

Possible Pleistocene Pinniped Ichnofossils on South Africa's Cape South Coast

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ABSTRACT

Helm, C.W.; Carr, A.S.; Cawthra, H.C.; De Vynck, J.C.; Dixon, M.; Stear, W.; Stuart, C.; Stuart, M., and Venter, J.A., 2022. Possible Pleistocene pinniped ichnofossils on South Africa's Cape south coast. *Journal of Coastal Research*, 38(4), 735–749. Coconut Creek (Florida), ISSN 0749-0208.

Exposed surfaces of cemented foreshore deposits and aeolianites on the Cape south coast of South Africa have been demonstrated to contain numerous Pleistocene vertebrate tracksites. Two ichnosites have recently been identified that appear to demonstrate traces made by seals. These would be the first seal trace fossils thus far described in the global fossil record. The sites are situated 560 m apart in the Goukamma Nature Reserve. One site exhibits apparent flipper traces and a furrow, and the other site exhibits impressions consistent with moulds of juvenile seals. In conjunction with new luminescence dating of the associated sediments, these findings suggest a seal presence on Cape south coast beaches ~75,000 years ago in the mild glacial period of Marine Isotope Stage 5a.

ADDITIONAL INDEX WORDS: *Cape fur seal, ichnosites, ichnology, washover fan, MIS 5a.*

INTRODUCTION

The fossil record of Pinnipedia, the clade or suborder that includes true seals (Phocidae), fur seals and sea lions (Otariidae), and walruses (Odobenidae), extends from the Oligocene to the Holocene, with a global distribution (Valenzuela-Toro and Pyenson, 2019). Compared with this extensive body fossil record, the trace fossil record appears to be largely silent. This is notable, as pinnipeds are a widespread, distinctive, and familiar group of carnivores. Furthermore, they include the largest extant carnivores and the largest noncetacean marine mammals: the southern elephant seal (*Mirounga leonina*) is the largest and heaviest extant member of the Carnivora (Berta, 2002).

The sole hitherto published report on a pinniped ichnosite relates to Pleistocene walrus feeding traces from Washington, U.S.A. (Gingras *et al.*, 2007). The rarity of pinniped ichnological records may be attributed to these mammals spending much of their time in the ocean and, when they emerge onto land, to a preference for rocky habitats such as rocky islands, cliff-side rock ledges, boulder beaches, and pebble beaches (Reeves *et al.*, 2002). None of these habitats would be expected to register or preserve fossil pinniped traces. However, large colonies can also be found on sandy beaches (Reeves *et al.*, 2002), which could potentially leave a trace fossil record.

Extant pinnipeds on the coast of southern Africa include:

- (1) the Cape fur seal (the African race of the brown fur seal), *Arctocephalus pusillus pusillus*, which occurs in substantial numbers from Cape Cross in Namibia to Black Rocks in the Eastern Cape province of South Africa (Kirkman *et al.*, 2016; Reeves *et al.*, 2002);
- (2) the southern elephant seal (*Mirounga leonina*), which occasionally hauls up during times of moulting (Skinner and Chimimba, 2005);
- (3) a number of vagrants, including the sub-Antarctic fur seal, *Arctocephalus tropicalis* (Shaughnessy and Ross, 1980); the Antarctic fur seal, *Arctocephalus gazella* (Skinner and Chimimba, 2005); the leopard seal, *Hydrurga leptonyx* (Vinding *et al.*, 2013); and the crabeater seal, *Lobodon carcinophaga* (Ross, Shaughnessy, and Best, 1978).

Since its inception in 2007, the Cape south coast ichnology project has involved the documentation of more than 300 Pleistocene vertebrate tracksites along a 350 km stretch of coastline (Figure 1) between the town of Arniston in the west and the Robberg peninsula in the east (Helm *et al.*, 2020b). These sites occur on aeolianites and cemented foreshore deposits, the cemented remains of ancient dune and beach surfaces. Thus, the capacity of these surfaces to record events that transpired on them has been demonstrated, including unexpected trace fossil evidence of hatchling turtles (Lockley *et al.*, 2019), giraffes (Helm *et al.*, 2018a), crocodiles (Helm *et al.*, 2020a), and larger-than-expected birds (Helm *et al.*, 2020d). In

DOI: 10.2112/JCOASTRES-D-21-00131.1 received 5 October 2021; accepted in revision 24 December 2021; corrected proofs received 25 January 2022.

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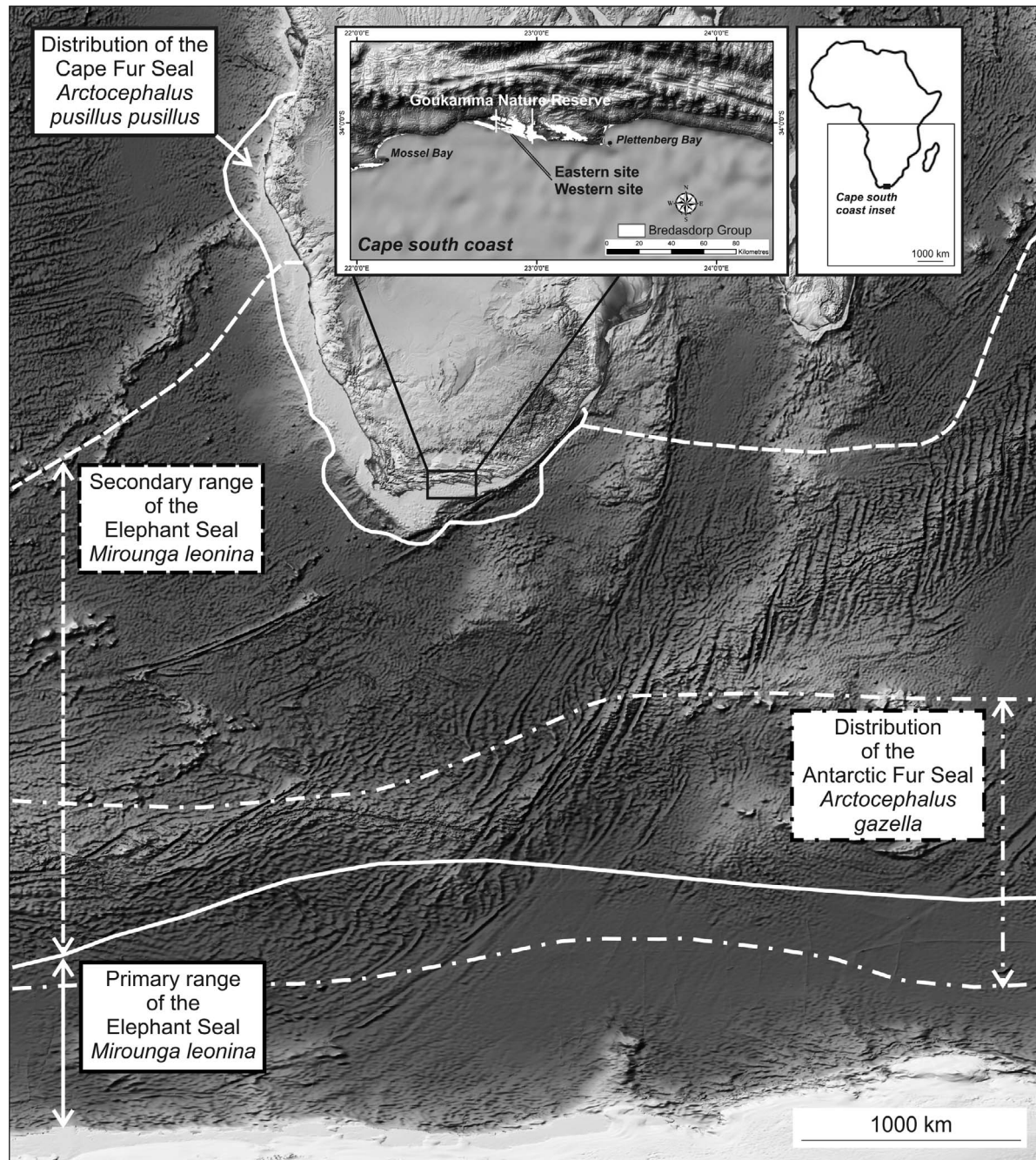


Figure 1. Locality of the two sites described, in relation to map of southern Africa. The line overlays show the distribution of the Cape fur seal *Arctocephalus pusillus pusillus* (solid line, close to the coast (Kirkman and Arnould, 2018)), the southern elephant seal *Mirounga leonina* (primary range furthest south to the marked solid line and secondary range up to the stippled line, (Hindell, 2018)) and the Antarctic fur seal *Arctocephalus gazella* (stippled and dotted lines bounding a zone in the south, (Forcada and Staniland, 2009)).

each case, palaeo-environmental inferences could be drawn. None of these findings had previously been suggested through the regional archaeological or body fossil record. Furthermore, a number of hominin tracksites (Helm *et al.*, 2018b, 2020c) have been identified, as well as evidence of other forms of Pleistocene human behavior (Helm *et al.*, 2019).

