

1 **Mobility and raw material procurement by Fishtail people in Uruguay: Evaluation**
2 **of silcrete long distance transport between campsites and outcrops during the late**
3 **Pleistocene (ca. 12,900-12,250 cal BP)**
4

5 Rafael Suárez^a, Flavia Barceló^b
6

7 ^a Departamento de Arqueología, Facultad de Humanidades y Ciencias de la Educación
8 (FHCE), Universidad de la República, Avenida Uruguay 1695, Montevideo, 11200,
9 Uruguay. (rafael.suarez@fhce.edu.uy - suarezrafael23@gmail.com)

10 ^b Facultad de Humanidades y Ciencias de la Educación - FHCE, Universidad de la
11 República, Avenida Uruguay 1695, Montevideo, 11200, Uruguay.
12 (barcelof27@gmail.com)
13

14 **Abstract**

15 Lithic artifacts from late Pleistocene manufactured in silcrete are used to understand
16 Fishtail behaviors linked to mobility, land use and raw material acquisition during early
17 prehistory in Uruguay. The data analyzed here include three categories of silcrete
18 evidence: 1) a database of Fishtail points, 2) regional outcrops of these lithic resource, 3)
19 debitage and unifacial tools from campsites. We calculated the cumulative cost of
20 movement between campsites and the nearest lithic resources in space, located within the
21 silcrete area, the distances involved in such movements, and the possible connection
22 routes between campsites and silcrete resources. We analyzed the raw materials, density
23 and spatial distribution of Fishtail points, and generated a Predictive Model of Transit
24 Pathways. The results obtained indicate that silcretes were transported over long distances
25 in mobility networks by an extensive Paleoamerican social landscape from outcrops
26 located in the western and southwestern to campsites in northwestern Uruguay at
27 distances ranging between 179 and 482 km. This new data confirms long distance
28 displacements, the high social value, and the preference of this lithic resource for the
29 production of tool assemblages by the Fishtail peoples of Uruguay.
30

31 **Keywords:** Peopling of America, Fishtail points, Hunter-gatherers mobility, Long
32 distance lithic resource procurement, Silcrete, GIS
33

34 **1. Introduction**
35

36 Fishtail points are a classic artifact that indicate early occupations, have a wide
37 distribution that includes different regions of Central America (Bird and Cooke, 1978;
38 Lohse, 2021) and South America (Politis 1991; Flegenheimer et al. 2013). Their
39 distribution includes an important diversity of environments ranging from north to south
40 in the highlands of the Andes (Rademaker et al. 2014), northern, central and southern
41 Chile (Bird 1938; Núñez et al. 1994; Loyola et al. 2018) through the low plains of
42 Uruguay and Pampa (Suárez 2015, Weitzel et al., 2018), Patagonia (Miotti and Terranova
43 2015) and Tierra del Fuego (Massone 2004, Martin et al. 2019). Its distribution also
44 includes the East-West axis, from the Pacific coast to the Atlantic coast, with a greater
45 presence of this point design in the Southern Cone of the continent (Suárez et al. 2023).

46 Research on hunter-gatherers of the late Pleistocene-early Holocene has been
47 steadily and continuously advancing knowledge on different aspects of mineral resource
48 provisioning in South America (Flegenheimer et al. 2003, 2015; Magnín 2012; Méndez
49 et al. 2018; Herrera et al. 2019; Skarbun et al. 2021). The transport of rocks over long

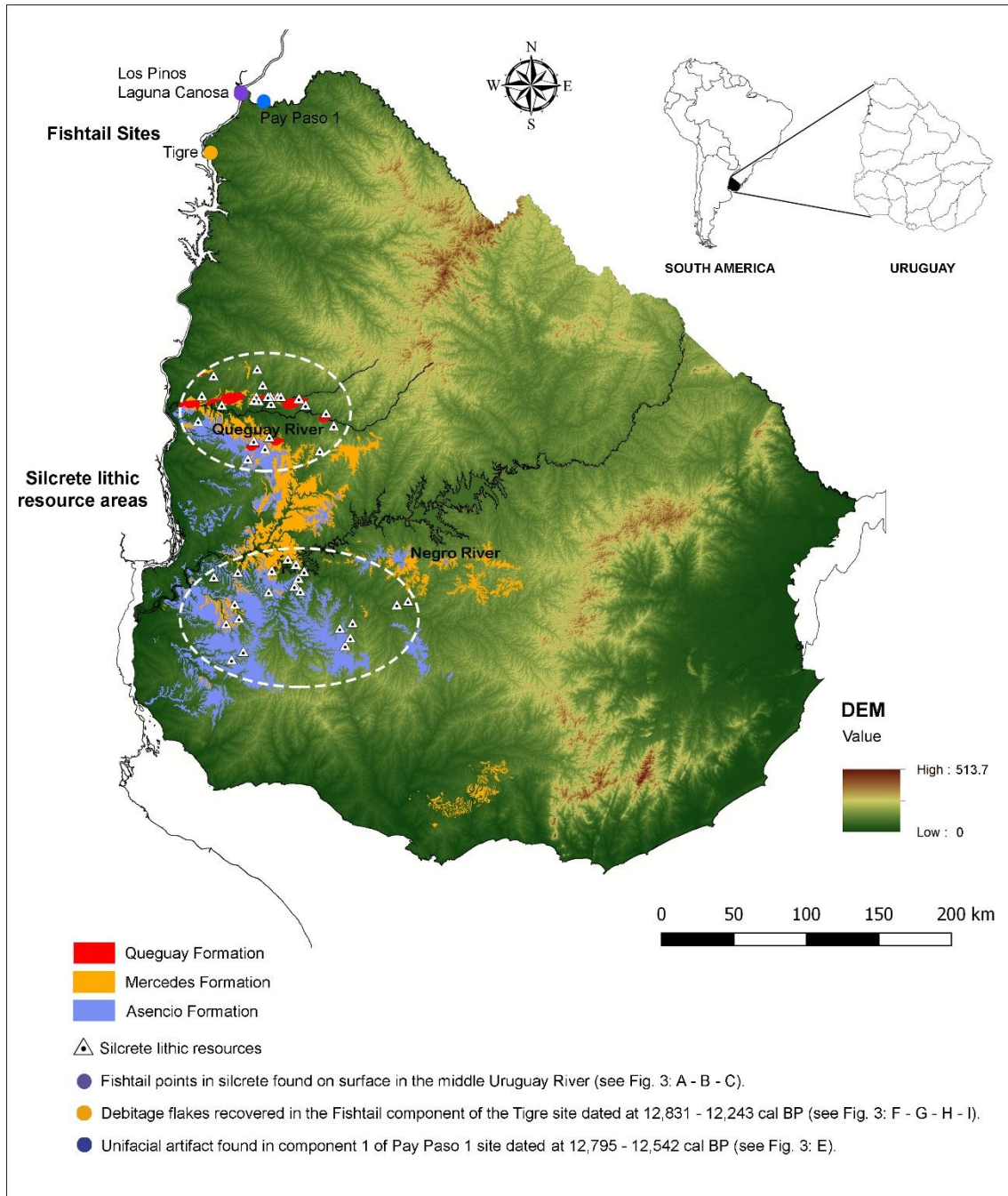
50 distances was recognized early among hunter-gatherers in Uruguay by a pioneer of
51 Uruguayan archaeology, J.H. Figueira (1892), 111 years later Flegenheimer et al. (2003)
52 recognized the transport of silcrete from Uruguay to Pampa Argentina.

53 The Fishtail people in Uruguay used silcrete (commonly known in Uruguay as
54 silicified limestone or *carneolita* Fig. 2B) to make part of their tool-kit (see Suárez 2011a,
55 Suárez 2015, Suárez 2019; Suárez et al. 2018, Suárez et al. 2023), and there is a marked
56 preference for this rock to make Fishtail points (Suárez 2000, 2011a, 2015; Nami 2007,
57 2017; López Mazz 2017). Silcrete outcrops are concentrated in a wide area of western
58 and southwestern Uruguay (Fig. 1), in primary deposits of the Queguay, Mercedes, and
59 Asencio Formations (Bossi 1966; Preciozzi et al. 1985; Tófaló et al. 2001; Veroslavsky
60 and de Santa Ana 2009; Martínez et al. 2015). Primary silcrete outcrops are located in the
61 Queguay limestone area (Fig. 2A, video link), where potential sources of supply are easily
62 identifiable because they are located in specific places in the environment.

63 The choice to establish seasonal or campsites is closely related to the accessibility
64 to different resources, whether sources of raw materials, proximity to watercourses,
65 sources of food resources (animal - plant), and/or symbolic aspects, among others
66 (Binford 1980, 1990; Kelly 1983, 1988; Bamforth 1986; Andrefsky 1994; Amick 1996;
67 Erlandson 2001; Flegenheimer 2004; Bayón et al. 2006; Dillehay 2008; Miotti 2010;
68 Flegenheimer et al. 2013; Politis et al. 2004; Suárez 2011a, Suárez et al. 2018). The study
69 and identification of the raw materials present in the archaeological record, together with
70 research aimed at identifying the location of these resources, contributes to understanding
71 aspects related to group mobility by the early hunter-gatherers who produced Fishtail
72 points (Suárez and Piñeiro 2002; Flegenheimer et al. 2003; Miotti and Salemme 2004;
73 Suárez 2010, 2011b; López Mazz 2017; Nami 2017; Hermo et al. 2022). In addition, the
74 study of lithic sources allows an approximation of understanding the past relationships
75 between humans and their social landscape.

