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The ichnology of White Sands (New Mexico): Linear traces and human footprints, evidence of transport technology?

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ABSTRACT

A travois is crafted from one or more wooden poles and is one of the simplest prehistoric vehicles. Although these devices likely played vital roles in the lives of ancient peoples, they have low preservation potential in the archaeological record. Here we report linear features associated with human footprints, some of which are dated to ~22,000 years old, preserved in fine-grained sediments at White Sands National Park (New Mexico, USA). Using a range of examples, we identify three morphological types of trace in late Pleistocene sediments. Type I features occur as single, or bifurcating, narrow (depth > width) grooves which extend in planform from 2 to 50 m in length and trace either straight, gently curved or more irregular lines. They are associated with human footprints, which are truncated longitudinally by the groove and are not associated with other animal tracks. Type II examples are broader (width > depth) and form shallow runnels that typically have straight planforms and may truncate human footprints to one side. Type III examples consist of two parallel, equidistant grooves between 250 and 350 mm apart. They trace gently curving lines that can extend for 30+ m. Human footprints are associated with these features and may occur between, and to the side of, the parallel grooves. We review a range of possible interpretations including both human and non-human explanations and conclude that the most parsimonious explanation is that they represent drag marks formed by travois consisting of a single pole or crossed poles pulled by humans, presumably during the transport of resources. As such this unique footprint record may represent one of the earliest pieces of evidence for the use of transport technology.

1. Introduction

Modern humans use a wide range of manual and/or mechanized transport technology, including sleds, carts, boats, planes, trains, and automobiles, among many others. As our ancestors became migratory they too must have had the need for transport technology as evidenced by sea passages (Derricourt, 2005; Hölzchen et al., 2022) and conveyance of raw materials (Houston, 2011). Indigenous narratives and ethnographic literature contain references to the use of travois fashioned from one or more poles and pulled by dogs, horses, and/or humans (e.g., Mason, 1896; Wissler, 1910; Wilson, 1924; Ewers, 1955; Driver and Massey, 1957). We use the term ‘travois’ broadly to include any form of vehicle fashioned from a single wooden pole with a load, as well as more complex vehicles consisting of two or more crossed poles. Ancient travois were most likely made of wood, so are not usually preserved in the archaeological record. Here we describe linear features associated with human footprints preserved in fine-grained sediments at White Sands National Park (WHSA), located in the Tularosa Basin (New Mexico, USA). We describe these linear traces and review potential origins, and conclude that they were likely made by humans dragging either single or multiple poles potentially as improvised travois although we cannot exclude the possibility that *some* of the traces observed were made by the transport of firewood. Examples are drawn from across White Sands in strata of varying or uncertain age. However, the presence of tracks of megafauna (e.g., proboscidean and giant ground sloth) on adjacent footprint horizons places the ages of these traces to at least the late Pleistocene (Bustos et al., 2018).

2. Sites and methods

White Sands National Park (WHSA) in New Mexico comprises one of the largest concentrations of Cenozoic vertebrate tracks in North America (Lucas et al., 2007, Fig. 1). The area consists of two primary geomorphological components: a gypsum dune field of terminal

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Pleistocene or Holocene age (Kocurek et al., 2007; Holliday et al., 2023) and Alkali Flat, an eroding playa that is the former bed of Paleolake Otero and associated lake margin sediments (Allen et al., 2009). Tracks and trackways of Proboscidea (mammoth/mastodon), Folivora (ground sloth), Carnivora (canid and felid), and Cetartiodactyla (bovid and camelid) occur on Alkali Flat along with humans (Bustos et al., 2018). Not only do the tracks occur in large concentrations, but they occur over a wide spatial area allowing individual trackways to be followed for extended distances. The unique properties of the site make it ideal to explore past life ways and behaviors.

Footprints at White Sands are of three broad types. Tracks occurs as dolomite-cemented pedestals (epirelief); as cemented tracks with a combination of positive and negative relief (epirelief + hyporelief); and negative impressions in consolidated, although largely uncemented, sediment (hyporelief) with sediment fill. Although linear features are found in association with all three track types, only tracks in hyporelief can be excavated.

Linear features are known from a central area of Alkali Flat, referred to colloquially as the "mammoth trample ground" due to the concentration of proboscidean tracks. Additionally, they are located on the eastern side of Alkali Flat eroding out of a low eroding bluff in the vicinity of WHSA Locality 2 (Bennett et al., 2021). U.S. Federal Law prohibits the disclosure of specific archaeological and palaeontological locality information within National Park Service areas (e.g., Archaeological Resources Protection Act of 1979, National Parks Omnibus Management Act of 1998, and the Paleontological Resources Preservation Act of 2009). As such, the precise locations of the sites referred to in this paper are withheld but interested parties can apply to the National Park Service for details.

Excavation at WHSA Locality 2 was undertaken in a phased manner over several years (Fig. 2). The site was originally identified in 2019 as a target for excavation due to the presence of several surfaces on which human footprint trackways could be traced under covering sediments. These surfaces also contained linear features (Fig. 3). The host sediments

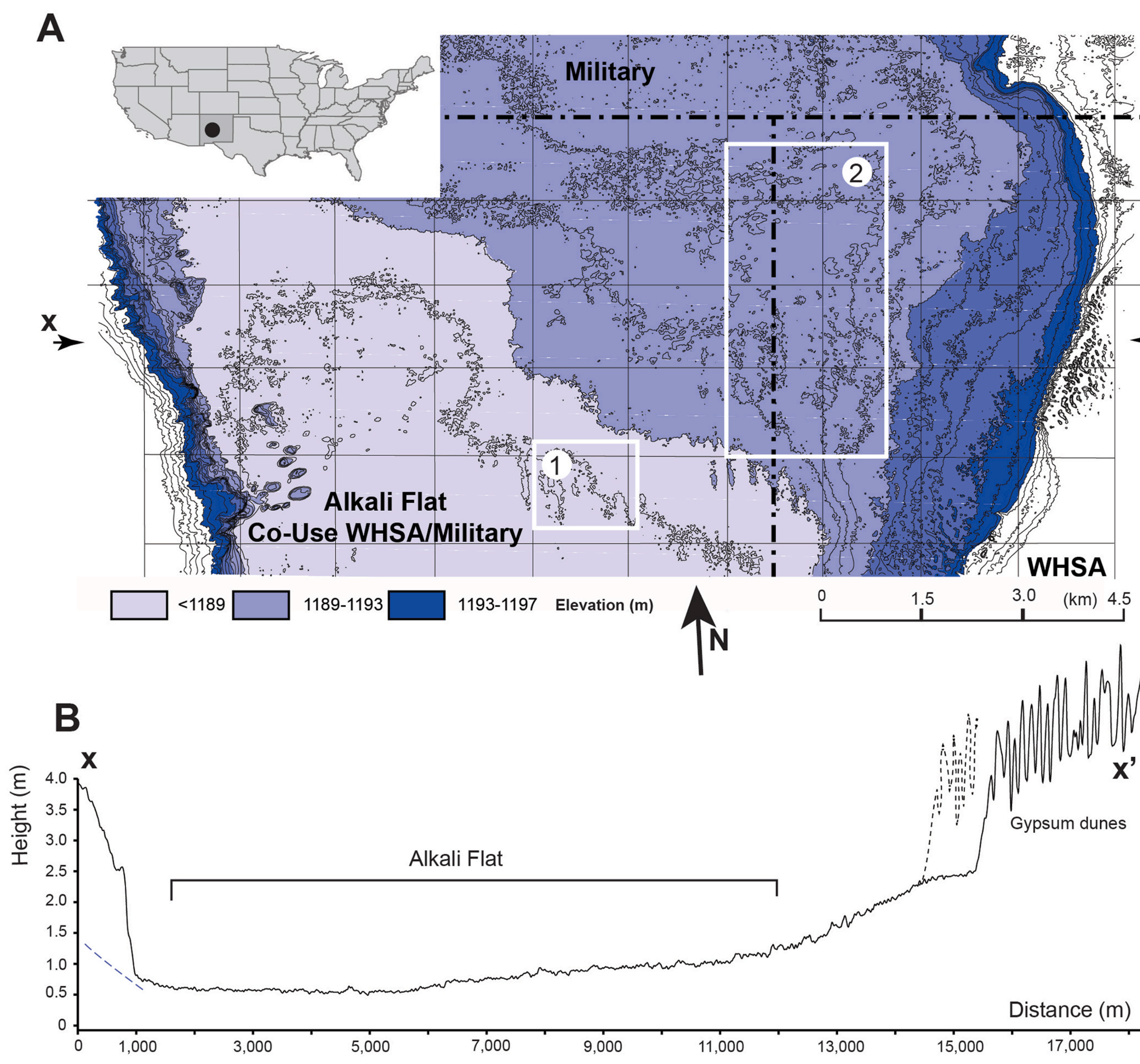

Fig. 1. Summary of topography, land use, and geological setting of the tracks in the northern part of White Sands National Park (WHSA). Elevation data is based in INSFAR data. The mammoth trample ground is in box (1) and WHSA Locality 2 and associated sites are within box (2). Dotted line in the cross-section indicates dune migration.

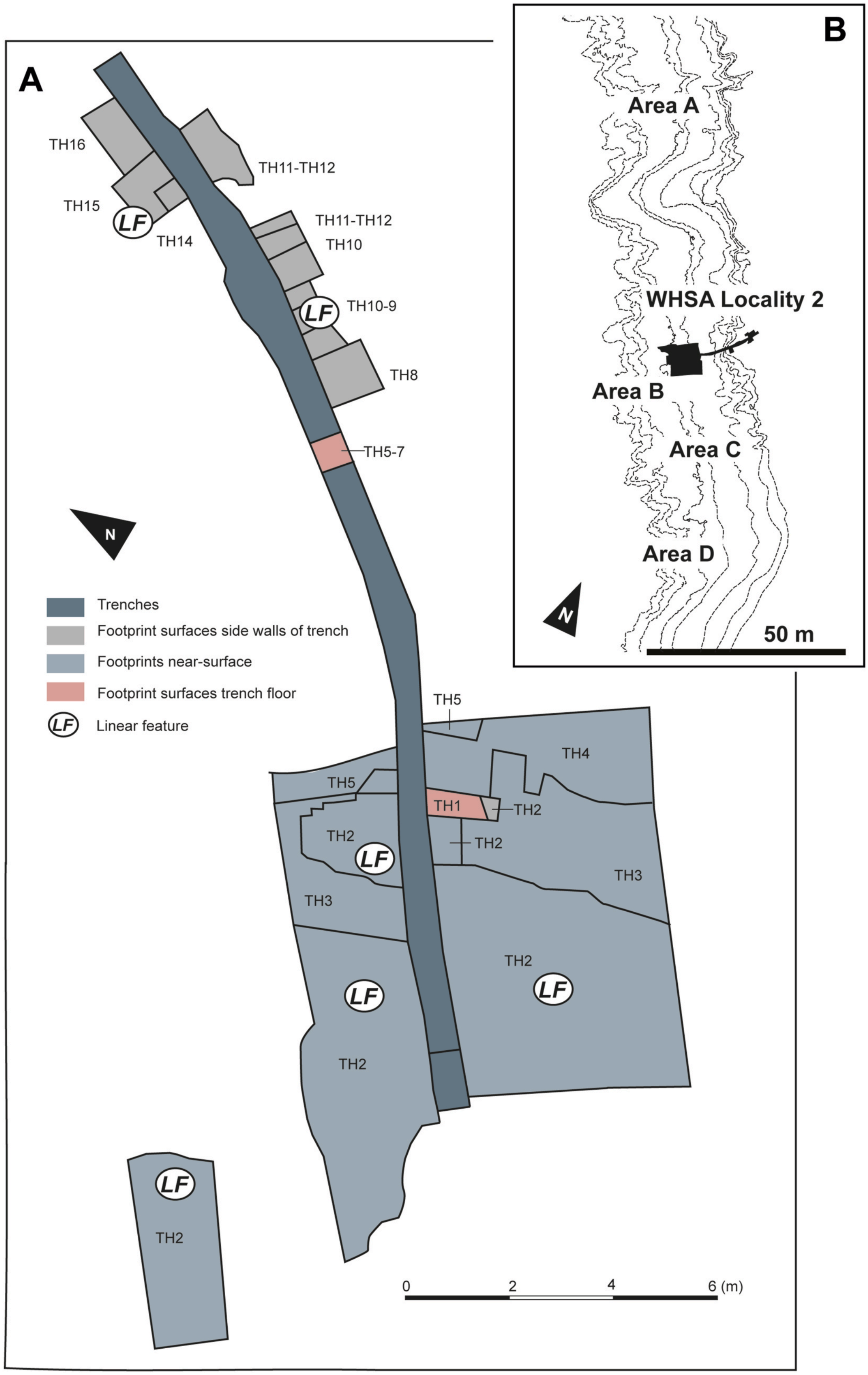

Fig. 2. Details of the WHSA Locality 2 excavation as of January 2022 showing the footprint surfaces (TH2 to TH16). The inset shows the locations of Areas A to D in relation to the excavation with contour intervals of 0.2 m.

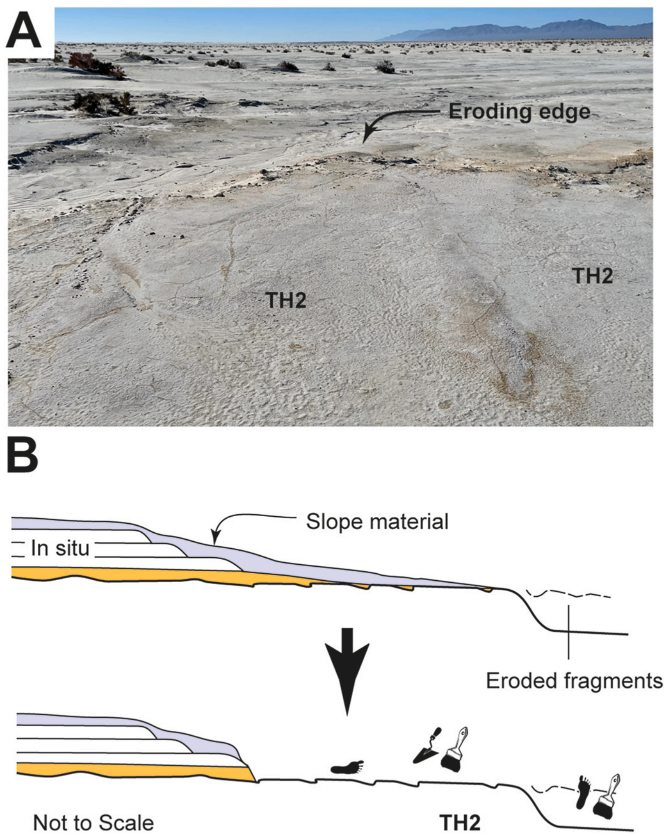

Fig. 3. Area A of WHSA Locality 2. **A.** View of the surfaces in this area looking out towards Alkali Flat. When the surfaces are cleaned of slope wash and salts, they look like that in Figs. 5 and 6. **B.** Schematic sketch of the surfaces in Area A, they correspond to Track Horizon 2 (TH2).

containing the linear features vary in competence and degree of induration, but as a general guide cannot be easily dug without a pickaxe or mechanical tools. The locality has three types of footprint exposures: (1) excavated surfaces adjacent to, and in the base of, a main trench that was generated for study (Bennett et al., 2021); (2) ichno-surfaces excavated from beneath a thin layer of salt crust, slope wash, and other sediments; and (3) indurated ichno-surfaces exposed on the current surface.