Klein and Cruz-Urbe (1996) discussed the exploitation of the Cape fur seal at Middle Stone Age (MSA) and Later Stone Age (LSA) sites in South Africa. Marean (2010) described the role of seals in MSA hunting practices and human diet from the archaeological record of Pinnacle Point Cave 13B, on the Cape south coast. Marean *et al.* (2014) discussed evidence in the

archaeological record, ranging from Marine Isotope Stage (MIS) 6 through to the Holocene, of exploitation of seals at sites on the Cape south coast; the presence of seals in this record was used as a proxy for a relatively nearby coastline.

Pinnipeds, and in particular the Cape fur seal, are therefore part of the suite of Pleistocene vertebrates that could theoretically be expected to leave ichnological evidence of their presence on the Cape south coast. Two ichnosites have been identified within the Goukamma Nature Reserve that appear to be consistent with a pinniped origin, which at a global level may be the first of their kind to be described. This article aims to describe these sites, to discuss the nature of seal traces, to provide age estimates for their formation, and to consider the implications of these findings.

Geological Context

Along the Cape south coast, Pleistocene aeolianites comprise the Waenhuiskrans Formation (Malan, 1989) and cemented foreshore deposits, along with shallow marine, lagoonal, and estuarine deposits, comprise the Klein Brak Formation (Malan, 1991). The Waenhuiskrans Formation and Klein Brak Formation form part of the Cenozoic Bredasdorp Group (Figure 1). As Quaternary tectonic activity is considered minimal along this coastline (Fleming *et al.*, 1998; Roberts *et al.*, 2012), *in situ* sedimentary bedding in the Pleistocene formations lies at or close to the original angles of deposition. In the case of aeolianites, this is often the angle of repose of wind-blown sands, with dip angles of $\sim 10\text{--}30^\circ$ (Roberts, Cawthra, and Musekiwa, 2013). Interdune swales and cemented foreshore deposits typically exhibit bedding plane orientations that lie closer to the horizontal plane (*e.g.*, Roberts *et al.*, 2008). Given the frequency of transition zones between beaches and dunes, and sea-level fluctuations that prompt calcium carbonate diagenesis at different levels of the stratigraphy, it is not surprising that distinguishing between cemented beach deposits and cemented dunes is not always straightforward, even with the use of microscopy.

The two ichnosites lie within the Wilderness Embayment (Bateman *et al.*, 2011, 2004; Illenberger, 1996). Here the Pleistocene stratigraphy largely consists of MIS 6 and MIS 5 aeolian deposits that have coalesced to form several shore-parallel dune “cordons”, the most seaward of which is draped by an unconsolidated unit of Holocene and modern—largely parabolic—coastal dunes (Bateman *et al.*, 2011). Nonaolian facies are identified within the cordons, including last-interglacial estuarine facies. Martin and Flemming (1987) also noted that, a few km west of the sites described here, “overwash bar facies are suggested by . . . fine-grained landward dipping planar bedding”, thus adding a further feature that would fall within the Klein Brak Formation. Martin and Flemming (1987) further suggested that such facies corroborated the interpretation of the overlying aeolianites as back-beach foredunes.

Optically stimulated luminescence (OSL) dating studies from sites on the Cape south coast have demonstrated that the majority of Pleistocene deposits date to MIS 5, indicating an age range of 130–80 ka (Bateman *et al.*, 2011; Carr *et al.*, 2010; Cawthra *et al.*, 2018). Further OSL studies also indicate the presence of both older and younger deposits. Roberts *et al.*

(2012) demonstrated that at Dana Bay both MIS 11 and MIS 5 deposits are present, with the MIS 11 deposits dating to ~ 400 ka. In contrast, Carr *et al.* (2019) demonstrated MIS 3 deposits on the Robberg Peninsula as young as 35 ka.

Analysis of Pleistocene rocks exposed on the Cape south coast requires an awareness of the dramatic sea-level oscillations that characterized that epoch; the glacial-interglacial and associated sea-level cycles that prevail were set in place at the time of the mid-Pleistocene Transition at ~ 900 ka (*e.g.*, Clark *et al.*, 2006). For example, around 137 ka, during the MIS 6 glacial maximum, global sea levels were as much as 129 m lower than at present (Waelbroeck *et al.*, 2002), and the coast may have been as much as 96 km seaward of today’s shoreline at Mossel Bay (Fisher *et al.*, 2010). In contrast, during the MIS 11 high-stand, regional studies indicate that sea level was 13 m above current levels (Roberts *et al.*, 2012), and during the MIS 5e high-stand, around 126 ka, sea level was 6.6–8 m higher than at present (Carr *et al.*, 2010).

Once Pleistocene track-bearing surfaces are exposed on this coastline, for example through cliff collapse or storm surges, they frequently are ephemeral, as similar forces of erosion act upon them. It is not unusual for this time-window, during which the surfaces are amenable to interpretation, to be as short as months or weeks. Furthermore, littoral sediment distribution varies with time, often seasonally in cycles of accretion and erosion on the Cape south coast (Rogers, 1971). This results in some ichnosites on modern beaches being only occasionally and briefly exposed. A further challenge lies in the fact that aeolianites and cemented foreshore deposits often do not exhibit exceptional track preservation compared with finer-grained substrates, such as the cave floor deposits or volcanic deposits documented elsewhere in the global record. Belvedere and Farlow (2016) introduced a four-point scale (0–1–2–3) in order to assign a numerical value to the preservation quality of vertebrate tracks. In general, tracks in dune facies and coarse beach sand rarely rise above level 2 on this scale.

Morphological Review of Seal Traces

Stuart and Stuart (2019) address the topic of traces of the Cape fur seal and the southern elephant seal. These descriptions explain the significant differences in locomotion between fur seals and true seals. It does not appear that there are any factors that would permit ready distinction between surface traces of fur seal species.

For the Cape fur seal, as noted by Stuart and Stuart (2019), on land the heavy body is supported by the front flippers, which extend to the sides. The area of the front flipper that comes into contact with the ground is used to pull the animal forward and leaves impressions in soft sand. The large body leaves a drag mark between the front flipper traces. Seals may move their flippers alternately or together in a hopping motion if they need to move fast. The hind flippers are held under the body when moving, and usually only the inner base or “heel” leaves a clear impression in the sand, registered over the body track mark.

As noted further by Stuart and Stuart (2019), true seals, exemplified in southern Africa by the southern elephant seal, move on land by humping the body in a caterpillar-like fashion, alternating the weight between the chest and pelvic areas. The front flippers are usually used to assist the animal in moving



Figure 2. (A) Front flipper of Cape fur seal. (B) and (C) show hind flippers of Cape fur seal. (D) Cape fur seal in typical posture, with front flippers aligned perpendicular to the sagittal plane. (E) Northern elephant seal, demonstrating front flipper. (F) Hind flippers of northern elephant seal.

forward. The hind flippers always drag behind and do not assist in locomotion on land. A clear trough is left by the dragging of the body and the deeper indentations left by the front flippers on either side of it. Photographs of Cape fur seal front and hind flippers, and northern elephant seal front and hind flippers (essentially similar to those of the southern elephant seal) are presented in Figure 2.