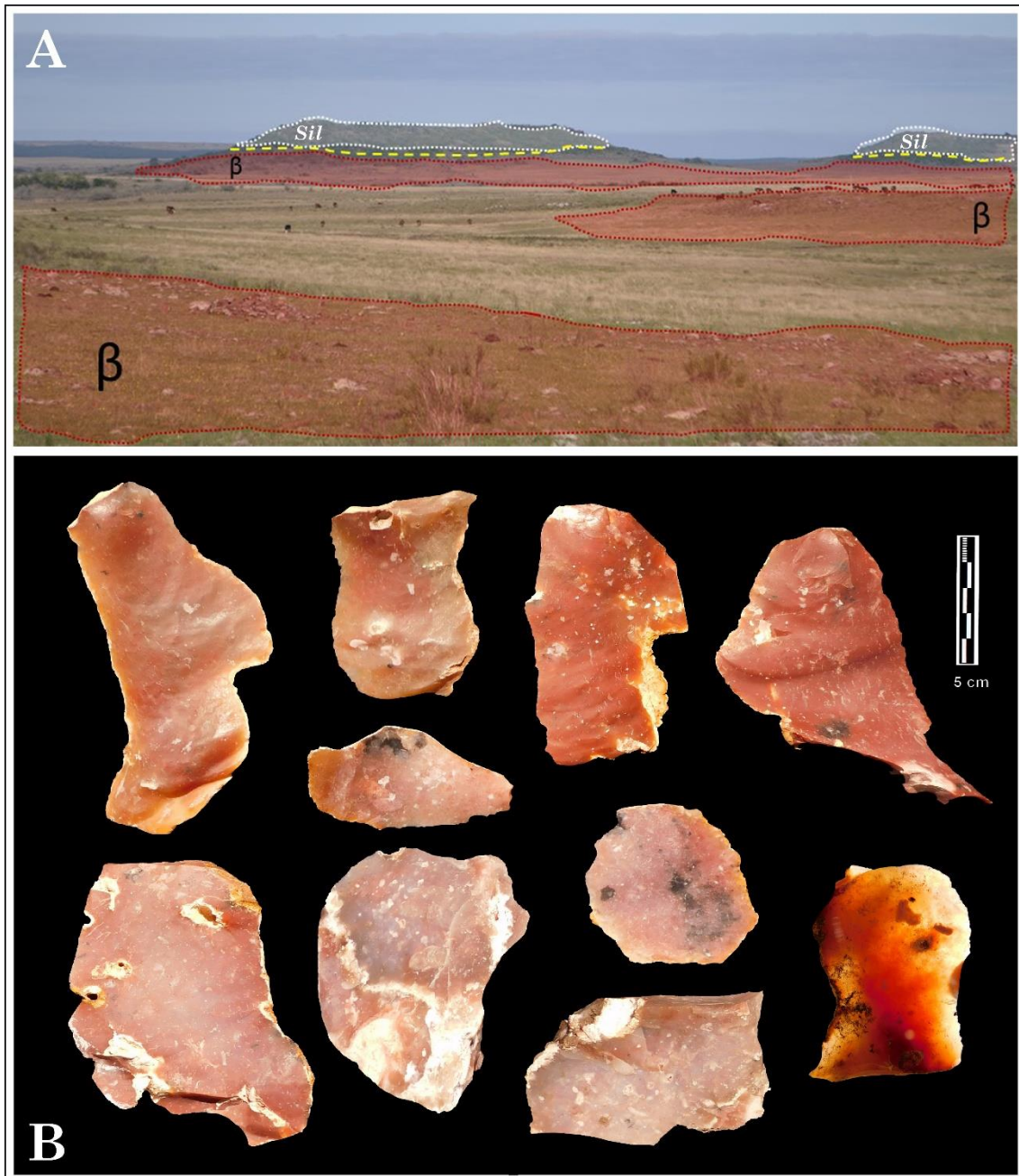
76 This paper establishes potential access routes to the silcrete resource and evaluates
77 its transport to Fishtail campsites in the middle Uruguay River region. At the Pay Paso 1
78 and Tigre sites finished tools and debitage of silcrete have been recovered in stratigraphic
79 contexts dated between ~12,900-12,250 cal BP (Fig. 3 E-I). Additionally, in the middle
80 Uruguay River region (Los Pinos and Laguna de Canosa sites) there are also Fishtail
81 points of silcrete (Fig. 3 A, B, C). These localities indicate the transport of this resource
82 during the Fishtail times from the southwestern silcrete outcrops to the northwestern
83 campsites. To establish the access routes to the silcrete, we used Geographic Information
84 Systems (GIS) because they are a useful tool for spatial analysis at different scales
85 (Anderson and Gillam 2000; Anderson et al. 2010; Skarbun and Frank 2011; Magnín
86 2012; Figuerero Torres and Izeta 2013; Gianotti 2014, among others).

87



88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104

Fig. 1. Map showing distribution of main silcrete outcrops (triangles) in the western and southwestern of Uruguay Queguay, Mercedes and Asencio Formations and Fishtail campsites of Pay Paso 1 and Tigre (orange and blue dots) where artifacts and debitage in silcrete dated between ~12,900-12,250 cal BP have been recovered.



105
 106
 107
 108
 109
 110
 111
 112
 113
 114
 115
 116
 117
 118
 119
 120

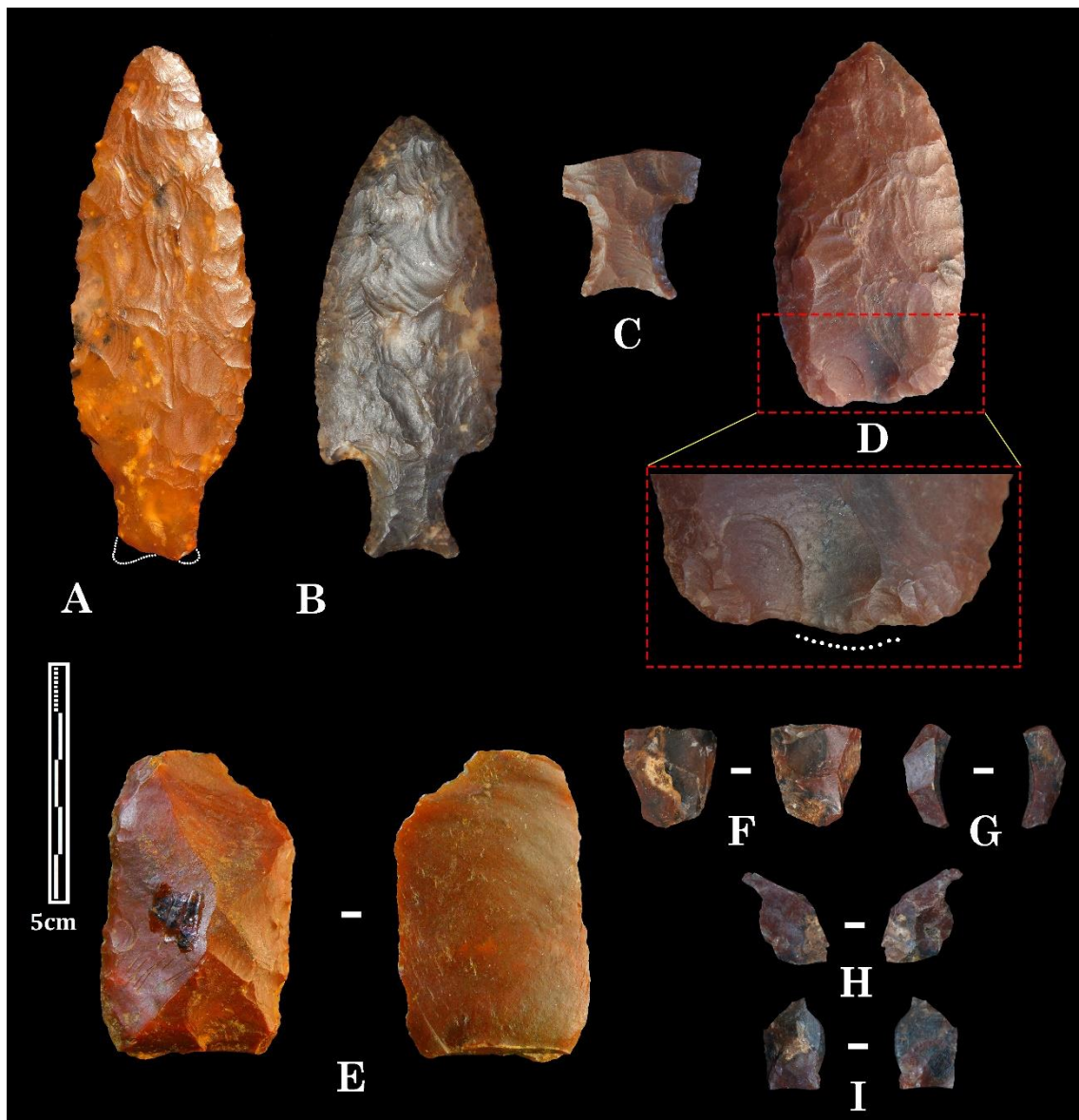
Fig. 2. (A) View of the landscape of the Queguay Formation (limestones) in the western of Uruguay. In white on the top of the hills silcrete outcrops *SIL*, β Basalt (Arapey Formation). (B) Different variants of silcrete from Uruguay, note red, pink, gray colors and inclusions (black and white dots) and translucent variant (bottom right).

2. Archaeological and Geological background

2.1. Fishtail occupations

Fishtail points in the southern cone mark one of the most successful early human adaptations at the continental level for the period ~12,900-12,200 cal BP (Flegenheimer et al. 2003; Politis et al. 2004; Hermo and Terranova 2012; Flegenheimer et al. 2013; Miotti and Terranova 2015; Waters et al. 2015; Nami 2017; Suárez 2011a, 2018, 2019; Suárez and Cardillo 2019; Prates et al. 2022; Hermo et al. 2022).

