surroundings. Photo cropped and reproduced with permission of Josef de Beer. (b) Author Charles Helm, #Oma Daqm, and /Uce N‡amce examine hominin tracks preserved in hyporelief on the ceiling of a tight coastal cave. Reproduced with permission from #Oma Daqm and /Uce N‡amce.

with varying features along its dynamic pathway – gait length, depth, associated droppings, feeding signs, grass displacement, direction, and more – offers multiple signals to help the hunter build the prey model and ultimately locate the prey. Tracks preserved in aeolianites and cemented foreshore deposits, in contrast, typically provide fragmentary clues that rely mostly on the sense of vision.

Furthermore, the Cape South Coast fossil tracks occur on relatively coarse-grained surfaces, where high-resolution anatomical fidelity usually does not occur. Moreover, the fossil tracks with the highest quality are often formed by the infill layer (i.e., they are preserved in hyporelief), rather than on the original epirelief surface, which has frequently been eroded away. The finest tracks are thus often found projecting down from the ceilings of caves and overhangs, and they often occur in cramped surroundings (**Figure 3**).

Despite these challenges, the temporal proximity of the Pleistocene to the present implies that most track morphologies that might be encountered would be familiar. The tracks of extinct species, such as the long-horned buffalo (*Syncerus antiquus*), giant Cape zebra (*Equus capensis*), blue antelope (*Hippotragus leucophaeus*), and giant warthog (*Metridiochoerus*), were explained through reference to the tracks of extant species [31, 32].

Once the instruction phase in palaeo-ichnological principles was complete, and modern analogues on Cape beaches had been examined for context, practical training followed in an area that harboured numerous known tracksites, preserved in epirelief, hyporelief, and profile. With proficiency achieved, the Ju/'hoansi trackers readily exceeded our expectations. They were soon walking the beaches independently, searching out candidate tracks and trackways, and offering identifications and explanations. Their accounts, along with those of the Western-trained team members, were then compared.

For sites that could not be visited, photographs and 3D photogrammetry models were reviewed together and discussed. The 3D photogrammetry models were generated with Agisoft MetaShape Professional (v. 1.0.4) using an Olympus TG-5 camera (focal length 4.5 mm; resolution 4,000 x 3,000; pixel size 1.56 × 1.56 μm). The final images were rendered using CloudCompare (v. 2.10-beta) [33, 34]. Photographs and photogrammetry models were reviewed together and discussed. For the Western-trained team members, five southern African tracking manuals provided reference information [35–39].

Artiodactyl tracks (especially those of bovids and suids) present a special challenge, as numerous southern African species leave tracks that are morphologically quite similar. In addition to reviewing examples in the field, an inventory of photographs and photogrammetry models of artiodactyl tracks was examined via Zoom. Consensus was reached on trackmaker identity where possible, although in some cases, definitive conclusions remained elusive.

To minimise bias, the *modus operandi* was for interpretations and opinions not to be initially shared when a site was visited together for the first time. The Master Trackers were able to review the site with no preconceived notions as to the trackmaker's identity and would examine the site and confer at length with each other. They would then present their interpretation to the Western-trained team members. Discussion would ensue, almost always leading to a conclusion by consensus.

3. Results

Nine trackmaker groups are discussed here. Together, they illustrate the type of collaboration that has occurred and the insights that the Ju/'hoansi team members have contributed.

3.1 Hyena trackway

At Dana Bay, west of Mossel Bay, citizen scientists Aleck and Ilona Birch had, for years, observed how sand coverage on the beach below their home would vary, often substantially. Then, for a few days, a new rock surface composed of MIS 11 aeolianites was exposed before the sand returned. On that surface was an intriguing trackway [40]. They were instructed (all the way from Canada) on how to take photographs for photogrammetry. Once the images were processed and the 3D model was available, it became apparent that this may have been the first hyena trackway ever to be documented. The brown hyena (*Hyaena brunnea*) has an unusual trackway pattern, which includes a forefoot track that is significantly larger than that of the hindfoot [39].

The site was visited together, and Aleck and Ilona Birch indicated where they hoped the rock surface lay buried. An excavation of beach sand then occurred. Fortunately, the track-bearing surface was reached about a metre below the beach surface, and the trackway was exposed and briefly examined before the incoming tide put an end to such activity. Later, the photogrammetry model (**Figure 4a**) was reviewed together. Without any priming, the conclusion of the Master Trackers was clear: these were hyena tracks. The resulting published scientific paper was the first that we jointly authored [40].