Considering these points, fur seals are more likely to leave hind flipper impressions, both families leave front flipper impressions, and both leave central drag marks, although true seals may be more likely to create a deeper trough. While traces left on relatively level beaches may readily be interpreted, steeper surfaces may preserve different features. Figure 3A–E illustrates examples of traces of extant fur seals that had

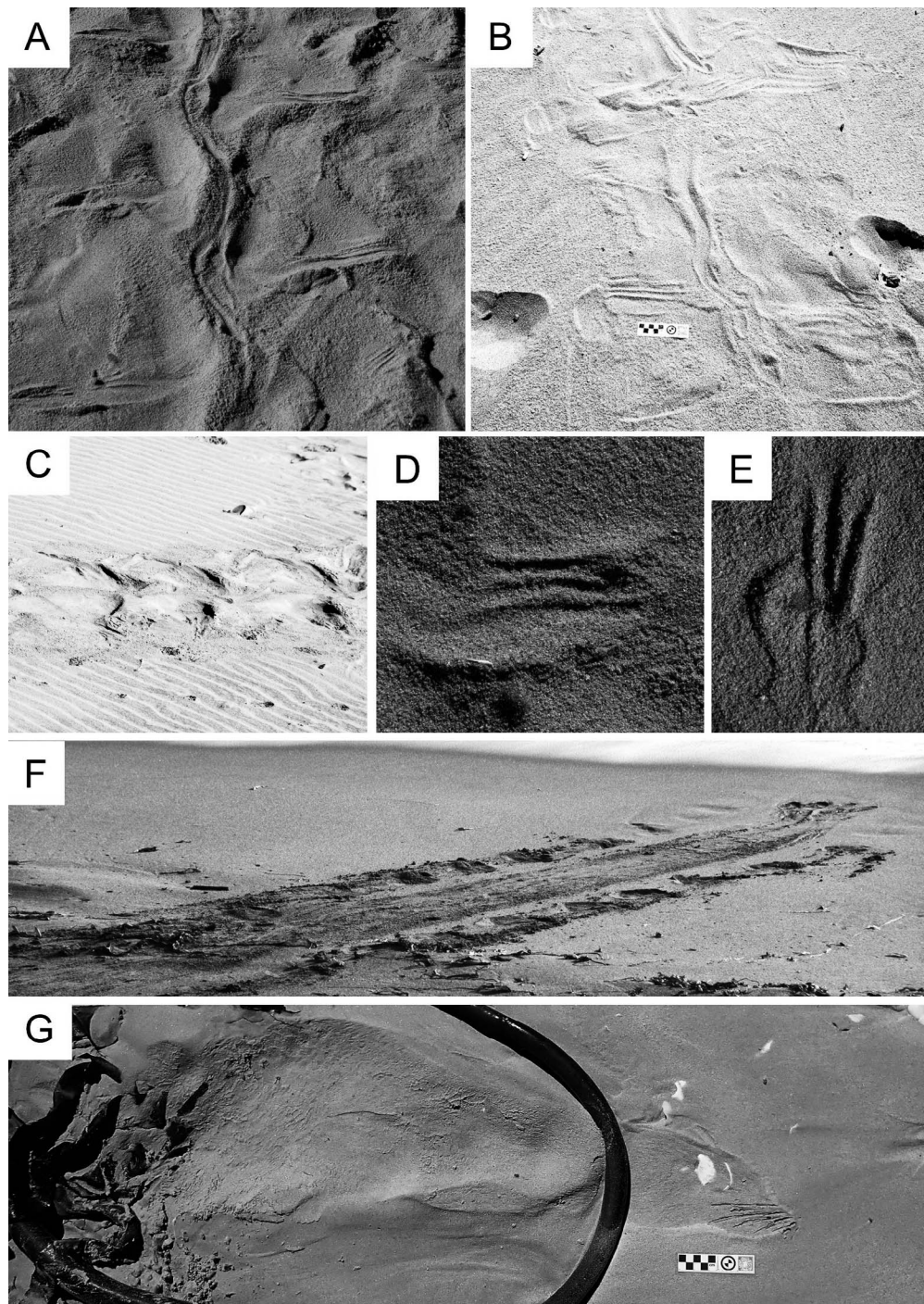


Figure 3. (A) Trackway of Cape fur seal, showing sinuous central depression and, perpendicular to it, front flipper impressions. (B) Trackway of sub-Antarctic fur seal, showing central depression and both front and hind flipper impressions (scale bar = 10 cm). (C) Trackway of Cape fur seal. (D) and (E) show isolated fur seal front flipper impressions. (F) Trackway of northern elephant seal. (G) Natural mould of a Cape fur seal on a modern Cape south coast beach, including impressions of vibrissae (scale bar = 10 cm).

hauled up on Cape south coast beaches. These include a combination of a shallow, central, sinuous depression, parallel linear grooves, or nested curvilinear grooves made by the front flippers (usually aligned perpendicular to the central sinuous

depression), and midline depressions made by the hind flippers. Figure 3F illustrates traces made by an elephant seal.

Furthermore, seal rookeries on beaches may contain dense concentrations of seals of various ages and sizes, often in close

Table 1. Details of the equivalent dose determinations and the final sample ages. The measured water contents were obtained in the laboratory after sampling, shipping, and storage, and are not considered representative of the likely average water content during burial (a value of $3 \pm 3\%$ was applied for dose rate calculation). The stated CAM De and overdispersion (OD) for Leic20026 is that obtained following the removal of three outlier aliquots, with the values for all otherwise acceptable aliquots shown in Figure S1.

Sample	Lab Code	Average Burial Depth (m)	Measured Water Content (%)	Applied Water Content (%)	Grain size Faction (μm)	Aliquots Accepted/ Measured	CAM De (Gy)	OD (%)	Total Dose Rate (Gy ka^{-1})	Age (ka)
Gou D (western site)	Leic20026	10	0.3	3 ± 3	180–250	19/24	44 ± 2	9 ± 3	0.60 ± 0.03	73 ± 5
Gou Coprolite (near eastern site)	Leic21013	10	0.5	3 ± 3	212–250	22/24	43 ± 2	12 ± 3	0.57 ± 0.02	76 ± 5

proximity to one another: Cape fur seals often gather into rookeries in numbers ranging from 500–1500 (King, 1983), and some rookeries are even larger, containing hundreds of thousands of seals, *e.g.*, at Kleinsee and Cape Cross. Seals in rookeries on beaches may create depressions in the sand that are moulds of their outlines. Figure 3G depicts a single partial mould of a Cape fur seal on a modern Cape south coast beach, in which impressions of vibrissae are well preserved. This suggests that such features may also be sought as trace fossils.

METHODS

The two sites described below were visited at low tide, during a period in which they were exposed and not covered by sand. Dimensions of traces (length, width, and depth) were recorded in centimeters. Global Positioning System readings were taken, using the World Geodetic System 84 data. Stratigraphic comparison to nearby OSL-dated sites was performed.

Standard field techniques were applied in understanding tracksite context. Dip and strike measurements were taken on *in situ* bedding, and bed thicknesses were measured. Petrographic thin sections were made from both sites for transmitted-light microscopy.

Locality data were repositied with the African Centre for Coastal Palaeoscience, to be made available to researchers upon request. Photographs were taken, including photogrammetric analysis (Matthews, Noble, and Breithaupt, 2016). Three-dimensional models were generated with Agisoft Metashape Professional (v. 1.0.4) using an Olympus Tough model TG-6 camera (focal length 4.5 mm; resolution 4000×3000 ; pixel size $1.56 \times 1.56 \mu\text{m}$). The final images were rendered using CloudCompare (v.2.10-beta).

To provide chronological control for the trackway sites, two samples for OSL dating were obtained. These comprised sample “Gou D” (Leic20026), which was obtained from the *in situ* track-bearing bedding plane at the western site, with an additional *in situ* sample (“Goukamma coprolite”; Leic21013) obtained from ~ 100 m west of the eastern site. The sampled block samples were shipped to the University of Leicester (U.K.) where they were broken up under subdued red light conditions to obtain sand-sized sediment unexposed to light. Details of the OSL dating sample preparation, analytical equipment, and analysis methodologies are provided in the supplementary material. In short, analyses were conducted on the coarse grained (180–250 μm) quartz fraction, and sample equivalent doses were obtained using the single aliquot regeneration protocol (Murray and Wintle, 2000, 2003; Table 1). Environmental dose rates were obtained using elemental concentrations obtained via ICP-MS analyses and beta counting (Table S1).