121 In northwest Uruguay there are sites where Fishtail points and preforms in silcrete
122 have been recovered (Los Pinos, Laguna Canosa and Pay Paso sites) (Fig. 3 A, B, C, D),
123 and stratigraphic sites where debitage flakes and unifacial artifacts in silcrete have been
124 found in situ (Pay Paso 1 and Tigre sites) (Fig. 3 E and F-I). The Fishtail component of
125 the Tigre site has 9 radiocarbon ages (AMS) that allow us to chronologically place the
126 Fishtail occupations in the region between ~12,831 - 12,243 cal BP (Suárez 2019) (Table
127 1). At this site, a Fishtail point made of translucent quartz was recovered at the base of
128 stratigraphic unit 2 (SU2, Level 12) (Suárez et al. 2018, Suárez 2019). In association with
129 this find, bifaces, preforms, and debitage flakes were also identified, which allow
130 reconstruction of the different processes involved in the operational chain of the
131 manufacture of this type of point (Suárez 2019). Among the debitage, 15 silcrete flakes
132 were identified; their low representation (3%) and their spatial association indicate the
133 occurrence of tool rejuvenation events in the Fishtail level of Tigre site (Fig 3 F-I).
134
135



136
137 **Fig. 3.** Silcrete artifacts from Fishtail campsites of northwestern Uruguay (Uruguay river). (A)
138 Translucent variant of silcrete from Laguna Canosa site (see supplementary Fig. S5 for a photo
139 showing the translucence of this point). (B) Fluted Fishtail points recovered at the Laguna Canosa.

140 (C) Fishtail fragment from Los Pinos site. (D) Fishtail preform with end thinning flake scare,
 141 abrasion and nipple isolation for fluting on the base from Pay Paso 4. Detail of base preform with
 142 nipple isolation (white dots indicate abrasion). (E) Reddish silcrete unifacial artifact recovered in
 143 U2a of the Pay Paso 1 site dated at 12,795-12,542 cal BP (Fishtail component). (F – G – H and
 144 D). Examples of silcrete debitage flakes recovered in the Fishtail component of the Tigre site dated
 145 at 12,831-12,243 cal BP.

146

147 On the other hand, at the Pay Paso 1 site, the Fishtail component is located within
 148 stratigraphic unit 2a (SU2a), a 24 cm sediment layer composed of abundant
 149 archaeological material and bone remains of current (*Myocastor coypus*, *Rhea*
 150 *Americana*, *Megaleporinus sp.*) and Pleistocene fauna (*Equus sp.*, *Glyptodon sp.*) (Suárez
 151 and Rinderknech 2003, Suárez 2011a). The 12 radiocarbon ages obtained by the AMS
 152 method place this occupation between 12,795 and 12,542 cal BP, a chronological range
 153 similar to that obtained at the Tigre site (Table 1). At Pay Paso 1 silcrete is also
 154 represented in a smaller number of debitage flakes (0.30%), and somewhat more
 155 represented in the unifacial artifacts recovered (5.64%). A total of 5 flakes derived from
 156 a small resharpening event and 7 silcrete formal artifacts, among which scrapers (n=1),
 157 end-scrapers (n=3), and a blade with a retouched edge stand out, are evidence of the use
 158 of this lithic resource at the Pay Paso 1 site. These data suggest the transport of unifacial
 159 formal artifacts (Fig. 3 E) over long distances, because there are no silcrete outcrops
 160 within a radius of hundreds of km at the Pay Paso 1 and Tigre sites.

161 The study area, located in the department of Paysandú, is important because it is
 162 the northern limit of the silcrete outcrops of the Queguay Formation (Fig. 2A), and
 163 therefore the closest to the sites of Tigre and Pay Paso 1 located in the middle Uruguay
 164 River valley, where we have identified this raw material in early stratified archaeological
 165 contexts dated during Fishtail times, ca. 12,900 - 12,250 years cal BP. Approximately 20
 166 km north of the Queguay Chico river there are no outcrops of silcrete. Towards the south,
 167 the secondary deposits of silcrete have the best quality, totally homogeneous, with
 168 translucent variants (see supplementary material Fig. S5 and Fig. S6 for photos of this
 169 rock type) without gaps, fissures or holes in the Soriano and Flores departments (Fig. 2
 170 B).

171

172 **Table 1.** AMS radiocarbon dates from Fishtail components of the Pay Paso 1 and Tigre sites
 173 (northwestern Uruguay).

Site	Radiocarbon dating (^{14}C BP)	2σ Calibrated age (cal BP)	Median Probability	Laboratory Number	Stratigraphic Unit
Tigre	10.955 \pm 50	12.968 – 12.746	12.831	UCIAMS 125383	U2 (base)
Tigre	10.930 \pm 20	12.888 – 12.752	12.795	UCIAMS 125384	U2 (base)
Tigre	10.905 \pm 20	12.833 – 12.744	12.766	UCIAMS 125381	U2 (base)
Tigre	10.595 \pm 25	12.688 – 12.485	12.529	UCIAMS 125379	U2 (base)
Tigre	10.580 \pm 50	12.696 – 12.209	12.555	UCIAMS 125393	U2 (base)
Tigre	10.510 \pm 45	12.618 – 12.098	12.480	UCIAMS 145434	U2 (base)
Tigre	10.425 \pm 20	12.469 – 12.092	12.283	UCIAMS 125380	U2 (base)
Tigre	10.410 \pm 60	12.576 – 11.960	12.243	UCIAMS 145433	U2 (base)

Pay Paso 1	10.930 ± 20	12.888 – 12.752	12.795	UCIAMS 21631	U2a (base)
Pay Paso 1	10.910 ± 30	12.888 – 12.743	12.778	UCIAMS 27738	U2a (base)
Pay Paso 1	10.895 ± 30	12.837 – 12.740	12.766	UCIAMS 27744	U2a (base)
Pay Paso 1	10.880 ± 25	12.827 – 12.738	12.758	UCIAMS 27745	U2a (base)
Pay Paso 1	10.680 ± 20	12.707 – 12.620	12.662	UCIAMS 21637	U2a (middle)
Pay Paso 1	10.630 ± 25	12.692 – 12.496	12.630	UCIAMS 21636	U2a (middle)
Pay Paso 1	10.595 ± 30	12.689 – 12.484	12.534	UCIAMS 27746	U2a (middle)
Pay Paso 1	10.580 ± 20	12.623 – 12.484	12.530	UCIAMS 21644	U2a (middle)
Pay Paso 1	10.555 ± 20	12.617 – 12.480	12.552	UCIAMS 21645	U2a (upper)
Pay Paso 1	10.540 ± 35	12.621 – 12.203	12.552	UCIAMS 27747	U2a (upper)
Pay Paso 1	10.520 ± 20	12.609 – 12.335	12.560	UCIAMS 21643	U2a (upper)
Pay Paso 1	10.500 ± 25	12.607 – 12.191	12.542	UCIAMS 27740	U2a (upper)

Calibration with Calib 8.20 SHCal20 ¹⁴C, (two sigma rates). Hogg et al. (2020)

2.2. Geological context: Silcrete outcrops

Our research team has been making progress in the identification of silicified lithic resources used by early hunter-gatherer groups, including silicified sandstone, agate, jasper, and chalcedony, among others (Suárez 2010, 2011a, 2011b). Prospecting carried out in the last 4 years has identified extensive silcrete outcrops within the area informally known as Queguay limestones formation (Fig. 4 and Fig. 5).

The following is a synthesis of the geological context in which the silcrete outcrop. The lithostratigraphic assignment of the Cretaceous-Paleogene limestones and silcreted in Uruguay is a controversial issue. According to some authors, they belong to the Mercedes Formation (Bossi et al. 1975) and others to the Queguay Formation (Goso 1965 in Bossi 1966, Goso Aguilar and Perea 2003), with outcrops mainly in the West littoral basin (Goso 1999) and Santa Lucía basin (Veroslavsky et al. 1997). These units extend discontinuously through south-central and western Uruguay, with the highest density of outcrops and best exposures in the hills located in the proximities of the middle and lower course of the Queguay River, and in the lower part of the Negro River, where it was defined in the subsurface (Martínez and Veroslavsky 2004; Veroslavsky and de Santa Ana 2009; Martínez et al. 2015).

The Queguay limestones were first defined by Lambert (1939, 1940). They were later interpreted as rocks generated by energetic calcretization and silcretization processes, mainly under warm and arid to semi-arid conditions (Veroslavsky et al. 1997; Tófaló and Morrás 2009; Tófaló and Pazos 2010). Different thin sections of calcretes and silcreted are presented in the supplementary material (Fig. S1).