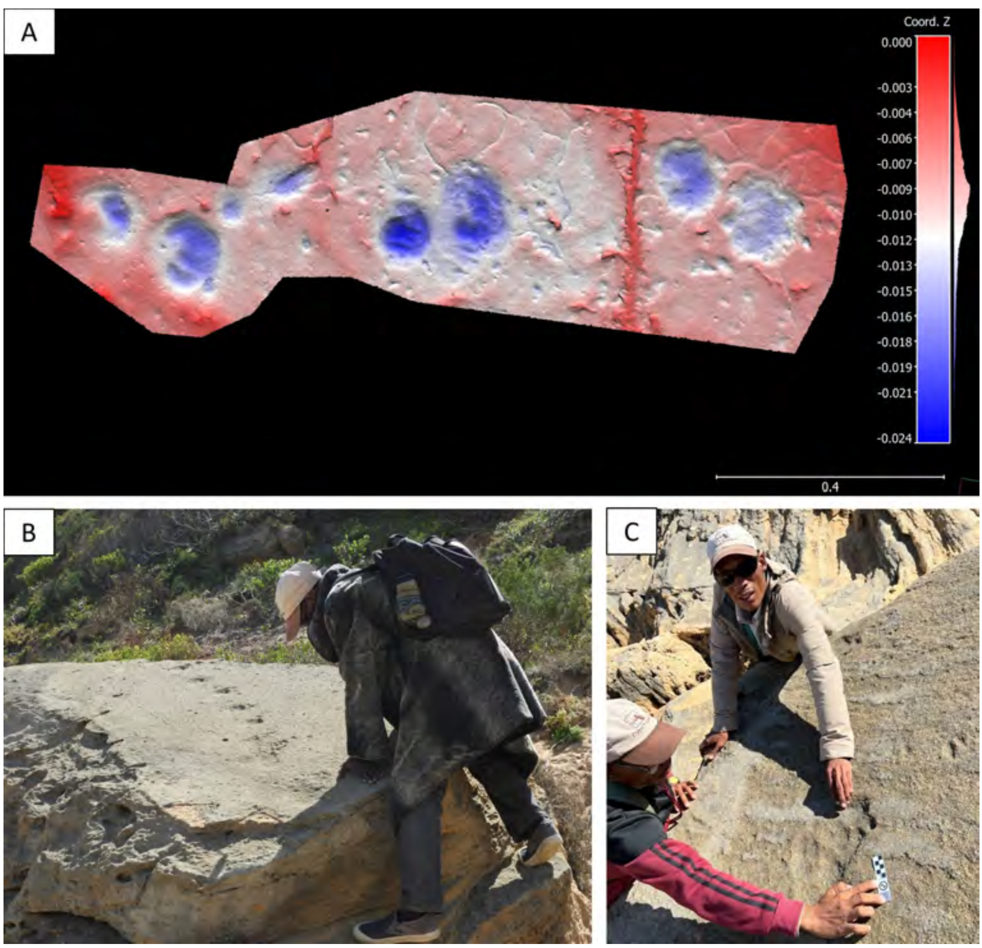

Figure 4.
(a) This 3D photogrammetry model was examined together after the tracksite had been re-exposed. A hyena trackmaker was confirmed – note how much larger the forefoot impressions are than the hindfoot impressions in a repeating pattern. Horizontal and vertical scales are in metres. (b) A master tracker closely examines a trackway on a loose fallen block, prior to the identification of the trackmaker as a pangolin. (c) #Oma Daqm points to lion tracks, watched by /Uce N‡amce. Reproduced with permission from #Oma Daqm and /Uce N‡amce.

3.2 Pangolin trackway

In terms of public perception and the profound nature of the identification, the next published paper had the most impact, eclipsing even our report of hyena tracks. Renée Rust and her family had reported an intriguing trackway to us on a large fallen aeolianite block that had become dislodged from overlying cliffs and come to rest at the upper end of a beach below her home, east of Still Bay near Geelkrans (**Figure 4b**). The subtle findings had eluded us, and we stuck with the term 'enigmatic' [41].