In January 2020, the main trench referred to above was dug for the purpose of revealing the stratigraphic context of buried footprint surfaces after consultation with the Indigenous Tribes and Pueblos affiliated to the park. This trench was excavated using a dirt-rated chainsaw as described in Bennett et al. (2021). Briefly, two deep (~0.75 m), parallel cuts were made perpendicular to the strike of in situ sediment layers. Shallow (~0.5 m) transverse cuts were made between these parallel cuts to allow blocks to be removed manually and stacked to one side. The base of the trench, exposed in this manner, was then excavated further (where possible) by a process of slab-hinging. For this, a chisel and/or pry-bar was placed at the edge of steps in the trench floor and used to leaver up indurated slabs which hinged upwards to reveal natural surface partings on which footprints were sometimes visible. In situ surfaces adjacent to the trench were cleaned of slope debris and intact sediment layers so they could be traced laterally into the stratigraphy exposed in the trench walls. Footprints on these surfaces were documented using photogrammetry (Bennett et al., 2021).

In January 2022 the main trench was further extended using similar methods and additional footprint horizons identified in the trench walls were uncovered via lateral benches on the trench shoulder by excavating downward either by slab hinging or by manual scraping layer by layer. Surface lowering was done carefully to reveal the topography of the original ichno-surface rather than maintaining a horizontal surface as is sometimes common in more traditional archaeological excavations. In January and April 2022 and in January, April, and November 2023, near-surface, horizons were excavated to the north of the main trench in Area A (Fig. 2). On the outward edge of these surfaces there are eroding relics of indurated linear structures. As one moves eastwards and up slope, the surface is revealed 10–25 mm beneath a thin veneer of salt crust, blown sand and slope wash (Fig. 3). This surface was correlated with the Track Horizon 2 (TH2) in the main trench based on lithostratigraphy (Bennett et al., 2021). This surface was excavated to expose the original surface topography in several phases. Initially in April 2022 the surface was scraped of the salt crust to reveal the 2D surface and the tracks visible on it. In April and November 2023, a distinctive orange/red sediment infill was removed to expose the footprints and associated linear features.

Areas B, C and D consist of surfaces that are more continuously indurated with distinct footprints and linear features picked out in a combination of epirelief and hyporelief. These again equate to TH2 in the context of the stratigraphy and can be traced into the main trench (Bennett et al., 2021). Excavation of these surfaces was not possible due to their indurated nature. When probed, they broke and are also subject to surface damage by unnecessary trampling and are eroding rapidly. In this case all that can be done is to remove, by a combination of brush and air-blower, wind-blown sediment and surface wash. At the eroding edges of these surfaces, it is possible to expose the softer underlying stratigraphy in a few places. Additionally, these indurated surfaces can be traced laterally into the slope to confirm their primary stratigraphic origin and position.

Recognition of human tracks is based on two basic criteria; firstly, the presence of anatomical features, namely toes and heel, and secondly multiple steps forming trackways. Where tracks are truncated by linear features recognition is based on anatomy and typical shapes produced by modern analogue observations discussed later in this work. Notation of footprint surfaces follows that established in previous work (e.g., Bustos et al., 2018; Bennett et al., 2021). As a general principle, and in keeping with the wishes of Indigenous peoples consulted, a minimum number of tracks was excavated. Most of the surfaces reported here were examined first as 2D surfaces using photographic orthomosaics generated with Agisoft Metashape Pro v.1.8.2 (https://www.agisoft.com). This was partly due to the indurated nature of the sediments and a conscious decision to leave as much of the ichno-fossil-bearing surface unexcavated as possible. Loose and excavated sediment was sieved, but no artifacts were recovered. Where excavation was possible, and desirable, tracks were captured in three-dimensions using between 40 and 150 oblique photographs taken with a Canon EOS 1200D and fixed lens or with an iPhone 12/15. Individual models were scaled and rotated to the principal plane. Colour rendering was undertaken in Cloud Compare (V2 12.4, Kyiv; https://www.danielgm.net/cc) having first applied a 2.5D Delaunay triangulation. Best practice was followed, as set out by the ichnological community (Falkingham et al., 2018; Bennett and Budka, 2019).

Inferences of stature from footprints were made using the 15% value (walking, firm substrate) indicated by Wiseman and De Groote (2021). Age estimates of the humans who made the tracks was based on data from UMTRI/CPSC Child Anthropometry Study (Snyder et al., 1977), supplemented by observations from the authors' own data set (N = 3901). For each whole number foot length in this dataset the range of associated subject ages was used to generate a standard deviation and mean from which bootstrapped samples were generated (N = 1000). Despite this the number of values in some size classes is small or zero. To counter this problem sampling windows of 3, 5 and 7 size classes (i.e., 1, 2 and 3 classes ± a given foot size class) were used. Differences in mean values were negligible but in all cases the error margins were smaller when using a larger sampling window. The age means and errors used here are all based on a 5-column window (i.e., foot size ± 2 mm). It is important to recognise that a range of studies recognise a difference in footprint and foot lengths (e.g., Hatala et al., 2020), often by as much as

5%, moreover intra-trackway variability may add further uncertainty. Consequently, age estimates should be taken as approximations only. Mineralogy of samples from TH2 were collected in January 2022 and analysed by XRD at Triclinic Labs in Lafayette, IN.

3. Results

3.1. Area A

The naturally eroding surface of Area A lies approximately 60 m to the north of the trench dug at WHSA Locality 2 and is located at the base of the north-south trending bluff which rises from the floor of Alkali Flat to the east (Figs. 2 and 3). In April 2022 it was scraped clear of salt and slope debris to expose, in two-dimensions, a series of proboscidean tracks and linear features infilled by a distinctive red silty fine sand (Fig. 4). The surface can be divided into southwest and northeast sub-areas. In April 2023 part of this surface was uncovered again and the red silty fine sand removed (Fig. 5). Several linear features became clear, as did a trampled (toe-heel) line of footprints which are cemented by dolomite (Fig. 6). Whether this unusual line of tracks is due to children at play or simply the result of multiple people walking along the same line is unclear. The presence of dolomite was confirmed by XRD (dolomite = 88%; gypsum = 4%; quartz = 6%; halite = 3%).

In general, the linear features extend for several meters, are bifurcated in places, absent over short sections, and vary in width from less than 20 to over 65 mm. While the surface contains proboscidean tracks, they do not parallel the linear features. Human tracks do occur parallel to the linear features and are commonly crosscut longitudinally by them. The bifurcating linear grooves are associated with human tracks and the grooves truncate them longitudinally or obliquely (Fig. 7). The north-eastern part of this surface was excavated in November 2023 (Fig. 8). There are three broad features on this surface. On the left of Fig. 8, west side, there is a lozenge-shaped area of trampled ground with a line of human tracks heading from to the north. This area contains multiple crosscut human tracks consistent with an area of damp ground and trampling. The tracks are small (~160 mm) and may have resulted from children at play. The number of human tracks in this area exceeds 90. More tracks than are currently visible to the excavators may become visible in the future with wind etching. Of those that are complete and can be measured (N = 87) the tracks range from 140 to 295 mm in length. Using a Mixtures Analysis two distinct populations can be identified (Akaike IC: 720.6; Akaike, 1974; Dempster et al., 1977), one with a mean of 210 mm and another with a mean of 291 mm (Fig. 9). A track size of 210 mm equates to a track-maker age of 10 ± 0.2 years while the larger track is likely that of an adult. It is important to note that this may represent only a small number of individuals. Using the Minimum Number of Individuals approach set out by Webb et al. (2014) we get an estimate of 6 individuals using an intra-trackway variance of 6.67 mm (see also: Belvedere et al., 2021).

To the east, in the middle of Fig. 8, there is a prominent linear feature that stops and starts in an en echelon fashion to the north. There are a series of footprints associated with these linear features as well as a general set of poorly defined trackways moving diagonally (southeast to northwest) and obliquely to the linear grooves. Discounting those tracks which are moving obliquely to the linear grooves one is left with a set of footprints parallel to the features and potentially indicating a lifting and/or switching of the groove-making indenter. Further to the right, east side, of the surface shown in Fig. 8 another prominent groove is visible (10–50 mm wide, 30–60 mm deep). This contains footprints of at least two persons, based on their size. The larger tracks (260 mm long; 15 ± 0.2 years) are visible in the side wall and floor the main groove, while a smaller child's track (150 mm long, 3 ± 0.2 years) is truncated longitudinally by the groove (Fig. 10). This sequence of tracks is instructive and implies the presence of a child and an adult. We infer that the child walked in front of the adult who in turn was dragging something that made the linear feature behind them.

3.2. Area B

This area is located in the immediate vicinity of the main trench at WHSA Locality 2 (Fig. 11). Linear feature (LF) LF-1 to LF-4 all occur on TH2 and are between 1 and 2.5 m in length and extend into the slope below overlying layers on the west (down slope) they are truncated by erosion. They are all preserved in dolomite epirelief. They vary in width from broad, shallow runnels such as LF-1, to narrow runnels such as LF-2 (Fig. 12A). LF-3 appears to have been overprinted by human tracks in places and crosscut longitudinally by human tracks in other places (Fig. 12B and C). LF-19 consists of a much broader runnel which varies in width, may have additional grooves to one side in places and crosscuts at least four human tracks longitudinally (Fig. 12D and E). These three examples show the morphological range of the larger, more linear features and contrast with the narrow deep grooves in Area A. However, LF-5 located on TH3 immediately above this indurated dolomite surface shows a return to this deeper, more irregular, groove morphology. We note that TH3 is not indurated by dolomite and therefore the infill could be removed (Fig. 13). LF-5 consists of either a single or bifurcating V-shaped groove which causes deformation into the underlying sediment. This deformation consists of small diapir-like structures to either side of the linear feature, minor compression of layer below it, and associated flame structures (Fig. 13). These linear features are associated with a total of 61 human tracks and gives a bimodal size range with three populations identified using a Mixture Analysis (Akaike IC: 485.9; means 1545 and 218 mm). One mode corresponds to a potential child age of 4 ± 0.1 years and another slightly older at 11 ± 0.3 years. There is also an outlying value which was likely made by an adult (Fig. 9B). The Minimum Number estimate is 6 individuals for this assemblage of tracks.

Higher in the stratigraphic sequence (TH10), there is a short linear feature exposed on the trench shoulder that is not indurated (Fig. 14). This feature was first identified by the lighter, more gypsum-rich fill which also had a human footprint imprinted on it (Fig. 14A). Excavation of this feature revealed it to be a curved groove approximately 150 mm wide and 60 mm deep. Deformation of the sediment beneath the groove is visible with small diapiric-like structures on either side and minor compression of underlying strata. There are several eroded fragments of an indurated linear feature in the vicinity of Area B. These fragments can be inverted to reveal the basal form and consist of a range of curved bases consistent with formation by a rounded indenter. The basal surface also shows linear striations indicative of movement along the length of the feature (i.e., dragging). A particularly fine fragment shows the complexity of the preservation in both negative and positive relief (Fig. 11C).