RESULTS

Two sites are described here, both located in the Goukamma Nature Reserve, between the towns of Sedgfield and Buffels Bay. The traces appear in concave epirelief. In both cases, the surfaces are sometimes covered by sand, and at other times are buffeted by waves during high tides. The sites are separated by a distance of 560 meters and are described here from west to east.

The Western Site

The western site comprises a north-facing, *in situ*, ripple marked surface with a strike of 90° and a dip angle of 30° (suggesting a possible slipface). The bedding of this outcrop and adjacent outcrops (which extend in a shore-parallel direction along strike for ~ 20 m) is relatively uniformly parallel and planar, or low-angle cross-bedded, but without evidence of aeolian forests (Figure 4A). This unit has a different orientation to the aeolianite layers in the overlying cliffs and adjacent coast, which are the result of prevailing westerly or south-westerly palaeo-winds.

Maximum dimensions of the surface containing the traces are $7 \text{ m} \times 2 \text{ m}$ (Figure 4B). The north-facing surface is described here as viewed when facing south (seawards). The most prominent features are two furrows, 15 cm in width, which extend for 1.5 m from the top edge of the surface to the bottom. The west (right) furrow appears relatively straight, and a crack runs along a portion of its base. The east (left) furrow is more sinuous, with a widened area towards the bottom and a smaller, wider area towards the top.

This upper widened area also contains ten parallel, longitudinally orientated, closely spaced, shallow grooves, 8–12 cm in length, over a width of 22 cm, and extending beyond the furrow section to the west (to the right in Figure 4C and Figure 4D) to two fainter grooves, which are parallel to the other grooves. The orientation of these groove features is the same as that of the furrow. Downslope, within the furrow, there are further, smaller depressed areas, associated with fainter groove features that lie in a similar orientation to those described above. These features are apparent in Figure 4C and Figure 4D and in the photogrammetry image (Figure 5).

In addition, there are at least three further areas of narrow groove impressions in varying patterns elsewhere on this surface (Figure 6A). To the left of the furrows, near the upper end of the surface, is a series of five shallow, subparallel curvilinear grooves, just over 4 cm apart from each other, with maximum length of 37 cm, and approximately parallel to the ripple crests (Figure 6B). Towards the bottom left of the surface (and ~ 35 cm from the lower edge of the surface) is a tight

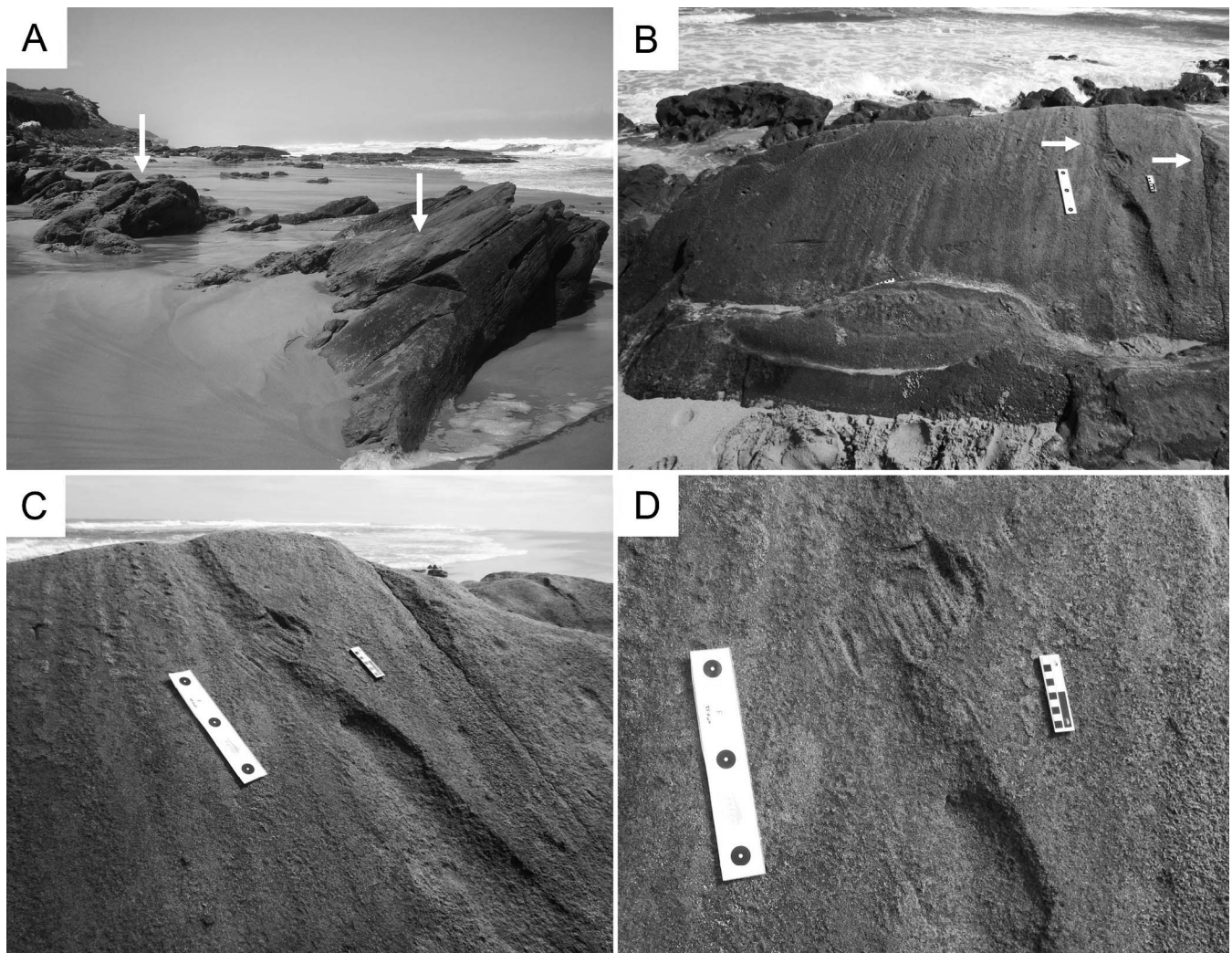


Figure 4. (A) View of the western site area looking east along the coast. The left arrow indicates the site of the possible ammoglyph, and the right arrow indicates the track-bearing surface. (B) The western site track-bearing surface, looking south. White arrows indicate the two furrows (scale bars = 30 cm and 10 cm). (C) View of the east furrow, showing areas of widening and the parallel striations (scale bars = 30 cm and 10 cm). (D) Detail view, showing parallel striations.

collection of shallow parallel grooves, 25 cm long, with a total width of 3 cm, that are perpendicular to the ripple crests (Figure 6C). Between this area and the furrows is a series of ten shallow curved grooves, approximately 8 cm long, over a total width of 34 cm, and often 2.5 cm apart from each other, forming a nested pattern that lies oblique to the ripple crests (Figure 6D). Thus, there is no consistent relationship between the orientations of these three areas of groove features and the orientation of the prominent ripple marks on this surface.

Situated six meters from this surface, and 3 m higher in the section, is another *in situ* surface, with similar orientation and slope. It exhibits a radial pattern in epirelief, interpreted by Helm *et al.* (2019, figure 10) as a possible ammoglyph, a term coined by Helm *et al.* (2019) to describe an anthropic pattern created in sand that is now evident in rock.

Sediment from this outcrop was subjected to petrographic analysis. Transmitted light thin section images are shown in

Figure 7. The clasts are moderately sorted, subangular to subrounded in shape, and made up of medium- to very coarse-grained sand. Although voids are observed, there are two generations of calcium carbonate cement. In the first instance, micrite rims have bounded clasts at sites of grain contact. Thereafter, calcite spar identified from its blocky character has filled in voids and added a veneer of cement to existing micrite rims. The composition of the sedimentary particles in this outcrop is quartz, shell fragments and lithics, especially coarse-grained sand size fragments of quartzite.