We showed it to our Master Tracker colleagues, not expecting them to provide a definitive opinion. However, we were wrong. They confidently announced that it had been made by a pangolin. This would be the first fossilised pangolin trackway ever reported anywhere in the world, so we were aware of the importance of the moment. They carefully explained their rationale, pointing out the salient features one by one. We later showed images of the tracks and trackway to top experts in the southern African tracking community, who concurred.

In the resulting joint scientific paper, published in the *South African Journal of Science*, we celebrated the fusion of two scientific approaches into something that was greater for its diversity, and we drew attention to the global plight of pangolins [41]. A subsequent feature in *The Conversation Africa* garnered more than 25,000 reads across the world.

3.3 Rhinoceros tracks

A recently published paper summarised the evidence from seven potential rhinoceros tracksites along the Cape coast [42]. The main contribution of the Master Trackers lay in assessing sites in the Walker Bay Nature Reserve, where they helped uncover a previously hidden trackway registered either by a rhinoceros or a hippopotamus. Distinguishing between these two large trackmakers is not always straightforward. An important discussion then ensued on assigning the tracks to a trackmaker, which led to a nuanced description in the scientific paper.

3.4 Lion tracks

One paper documenting a lion tracksite on the Cape South Coast in the Goukamma Nature Reserve had previously been published [43]. The tracks, preserved in concave epirelief on a loose aeolianite block, were of 'textbook quality' and left no doubt as to the trackmaker's identity. We reviewed the site together, and the Master Trackers provided further interpretation, noting the passage of both a male and a female lion (**Figure 4c**).

At a site in De Hoop Nature Reserve, a tentative identification of lion tracks on an in situ aeolianite surface had been made by the Western-trained team members. The Master Trackers confirmed the identification and provided further interpretation.

At a third site, east of Witsand, the Master Trackers made an independent identification of lion tracks, now preserved in concave epirelief, progressing along a steep slope. Fossilised lion tracks are globally rare [10, 43]. The three South African sites thus contribute substantially to the global record. A scientific paper documenting the findings is currently under review.

3.5 Tortoise tracks

An unexpected finding in Cape South Coast aeolianites was the presence of tracks of very large tortoises, given the absence of such evidence in the regional body fossil record; either an extinct giant tortoise or a large Pleistocene 'chrono-subspecies' of the leopard tortoise (*Stigmochelys pardalis*) was postulated [44]. Also unusual was the fact that the global palaeo-ichnology record does not include evidence of the distinctive tortoise tramway pattern [44].

The recent identification of this pattern at aeolianite sites in Walker Bay Nature Reserve and De Hoop Nature Reserve was thus of considerable importance. In addition, one of the loose track-bearing slabs in the Walker Bay Nature Reserve appeared to feature the digit impressions of a very large tortoise. The Indigenous Master Tracker team members were independently able to reach an identical conclusion to that of the Western-trained team members and add substantially to the interpretation of a complex tracksite (**Figure 5a**). The revision of the scientific paper that has been developed is currently under review.

3.6 Artiodactyl tracks

During time spent together 'in the field', artiodactyl tracks were reviewed together. One example was the confident identification of an eland (*Tragelaphus oryx*) track by the Master Trackers (**Figure 5b**). The challenge lay in distinguishing tracks of species which superficially appeared very similar [28–32], as well as the large number of candidate bovid species (at least 23) known from the body fossil record to have inhabited the region during the Pleistocene [31]. In addition, substrate conditions have the capacity to affect track morphology and preservation quality [9].

Our interest in this topic stemmed from the potential of identifying tracks of two extinct artiodactyl species, the bloubok (also known as the blue antelope – *Hippotragus leucophaeus*) and the giant warthog (*Metridiochoerus*) [31]. We therefore reviewed an inventory of artiodactyl track photographs and 3D photogrammetry models from 50 Pleistocene tracksites together. If tracks could not be identified to the level of artiodactyl or perissodactyl (e.g., equid), they were excluded from the inventory. Once the artiodactyl inventory was examined, tracks of bovids that were too large or too small to be bloubok candidates were readily excluded. A scientific paper on possible bloubok tracks is currently under preparation.

A welcome development from reviewing this inventory together was the observation of several examples of fossil suid tracks within the inventory. Some of these were consistent in size with tracks of the extant warthog (*Phacochoerus africanus*). Others, somewhat larger, were more consistent with tracks of the extant bushpig (*Potamochoerus larvatus*). Others still, substantially larger, appeared to have been registered by *Metridiochoerus*. A joint scientific paper on suid tracks is currently in progress.