3.3. Area C

Area C is located 50 m to the south of the main trench at WHSA Locality 2. It consists of an indurated surface of dolomite which is fragmenting under erosion. It is also covered in places by windblown sand and slope wash. The linear features occur in epirelief with an inversion of relief such that footprints occur on pedestals and the grooves of linear features now upstand. Inversion in this way is typical of the surfaces indurated with dolomite at White Sands. This occurs because of the action of algal mats preferentially retaining sediment in damp tracks (Marty et al., 2009) which then dolomitize under a regime of wetting and drying (Kim et al., 2023). In this area there is a distinctive X-shaped convergence of two linear features (Fig. 15). The first element (LF-11) is a straight feature about 250 mm wide consisting of two parallel and equidistant grooves which now upstand by a 10–25 mm. The linear feature extends for 8 m horizontally and continues beneath overlying strata. Sediment splays either side of the feature, forming mushroom-like shapes in cross section and appears to have formed by sediment displacement to form a wake. Human footprints occur to either side and are superimposed on the linear feature, but no other animal tracks have been found. At the eroding edge of the surface, it is possible

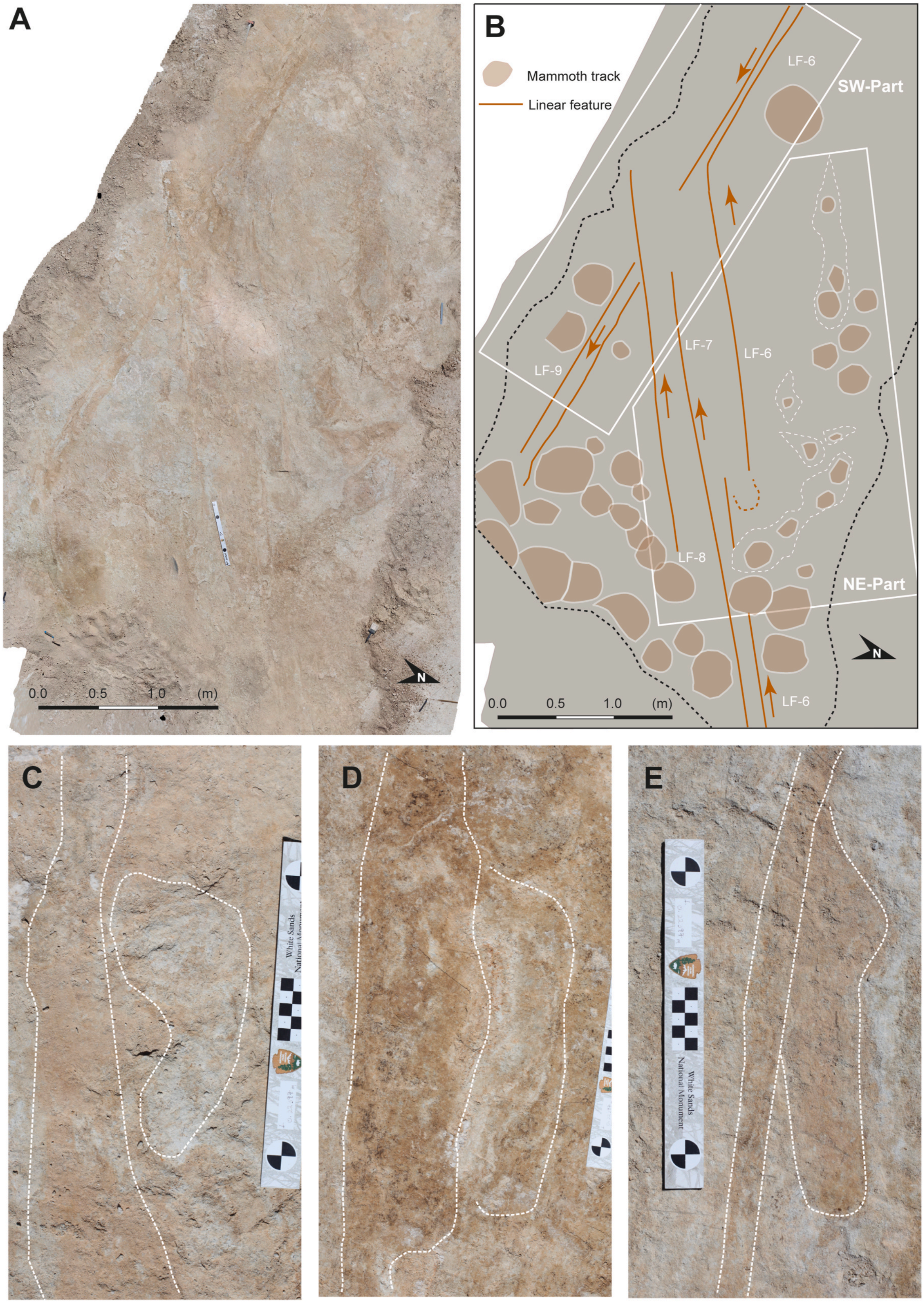

Fig. 4. Main surface examined in Area A. **A.** Surface cleaned of salt and slope debris, without any removal of red silty sand from visible structures. Note the prominent linear features. Photographic orthomosaic from oblique photographs captured using a step ladder. **B.** Interpretation of the two-dimensional surface in panel A. **C.** Example of an unexcavated human footprint with the same orientation as a linear feature. **D.** Unexcavated human footprint truncated longitudinally by a linear feature. **E.** Unexcavated human footprint obliquely truncated by a linear feature.

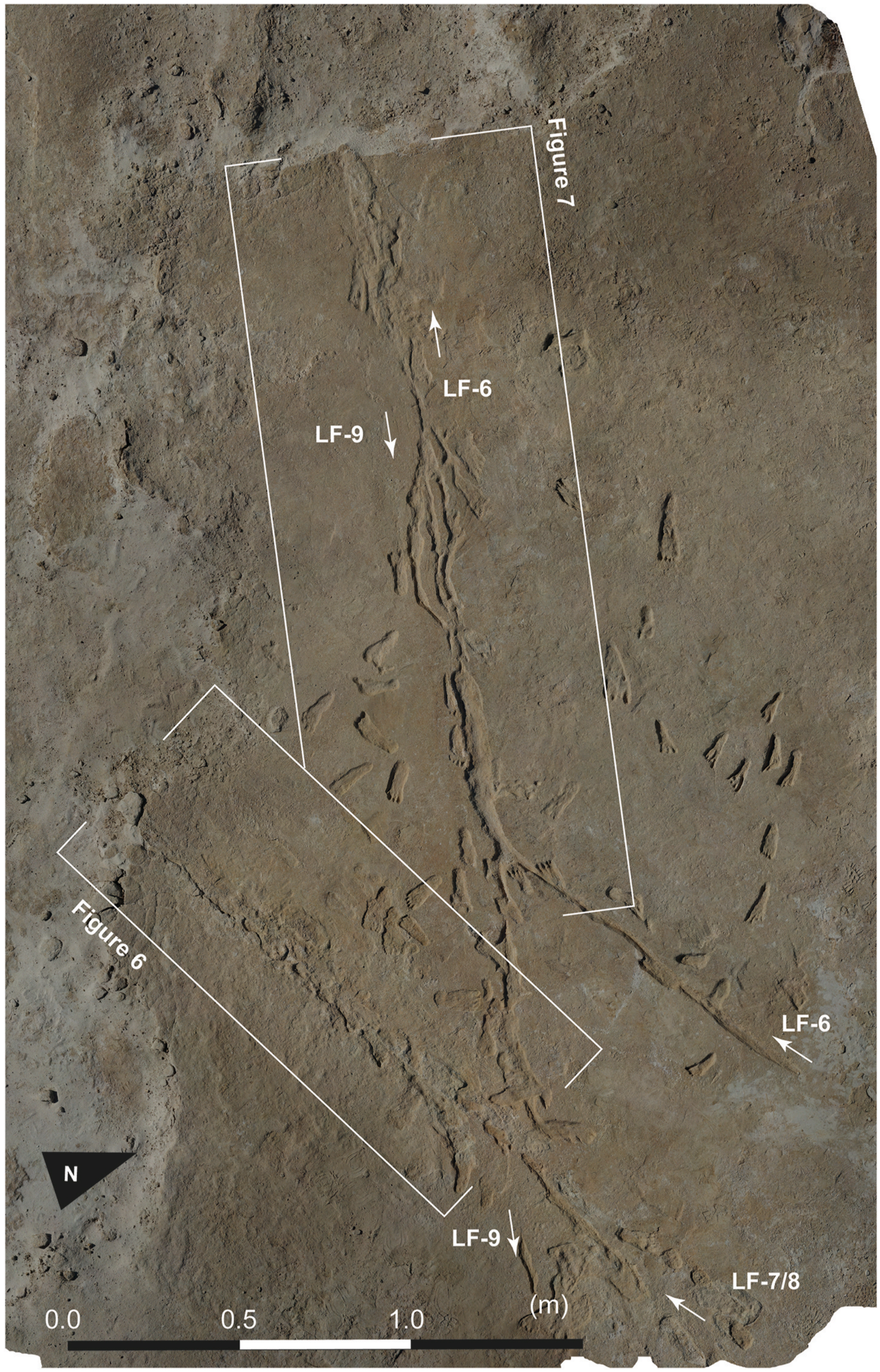

Fig. 5. Southwest part of Area A with the red silty sand removed to reveal a series of linear features and human footprints.

to uncover the softer, unlithified, sediment below to reveal deformation structures (i.e., bed compression) and the presence of what appears to be water-cut rills, namely slightly sinuous channels of a few centimetres width and depth heading down slope. This straight linear feature is intersected by a curving example to form an X-shape in planform. The curving example stops abruptly just after it has passed the first linear feature. It consists of a single shallow groove which has a base which undulates longitudinally as if the indenter dug in, bounced and dug in repeatedly. Sediment has been ploughed to either side forming a wake (or levees) of variable width and footprints are truncated either side and occur in epirelief.

In the same general area, LF-14 consists of two parallel grooves, with inverted dolomite relief (Fig. 16). The grooves are only 180 mm apart and equidistant although the eastern end is narrower due to erosion. The feature outcrops for about 8 m before disappearing beneath overlying, and in situ, material to the east. The footprints of several humans occur either between the two grooves or are truncated to one side (Fig. 16).

3.4. Area D

South of Area C, the indurated surface (TH2) continues in Area D where it is eroding from its western edge and covered by in situ material

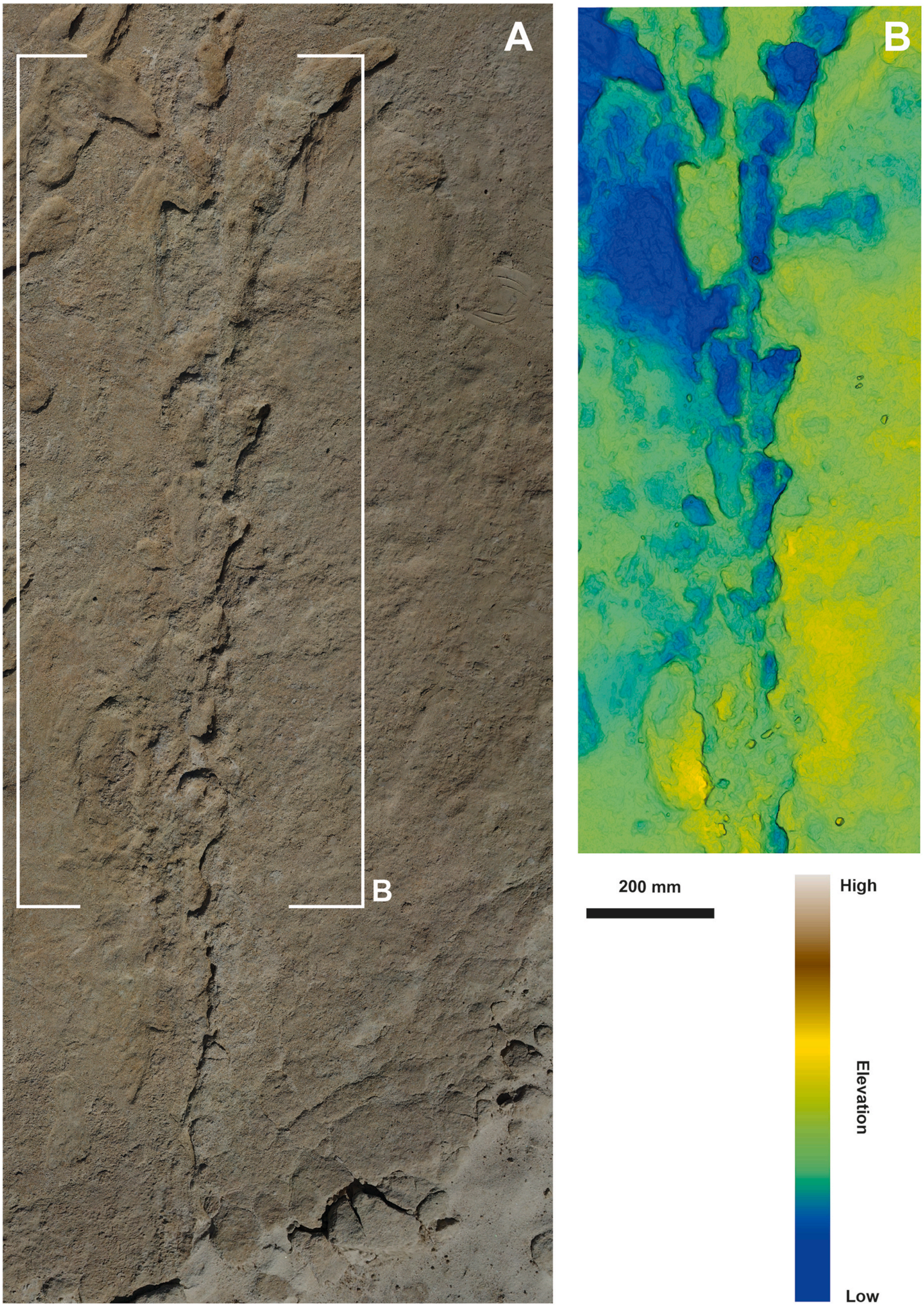

Fig. 6. Linear feature on TH2 in Area A (SW) which shows a trampled line of tracks. These tracks are cemented by dolomite and occur in a combination of positive and negative relief. They are too cemented to be excavated. **A.** Photographic orthomosaic of the feature. **B.** Colour rendered height map.

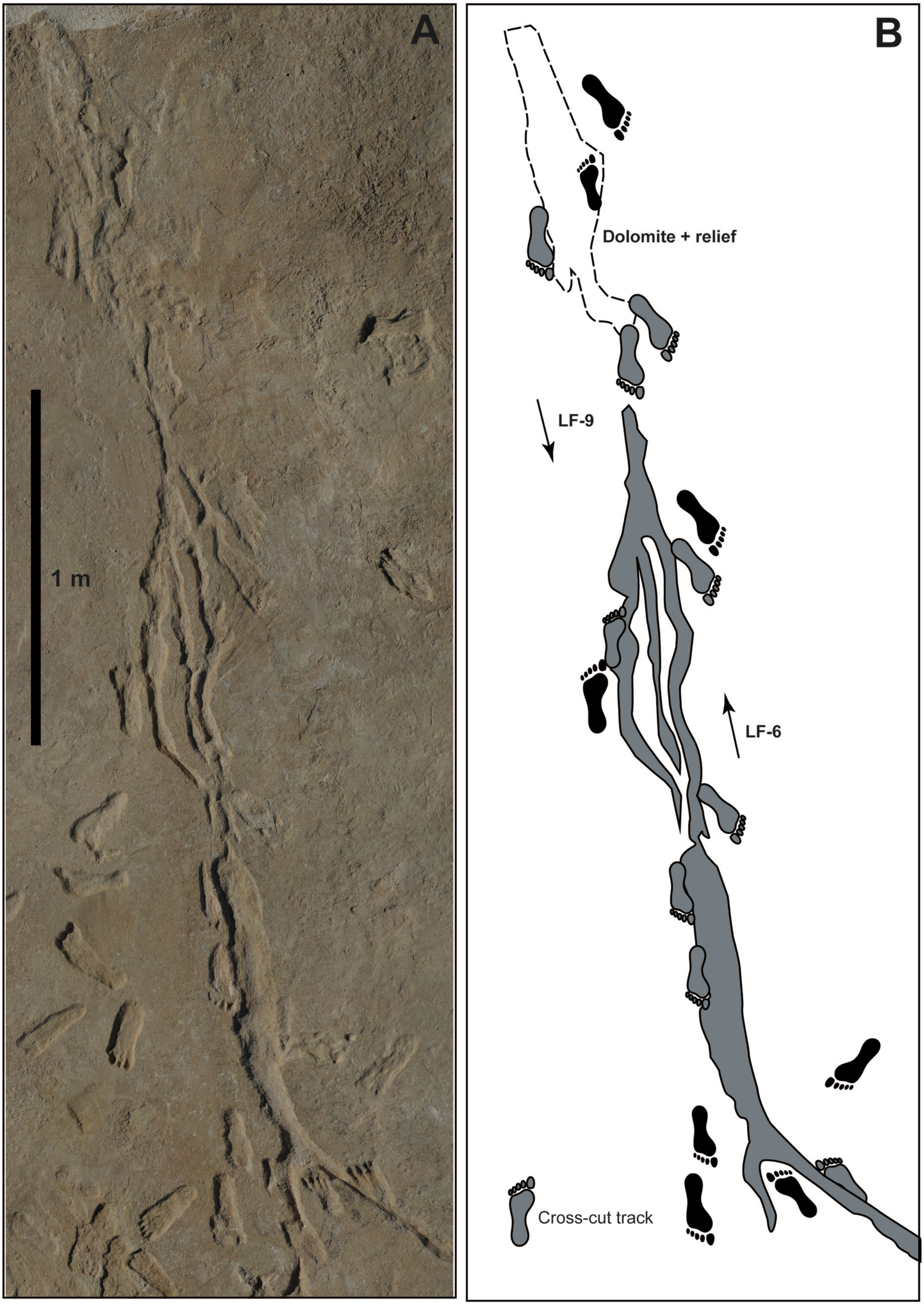

Fig. 7. A bifurcating linear feature on Area A (SW) showing the relationship between human footprints and the bifurcating groove. Black footprints are distinct from the linear feature, while grey tracks are truncated in some way by the feature.