The Eastern Site

At the eastern site, a collection of loose slabs lies at the bottom of coastal cliffs. They may have originated in cliff layers 5–6 meters above. On the surface of one of these slabs are four large, deeply depressed features (Figure 8). The surface is described here when viewed facing north (away from the sea).

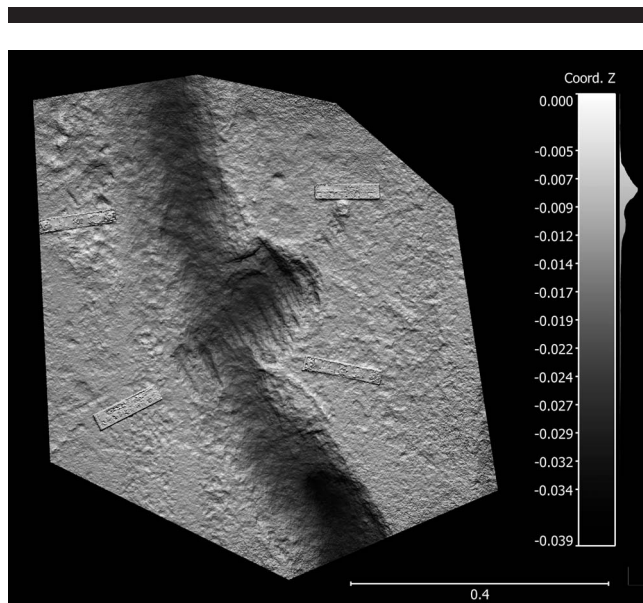


Figure 5. Photogrammetry mesh of the east furrow at the western site. Vertical and horizontal scales are in metres; 28 images were used; photos were taken average 55.4 cm from the surface; the reprojection error is 0.421 pix.

The lower three features are orientated approximately parallel to each other in a row, although the outline of the bottom left feature is not well defined, and measurement of this feature cannot accurately be determined. These three depressions appear to be wider at their upper ends.

The middle feature in the bottom row is 83 cm in maximum length and 28 cm in maximum width. The right feature in the bottom row is 88 cm in maximum length and 38 cm in maximum width, although the length measurement is likely to be an underestimate, as the bottom edge of the rock truncates the depressed feature. Maximum depth of this feature is 11 cm.

In contrast, the fourth depressed feature lies at a sub-perpendicular angle to the other three and lies horizontally in relation to the orientation of the loose slab. Maximum length is 100 cm. It differs from the other three depressions in terms of its more irregular outline. This outline includes a protuberance at its lower edge, which has maximum dimensions of $\sim 13 \text{ cm} \times 10 \text{ cm}$. Maximum width is 49 cm if this feature is included, and 36 cm if it is not included. Furthermore, while displacement rims are evident at the margins of all four depressions, they are particularly prominent at the margins of this depression and at the margin of the protuberance described above.

Macroscopically, the sedimentary composition of this surface has a coarser grain size and thicker beds than are usually seen in dune sediments and is sedimentologically more consistent with a beach environment. However, it was not possible to determine the specific beach facies/environment of deposition because the primary structures were no longer observable *in situ*.

A petrographic thin section from the eastern outcrop area reveals similar features to those reported from the western site: a high incidence of voids in the sample, poorly sorted medium-

to coarse-grained sand sized clasts, and a composition of quartz (dominant), lithic fragments of quartzite and older calcarenite rock, shell fragments (mostly broken), biogenic materials, and glauconite (Figure 7). This deposit is lightly cemented and isopachous and fibrous-textured rim cements fringe individual grains, and fuse adjacent clasts. Relating these textures to previous work on both diagenetic materials (*e.g.*, Voutsdoukas, Velegrakis, and Plomaritis, 2007) and studies on similarly aged and deposited rocks in South Africa (*e.g.*, Cawthra, Uken, and Oveckhina, 2012; Cooper and Flores, 1991), it is inferred that this style of cementation is micrite. The clastic sedimentary characteristics and primary field structures point toward deposition on a beach environment, under conditions of moderate- to high energy.

OSL Dating Results

Results of the OSL dating are presented in Table 1. In short, the sample from the western site (Leic20026) yielded an age of $73 \pm 5 \text{ ka}$, while the sample 100 m west of the eastern site (Leic21013) produced an age of $76 \pm 5 \text{ ka}$.

DISCUSSION

The two sites in Goukamma Nature Reserve clearly preserve substantially different features. First, the evidence is presented here that suggests a pinniped origin, after which other possible origins of these features are considered before a discussion of their implications.

The features observed at the two sites are unusual and are unlike any other traces that have been documented thus far from the Cape south coast. Consequently, there are no other examples for comparison to help inform what has been noted and recorded at these sites.

Field observations and petrographic microscopy suggest that both sites are remnants of beach environments. The steepness of the surface of the western site would lend itself to the formation of furrows, of the kind noted, should seals progress downslope. The juxtaposition of furrows, parallel grooves, and nested grooves requires explanation. While these features could represent unrelated activities by different trackmakers, the proximity of these features to each other, and their rarity in the regional ichnological record, make an “Occam’s Razor” argument plausible, whereby the likeliest explanation is that they were created by one species.

In this regard the most parsimonious explanation for the 10–12 parallel grooves that occur in the widened portion of one of the furrows (and with the same orientation as that of the furrow) is that they represent the dragging of the hind flippers during downslope progression. Their presence in a widening of the furrow indicates that the furrow was created first, followed by the parallel grooves. This would be more consistent with fur seal traces than those of a true seal. The presence of similar (albeit fainter) features downslope within the furrows supports such a contention. The width of the furrow suggests that it was made by a pup or juvenile, rather than an adult. Furthermore, the presence of at least three features on other parts of the surface, consisting of curvilinear, nested grooves with variable degrees of separation, appears consistent with the interpretation of pinniped front flipper impressions.