3.7 Ostrich tracks

A puzzling aspect of our ichnological discoveries on the Cape south coast was the relative absence of ostrich (*Struthio camelus*) tracks. We had expected them to be a common phenomenon. The only convincing ichnological evidence that we had found was a possible trackway on a loose aeolianite slab in the Robberg Nature

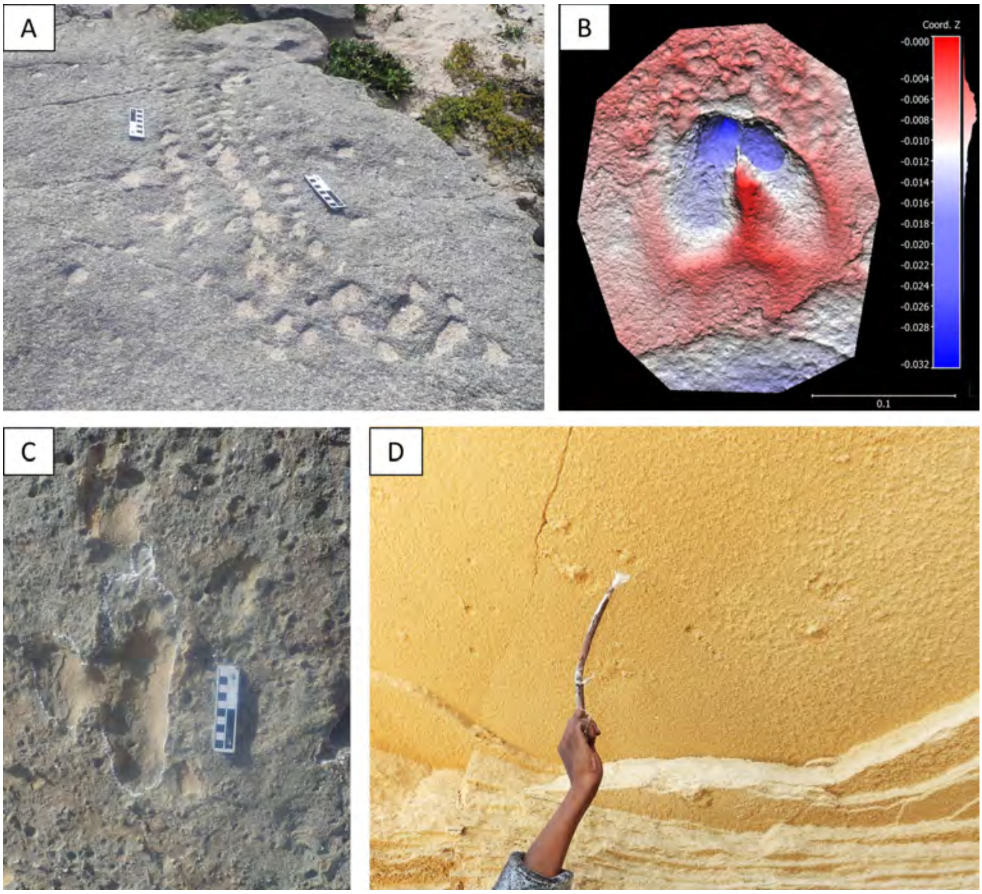

Figure 5.
(a) At this complex site, the Master Trackers provided interpretation of the enigmatic features, contributing to an enhanced understanding of the trackway pattern registered by a tortoise; scale bars = 10 cm. (b) 3D model of an artiodactyl track, immediately identified by the Master Trackers as that of an eland; horizontal and vertical scales are in metres. (c) An ostrich track has been outlined in chalk by the Master Trackers, scale bar = 10 cm. (d) One of the Master Trackers points out the salient features of a hare trackway on the underside of a ceiling. Photo cropped and reproduced with permission of Kimball Pitcher.

Reserve [45] – Site 9 and ostrich eggshell fragments embedded in aeolianites east of Still Bay in the Geelkrans Nature Reserve [45] – Site 2. When we visited the latter site with our Master Tracker team colleagues, they noted the eggshell fragments and proceeded to outline in chalk several adult and juvenile ostrich tracks (**Figure 5c**). They declared that we might be looking at the vestiges of an ancient ostrich nesting hollow. The presence of tracks and eggshell fragments in close proximity to each other allowed us, for the first time, to reach a confident interpretation of the site.