Fig. 8. Linear features in the northeastern part of Area A on TH2. Photographic orthomosaic from images taken using a high pole.

to the east. Fig. 17A shows a vertical image of this area on which several linear features are visible. It is important to note how these features disappear to the east under overlying and undisturbed sediment layers. While LF-14 and -15 are subparallel, they are not equidistant from one another and follow subtly different trajectories as do LF-17 and -18. Isolated human footprints do occur, but are not well represented, and no animal tracks are present on this surface. The linear features consist of equidistant grooves which have been inverted during dolomitization. The two grooves are typically 250–350 mm apart and in the case of LF-18, they appear to be composed of more than one set of parallel grooves (Fig. 18A). Fig. 19 shows part of LF-15 and the multiple lines which together compose a broader groove.

3.5. Mammoth trample ground

Linear features such as those described from the vicinity of WHSA Locality 2 also occur at other locations across Alkali Flat. They are common, for example in an area known for its concentration of proboscidean tracks colloquially known as the "mammoth trample ground" (Fig. 1). Here the linear features are eroding rapidly and occur in association with a high concentration of proboscidean tracks. The features consist of single lines, often with a curved cross-profile (Fig. 18B) and when first observed in many cases extend for over 50 m in length. They crosscut proboscidean tracks (Fig. 19C). In this area, short (<0.5 m), shallow, and strongly curved channels can be found around proboscidean tracks and resemble the trunk marks described by Haynes (2012). These are different in morphology from the straight linear features described from this site.

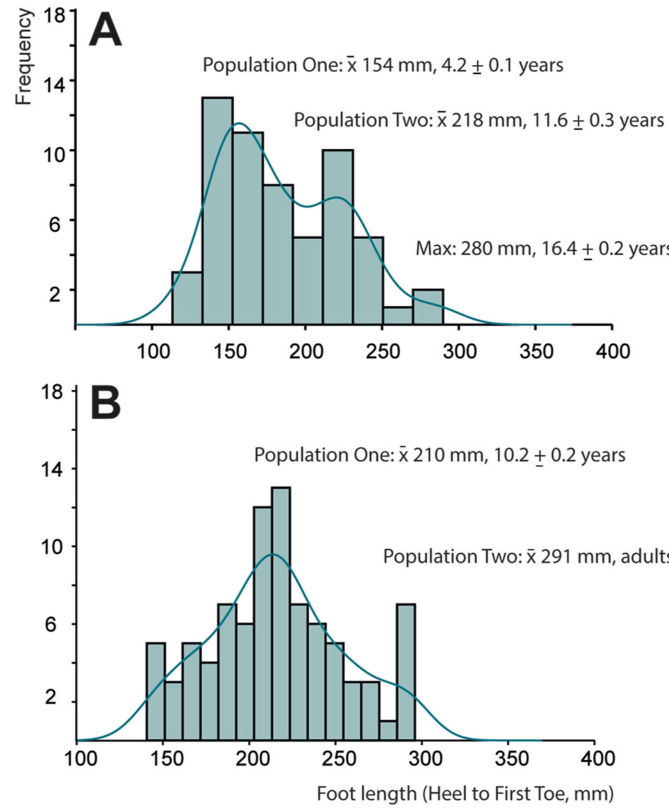

Fig. 9. Length of human footprints from heel to first toe. A. Data from Area A (N = 87). B. Data from the TH3 surface in Area B (N = 61).

3.6. Typology of linear features

Based on the foregoing descriptions, we recognise three broad morphological types of linear features. Type I features consist of simple linear grooves (width < depth) that extend several meters or more in length (Fig. 20). They frequently transect human footprints longitudinally have a striated basal plane with markings that are parallel to the long axis of the groove and exhibit a range of cross-section shapes. Sediment is displaced either side of the groove into ridges which give a mushroom-like morphology to some of the indurated fragments when viewed in cross-section. A variation on this theme is exhibited by LF-5, which consists of two intertwined and twisting grooves. Type II features tend to have broader, shallow, runnel-like morphologies (width > depth) and are straighter. These grooves can be up to 374 mm wide, are invariably straight, and can have either symmetrical (LF-1 and LF-2) or asymmetrical cross-sections (LF-19). Planform width may vary along the length of the runnels as in the case of LF-13. In some cases, Type II features are complicated by multiple overprinted human tracks (e.g., LF-3 and LF-4). Finally, Type III features consist of two parallel lines with spacing that ranges from as little as 50 mm to more than 300 mm. The key characteristic of this feature type is that there is a fixed spacing (250-300 mm) between the grooves. Several examples of these features are present in Area D. In addition, there are several locations where two sets of Type III features run sub-parallel to each other, but each linear feature has a subtly different trajectory with the distance between the Type III features indicating divergence. Each of the Type III features is made up of a series of parallel ridges and human footprints occur between the ridges as well as to the side.

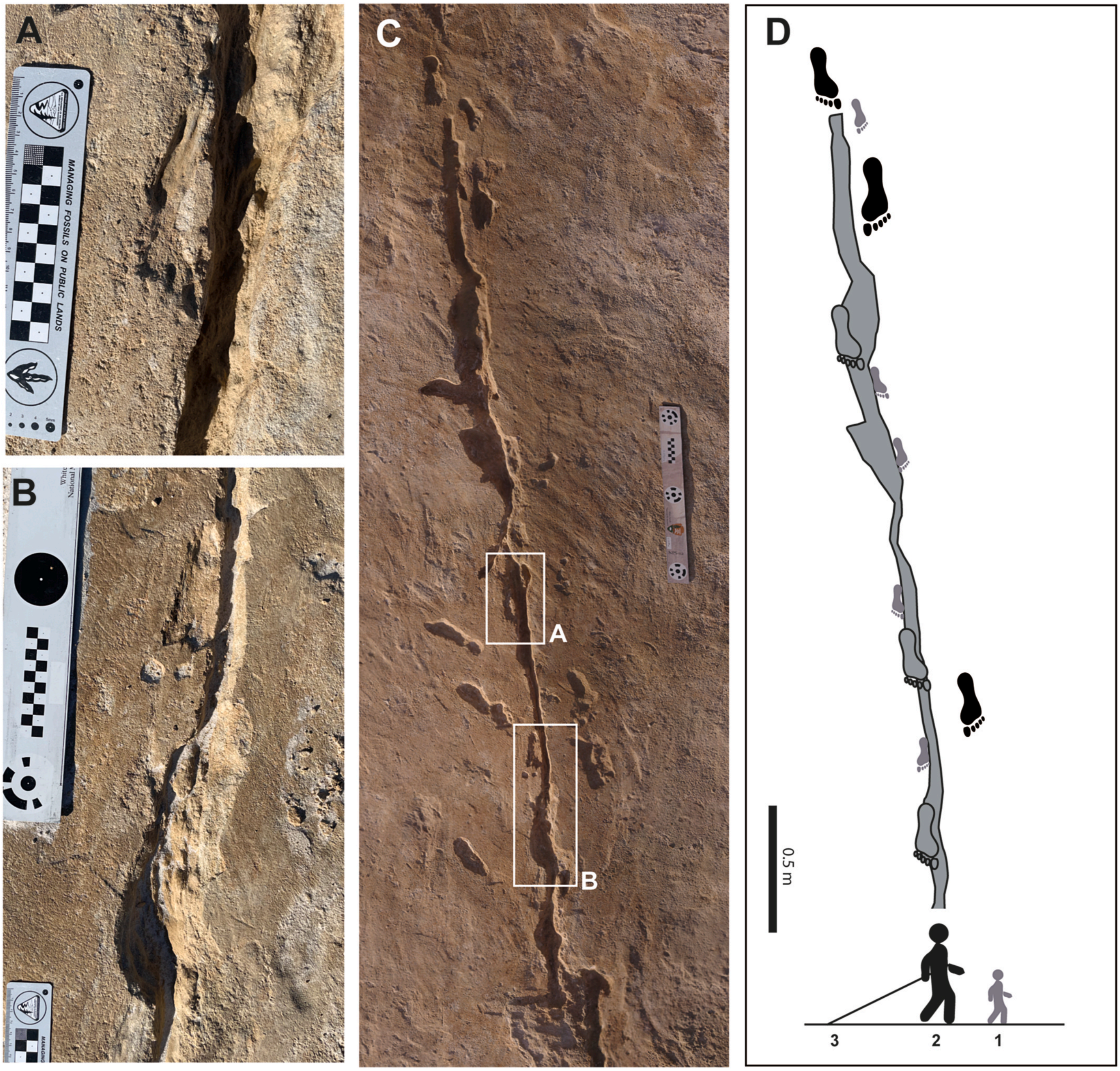

Fig. 10. Linear features on the northeastern part of Area A (TH2). **A-B.** Show both an adult and child track truncated longitudinally by the linear groove. **C.** Shows the position of these footprints on the groove and the presence of other similar features. **D.** Shows the interpretation of the tracks observed.

4. Discussion

The three types of linear features described here have the following general characteristics in common. First, they all show evidence of movement across a surface by an indenter consistent with a circular stick/pole made of wood. While these indenters could hypothetically be made of bone it is difficult to envision animal bones of appropriate weight, length, and limited width, that could be moved across the surface in this way. For example, mammoth tusks are prohibitively heavy and unwieldy, and long, large bones tend to have asymmetrical or angular articular surfaces and edges, as opposed to rounded or cylindrical ones (Haynes and Klimowicz, 2015; Boeskorov et al., 2020). Each feature extends over considerable distances (1–50+ m) and can be traced into the site stratigraphy. Frictional striations are visible in some grooves, as is the displacement of sediment to either side in lobate splays, or curls. Second, in some cases, deformation of underlying sediment occurs, which suggests that the poles may have been loaded. In others, transverse ridges along the axes of the linear features are suggestive of bouncing of a pole over firmer ground. Groove depths vary along the length of some of the linear features resulting in asymmetrical undulations that are consistent with the poles gradually digging into the subsurface before bouncing free. Third, the width and depth of individual grooves vary, and, in some cases, they consist of broad, straight runnels perhaps suggesting a larger, distributed contact area. Fourth, many of the linear features are directly associated with human footprints, as the features crosscut footprints longitudinally and adjacent human tracks faithfully follow their strike. Notably, the linear features are not associated with animal footprints, although they do occur on surfaces with other animal tracks. Finally, while there are examples of single grooves in all the surfaces we excavated, there are also several

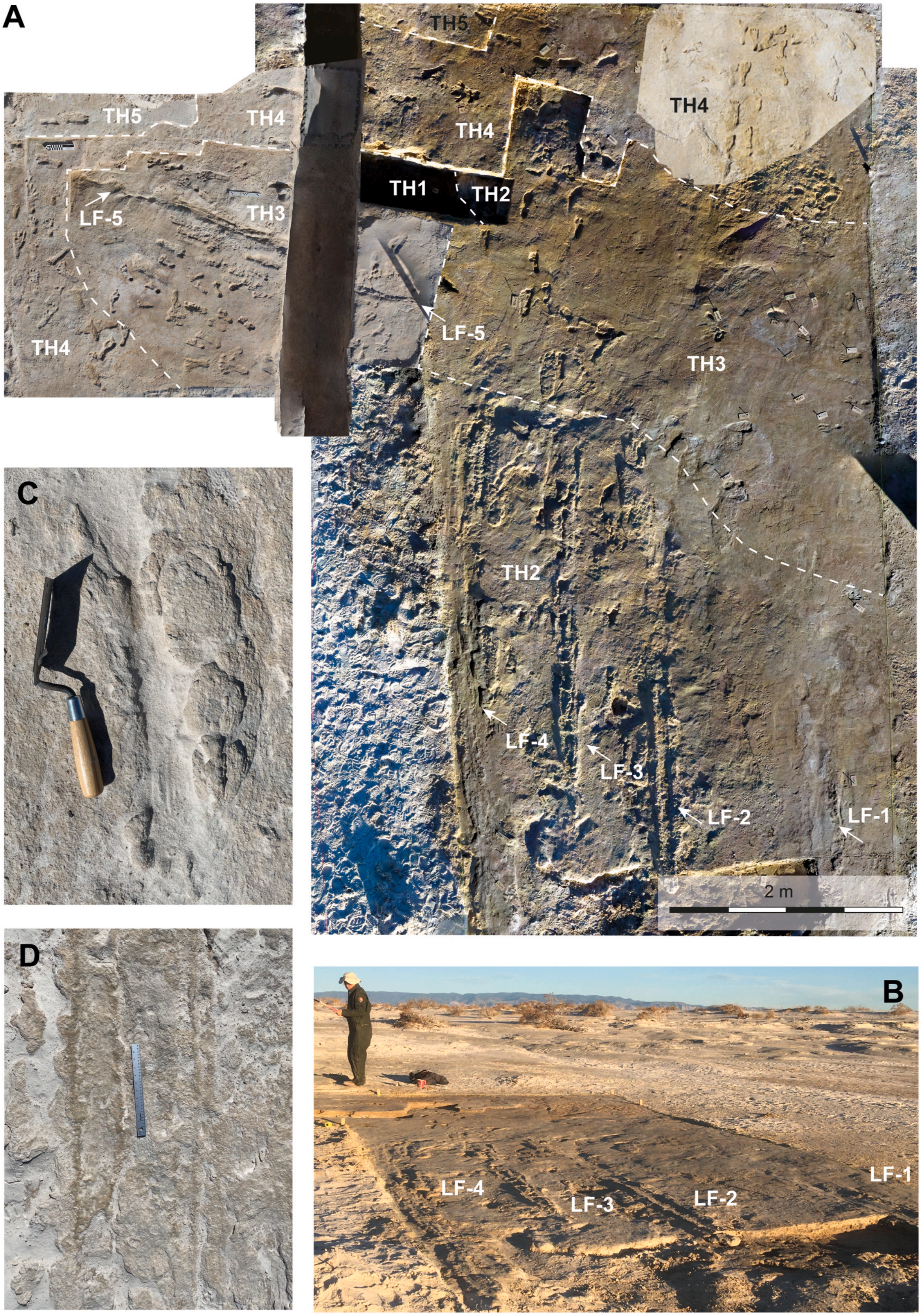

Fig. 11. Linear features in Area B. **A**. Linear features adjacent to the main trench in January 2022. **B**. Oblique photograph of the linear features in the vicinity of the main trench as of January 2020. **C**. Gently curving linear feature and truncated human footprint in dolomite epirelief. Note how the tracks are cut longitudinally. **D**. A linear feature consisting of two equidistant parallel grooves in Area C.