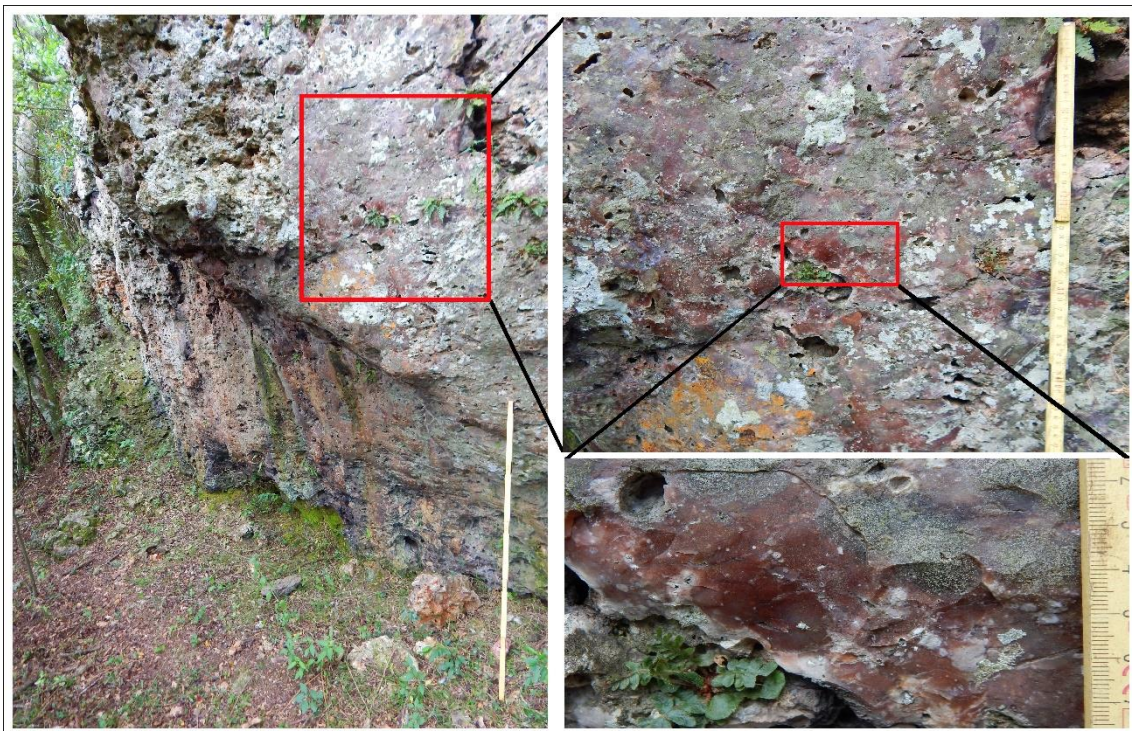
Their age and origin has been a matter of debate throughout the last decades, due to the different stratigraphic relationships and their fossiliferous content. Several authors have proposed different names and lithostratigraphic assignments for these deposits, such as the Queguay Formation assigned to the Lower Tertiary (Goso 1965; Bossi 1966; Goso Aguilar and Perea 2003), the Algorta Member within the Asencio Formation assigned to the Late Cretaceous (Preciozzi et al. 1985), its inclusion in the Mercedes Formation also of the same age (Campanian - Maastrichtian) (Bossi et al. 1975, Preciozzi et al. 1985), as well as the Queguay Chemostratigraphic Unit (Goso and Perea 2003).

207 In more recent works, the lacustrine origin initially proposed by Lambert (1940)
208 was discarded and the limestones were interpreted as calcretes of pedogenic and
209 subterranean origin (Goso Aguilar and Perea 2003; Martínez and Veroslavsky 2004).
210 Indicating that the calcretization process would have occurred during the Paleocene and
211 the associated fossils (gastropods, insect nests, seeds and roots) are linked to that time
212 (Veroslavsky and Martínez, 1996; Veroslavsky et al., 1997; Goso Aguilar and Perea
213 2003; Veroslavsky and de Santa Ana 2009).

214 These processes involved silica dissolution and mobilization, carbonate-rich water
215 circulation, carbonate precipitation and silica reprecipitation (Martínez and Veroslavsky
216 2004). Petrographically, the siliceous and CaCO₃-siliceous facies associated with the
217 "*Calizas del Queguay*" are characterized by the presence of cherts that present a tabular
218 stratification, although lentiform bodies are also observed. They vary in color, including
219 intense shades of red, black, white and whitish, attributable to the presence of various
220 impurities in their internal composition (Tófalo and Pazos 2010). Under the microscope,
221 quartz, well-crystallized microquartz and sometimes even mega quartz crystals are
222 identified in them, together with the subordinate presence of chalcedony and opal
223 (Flegenheimer et al. 2003; Veroslavsky and de Santa Ana 2009; Tófalo and Pazos 2010;
224 Loponte et al. 2011).

225 At regional level, different correlations have been proposed for this geological
226 record with equivalent units in Argentina, such as the Puerto Yeruá Formation (Tófalo
227 1986; Tófalo and Pazos 2002) and the Arroyo Castillo Formation (Garrasino 1989). No
228 outcrops of this type of silicified rock have been reported in southern Brazil.

229



230

231 **Fig. 4.** Example of extensive vertical outcrop of several meters of red silcrete identified in the
232 Queguay Formation (Department of Paysandú, western of Uruguay). General view and detail
233 showing the red high silicification of the silcrete.

234

235 In recent years, Argentine colleagues have petrographically characterized these
236 type of rocks found in the neighboring country, both on surface and in excavations, and
237 have compared them with rocks from Uruguay, in order to establish their provenance.
238 These studies have shown that both the rocks found on the right bank of the lower

239 Uruguay River in Argentine territory (El Palmar National Park), as well as those found
240 in pampas (*Meseta El Fresco*); *Cerro el Sombrero - Cima*, at macro and microscopic level
241 present similar petrographic characteristics with those from Uruguay (Flegenheimer et al.
242 2003; Loponte et al. 2011).
243



244
245 **Fig. 5.** Example of red silcrete block, Cuervos Hill (Dept. Paysandú, Uruguay).
246

247

248 **3. Material and methods**

249

250 The data analyzed here include three categories of evidence: 1) a database of Fishtail
251 points manufactured in silcrete, 2) regional silcrete lithic resources base and 3) debitage
252 and unifacial tools on silcrete from early campsites.

253 Considering that the sample is relatively large and includes several variables
254 capable of being subjected to different analyses, it was decided to use GIS as a
255 methodological tool for analysis. The volume of data implied analyzing different spatial
256 scales, ranging from a regional scale for the analyses applied to the Fishtail point sample,
257 to a local scale for the spatial analyses used to propose hypothetical transit
258 routes/corridors to access the lithic resources (silcrete) from the campsites in the
259 northwestern (Pay Paso 1, Tigre and Laguna Canosa / Los Pinos).

260 The sample of Fishtail points used as a database includes a total of 97 points,
261 belonging to various archaeological collections (public and private), from 4 different
262 geographic regions (supplementary Table S1). This sample was entered into the QGIS
263 software including data concerning the place, area, or site of discovery. Those specimens
264 for which such data is not available will not be taken into account at the time of spatial
265 analysis, because of this, the sample was reduced from 97 to 79 points, but will be

266 considered all the sample for the purpose of noting other specific qualities, as well as the
267 type of raw materials used in their manufacture.

268 To determine the density of Fishtail points in Uruguay, heat maps were used due
269 to the unequal distribution of datasets in space (Bonnier et al., 2019; Wheatley and
270 Gillings, 2002). We used the heat map plug-in of QGIS, a raster analysis tool which
271 employs the Kernel Density Estimation algorithm to calculate the density of a layer of
272 input locations. For this, it calculated the density of each of the points present in a given
273 area and within a previously established radius where each point is assigned an influence
274 value for itself and for its close neighbors located in the rest of the layer; this radius is
275 known as Kernel Bandwidth, and determines the search zone for the heat map (Conolly
276 and Lake 2006, Baxter et. al 1997). Due to the fact that the working sample covers the
277 whole country, it was decided to establish a radius of 20 km² to calculate the density of
278 Fishtail points, to obtain a broad and representative view of the spatial distribution of
279 these points in the research area.

280 For the calculation of distance and time costs, as well as predictive models of
281 transit routes, we used ArcMap software, specifically its Spatial Analyst Tools functions.
282 We followed the proposals of Tobler (1993); Wheatley and Gillings (2002); Conolly and
283 Lake (2006), Fábrega Álvarez and Parcero Oubiña (2007); Magnín (2012) and Gianotti
284 (2014), adapted to our study area.

285 To carry out these spatial analyses, base maps were downloaded and created. The
286 Digital Terrain Model (DTM) of Uruguay provided by Renare (*Dirección General de*
287 *Recursos Naturales Renovables, Ministerio de Ganadería, Agricultura y Pesca*), with a
288 resolution of 30 x 30 meters, was used. From the DTM, a terrain slope map was generated
289 and used as a friction surface in the calculations of movement cost and optimal transit
290 routes between campsites and raw material outcrops. Regarding hydrological mapping,
291 unfortunately there are no SHP (shape) files that simulate the composition of the
292 Uruguayan water system during Fishtail times. And although there are works about the
293 position of the oceanic coastline and the estuary of the La Plata River (Inda et al. 2011;
294 Beovide et al. 2017), there is no further information regarding the interior of the territory,
295 so we used current hydrological data.

296 The accumulated cost or cost distance was calculated taking into account the
297 friction surface of the terrain, this calculation indicates the amount of effort required to
298 move from a point of origin and the distance that must be traveled. However, it is
299 important to note that it is not the straight-line distance between two points (Euclidean
300 distance). In this calculation, the friction surface previously created, such as the map of
301 slopes or terrain inclinations classified in degrees, was used as a movement variable. This
302 is because terrain heterogeneity influences the cost associated with displacement (Bell
303 and Lock, 2000; Wheatley and Gillings, 2002; Conolly and Lake, 2006; Magnín, 2012).
304 This allowed us to estimate the difficulty of travel between campsites and raw material
305 outcrops. The result of this analysis is a radial map showing, through a gradation of colors,
306 the amount of effort required to move over a surface. In order to have a more precise idea
307 of the distances involved in the journey, the resulting data were expressed in kilometers.
308 Subsequently, the lithic resource location layer (outcrops) in vector format was
309 superimposed on this map. This allowed us to estimate the cumulative cost of movement
310 in kilometers between outcrops and campsites.