3.8 Lagomorph tracks

Hares have a distinctive bounding gait, whereby the front feet are sequentially planted first (one ahead of the other), and the larger rear feet come around and over, and are then planted ahead of the front foot tracks, beside each other and a few centimetres apart. This creates a distinctive trackway pattern [39]. Our Master

Tracker colleagues immediately recognized and commented on this pattern at a tracksite preserved in convex hyporelief on an overhanging aeolianite surface east of Still Bay in the Geelkrans Nature Reserve (**Figure 5d**). Either the Cape hare (*Lepus capensis*) or scrub hare (*Lepus saxatilis*) is the likely trackmaker.

3.9 Hominin tracks

The great majority of hominin tracksites in the world, greater than 40 ka, have now been identified on the Cape coast of South Africa. The first findings were published in 2018, followed by the identification of more sites in 2020. Subsequent publications have involved the oldest known possible shod-hominin tracks, evidence of ancestral hominins having used sticks, and a globally unique cluster of hominin tracksites [27, 46–50].

The joint visit to the first identified site, at Brenton-on-Sea, was particularly poignant. #Oma Daqm and /Uce N‡amce were visibly moved by the experience, relating it to the oral history of their ancestors long ago inhabiting lands near the sea. They emerged from the cave that houses the tracks and demonstrated how hard their hearts had been beating (**Figure 6**). For all of us, it was a memorable moment.

Subsequent joint exploration has yielded a similar site east of Witsand, also with tracks preserved on a cave ceiling in hyporelief, showing evidence of a hominin running fast. The Master Tracker team members provided a concise comment: 'Dis 'n mens!' (Afrikaans for 'It's a human!'). Once dating results are available, a scientific paper on this site will be submitted for publication. Of note is that a large rockfall subsequently occurred, precluding further access to the site. This underlines the importance of the initial detailed documentation.

4. Discussion

In summary, the collaboration between Western-trained scientists and Ju/'hoansi Master Trackers has yielded numerous benefits. The latter were able to add nuanced interpretations of sites where trackmakers had already been identified with confidence and reported. At other sites, they were able to confirm tentative identifications that had been made, leading to an increased level of confidence in reporting and publishing on these tracks and trackways. Arguably more important still has been their ability to provide novel trackmaker identifications (e.g., the pangolin trackway and one of the lion tracksites). The identification of the tracks of extinct species is of particular importance.

The plethora of Pleistocene hominin tracksites on this coastline presents further opportunities for collaboration, cementing the bond that has formed within our research team. This bond is rooted in the shared appreciation that the trackmakers were almost certainly common ancestors to us all.

4.1 Co-authorship

The art of tracking has memorably been called 'the origin of science' [51]. We respect our Master Tracker colleagues not just as experts in their field but as fellow scientists. Our skill sets are derived differently but converge in their application. The Master Trackers' track-reading prowess is clearly superior to ours, having been

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Figure 6.
#Oma Daqm and /Uce N‡amce after emerging from a cave containing hominin tracks; in the foreground are their own footprints in the sand. Reproduced with permission from #Oma Daqm and /Uce N‡amce.

honed from an early age and developed continuously since then as a life-long learning experience. Our quest to 'track' is driven by intellectual and academic curiosity; theirs by something far more visceral – the survival imperative. That distinction provides another trenchant explanation for their edge.

As fellow scientists, we have naturally been co-authors on our published papers thus far and are continuing this practice in those papers that are in preparation. This has sometimes perplexed journal editors, who traditionally insist on an institutional affiliation. Thus far, when we have constructively discussed this issue with editors, they have been appreciative of our perspective and have recognized 'Nyae Nyae Conservancy' as an affiliation.

Another hurdle relates to click consonants. The Ju/'hoan language has four basic click types, used to generate well over 50 click consonants. This phonemic richness, compared to other languages dispersed around the world, has been put forward to bolster the genetic, palaeontological and archaeological evidence for the 'Out-of-Africa' human origin thesis [52]. Our challenge with these language features has been more prosaic: having to explain to copy-editors that the symbols '#,' '/,' and '‡' in our author lists are not clumsy typographical errors but an accurate representation of our colleagues' initials and names.