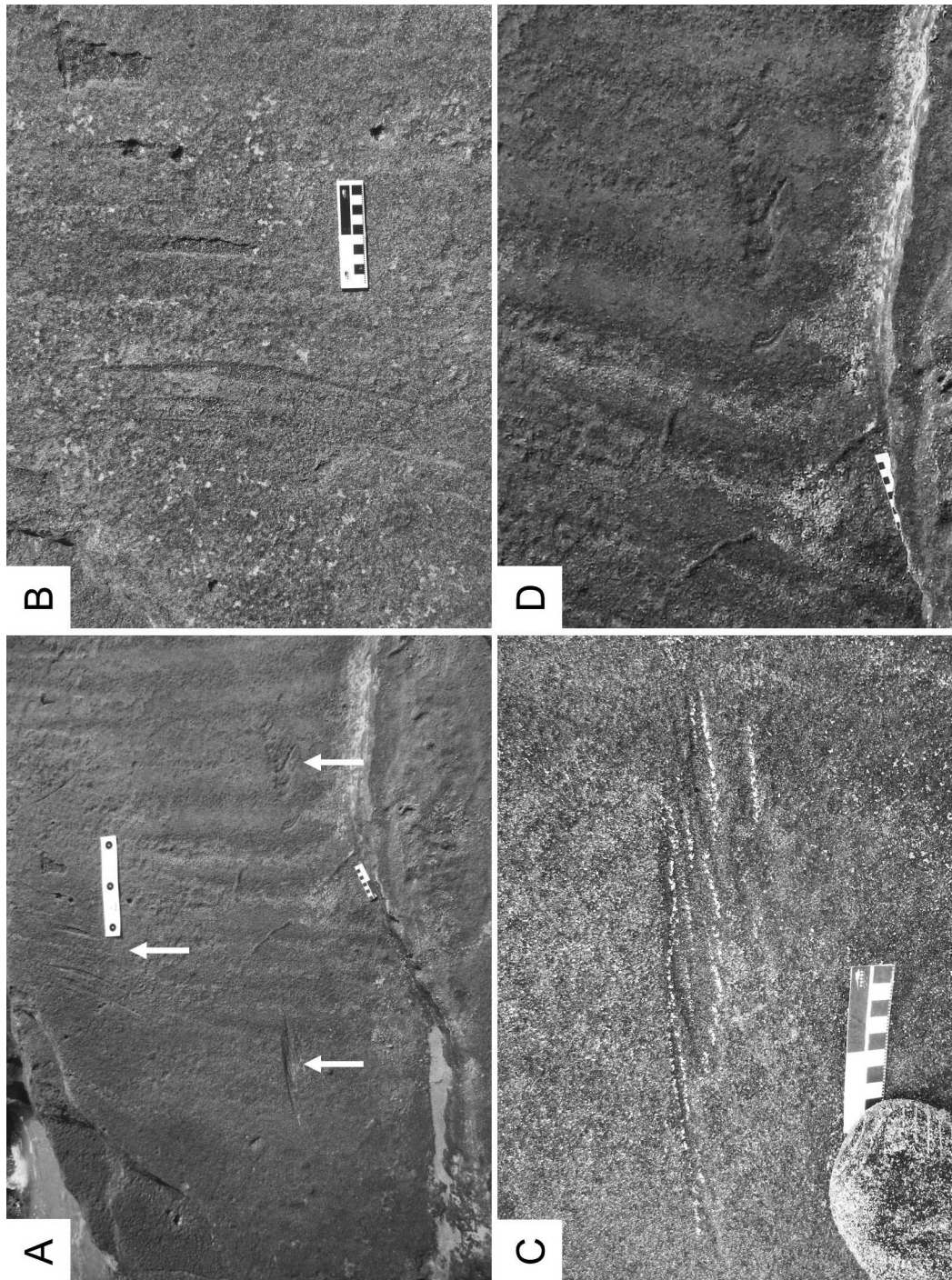


Figure 6. (A) The portion of the western site surface containing possible front flipper impressions, which are indicated by white arrows (scale bars = 10 cm and 30 cm). (B) Magnified view of the upper impressions in (A) (scale bar = 10 cm). (C) Magnified view of right lower impressions in (A) (scale bar in cm). (D) Magnified view of right lower impressions in (A) (scale bar in cm).

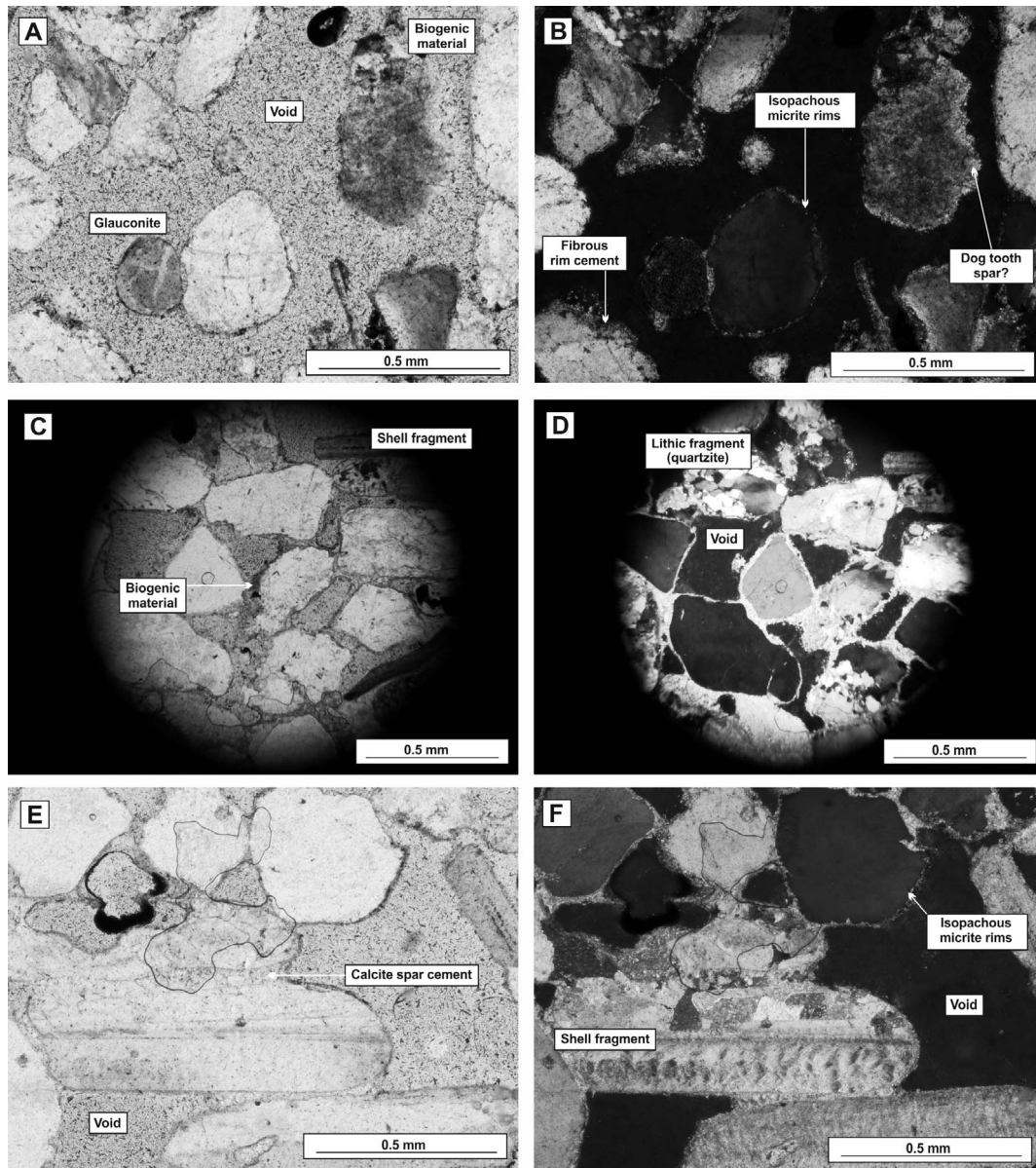


Figure 7. Petrographic thin section images of lithological characteristics of the western and eastern sites. (A), (C), and (E) are planar polarised light, and (B), (D), and (F) show crossed polarisers. Clasts are weakly bound by calcium carbonate cement, likely of micrite origin, identified by its structure, and a second generation of calcite spar has filled in selected voids. The porous nature of the deposit is clear, with voids occupying 35–40% of the samples.

The possibility that the surface represents part of a north-facing washover fan deposited over a berm in the backbeach, of the kind described by Martin and Flemming (1987), and shown in Figure 9, would be consistent both with a seal presence and with beds that dip landward. The absence of body drag marks in the portion of the surface with the putative front flipper impressions arguably presents an interpretation dilemma. However, one explanation for this is that front flipper tracks may leave deeper impressions than body drag marks.

At the eastern site a repeating pattern is evident, and the outlines of the documented depressions approximate those of

gross seal morphology, being much longer than they are wide, and somewhat wider at one end. These resemble the moulds or impressions potentially created by densely concentrated juvenile seals at a rookery in the underlying substrate.

Cape fur seal males average 2.3 m in length, while females average 1.8 m in length (King, 1983). For southern elephant seals these numbers are, respectively, 4.2–5.8 m and 2.6–3 m (King, 1983). The size of the depressions is consistent with the dimensions of seal pups or juveniles. The prominent rims that occur at the margins of these depressions indicate the presence of a compressive force with the capacity to create considerable