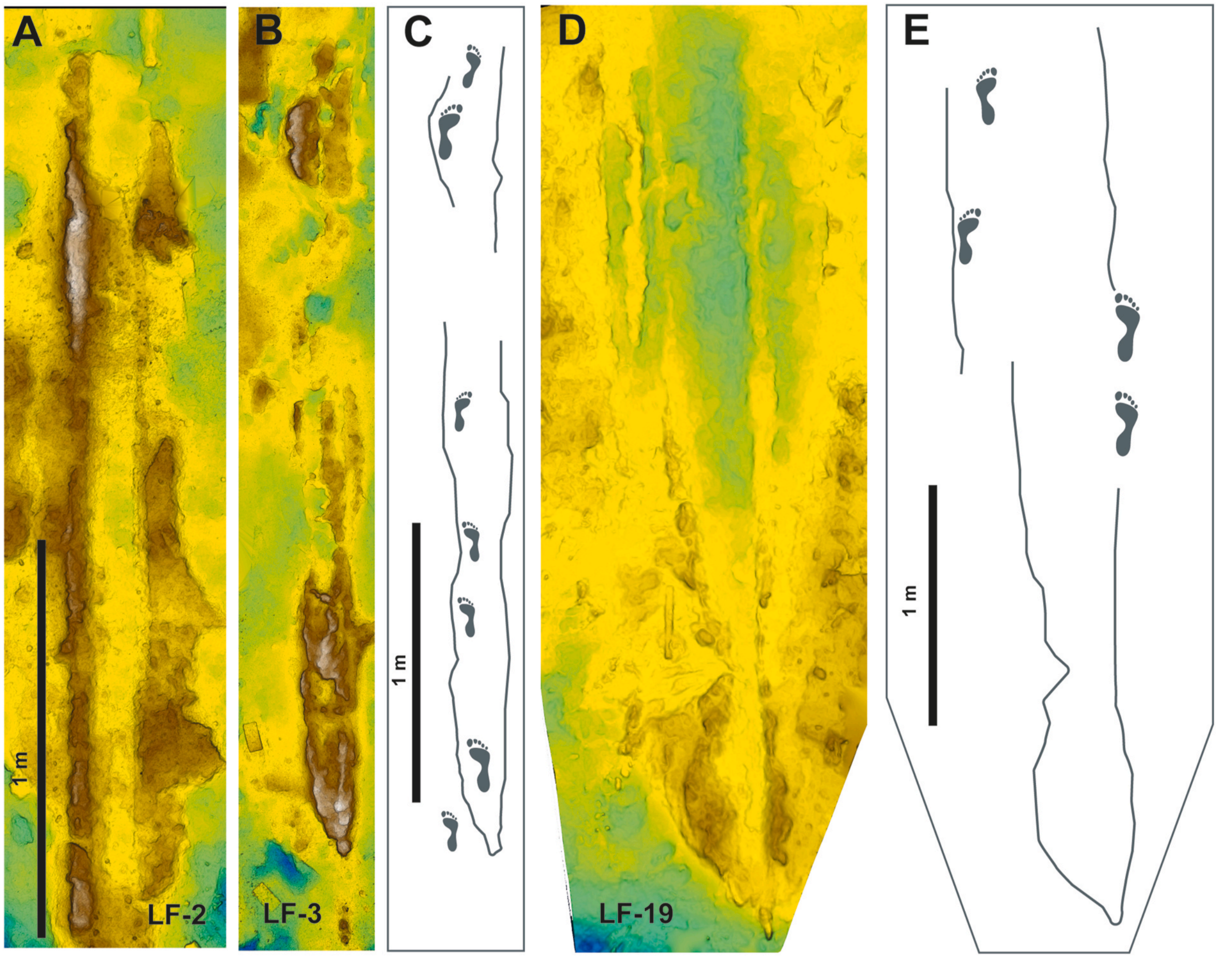

Fig. 12. Three-dimensional models of linear features adjacent to the main trench at WHSA Locality 2, colour rendered by depth. Human tracks are shown in the interpretations (C and **E**). Note that the identified tracks were not necessarily made by the same individual.

examples of parallel grooves consistent with two indenters moving equidistant from one another in a fixed manner, implying some sort of stable crossing structure that maintained the spacing between the poles.

Before examining potential explanations, it is important to discount their formation historically by the movement of modern military or civilian off-road vehicles. Infill by in situ sediments, such as that observed in Areas A and B, coupled with the fact that the features can be traced into the site stratigraphy (Bennett et al., 2021), unquestionably preclude a historical origin. These features were formed on discrete surfaces that were buried shortly thereafter and preserved in the geologic record. We therefore discount a historical origin for the linear features.

4.1. Possible explanations

We can group possible explanations into four broad categories: (1) non-human animals; (2) flotsam; (3) boat-related keel marks; (4) firewood; (5) and/or human transport technology. Modern elephants, and therefore presumably mammoths/mastodons, can drag branches and tree trunks (Haynes, 2012). They are also known to create a range of drag marks with their trunks (Haynes, 2012), and possible examples have been proposed from the ichnological record (Helm et al., 2022). Trunk-traces are generally short and often curvilinear in planform. Dragging of tree trunks or branches would require mammoth tracks to be aligned or associated with the linear features and in the study area they are not. Modern beavers are known to drag wood into water from riverbanks leaving scratch marks (Johnston, 2017), and the North American Pleistocene giant beaver (genus *Castoroides*) could have done so on a larger scale. However, the known distribution of fossil *Castoroides* does not currently include the American southwest (Cahn, 1932; Plint et al., 2019) and crucially no beaver tracks have been found at White Sands. In addition, observations of modern beavers suggest that they transport wood primarily by rafting. When beavers do drag wood, they are usually moving whole trees, with branches intact, and they are pulled from the base of the trunk which leaves multiple scratch marks (e.g., Danilov et al., 2011; Nummi and Kuuluvainen, 2013; Johnston, 2017). Tail drags from giant ground sloth are also hypothetically possible and sloth tracks have been found at White Sands (Bustos et al., 2018). However, this would require that the linear features are associated with sloth tracks but in the study areas they are not.

Some of the linear features could be the imprint of flotsam (trunks, branches, etc.) washed ashore from Paleolake Otero. However, this explanation is inconsistent with the longitudinal striations and evidence of dragging and does not fit stratigraphically because the features are always above, and not within, lake sediment (Bennett et al., 2021). The marks are also inconsistent with roots or rodent burrows, which exhibit variability both laterally and vertically (Gregory et al., 2004; Turner and Makhlouf, 2005).

Given that a lake was once present at the site, although at a lower stratigraphic level than the features studied, some form of boat-related keel-mark provides a possible explanation. The term “keel” is used here for any watercraft with a linear ridge running along the longitudinal axis of the hull, as opposed to an actual keel that plays a structural role in larger sailing vessels (e.g., Forster Laures, 1985; Lines, 2007).

Fig. 13. Track Horizon 3 on the north flank of the main east-west trench at WHSA Locality 2. **A.** The bifurcating groove is visible with several footprints with similar orientations either side. **B.** Annotated cross-section showing deformation below the linear feature.

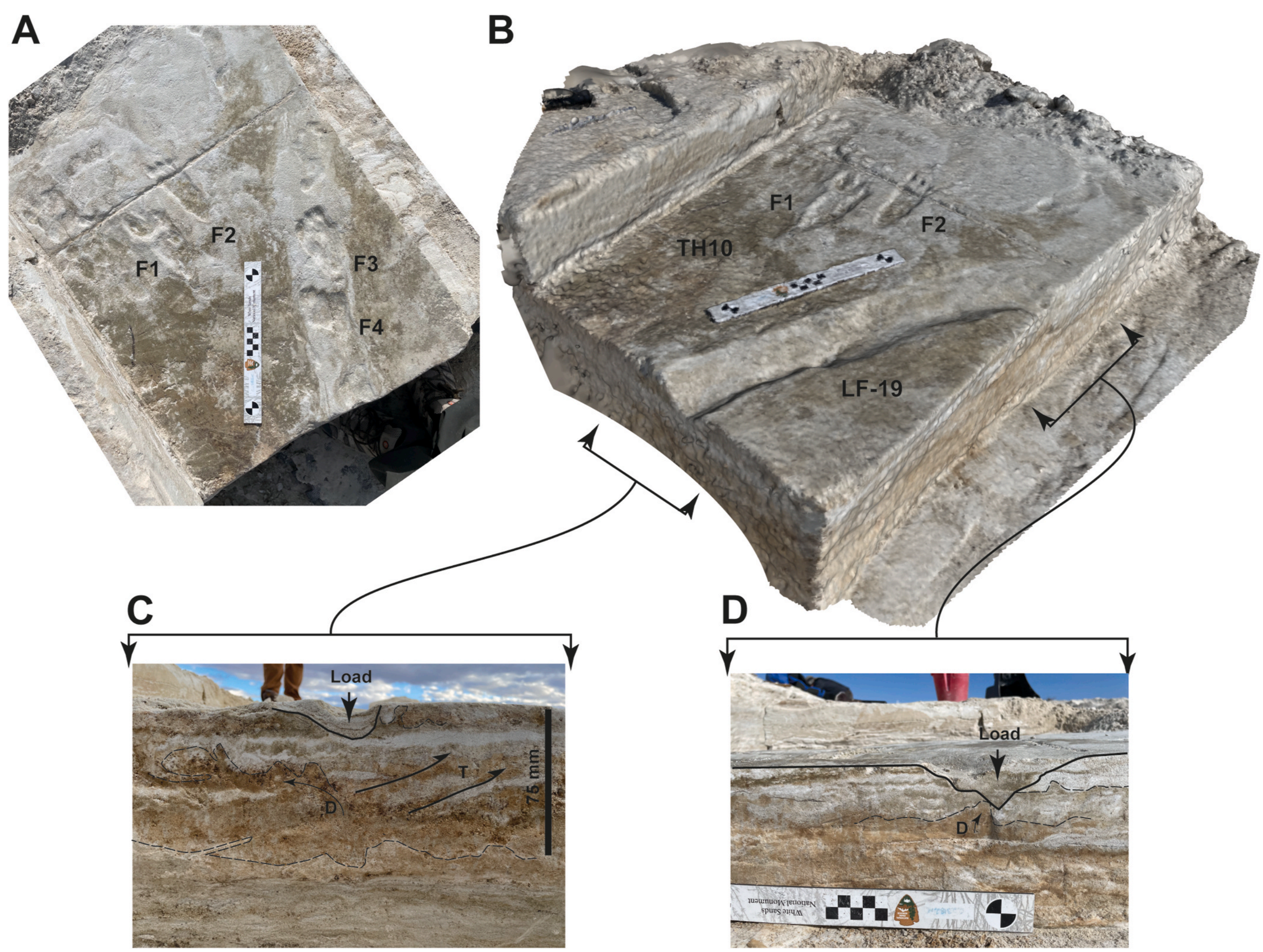

Fig. 14. Linear feature on TH10 at WHSA Locality 2. The feature was originally infilled by light coloured gypsum sand. Small thrusts and diapirs are visible below the axis of the groove. F = footprint.

Today, keel-marks, and associated human footprints, can be found on modern lake shores or coastal beaches created by simply dragging a boat either on shore or off. It is possible that some of the more regular Type I and II linear features could be formed in this way and could be associated with footprints of the crew. Because of the lack of direct evidence of Palaeolithic boats, ethnographic observations of Native American watercraft serve as evidence of potential vessel types. At first European contact, the types of boats among indigenous peoples of the Americas that were encountered by early colonizers were floats, rafts, reed/tule boats, bark and dugout canoes, and different types of skin boats (Jodry, 2005). Because raw material that is suitable for the construction of specific types of boats is tied to certain environmental conditions, the reconstruction of the Tularosa Basin's paleoclimate and landscape plays a role in assessing a keel mark origin. The southwest United States was probably 5–6 °C cooler during the Last Glacial Maximum than today (Betancourt et al., 2001), with an increase in precipitation (Brook et al., 2006; Wagner et al., 2010; Oster et al., 2015). This led to pinyon-juniper–oak forests to reach lower elevations today than during the late Pleistocene, whereas valley and basin floors with deep soils supported C_4 grasslands (Brook et al., 2006). The Tularosa Basin, developed into a lake-system with fine-grained gypsum deposits by 36,000 years ago and contained dense vegetation along the shallow margins of the lake (Allen et al., 2009). It is therefore possible that tall grasses or bulrush that grew in the wetlands close to the lake could have served as material to make reed or tule boats. Jodry (2005) suggests that late Pleistocene/early Holocene hunter-gatherers likely used tule boats on inland lakes in the Americas for fishing and subsistence activities. Such tule balsas, however, are traditionally made from bundles of reed tied together (Wheat, 1967; Fowler, 1990), which form a broad, shallow keel and are unlikely to leave a deep or defined groove (i.e., not Type I). Moreover, depending on the size of the vessel, small tule boats were typically light enough to be lifted with one hand (Wheat, 1967; Jodry, 2005). Consequently, pulling a tule boat over ground may not have been the preferred mode of portage.