4.2 Working with the Master Trackers

Our interactions with the Master Trackers come with challenges. As is so often the case, we of European extraction do not speak their language, but we rely on them to communicate with us in ours. We strongly suspect that much gets missed in translation. Theirs is an expressive language – for instance, what we know rather plainly as the African hawk eagle (*Aquila spilogaster*) is, for them, the action-oriented àri-n‡àmn‡à’m – the ‘guineafowl-catcher’ (‘ari’ is a guineafowl in Ju/’hoan).

Upon first inspection of a site of interest, the Master Trackers typically discuss matters at length in their rich vernacular. They then convey what is clearly their nuanced Ju/’hoan account to us in abbreviated Afrikaans sentences, leaving us to interrogate the message further in halting exchanges as we try to capture more faithfully the full texture.

For example, when #Oma Daqm and /Uce N‡amce were trying to explain – in the face of our quizzical scepticism – why the trackway depicted in **Figure 4a** had almost certainly been registered by a pangolin, they drove home their case by patiently explaining in Afrikaans that an old pangolin track is ‘like a round stick that has been poked in the ground’ (‘soos ‘n ronde stok wat in die grond ingedruk is’).

On another occasion, when we pointed out to them a well-known set of hominin tracks on an overhead rock face, with the extra advice that we could see there may have been half a dozen track-makers, their deliberate but swift response was that a band of at least 20 people must have passed that way. They referred to what they had previously shown us about counting footprints when coming across a similar set of present-day tracks on a walking trail in the Kruger National Park.

When language fails, enactment helps. The gait of a bounding kudu was played out to us in animated visual terms. The pinched claws of a crouching lion were demonstrated by way of a clenched fist to explain some of the lion tracks mentioned earlier.

4.3 Science or magic?

The prowess of San trackers has, at times, been associated with supernatural factors [4, 5]. Others essentially see logic and the scientific method at work, however culturally clad. Roger Chennells, who has worked closely with Indigenous communities in the Kalahari, covers both bases in an instructive vignette:

> *‘Vet Piet, a renowned San tracker . . . shared his tracking gift with many admiring tourists, yet he was still unable to explain how the tracking ability worked. At about midday on a normal Kgalagadi day, dry and 38 degrees in the shade, while driving my Land Rover with Vet Piet and friends, we came across a large herd of eland, charging in the same direction about fifty metres to the right of our dirt track. . . . Someone pleaded that I turn the vehicle sharp right and head towards the moving herd so that he could get a few close-up photos. I looked at Vet Piet who shook his head. Instead, Vet Piet indicated, we should rather drive straight towards a tree about three hundred metres ahead, and wait there: There the eland will stop running, they will turn to the left, and will walk right past us’.*

I knew to not ask questions, so drove towards the small tree as instructed. Intuitively it seemed the wrong thing to do. Surely the eland would carry on running away from us? As if being guided by some magic control panel, the galloping herd slowed to canter, then into a trot and finally to a brisk walk. Next the leaders swung to the left and within minutes close to three hundred eland walked past our vehicle, no more than thirty metres away, precisely as Vet Piet had predicted.

. . . I needed to understand what we had witnessed. [Later] I strolled to where the stocky Bushman sat under a camel thorn tree puffing on a Lexington. 'Vet Piet. How on earth were you able to predict the behaviour of those eland?' Amused by my question his response was. . . 'I simply knew'. I was not satisfied. . . I asked him to please go and think carefully about what knowledge he had utilised. . .

He agreed good-naturedly and sat pondering my request. After while he returned to where I was sitting, smiling shyly as if having discovered something surprising. . .

He went on to say that he had now worked out every step in the process. It was all about observation, he explained, followed by deduction. His observations were firstly that the herd of eland, heaviest of all African antelope, were running for fun that day, and not out of fear, for example, from lions. Secondly, they've been running at full speed for about seven hundred metres, which one could deduce from the height and the length of the plume of dust behind them. Thirdly, the wind was blowing from their right to their left, in other words across them, which one could also tell from the plume. Finally, it was a particularly hot day.

Then his deductions: One, an eland's body gets hot quickly, when running so hard. They soon overheat, and in about 300 m time (approximately near that single tree) they would need to cool down urgently; two, eland cool down through their nostrils, so they would need to turn into the wind blowing from left to right; and three, the herd would thus need to walk from that way, towards that tree. And so the huge herd walked slowly in front of our vehicle, as predicted'.