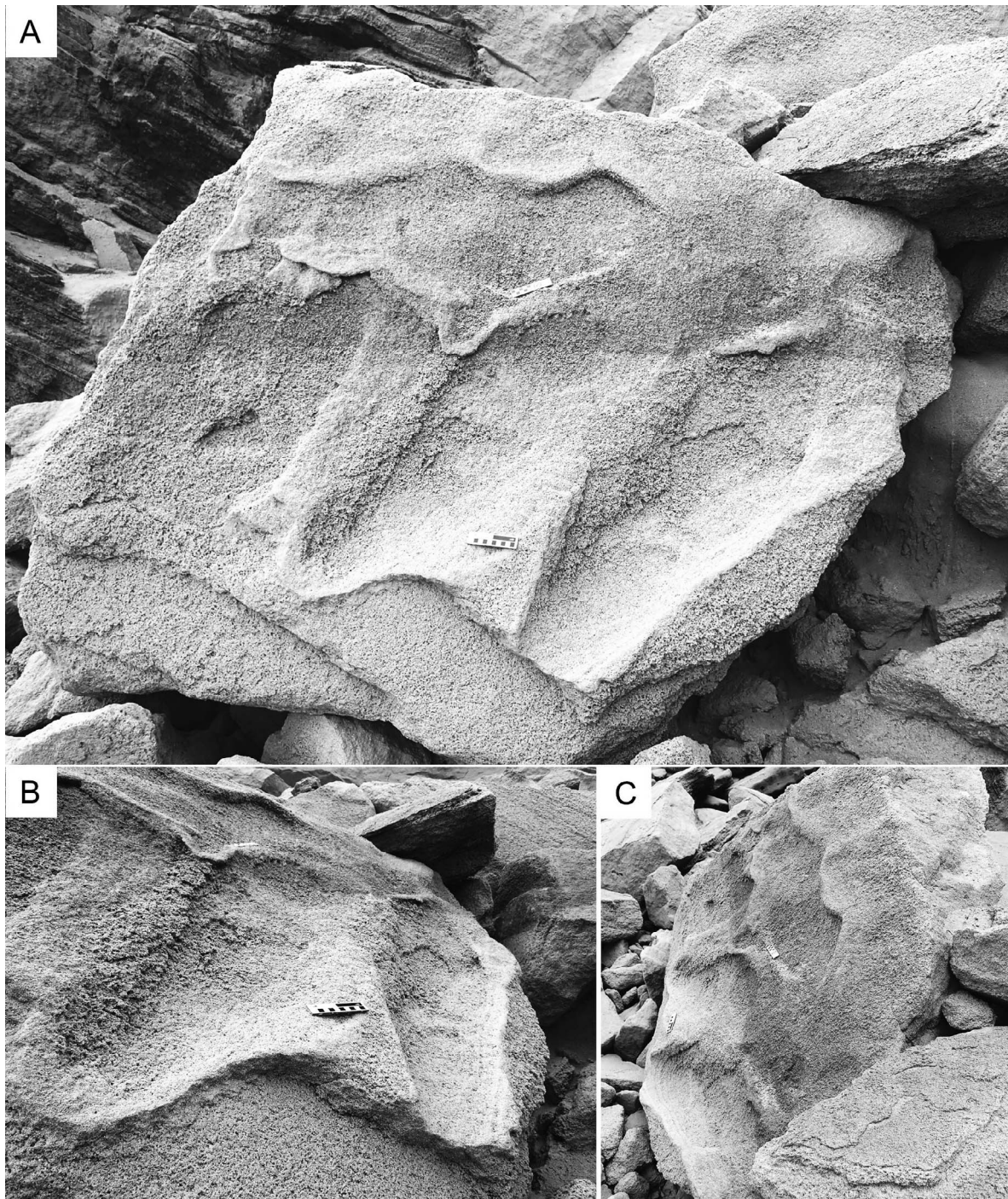


Figure 8. (A) View of the eastern site (scale bars = 10 cm). (B) Angled view illustrating the depth of features at the eastern site (scale bar = 10 cm). (C) View facing west of the eastern site (scale bar = 10 cm).

displacement of sand. In addition, the depression at the upper end of the rock contains a protuberance, which resembles the outline of a front flipper.

Given that the claims made here of possible pinniped traces are unprecedented, alternative explanations need to be

considered. For example, furrows on aeolianite or palaeo-beach surfaces are not uncommon on the Cape south coast; they may have formed in a post-depositional phase and can thus be more recent phenomena, representing erosion channels. However, the presence of the striated groove features and widenings in

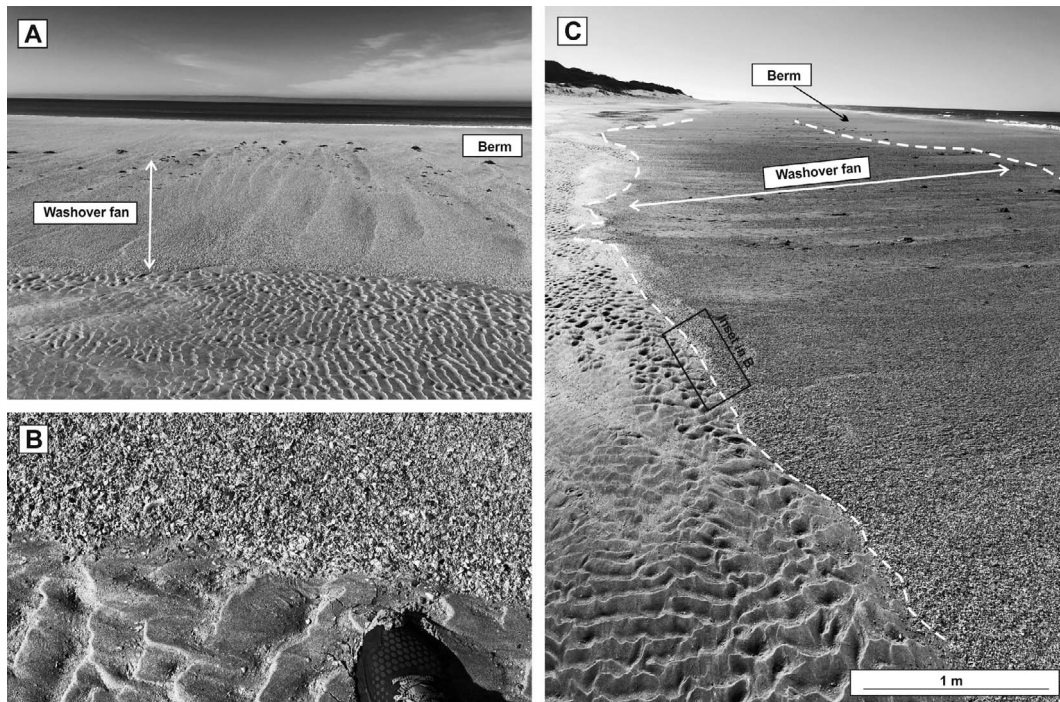


Figure 9. Modern analogue of a washover fan facies, taken on the Cape southeast coast (St. Francis Bay) following a large wave event associated with a southwesterly swell. The poorly sorted, shell-hash-dominated deposits overtopped the beach berm; this deposit was more than 20 cm in thickness.

the one furrow indicate that these features were registered penecontemporaneously (and soon after the furrow was created), and before the surface was covered by further sediment or exposed to further erosion.

Furrows can also represent tree casts or branch casts, but the furrow surface typically assumes a different consistency in such cases, due to chemical changes associated with rhizolith formation which are not present in this case. Seals are not the only vertebrates capable of creating body drag impressions that can form furrows. Crocodiles are in this category as well, and Pleistocene crocodylian traces have recently been described from the Cape south coast (Helm *et al.*, 2020a). However, crocodylian tail drag traces are typically less U-shaped and more V-shaped than is evident in the furrows at the western site. Furthermore, the ten parallel striations cannot be explained through a crocodylian origin and, as described below, the other features on the surface do not appear consistent with crocodylian traces (*e.g.*, Milàn and Hedegaard, 2010). Similar considerations apply to the traces of large lizards such as monitor lizards.

Whereas erosive forces of wind or water forming structures, such as large scour marks or flute casts, should be considered for the three similarly-orientated depressions at the eastern site, the upper depression, which has a different orientation, is inconsistent with such a scenario. Besides, the rims that nearly encircle these depressions argue for a compressive displacement force, rather than an erosive force. While suggestions regarding other possible causes are welcomed, it is contended here that the likeliest explanation is that the depressions are

natural moulds that were made by large animals on surfaces of unconsolidated sand.

The parallel striations and nested curvilinear lines forming rainbow patterns fall into a different category. Potential causes of such lines were previously considered in detail when considering potential anthropic patterns that have been noted on Pleistocene Cape south coast surfaces (Helm *et al.*, 2019).