311 To determine the times required to cover these distances, we chose to apply
312 Tobler's (1993) trekking or hiking function. This is an exponential function that calculates
313 the estimated time to traverse a given landscape and is based on the idea that the difficulty
314 of a hiking route is influenced by multiple topographic factors, such as slope, roughness
315 of the terrain and altitude. This function adjusts the walking speed according to the degree

316 of slope to be traversed, proposing a base speed of 6 km/h in downhill terrain. In this
317 work it was applied as used by other authors (Fábrega Alvarez and Parcero Oubiña, 2007;
318 Magnín 2012; Gianotti 2014).

319 Finally, to generate predictive model of transit pathways between campsites and
320 raw material outcrops, *cost back link* and *cost path* calculations were used in ArcMap
321 software. First, the calculation known as cost back link or least cost link was performed.
322 This calculation generated a map showing the type of movement required to move
323 between a cell and its neighboring cell. The value of each cell crossed varies and depends
324 on the slopes of the terrain as mentioned above, and the direction of travel (Conolly and
325 Lake, 2006; Magnín, 2012). The next step was to apply the calculation called cost path.
326 Unlike the previous maps, in this case we start from the place marked as the destination,
327 since we seek to calculate the route with the lowest cost to return to the site that was
328 established as the origin from the beginning (Conolly and Lake, 2006; Giannoti, 2014).
329 After entering the destination point, the previously generated *cumulative movement cost*
330 *distance map* and the *cost back link map* were entered. These calculations allowed us to
331 determine the least cost route from a destination point to the origin site. With this
332 information, we generated a network of roads or transit routes that connect the campsites
333 to the silcrete outcrops.

334

335 4. Results

336

337 4.1. Raw materials used in the manufacture of Fishtail points

338

339 The Fishtail point sample includes 97 pieces that were manufactured using 10
340 different lithic resources (Table 2). Silcrete was the most used raw material for Fishtail
341 knappers to make their points (53.7%); more than half of the sample of Fishtail points
342 from Uruguay were made from this raw material. Chert is the second raw material with
343 10.3% of the sample, followed by Jasper with 9.3%. Other resources such as opal and
344 quartzite (7.2% respectively), quartz (5.2%), silicified sandstone (4.2%) and others three
345 rocks with (1% each one) which together make up the remaining 46.3% of the sample
346 (Table 2). This distribution allows us to observe the important social value of silcrete for
347 Fishtail knappers.

348

349 4.2. Density and spatial distribution

350

351 The sample of Fishtail points includes a total of 79 pieces from various basins of
352 Uruguay. These type of points have a high representation, with findings reported in
353 practically all of the country. The sample analyzed in this study includes 4 geographic
354 regions (Fig. 6 and supplementary Table S1). The reduction from 97 to 76 points in the
355 total number of samples is due, as mentioned above, to the lack of data on the location or
356 area of discovery for some of the pieces analyzed.

357

358 **Table 2.** Raw materials used to manufacture Fishtail points in Uruguay.

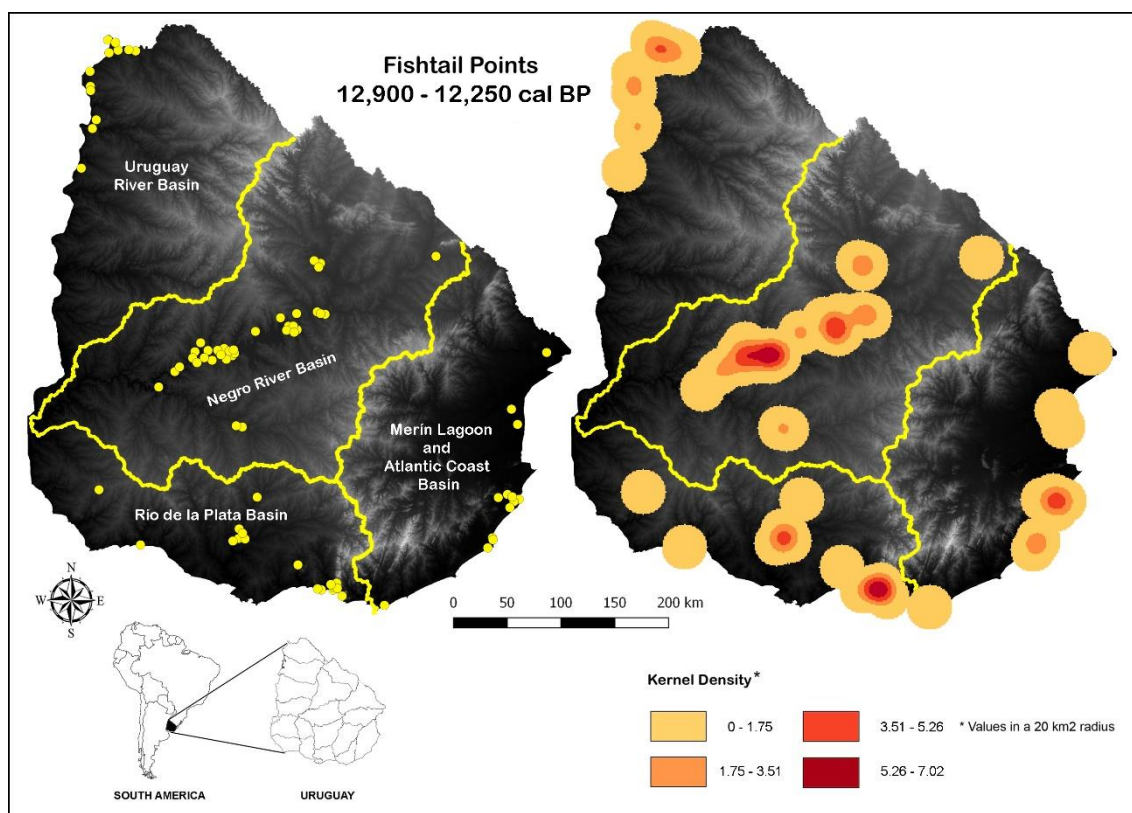
359

Raw material	N	Percentage
Silcrete	52	53.7 %
Chert	10	10.3 %
Jasper	9	9.3 %
Quartzite	7	7.2 %
Opal	7	7.2 %
Quartz	5	5.2 %

Silicified sandstone	4	4.1 %
Rhyolite	1	1 %
Agate	1	1 %
Chalcedony	1	1 %
Total	97	100 %

360
361
362
363
364
365
366
367

Regarding the distribution by region of discovery, it is observed that the Río Negro basin has the highest values, with 36 Fishtail points (46%). It is followed by the Río de la Plata basin with 18 (23%) and Atlantic coast/Merín Lagoon basins with 13 (16%) pieces. Finally, the middle Uruguay River has a lower representation, with a total of 12 points (15%) (Table 3). These new data confirm previous statements (Suárez and López 2003).



368
369
370
371
372

Fig. 6. Spatial distribution and Kernel density estimation (KDE) of Fishtail points in Uruguay

Table 3. Frequency of Fishtail points by Region.

Region	N	Percentage
Negro River Basin	36	46 %
Río de la Plata Basin	18	23 %
Atlantic coast and Merin Lagoon Basin	13	16 %
Middle Uruguay River Basin	12	15 %
Total	79	100 %