Skin-covered boats such as bullboats or coracles are another possibility and such vessels were created by a basket-like framework made of willow shoots and covered with buffalo hides (Adney and Chapelle, 1964). The use of bullboats and tule boats is documented for several Indigenous tribes in the Great Plains and in the Great Basin of North America. The Hidatsa, Yokuts and Chumash peoples all created bullboats while the Paiutes of the Great Basin made tule boats. This construction gives a flat or nearly flat bottom (McGrail, 2015, Fig. 8.10) and would therefore not have left narrow, deeply defined linear drag-marks if dragged (i.e., not Types I and III). Rafts were another watercraft known to have been used frequently in the southwestern USA as means for crossing waterways (Driver and Massey, 1957; Jodry, 2005). But just as with the other types of watercrafts discussed above, log rafts rarely have a keel sharp enough to leave a narrow deep furrow (i.e., not Type I).

There are certain types of boats that do traditionally have a keel such

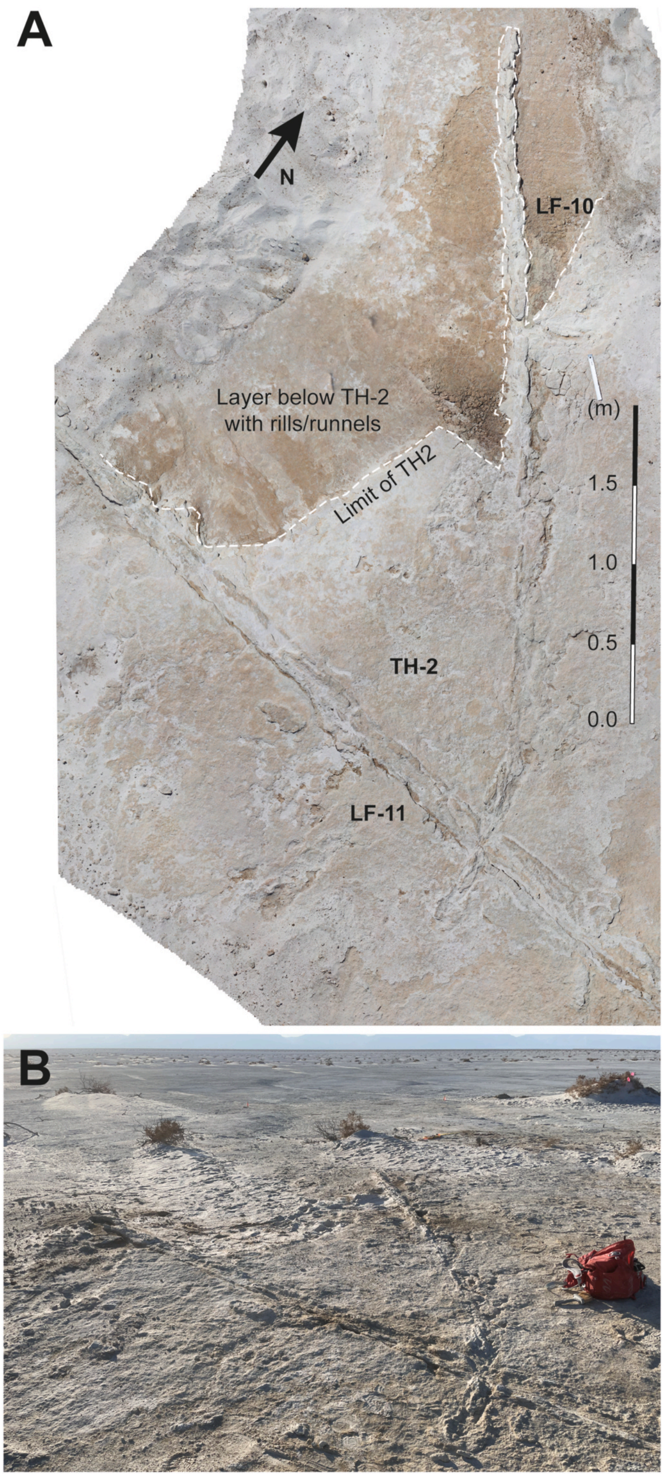

Fig. 15. Two linear features cross-cutting to form a large "X" when viewed from above. **A.** Vertical view of the feature. The curved linear feature (LF-10) ends abruptly at a slight swelling with a surrounding trampled area although no distinct human tracks are visible. **B.** Oblique view of the linear features.

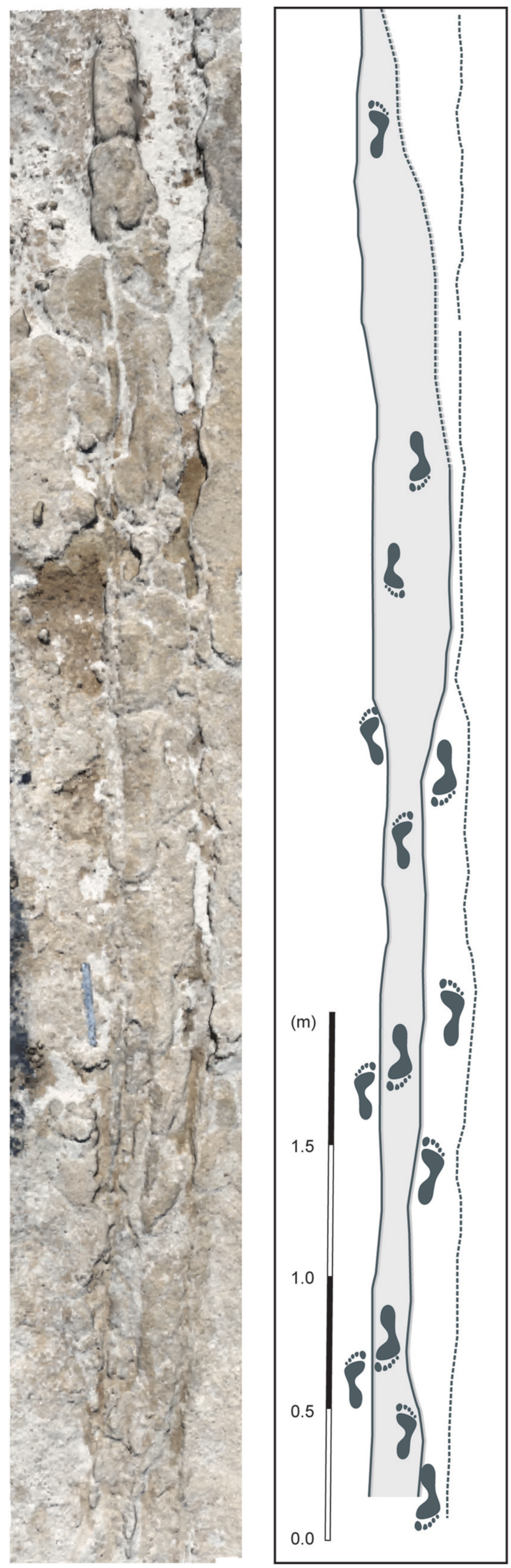

Fig. 16. A linear feature in Area C (LF-14) which consists of two parallel and equidistant grooves. Visible human tracks are identified in the adjacent interpretation.

as kayaks, baidarka and bark canoes. Skin-covered kayaks were used on both sides of the Bering Strait as hunting craft (Adney and Chapelle, 1964; Fitzhugh and Luukkanen, 2019). Some kayak types have a flat bottom, while others have a V-shaped base and yet others have a more conventional keel (Adney and Chapelle, 1964). The baidarka is a large, open, skin-covered boat that was used by Pacific coastal groups in north-eastern Siberia for long-distance travel, trade, and hunting whales

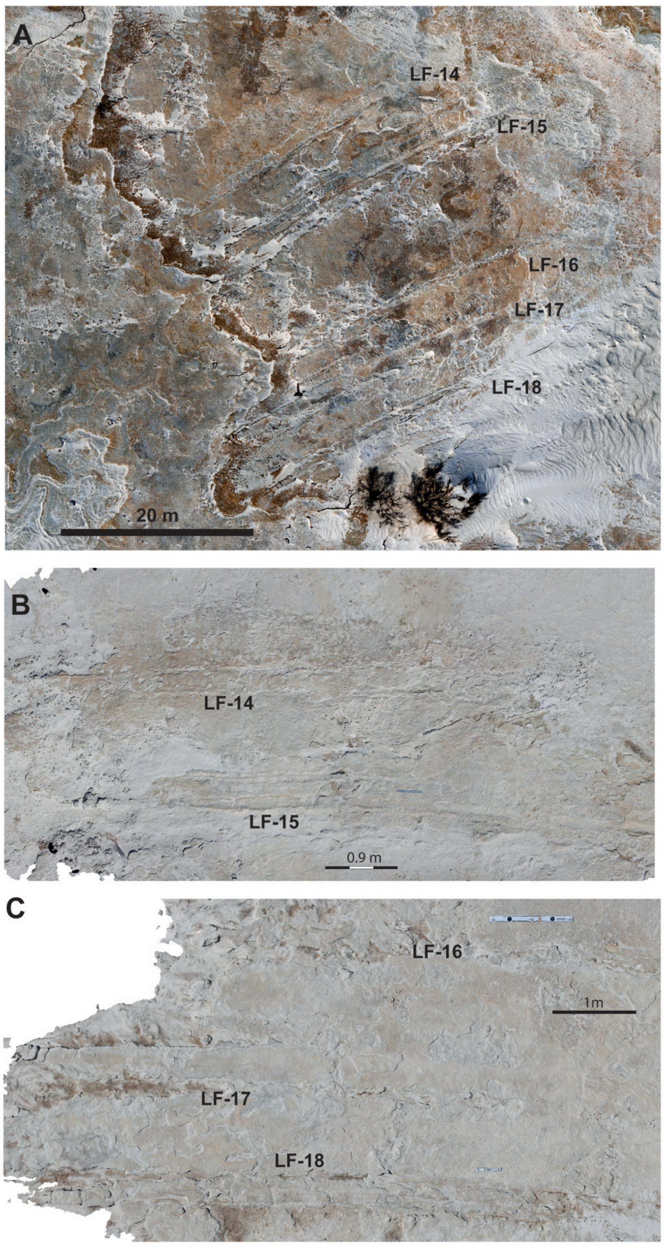

Fig. 17. Linear features in Area D. **A.** Image taken from a drone flown by the USGS in April 2023. Linear features consisting of two equidistant grooves can be seen exposed from the eroding edge of the surface (west/lefthand side) before progressing beneath overlying sediment to the east (righthand side). **B-C.** Photographic orthomosaic generated from oblique photographs showing the detailed morphology of LF-14 to −18.

and walrus (Jodry, 2005). It had a keel along the middle of the vessel's bottom, which added longitudinal strength (Fitzhugh and Luukkanen, 2019). It seems unlikely, however, that boats such as the bidarka would have been in use on small and potentially shallow inland waterways in the American southwest. In the sub-Arctic and adjacent areas to the south, as well as in northern Eurasia's boreal forests, bark canoes were the dominant type of boat for most or all aboriginal peoples (Driver and Massey, 1957; Fitzhugh and Luukkanen, 2019). Some bark canoes had keels or V-shaped bottoms but, because barked trees are essential for their creation, this type of boat has not been recounted in the southwest or the Great Plains (Driver and Massey, 1957, Fig. 89).

We have focused in this review on the role of the "keel" or boat base as an indenter. It is important to note that a boat with a pointed stern/bow also could be dragged in such a way as to create a furrow on soft ground. In this context, some canoes and kayaks have tapered ends (Fitzhugh and Luukkanen, 2019), as do some reed boats (Fowler, 1990, Figs. 73, 78 and 151), all of which could leave a groove if dragged bow/stern down. It appears to be more common for bark canoes, hide and reed boats to have been carried due to their light weight and fragile construction (Adney and Chapelle, 1964). In principle, it is possible that some of the linear features described here could have been made by boats (e.g., Type II). The more irregular, deeper and bifurcating grooves do not fit this explanation well. Moreover, linear features occur across Alkali Flat and are not associated specifically with shoreline or lake facies.

Linear features such as those in the Type I categories (examples LF-5 to LF-9) could be produced by dragging branches or sticks for firewood or similar uses. Cross-cultural ethnographic comparisons show that dead wood and driftwood are generally favoured as firewood (e.g., Heizer, 1963), and a study by Vidal-Matutano et al. (2017) has shown that Neanderthals in fact preferred dead wood as fuel. This is not only because deadwood burns better and does not need time to dry, but also because the felling of a live trees/branches is more energy-intensive. Another reason for collecting branches instead of cutting down trees for firewood is because children can help more easily (Jiménez-Escobar and Martínez, 2018). Among the Maasai in Kenya, for instance, young girls start to collect firewood from the age of three, and, as they become older, they go on longer trips in groups of two to nine (Tian, 2017; Lancy, 2018). Whether firewood is processed on-site or transported before being chopped up generally depends on the mode of transportation being used. For example, small bullboats were used as baskets to transport firewood on the Great Plains. Hidatsa peoples living along the Missouri River, caught or collected driftwood from the river with a noose during the summertime, because it was the closest timber source (Wilson, 1924). They piled up the wood on the shore and cut it on-site to make it fit in a small bullboat, or women would carry it from their necks using a strap. Longer sticks were clamped between arms and back or pulled with one end dragging on the ground (Wilson, 1924). This could give rise to Type I linear features and conceivably firewood, perhaps in the form of driftwood from Paleolake Otero, might have been dragged over the ground towards a bullboat (e.g., Lowie, 1954; Henderson, 1994).