'Good explanation, Vet Piet' I said.

But something important was missing. He had explained the basics of the recipe. A vital ingredient, that intuitive, almost a magical knowledge that comes from aeons of observation, was missing. !Ngate Xgamxebe [another tracker] said that 'tracking is like dancing, because your body is happy . . . You feel it in the dance. It tells you when you love tracking and dancing, you're talking with God'. Vet Piet would have chuckled and shaken his head . . .

'Sorry [Roger]. That thing I can't explain'. [[56], pp. 191–193; extract reproduced with the author's permission]

4.4 Reciprocal benefits

Our perspective, shared by our Master Tracker colleagues, is that the wisdom inherent in traditional, experiential scientific tracking methods – absorbed from early childhood (usually with the goal of supporting one's family through hunting and gathering) – blends well with an academic, institution-based approach. The benefits to Western science are readily apparent: the enhanced ability to identify and interpret fossilised Pleistocene tracksites leads to superior published papers and redounds to the credit of academic institutions such as Nelson Mandela University, the African Centre for Coastal Palaeoscience, and the Council for Geoscience. Perhaps less obvious are the potential benefits to the Master Trackers and the people of Nyae Nyae.

Awareness of the Ju/'hoansi of Nyae Nyae in the global arena was initiated by a book by Lorna Marshall, based on extensive studies from the 1950s of her work with the people she termed !Kung [53]. Her children, John Marshall and Elizabeth Marshall Thomas, continued her work, and the latter provided a 1989 update on the 'progress' that had occurred in Nyae Nyae, including the creation of the community of Tsumkwe [6]. Further updates [54, 55] have coincided with increased global attention, including the formation of the Kalahari Peoples Fund, an advocacy organisation based in the USA. More recent involvement of the Ju/'hoansi in international tracking projects and the awarding of the Indigenous Master Tracker designation through an accreditation program by CyberTracker (https://cybertracker.org/track/master-trackers/) have been alluded to above.

The remaining San communities in the countries that make up the Kalahari Basin of central southern Africa – Botswana, Namibia, Angola, Zimbabwe, and South Africa – are, for the most part, politically marginalised, geographically displaced, and impoverished. With few exceptions, such as in the case of the Nyae Nyae Conservancy, prohibitions on hunting have severed them from their natural environment and history. Work opportunities are scarce, and health outcomes are poor. Another exemplar of the world's rich Indigenous cultures is imperilled.

Recognition and empowerment are keys to a turn-around in fortunes. There are many initiatives through which San communities, often in conjunction with governments and NGOs, are looking to carve out a better future. The Master Trackers' engagement with the discipline of palaeo-ichnology, while modest in scale, has particularly gratifying features.

The benefits are manifestly reciprocal: the Trackers have advanced the discipline of palaeo-ichnology, as evidenced by published papers; this transfer from the realm of Indigenous knowledge to an area of contemporary scientific endeavour has happened in a clearly non-patronising way, and a new dimension has been introduced to the field. At the same time, deservedly-earned income has flowed to needy communities, and the initiative can serve as a prototype for others to follow, based on a more general appreciation of the extraordinary ichnological prowess of Indigenous Master Trackers. Furthermore, the initiative has contributed to the development of a new field for citizen scientists and eco-tourism (see https://www.dailymaverick.co.za/article/2024-11-13-citizen-scientists-and-san-trackers-on-the-trail-of-our-human-origins-along-southern-cape-coast/). Our hope is also that, through this initiative, the skills and wisdom of traditional ichnological knowledge will be preserved even as it is modernised.

5. Conclusions

Through this initiative, combining ancient traditional scientific knowledge and modern scientific approaches, novel insights and interpretations have resulted. As a result, the discipline of palaeo-ichnology has benefited. The peer-reviewed papers that have already been published, with the promise of more to follow, provide testimony of a partnership that is rich in its diversity, constructively blending two scientific approaches. Importantly, the advantages of a mutually beneficial partnership are evident. In a world in which traditional knowledge and wisdom are steadily being eroded, the collaboration of Indigenous Master Trackers and Western-trained scientists offers hope for the celebration and preservation of traditional skills and traditional scientific acumen.

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Conflict of Interest

The authors declare no conflict of interest, while noting that Clive Thompson is a trustee of the Discovery Wilderness Fund.

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