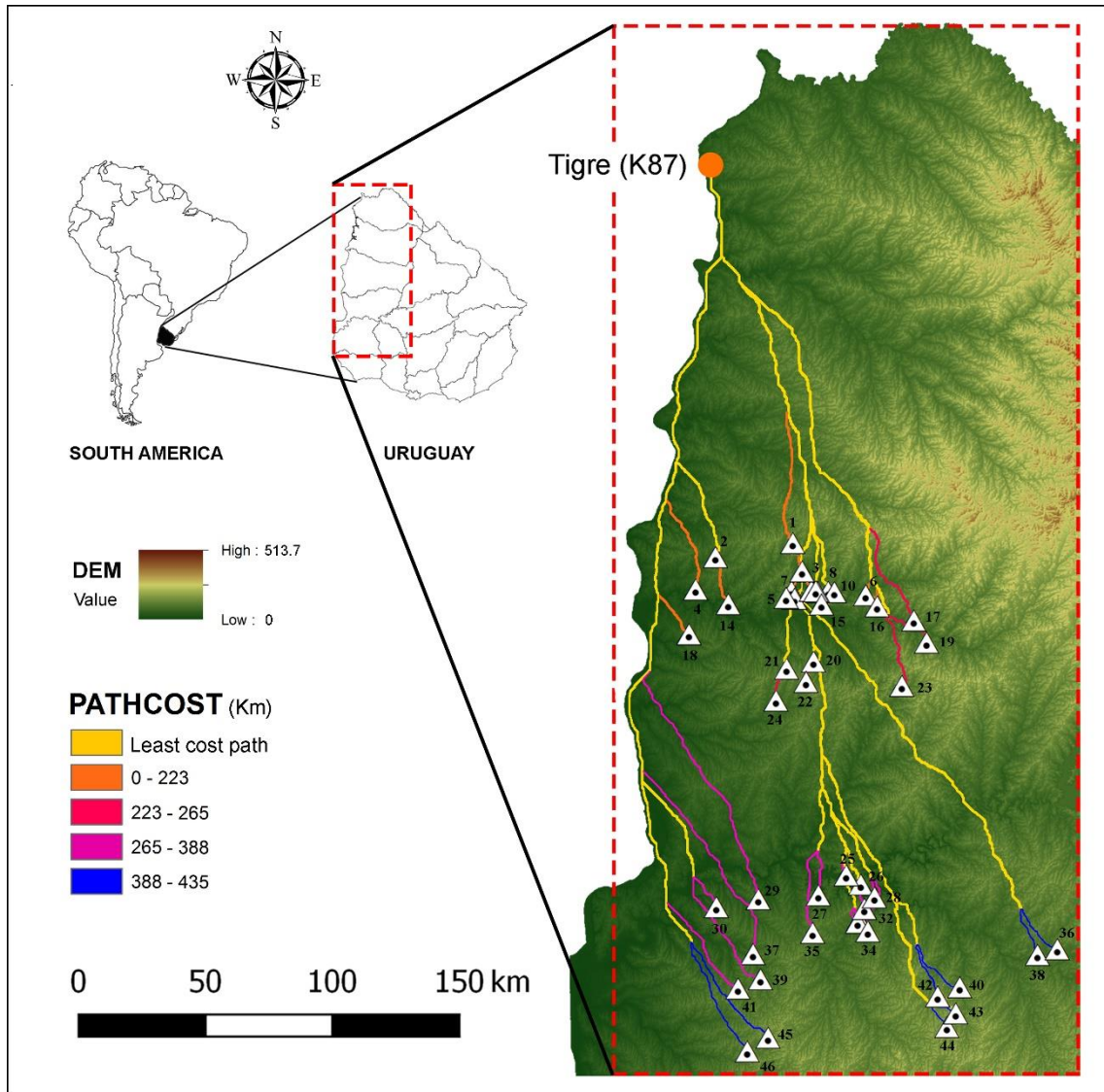
373

374 The heat map generated from the location of the pieces shows several
375 accumulations of values or "hot zones", which are divided into four ranges of values (Fig.
376 6). This distribution indicates the existence of multiple locations with a minimum density
377 of 1.75, while the highest concentrations (represented in shades of deep red) present
378 values between 5.26 and 7.02 Fishtail points within a radius of 20 km², corresponding to
379 the Río Negro basin and the southeast of the Río de la Plata basin.

380
381 *4.3. Analysis of terrain variables for the Tigre, Pay Paso, and Laguna Canosa / Los Pinos*
382 *sites.*

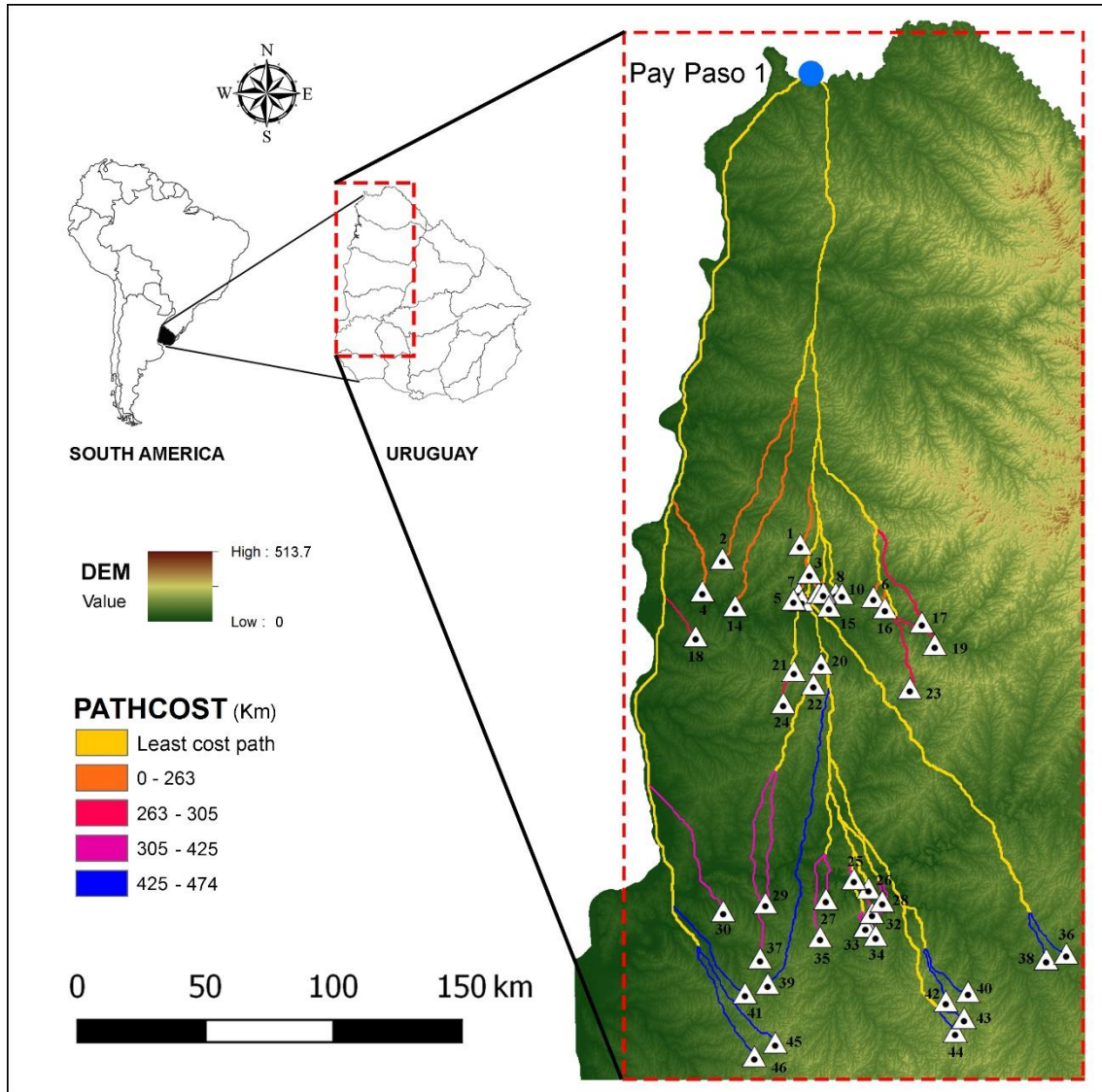
383
384 The following presents the results of the spatial analyses applied to four
385 representative sites of the early archaeological record (Tigre, Pay Paso 1, and Laguna
386 Canosa/Los Pinos) in order to investigate the mobility of Fishtail peoples that were
387 inhabiting and moving in search of lithic resources of silcrete in the period between
388 12,900-12,250 cal yr BP.

389



390
391 **Fig. 7.** Predictive Model of Transit Pathways between the Tigre site (northwestern) and silcrete
392 outcrops (triangles with number in the western and southwestern). The distance from the site to
393 the outcrops it is shown in supplementary Table S2.

394 Regarding the cumulative cost of movement required to make the Tigre site –
 395 silcrete connection, the distances obtained range between 160 and 480 km, while taking
 396 the Pay Paso archaeological locality as the point of origin of the movement, the analysis
 397 yields values between 166 and 499 km. For the Laguna Canosa / Los Pinos sites, however,
 398 the accumulated movement cost rises slightly; and ranges between 168 and 504 km (see
 399 supplementary Figs. S2, S3 and S4).
 400



401
 402 **Fig. 8.** Predictive Model of Transit Pathways between the Pay Paso 1 site (northwestern) and
 403 silcrete outcrops (triangles with number in the western and southwestern). The distance from the
 404 site to the outcrops it is shown in supplementary Table S2.

405
 406 As a complement to the calculation of the cost of distances expressed in km, we
 407 also decided to analyze the accessibility to the lithic resources by applying Tobler's
 408 trekking function (Tobler, 1993), thus estimating the time it would take to travel such
 409 distances. From the Tigre site, accessibility to the silcrete area concentration indicates a
 410 travel interval of 27 to 83 hours, while for the Pay Paso 1 site the interval is 24 to 86
 411 hours, and for the Laguna Canosa / Los Pinos sites it is in the range of 25 to 87 hours (see
 412 supplementary Figs. S2, 3S and S4; Table S2).

413 The Predictive Model of Transit Pathways created with the purpose of exploring
 414 the hypothetical connections, distances, and times existing between the Tigre site and the

415 silcrete outcrops, generated connection routes that present values that oscillate in the
416 range of 179 km for the closest outcrops and 435 km for those farther away from the
417 origin, presenting an average distance that is around 298 km and a standard deviation of
418 89.23 km. In turn, the time involved in accessing the resources presents a minimum of 30
419 hours, a maximum of 74 hours, and an average of around 50 hours (Fig. 7, supplementary
420 Table S2). On the other hand, when taking the Pay Paso 1 site as the origin, the connection
421 routes generated between it and the silcrete sources present distances between 220 and
422 475 km, with a mean distance of around 341 km and a standard deviation of 90.08 km,
423 implying a travel time interval of 34 hours for the closest resource and 78 hours for the
424 source farthest from the origin, with a mean of around 56 hours (Fig. 8, supplementary
425 Table S2). Finally, the routes generated taking the Laguna Canosa / Los Pinos sites as the
426 point of origin are the ones that present the highest values both in distance and
427 accessibility time; in this case the distance values are located in the range of 227 and 482
428 km, with a mean of 345 km and a standard deviation of 89.27 km (Fig. 9, supplementary
429 Table S2); while the times involved in the proposed routes show a minimum of 38 hours,
430 a maximum of 80 hours, and a calculated average of 58 hours.

431 When comparisons were made between the connection routes obtained for each
432 of the early sites, it was found that there were several shared stretches that connect them
433 with the areas in question, so it could be proposed that they were the main transit routes.