In the Dry Chaco of Sierra de Ancasti (Catamarca) in Argentina, both men and women participate in the collection of firewood, which consists of trunks, sticks and dry or fallen branches, which are typically tied into bundles and carried home in the collector's arms (Jiménez-Escobar and Martínez, 2018). When the Maasai girls of Kenya gather sticks around their homestead, they also process the wood by pruning twigs, cutting sticks into uniform lengths, splitting, and bundling them with rope to put the load on their backs and carry them home (Tian, 2017; Lancy, 2018) none of which would leave a ground trace. Women in prehistoric and historic Puebloan societies of the Colorado Plateau region transport their firewood with tump lines and burden baskets. They bundle loads of up to 35 kg and carry them on their heads, necks and shoulders (Osborn, 2023). Again, no ground trace would be made. In coastal Yup'ik villages of Alaska's Yukon-Kuskokwim Delta, driftwood is gathered from the riverbanks and loaded onto shallow skiffs or collected on the coast of the Bering Sea and transported on a simple cart. In some cases, the mode of transportation reflects gender roles: for example, in the Fang villages of Equatorial Guinea in central Africa, firewood is typically gathered as dead wood from their orchards (Gelabert et al., 2011). While the women would chop up the wood to make it fit in their *nkueiñ* (cylindrical baskets), men would transport the wood back as whole trunks since the baskets are regarded as exclusive property of women (Gelabert et al., 2011).

People living in the late Pleistocene of the Tularosa Basin likely gathered firewood, although it is not known precisely how this was done. Therefore, it is possible that lengths of word were dragged leaving groove like traces like those associated with Type I traces described above. However, the broader Type II and III traces do not fit this model.

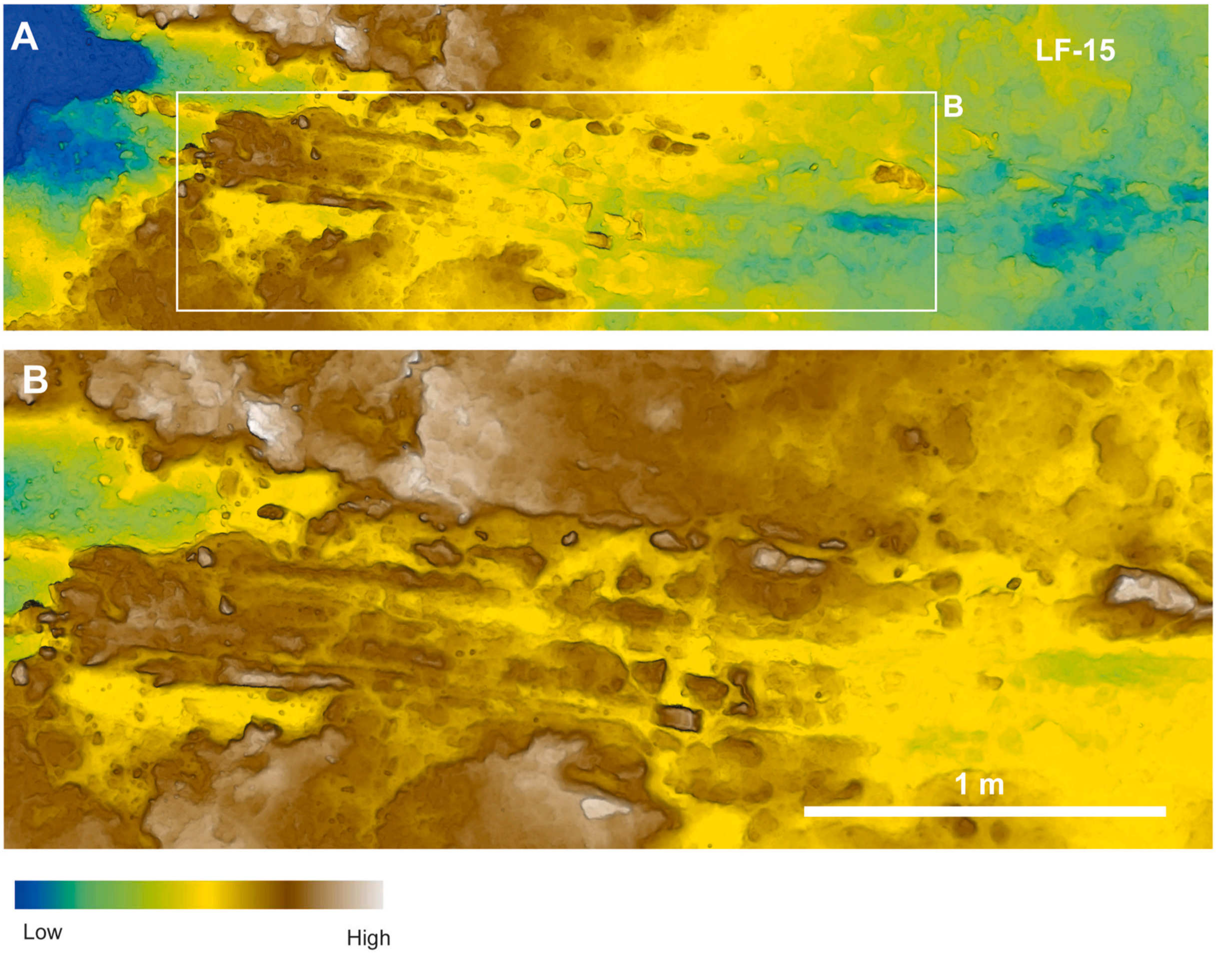

Fig. 18. Three dimensional models of LF-15 colour rendered by depth showing the detailed structure of the linear feature, with the outer parallel, equidistant grooves.

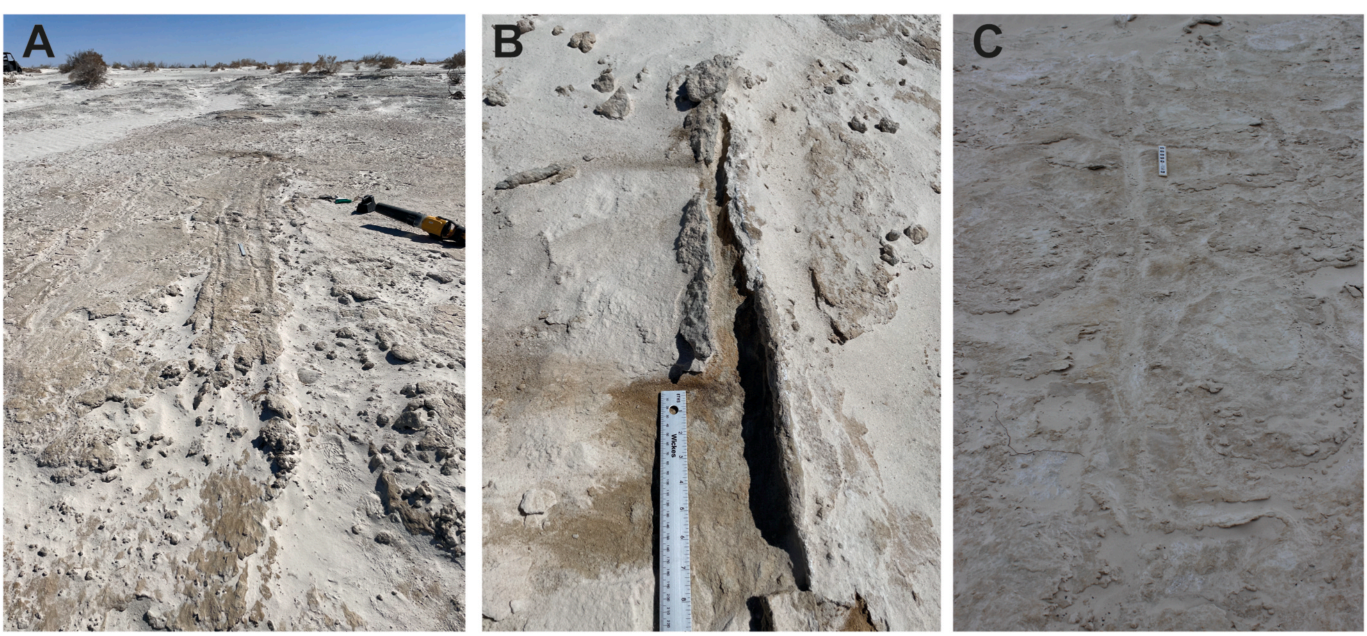

Fig. 19. Linear features. **A.** Oblique photography of LF-15 in Area D. Note how the feature consists of two superimposed structures both consisting of parallel grooves. The second, upper feature, is slightly oblique to the lower and appears to stop to the left of leaf blower. **B.** Curved cross section of a single linear feature in the trample ground. The sediment appears to have curled around a circular indenter. **C.** Example of a linear feature cross cutting proboscidean tracks in the trample ground. Note how straight this line is.

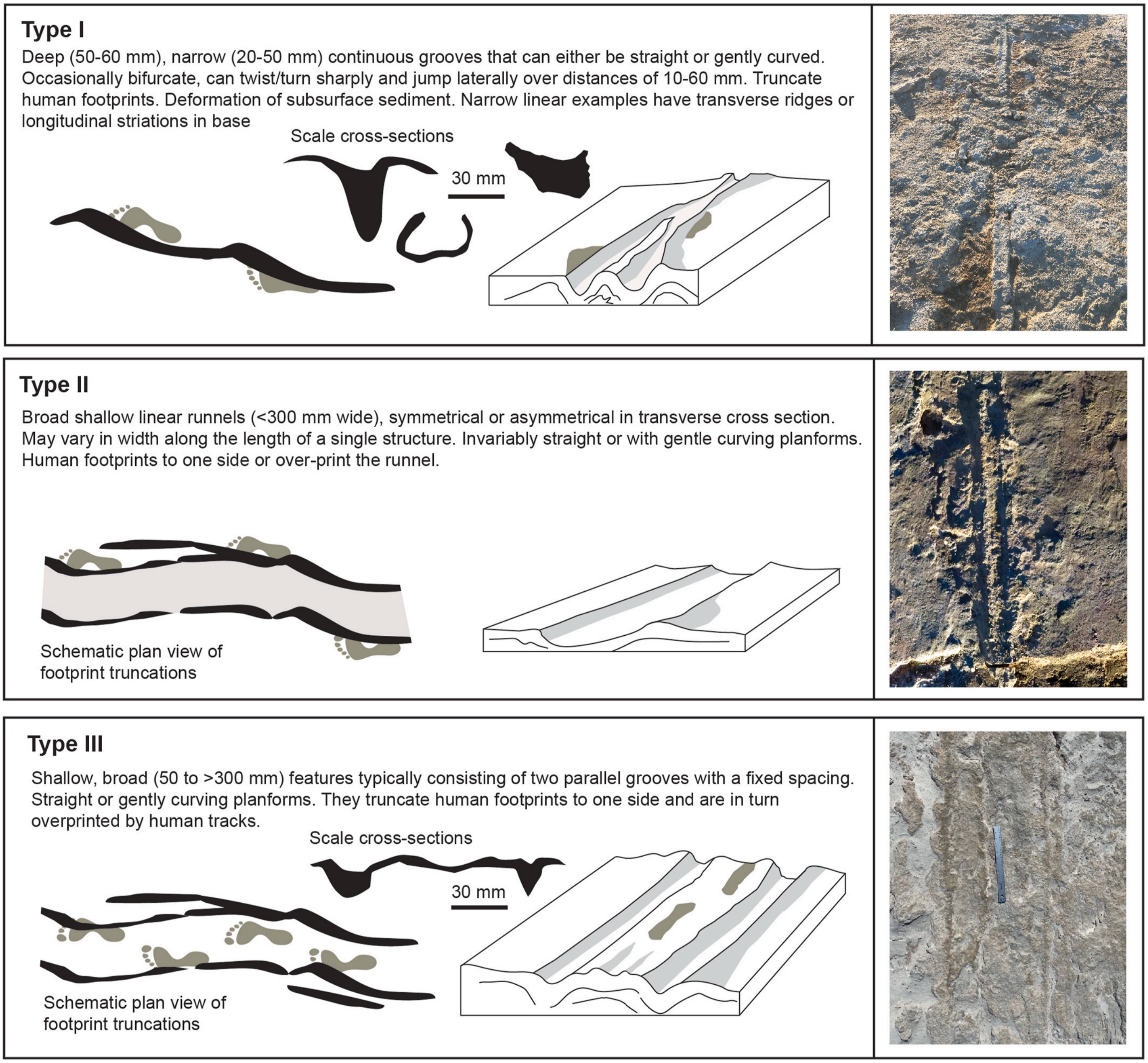

Fig. 20. Summary of the morphological variants of linear features present at White Sands.

The width of Type II features would require a substantial trunk dimension and likely have been associated with much greater depth. It is possible that a log with two branches or stubs could leave parallel and equally spaced grooves, but one would expect examples with more than just two grooves, but this has not been observed at White Sands. A range of traces from multiple parallel scratches to traces with just two or three parallel grooves would be expected. We have evidence only of single grooves and parallel grooves formed by two points of contact.

Our research team has spent many hours discussing the possible origins of these linear features with the Indigenous people involved in our research as collaborators, site monitors and most recently as part of our excavation crew. Based on their own experiences and oral traditions, they suggest that the most likely explanation is that the linear marks were made by some form of travois. Travois were simple transport devices used in the Great Plains, pulled by dogs and later by horses (Driver and Massey, 1957). They were typically created by two poles bound together to an A-shaped frame, with a connection of bars or a net-like basket to carry heavy or bulky loads (Wissler, 1910; Wilson, 1924; Lowie, 1954; Weltfish, 1977). At the time of early contact between European colonizers and Indigenous groups of the Great Plains, travois were a house-moving device, built from two tipi poles and pulled by horses (Driver and Massey, 1957). Aside from tipis and household furniture, children and old women would ride in travois as well (Michelson, 1933). Hidatsa peoples would create a shelter from several dog travois when they were forced to move through a treeless area (Wilson, 1924). Vertebral deformations on canid skeletons might suggest that the travois and tipi developed during a similar time in the northern Great Plains (900 to 5000 years ago: Driver and Massey, 1957; Welker, 2021). Travois were then historically connected with shelter-building and house-moving. Travois were also used in the transport of firewood and are mentioned in accounts of hunting (Lowie, 1954; Henderson, 1994). For example, a Hidatsa woman recalls that she once went hunting with her husband and they brought a bullboat on a dog travois (Wilson, 1924). More commonly, large cuts of meat were transported on these vehicles after leaving a killing site (Lowie, 1954; Weltfish, 1977; Lupo, 2021; Welker, 2021). The popularity of the travois on the Great Plains stems from its high functionality in landscapes with hard ground and short grass (e.g., Henderson, 1994; Monaghan, 2021). A similar environment may have existed in our study area based on the reconstruction of the palaeoclimate of the southwestern U.S. during the LGM, which favoured C_4 grasslands in valleys and basins (Brook et al., 2006).