In brief, the following potential causes of such patterns (both nonbiogenic and biogenic) were identified, either on palaeosurfaces or on currently exposed dunes and beaches:

- Bedding planes seen in cross section exhibit parallel line patterns, and the transition from one microbedding plane to the next on a differentially weathered palaeosurface can sometimes create a set of nested circles or ellipses;
- Wind-generated ripple mark patterns often take a distinctive sub-parallel, sinuous form with characteristic contours. These are orientated perpendicular to the wind direction. On such surfaces, tapered parallel grooves or ridges can occur downwind of surface protuberances;
- Similar ripple-marked surfaces can form subaqueously due to water movement, as is often seen on beaches during a receding tide or in lagoons. Water can also drag items, causing long, parallel, “tool mark” features;
- Rill-marked, cross-hatched patterns are often created on beach surfaces during ebbing tides. Water flowing over sand can also cause parting plane lineations or scour marks and flute casts;

- (e) Aeolianite rocks that grind against each other during erosive movement may create long, parallel groove features, which are usually straight but may be slightly curved;
- (f) Root casts and rhizoliths may sometimes present as a paired appearance of parallel lines;
- (g) Nesting arcs from plant fronds blowing in the wind assume concentric forms;
- (h) Invertebrate traces, especially if not well preserved, can appear as parallel lines, which may be straight or curved.

While the above potential causes all need to be duly considered, none of them are compatible with the variety of features noted at the western site. For example, the surface has prominent ripple marks, which can be readily distinguished from the described features. Likewise, whereas one set of grooves is orientated approximately perpendicular to the ripple marks, its curvilinear appearance makes a cause like “tool marks” unlikely. More germane to this discussion are a variety of vertebrate traces, which are discussed further below.

Parallel or subparallel groove features can be created by reptiles, birds, and mammals. Crocodylian swim traces have recently been reported from the Cape south coast (Helm *et al.*, 2020a), and these can indeed appear curvilinear in form and may resemble the three isolated features on the surface. One argument against this is palaeo-environmental: crocodylian swim traces are typically registered in a subaqueous or at least a muddy environment, which is not consistent with a sloping surface at the western site. Furthermore, the set of ten parallel striations is inconsistent with a crocodylian origin.

Sea turtles may also register flipper traces and central furrows. Lockley *et al.* (2019) provided the first records (also from the Cape south coast) of Pleistocene sea turtle trackways, in both an alternating and symmetrical gait pattern, inferred to represent traces respectively made by representatives of *Caretta* and *Dermatochelys*. The set of ten parallel striations does not appear compatible with a chelonian origin. See Lockley *et al.* (2019 and references therein) for a detailed description of sea turtle traces.

Tortoises commonly create parallel scratch marks behind their tracks, and carnivores running on dune and beach surfaces leave parallel grooves in addition to their tracks. Neoichnological studies demonstrate that such traces are inevitably found in association with tracks. The absence of carnivore tracks or tortoise tracks is an obvious counter to such an argument. Birds such as the white-breasted cormorant (*Phalacrocorax lucidus*) create a series of sets of parallel grooves during take-off and landing. This pattern is seen on level beaches, but not typically on inclined surfaces.

As for hominin causes, these can be divided into ancient and modern. Ways have been determined to distinguish modern graffiti from ancient images inscribed in sand (Helm *et al.*, 2019); it can be concluded that there is no evidence on the surface for graffiti. The presence of a possible ammoglyph nearby indicates a probable hominin presence, which therefore needs to be considered as a possible explanation for the features noted at the western site. For example, could the ten parallel striations also be an ammoglyph, and could the furrows represent areas where humans had dragged a load down a

sandy slope during the Pleistocene, and then inscribed the parallel lines? While such anthropogenic origins cannot be fully excluded, this appears extremely implausible compared with the likelihood of a pinniped origin.

The archaeological record on the Cape south coast indicates that Cape fur seals formed a part of the MSA hominin diet. Seals might have been harvested through hunting at rookeries, rarely through catching a seal resting on rocks, and through scavenging of wash-ups (Marean, 1986, 2010). Klein and Cruz-Urbe (1996, 2000) contrasted the evidence from two MSA sites (Klasies River mouth, 120 km to the east of the sites described here, and Die Kelders Cave 1, 325 km to the west) with that from a number of LSA sites, noting that the LSA sites contained a significantly greater proportion of young seals. They inferred that in the LSA there was more of a seasonal round, focused on the season of peak young seal availability.

Marean (1986) noted that seals have much higher fat levels than do all terrestrial mammals, and that the amount of blubber on Cape fur seals on the Cape coast varies significantly through the seasons, being highest in the winter months. This is the season when carbohydrate availability from plant sources in the region is at its lowest, and Marean (1986) postulated that seal blubber (rather than meat) formed an important part of the winter diet for the human inhabitants of the region. Marean (1986) compared the fat/lean meat ratio of a number of mammals. Not surprisingly, seals showed by far the highest fat/lean meat ratios. Within the seal group, the elephant seal had the highest fat/lean meat ratio. At Die Kelders Cave 1, Klein and Cruz-Urbe (2000) recorded large numbers of Cape fur seal bones in multiple layers from the MSA, but no elephant seal bones. In the LSA layer, a minimum number of individuals (MNI) of 108 was recorded for the Cape fur seal, and a MNI of two (from two bones) of the southern elephant seal. Washed-up elephant seals, although likely a rare phenomenon, would have provided a substantially greater meat and blubber supply than that of the Cape fur seal. If the sites described here do indeed provide ichnological evidence of seals, then the archaeological evidence suggests that these would have been Cape fur seals. As discussed above, the ichnological findings at the western site are consistent with the passage of a fur seal, rather than a true seal, which supports this contention. However, the possibility that the traces were registered by one of the vagrant species that are occasionally found on the Cape coast cannot be completely discounted.

The notion of seals having created the traces at the sites described could be refutable through OSL dating, as a nearby coastline is a prerequisite. The new OSL ages obtained for the two sites (Table 1) are indistinguishable, producing ages of 73 ± 5 ka (western site; Leic20026) and 76 ± 5 ka (eastern site; Leic21013). They are comparable to the younger OSL ages obtained by a previous study a few kms from the western and eastern sites, where an age range was reported from $\sim 136 \pm 7$ ka at the base of the section in the coastal cliffs, to $\sim 79 \pm 9$ ka higher up section (Bateman *et al.*, 2011). The same study (their figure 10) argued that the palaeo-coastline within the eastern Wilderness Embayment, in contrast to the western parts of the embayment, would have been close to the present throughout much of MIS 5. As such, the deposits sampled here and thus their accompanying ichnological record likely represent some

of the final MIS 5 deposits and trackways deposited in this locale, before the MIS 4 sea level regression after ~75 ka led the migration of the coastline onto the continental shelf. The notion that seals created the traces at the sites described is therefore plausible. The sedimentological facies, their ages and the presence of possible seal traces suggest that these sediments were plausibly laid down during or immediately prior to the sea-level regression at the end of MIS 5a.

In summary, while there are multiple agents that potentially can create the types of features described, it is difficult to plausibly relate them to these features. For the western site in particular, while in theory different trackmakers and agents may have created the traces, it appears more plausible that the features noted represent traces registered by a single species.

If this approach is taken, then the likeliest scenario is that they represent the activities of a fur seal, including front flipper impressions, striations from sliding hind flippers, and body drag impressions made while sliding down a sand slope, forming furrows. Combined with the features at the eastern site that suggest body impressions of juvenile seals, the most plausible inference is that fur seals created these traces during the Pleistocene.

If the western site is indeed a seal tracksite, and if the nearby radial pattern is an ammoglyph, this would suggest spatio-temporal convergence of the ichnological and archaeological evidence of a relationship between MSA hominins and seals. However, it is not possible to know the precise interval of time between the depositional events that led to the formation of these two palaeosurfaces.

CONCLUSIONS

Pinnipeds form a large and familiar clade within the class Mammalia and order Carnivora. Their almost complete absence until now from the palaeo-ichnological record represents a substantial gap, and contrasts with an impressive body fossil record. The findings described here are inferred to be most easily explained as fur seal traces, with the implication that Pleistocene seal populations occupied sandy shorelines ~75,000 years ago on the Cape south coast of South Africa. This may act as a spur for the search for and identification of similar traces in other suitable localities.

ACKNOWLEDGMENTS

We appreciate the assistance of Jack Carrigan, Johan Huisamen, Carina Helm, and Martin Lockley, and the staff of CapeNature. We appreciate the thoughtful and thorough comments and suggestions provided by two anonymous reviewers, which led to significant improvements to our manuscript.

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