434

435 **5. Discussion**

436

437 *5.1 Raw materials used in the manufacture of Fishtail points*

438

439 The results show and confirm that the different varieties of silcrete were used as
440 the preferred raw material by Fishtail point knappers in Uruguay (Suárez 2015). The high
441 percentage of silcrete (53.7%) indicates its importance in the production of these points.
442 As shown in Table 2, the remaining 46.3% of the Fishtail points from Uruguay were
443 manufactured in 9 different rock varieties (chert, jasper, opal, quartzite, quartz, sandstone,
444 agate, rhyolite and chalcedony), none of which exceeds 10.3% of the sample.

445 The preference and choice to use silcrete varieties of excellent quality may be
446 related to the physical and chemical properties and knapping techniques. This suggests
447 the social, cultural, technological and symbolic value of silcrete for fishtail knappers.

448 The preference for the silcrete is very clear, because the Fishtail knappers passed
449 up excellent rock resources as the highly silicified sandstones of the *arroyos Catalanes*
450 region that are located closer to campsites, in order to move long distances to search their
451 preferred resource. The low percentage of Fishtail points from silicified sandstone (4%)
452 is another indicator that Fishtail knappers practically ignored this lithic resource to made
453 points despite its high availability in the environment and relatively close proximity to
454 their campsites.

455

456 *5.2 Density and spatial distribution*

457

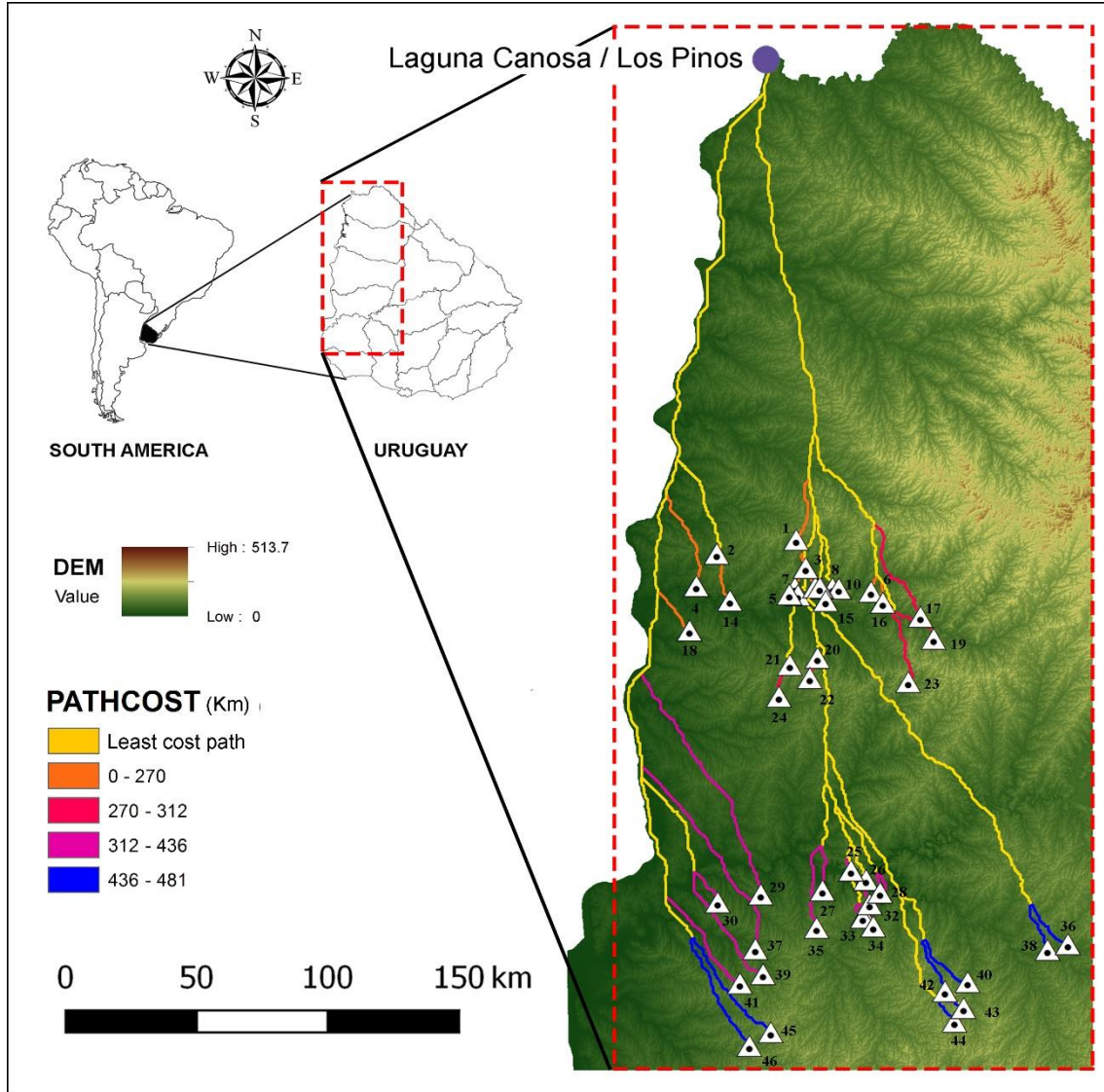
458 The results confirm that Fishtail points have a wide geographic distribution in
459 Uruguay (Suárez 2000, 2011a), with presence in the main river basins of Uruguay. The
460 Negro River basin stands out for having the largest number of specimens, followed by
461 the Río de la Plata Basin.

462 The heat map reveals the existence of areas with a higher concentration of Fishtail
463 points. The areas with the highest density are in the central and southern sectors of
464 Uruguay. These patterns may be associated with various factors, such as the mobility

465 routes of prehistoric groups, the proximity and availability of natural resources, the
466 human activities in each region and the exchange dynamics of the human groups in
467 question.

468 The analysis of the density and spatial distribution of Fishtail points provides
469 important information on past human occupation patterns and allows us to observe places
470 where these weapons can potentially be found in future investigations.

471



472
473 **Fig. 9.** Predictive Model of Transit Pathways between Laguna Canosa / Los Pinos sites
474 (northwestern) and silcrete outcrops (triangles with number in the southwestern). The distance
475 from the site to the outcrops it is shown in supplementary Table S2.

476

477

478 *5.3 Analysis of terrain variables for the Tigre, Pay Paso, and Laguna Canosa / Los Pinos* 479 *sites.*

480

481 The results obtained indicate that silcrete was a raw material that circulated over
482 long distances, it was transported from outcrops in western and southwestern Uruguay to
483 Fishtail campsites in northwestern Uruguay at distances of ~ 180 to 480 km. This
484 indicates high travel costs that could have been made in circuits that included
485 displacements through different regions of Uruguay during the end of the Pleistocene.

486 Accessibility to lithic resources, evaluated by estimated travel time, also reveals
487 the importance of silcrete as a lithic resource for Fishtail groups. The calculated travel
488 times suggest that many dozens of hours were required to reach the nearest outcrops, if
489 these were made to access the resource directly. In addition to the times proposed in the
490 results, it should also be taken into account that it would be necessary to add extra time
491 for sleeping, hunting, resting and other activities, which would result in a significant
492 increase in the total number of hours involved in these expeditions in search of resources.
493 On the other hand, if the access to the silcrete resource was carried out in circuits of
494 displacements that included visits to other regions and obtaining other resources, the
495 values obtained here should be reevaluated.

496 The presence of connection routes shared between the Tigre, Pay Paso 1 and
497 Laguna Canosa / Los Pinos sites could have facilitated the exchange of information,
498 goods and resources.

500 **6. Conclusions**

501
502 The data presented suggest and confirm that in Uruguay the Fishtail hunters
503 preferentially used silcrete to manufacture their points; 53.7% of the Fishtail points are
504 manufactured in this raw material. The remaining 46.3% of the Fishtail points from
505 Uruguay were made from 9 other rock variants including: chert (n=10, 10.3%), jasper
506 (n=9, 9.3%), quartzite (n=7, 7.2%), opal (n=7, 7.2%), quartz (n=5, 5.2%) silicified
507 sandstone (n=4, 4.1%), and agate, chalcedony, and rhyolite (1% each one).

508 Of the 9 rock types used less frequently, or 46.3 % of the sample, only the chert
509 exceeded 10%, which gives silcrete a greater importance and significance in terms of
510 preference for this rock to make the points. This preference is not due to the
511 overabundance of silcrettes over other rocks, since in Uruguay there are primary and
512 secondary lithic resources of silicified sandstone and agate that outcrop in large quantities
513 in the landscape (Suárez 2010, Suárez 2011a, 2011b). A clear example is the case of the
514 highly silicified sandstone resource where Fishtail knappers practically ignored this
515 resource despite being several hundred kilometers relatively closer to their campsites.

516 The density and distribution analysis also provided interesting data that allow us
517 to advance our knowledge about the mobility and circulation of Fishtail people. For the
518 period corresponding to ~12,900 - 12,250 years cal. BP the Fishtail people formed a social
519 landscape through which they circulated between northwestern, central, southern and
520 eastern Uruguay, these data correspond to the previously established mobility model
521 (Suárez 2011a, 2019).

522 As was established at the beginning of this work, the analyses carried out were
523 approached from a regional scale (the entire territory) to a local scale, so that once the
524 spatial variables were analyzed with respect to the densities of the Fishtail points and their
525 percentages according to the raw materials used for their manufacture, we proceeded to
526 the application of even more specific analyses.