4.2. Neo-ichnological experiments

The absence of non-human tracks parallel to the linear structures reported from White Sands suggests that, if a travois was responsible for the linear features, the draft animal was human. Because ethnographic literature on travois focuses on vehicles pulled by horses or dogs, there is little basis on which to explore what traces a human-drawn travois would leave and therefore we undertook a series of simple neo-ichnological experiments on a tidal mudflat (Poole Harbour, Sandbanks, UK). The aim of these experiments was not to replicate conditions, or potential travois design at White Sands, but simply to explore the ichnological traces that such vehicles could leave. The different travois used were constructed from pine poles 25 mm in diameter and 2.5 m long, secured using paracord in two configurations, a V-shaped and X-shaped design. In the case of the former, the experiments were run with and without a cloth pad over the ground-contact point. Loads varied from 0.5 kg to 2.5 kg. Figs. 21 and 22 show the typical ichnological traces obtained from each of the three experimental vehicles. Repeat traces made in this fashion were consistent across multiple runs and loads on a flat, low tide, mud surface with a similar moisture content.

In the same manner as our experiments if one is pulling, or pushing, a wheelbarrow or hand cart, the coronal plane of the body is held perpendicular to the direction of travel and is at right angles to the trackway of footprints created. In the experiments, the X-shaped design left two parallel grooves with a line of human tracks in the centre; no tracks were truncated, but depending on the height of the volunteer, the load would sometimes drag during the mid-stance phase of gait, forming a discontinuous skid-mark on the ground (Fig. 21C). In the case of the V-shaped design the human tracks were truncated longitudinally by the contact point (Fig. 21A and 22A and C), although with changes in travel

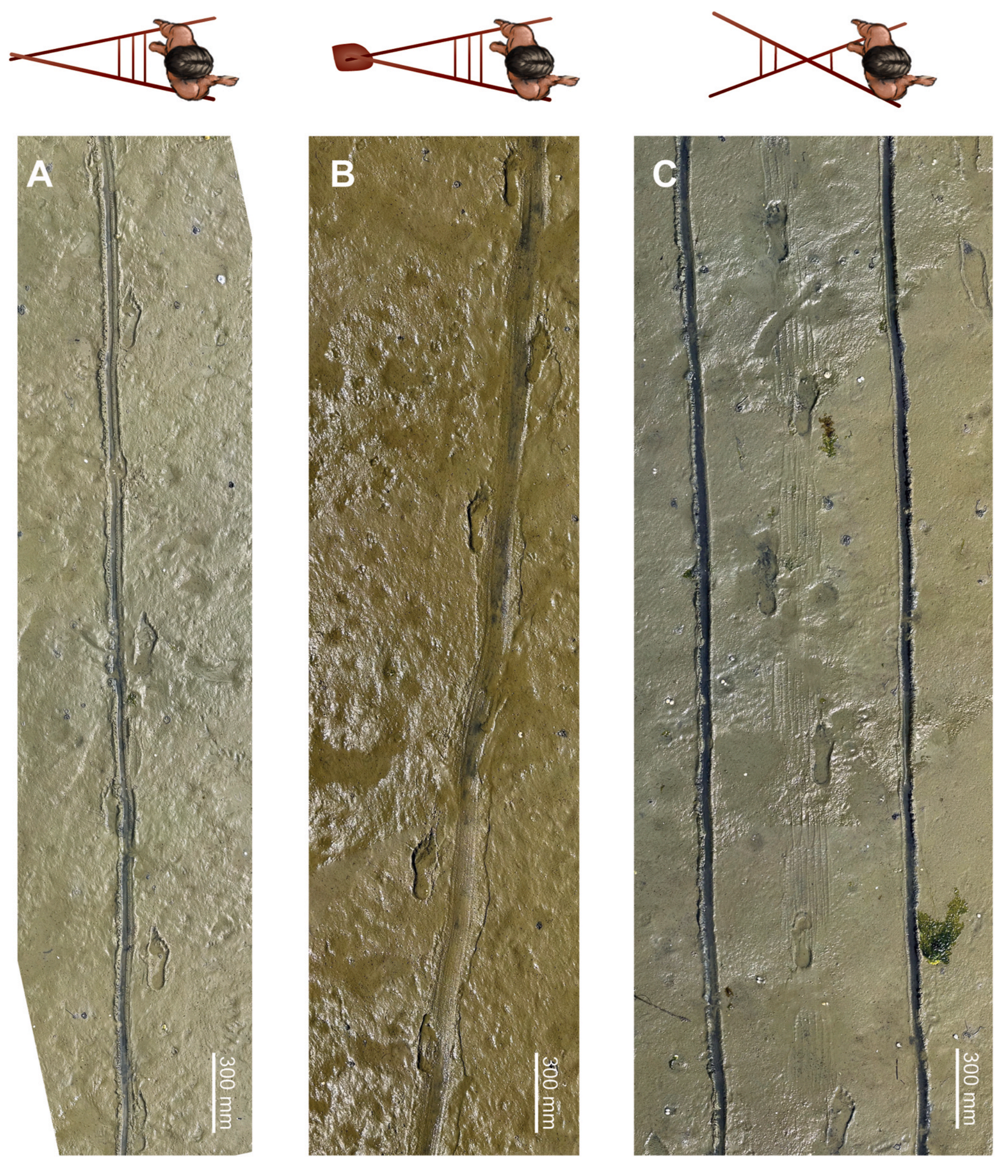

Fig. 21. Photographic orthomosaics created by photogrammetry of sections of experimental hand pulled travois. **A.** Results obtained using a V-shaped design. **B.** Results obtained using a V-shaped design where the contact point was wrapped in a padded bag. **C.** Results obtained using a X-shaped design. All experiments were undertaken in the Fall of 2024 on mudflats close the entrance of Poole Harbour in the UK.

Fig. 22. Results obtained from a range of experiments conducted at Sandbanks, Poole Harbour in the UK and in Maine (USA). **A.** Three-dimensional model of a typical footprint truncations using a V-shaped travois design. **B**. Three-dimensional model of a typical footprint truncations using a V-shaped travois design with a padded bag wrapped over the contact point. **C**. Close-up photograph of a typical truncated footprint with a V-shaped travois design. **D**. Three-dimensional model of an underarm log pull on a hard beach. Note how the right foot is twisted oblique to the axis of progression. **E.** Log pull on a beach in Maine showing how multiple contact points can make grooves that are parallel and equidistant. **F.** Log pull on soft beach sand in Maine. Note the rotation of the right footprints and the deep groove formed by the log.

direction, human tracks were sometimes left undisturbed to one side. Wrapping the contact point in a cloth bag reduced the perceived drag when pulling the V-shaped travois and in this case the central groove was shallower and runnel-like. With the cloth bag truncation of the footprints occurred to a greater degree, although in some cases the tracks were left visible below the runnel (Fig. 22B). Traditional dog or horse-drawn travois rely on the flexibility of the pole in contact with the ground to "bounce" over obstacles and reduce friction, something that does not appear to work well in mud. Here, the contact point tends to dig into the ground, although experimenting with a cloth pad seems to prevent this. To test whether drag was reduced by using the padded contact points, the horizontal force needed to pull the travois was measured using a strain gauge. The vertical weight of the travois was held by a volunteer while a second volunteer pulled the travois forward horizontally using the strain gauge. These experiments were undertaken with a fixed load of 18.2 kg. The results of these limited experiments suggest that an X-shaped travois is associated with a slightly greater horizontal force than one with a V-shaped configuration. The addition of a padded contact reduces the friction slightly, although by a statistically

Table 1
Horizontal force associated with the movement of a hand drawn travois with a fixed load of 18.2 kg. Kruskal-Wallis test ($P < 0.001$) indicates a statistically significant different between the median values.

	N-Runs of ~50 m	Average horizontal force (N)	SD Error	Standard deviation
X-Shape	11	127	2.45	26
V-Shape	8	100	0.61	8
V-Shape + Pad	8	94	0.94	13

significant amount (Table 1).

Observations were also made using a single, unloaded pole dragged over the shoulder or under the arm with the coronal plane of the body held at right angles. When a longer pole is used, the drag marks tend to be more wayward, are usually located to one side of the long axis of the trackway and rarely intersect the footprints. The pole is offset from the sagittal plane and tends to skip and jump as the person moves particularly when the lever is held on the shoulder. This movement is less pronounced as the weight of the pole increases. A short pole held tightly under the arm intersects some of the footprints but again tends to be offset to one side of the sagittal plane. There are different ways of dragging a large trunk or branch, but most involve rotating the coronal plane of the body such that the trunk passes under one arm and across the body being held by both arms. It is again held to one side of the sagittal plane, moreover the rotation of the coronal plane causes at least one of the footprints to become slightly oblique to the direction of travel, a feature accentuated further if the knees are bent and the weight of the body is used to help drag the item. The addition of multiple contact points on the dragged log, in the form of branches or stubs, creates multiple drag lines.

While far from definitive, these experiments are instructive. A hand-pulled travois functions well and is equivalent to using a small wheelbarrow or cart, and there is a clear advantage in moving bulky, and presumably heavy, items. The geometry of these vehicles is limited by the height of the individual conveyor, however, and X-shaped designs while more stable create more surface drag. Footprints are parallel to the sagittal plane of the body, which is held at right angles to the travois. V-shaped configurations leave a distinctive ichnological signature with human footprints truncated longitudinally in a fashion that is like that recorded for the linear features at White Sands. It is possible that dragged spears, tent poles and/or long sticks could leave similar traces. However, drag marks tend to be offset from the sagittal plane, and if held on the shoulder, are more unstable. Larger tree trunks or branches give a different ichnological signature when dragged. The body is typically rotated such that the trunk can be held by both arms and often against the flank. This rotates the footprints such that they become oblique to the sagittal plane and drag mark. Furthermore, these tracks locate more to one side, since holding the trunk to the body tends to rotate it outwards. This footprint signature is different from that observed at White Sands.

4.3. Interpretation

Based on the review of possible interpretations, we discount formation of the linear structures by proboscidean, giant ground sloth or other animal. One cannot discount the possibility that some of the features described from White Sands are the result of dragging sticks, poles, spears, or firewood (Types I). However, this does not explain all the features described in Types II and III. The latter consists of two parallel equidistant grooves, and while Fig. 22E does resemble some of the narrower Type III linear features at White Sands, we would expect examples with multiple parallel grooves in dragged firewood was the cause. The ends of logs are not always provided with just two branches or stubs, and we would expect, therefore, to see examples of three or more and we do not observe this. Hypothetically, the linear features could be formed by a boat's keel. However, their distribution at White Sands, and the nature of reed boats, which we consider the most likely type of boat to have been used, makes this explanation unlikely. We therefore favour some form of hand-drawn travois as the most parsimonious explanation, for at least some of the features described here. It is worth noting that the linear features occur near each other and are often iso-oriented. This suggests that a similar path was followed when travelling back and forth and/or that that several individuals were moving at the same time (as in transport carried out in a small working group). In this sense, an indication of the direction of travel may when mapped over a large area indicate potential routeways.

The travois that we hypothesize were used at White Sands are unlikely to have been curated items, such as the dog travois described in some of the historic literature (e.g., Henderson, 1994). In this context a curated item is something with a bespoke function and maintained for that purpose. We envisage something more ad hoc in which components may have had multiple functions, including firewood, tent poles, or as hunting aids. This was likely expedient rather than curated technology.

5. Conclusions

Linear features, in the form of single or parallel grooves, associated with human footprints, are prominent of the trace and track record at White Sands National Park. There are three basic morphological types of features, namely single, often deeply cut, grooves that may bifurcate or jump between parallel lines (Type I). Secondly, there are broader grooves that form runnels with either single or multiple lines. Finally, there is a third type, in which two parallel grooves move across the surface. These features occur across Alkali Flat, both in potential former shoreline locations, and out on the playa floor. In all cases, they crosscut human footprints and are not associated with other animal tracks, which implies a human agency in the formation of these traces. While some of the simpler traces may be formed by the movement of firewood, or simply the idle dragging of spears or tent poles, we suggest that those that involve the movement of two parallel grooves are likely produced by an improvised travois dragged by people.

These linear features, including those interpreted as the product of travois occur on several different ichno-surfaces. Some of these surfaces, although not all, have been securely dated. The surfaces containing linear features on Track Horizons TH2 and TH3 (Fig. 2) in the vicinity of WHSA Locality 2 can be traced into the site stratigraphy described and dated by Bennett et al. (2021), with geochronological confirmation provided by Pigati et al. (2023). These surfaces date from ~22,000 years ago at the height of the Last Glacial Maximum, as such the linear features on these surfaces would therefore provide the oldest known evidence of vehicle transport. While the dating has been the subjectg of debate for some researchers (e.g., Rhode et al., 2024; Pigati et al., 2024), this should not distract from the fact that these features, whatever their age, demonstrate traditional ancient Indigenous practices, driven by the universal human need to transport possessions and resources.

CRediT authorship contribution statement

Matthew R. Bennett: Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Thomas M. Urban:** Writing – review & editing, Conceptualization. **David F. Bustos:** Writing – review & editing, Investigation, Data curation, Conceptualization. **Sally C. Reynolds:** Writing – review & editing, Supervision, Project administration, Funding acquisition. **Edward A. Jolie:** Writing – review & editing, Validation, Investigation. **Hannah C. Strehlau:** Writing – review & editing, Data curation. **Daniel Odess:** Writing – review & editing, Resources, Investigation. **Kathleen B. Springer:** Writing – review & editing, Resources, Data curation. **Jeffrey S. Pigati:** Writing – review & editing, Resources, Data curation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Matthew Bennett reports financial support was provided by Arts and Humanities Research Council. All authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request and from https://doi.org/10.5066/P9HIM7IC.

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