527 We chose to work with four of the representative archaeological sites of early
528 settlement (Tigre, Pay Paso 1, Laguna Canosa and Los Pinos) some with very good
529 stratigraphic and chronological controls, where there are lithic artifacts manufactured in
530 silcrete (Fishtail points, unifacial artifacts and flakes). Seeking to establish mobility
531 circuits between early silcrete artifacts and its outcrops. The results obtained from the
532 applied spatial analyses have added new data on the distances between the campsites in
533 the northwestern zone and the outcrops existing in the western and southwestern zone. In
534 a previously published paper, it was proposed that the distances from the Tigre site to the
535 silcrete resources ranged between 190 and 350 km (Suárez 2019). Now new data confirm

536 this proposal and establish a better-defined range for the existing distances between the
537 early campsites and the outcrops of silcrete found further to the south. In turn, the time
538 values involved in the access to lithic resources and the distances to those outcrops located
539 in the southwestern limit of the silcrete outcrops are also added here, so that the maximum
540 values increased significantly, improving the previously suggested estimates. The results
541 obtained indicate that silcretes were transported over long distances in mobility networks
542 (Suárez 2017) by an extensive Paleoamerican social landscape from outcrops located in
543 the western and southwestern to campsites in northwestern Uruguay at distances ranging
544 between 179 and 482 km.

545 Once the accumulated movement costs were defined according to the slopes for
546 each of the locations involved, the calculation of possible transit or connection routes
547 between them was carried out. The result was a series of movement corridors or transit
548 routes that represent, according to the software, the optimal or ideal paths connecting two
549 points previously taken as origin and destination, showing the distances and times
550 involved. When the values obtained for each of the possible routes were examined, it was
551 observed that the distances presented notable changes for each of the study cases.
552 Regarding the Tigre site – silcrete outcrops connection, the minimum values increased to
553 179 km, while the maximum was 435 km and the average was 298 km. For the Pay Paso
554 1 site - silcrete outcrops connection, the minimum distance was 220 km, with an average
555 of 341 km and a maximum of 475 km. Finally, for the movement corridor connecting the
556 Laguna Canosa/Los Pinos Fishtail point sites and the silcrete outcrops, the distances
557 obtained had a minimum value of 227 km, a maximum of 482 km, and a mean of 345 km.

558 For the reasons mentioned above, we suggests the predilection for silcrete to made
559 Fishtail Points is due to cultural, social, and/or symbolic preferences (Suárez et al. 2018).

560 The access times calculated for the lithic resources indicate that accessibility to
561 them would be given in a time span ranging from ~ 25 to ~ 85 hours, taking the three
562 residential campsites as a starting point. It should also be taken into account that these
563 routes would not be continuous through space, but would be long logistical expeditions
564 or seasonal mobilizations that would involve several days of travel (Binford 1980, 1982;
565 Kelly 1983), so that the time ranges would actually be increased because the group would
566 also spend time on other activities such as reconnaissance of the terrain and possible
567 threats, maintenance of their weapons and tools, the search for food, and rest. Considering
568 this, access from the Tigre, Pay Paso 1 and Laguna Canosa/Los Pinos site to the silcrete
569 outcrops could take between a minimum of 1.5 days and 5-6 days.

570 It is important to note here that the predictive models proposed for the transit
571 routes will act as inputs for new surveys in the future, but may not be entirely realistic.
572 They involve hypothetical cases where the software itself looks for the ideal movements
573 that involve traveling the smallest slopes and crossing the places where the rivers have
574 the shortest distances, or simply skirting the courses. Likewise, these data can be used as
575 guides to locate possible new archaeological sites, especially those frequently used paths
576 that have been marked as main routes; and those places where they cross, because they
577 may have been used as meeting or exchange places.

578 From the analysis of the accumulated cost of movement according to the slopes
579 and the transit corridors created, one can conclude that the supply of formal artifacts
580 would be long distance. Expeditions to areas with large outcrops involve mobilizations
581 greater than 100 km, so these could also be considered as extra-regional.

582 Finally, the data presented here allow us to have an overall view of the human
583 occupation during the Pleistocene - Holocene transition. An attempt was made to show
584 the importance and potential of archaeological materials, both those found in stratigraphic

585 contexts and those on the surface, providing data on the mobility and circulation of
586 Fishtail people.

587

588 **CRedit authorship contribution statement**

589

590 **Rafael Suárez:** Conceptualization, Funding acquisition, Investigation, Resources, Data
591 curation; Supervision, Validation, Visualization, Writing – review & editing. **Flavia**
592 **Barceló:** Conceptualization, Methodology, Formal and GIS analysis, Investigation;
593 Software, Visualization, Writing – review & editing.

594

595 **Declaration of Competing Interest**

596 The authors declare that they have no known competing financial interests or personal
597 relationships that could have appeared to influence the work reported in this paper.

598

599 **Data availability**

600 Data will be made available on request.

601

602 **Acknowledgements**

603 This work was supported by Universidad de la República (CSIC I+D projects), FCE-
604 2021-1-166543 project ANII (Agencia Nacional de Investigación e Innovación), The
605 Wenner Gren Foundation for Anthropological Research (Post PhD grants #9978 and
606 #10581) and National Geographic Society, this agencies contributed with research
607 funding in different stages of the RS research. Geologist Dr. César Goso reviewed and
608 helped with section 2.2 regarding the geological context of the silcrete outcrops. Jenny
609 Volarich, Federico Rey, Julia Melián, Joaquín Astizarián and all the undergraduate and
610 post-graduate students who have been participating in the fieldwork. To all the private
611 collectors and public museums in Uruguay that have allowed to RS survey the Fishtail
612 points.

613

614 **References**

615

616 Amick, Daniel. S. 1996. Regional patterns of Folsom mobility and land use in the
617 American Southwest. *World Archaeology*, 27(3): 411-426.
618 <https://doi.org/10.1080/00438243.1996.9980317>.

619 Anderson, D. G., & Gillam, J. C. 2000. Paleoindian colonization of the Americas:
620 implications from an examination of physiography, demography, and artifact
621 distribution. *American Antiquity*, 65(1): 43-66. <https://doi.org/10.2307/2694807>.

622 Anderson, D. G., Miller, D. S., Yerka, S. J., Gillam, J. C., Johanson, E. N., Anderson, D.
623 T., ... & Smallwood, A. M. 2010. PIDBA (Paleoindian Database of the Americas)
624 2010: current status and findings. *Archaeology of Eastern North America*, 38: 63-
625 89.

626 Andrefsky Jr, W. 1994. Raw-material availability and the organization of
627 technology. *American antiquity*, 59(1): 21-34. <https://doi.org/10.2307/3085499>.

628 Bamforth Douglas B. 1986. Technological efficiency and tool curation. *American*
629 *Antiquity*, 51(1): 38-50. <https://doi.org/10.2307/280392>.

630 Bayón, C., & Flegenheimer, N. 2004, Cambio de planes a través del tiempo para el
631 traslado de roca en la pampa bonaerense. *Estudios Atacameños*, 28:59-70.
632 <http://dx.doi.org/10.4067/S0718-10432004002800006>.

633 Bayón, Cristina, Nora Flegenheimer, and Alejandra Pupio. 2006. Planes sociales en el
634 abastecimiento y traslado de roca en la pampa bonaerense en el Holoceno temprano

- 635 y tardío. *Relaciones de la Sociedad Argentina de Antropología* XXXI:19–45.
636 <http://sedici.unlp.edu.ar/handle/10915/21049>.
- 637 Baxter, M. J., Beardah, C. C., & Wright, R. V. 1997. Some archaeological applications
638 of kernel density estimates. *Journal of Archaeological Science*, 24(4), 347-354.
639 <https://doi.org/10.1006/jasc.1996.0119>.
- 640 Bell, T., & Lock, G. (2000). Topographic and cultural influences on walking the
641 Ridgeway in later prehistoric times. *Nato ASI Series A Life Sciences*, 321, 85-100.
- 642 Beovide, L., Martínez, S., & Norbis, W. 2017. Space Use Patterns and Resource
643 Exploitation of Shell Middens from the Río de La Plata Coast (ca. 6000–2000 Years
644 BP), Uruguay. In: Mondini, M., Muñoz, A., Fernández, P. (Eds.) *Zooarchaeology
645 in the Neotropics* (pp. 81-101). Springer, Cham. [https://doi.org/10.1007/978-3-319-
646 57328-1_6](https://doi.org/10.1007/978-3-319-57328-1_6).
- 647 Bird, J. 1938 Antiquity and Migrations of the Early Inhabitants of Patagonia. *Geographical
648 Review* 28 (2): 250-275.
- 649 Bird, J., Cooke, R., 1978 The Occurrence in Panama of Two Types of Paleoindian
650 Projectile Points. In *Early Man in the America from a Circum-Pacific Perspective*,
651 edited by A.L. Bryan, pp. 263-272. Occasional Papers N° 1. Department of
652 Anthropology, University of Alberta, Edmonton.
- 653 Binford, Lewis R. 1980. Willow smoke and dogs'tails: hunter-gatherer settlement
654 systems and archaeological site formation. *American Antiquity*, 45(1): 4-20.
655 <https://doi.org/10.2307/279653>.
- 656 Binford, L. R. 1982. The archaeology of place. *Journal of anthropological
657 archaeology*, 1(1), 5-31.
- 658 Binford, Lewis R. 1990 Mobility, housing, and environment: a comparative study.
659 *Journal of Anthropological Research*, 46(2): 119-152.
660 <https://doi.org/10.1086/jar.46.2.3630069>.
- 661 Bonnier, A., Finné, M., & Weiberg, E. 2019. Examining land-use through GIS-based
662 kernel density estimation: A re-evaluation of legacy data from the berbati-limnes
663 survey. *Journal of Field Archaeology*, 44(2), 70-83.
664 <https://doi.org/10.1080/00934690.2019.1570481>.
- 665 Bossi, J. 1966. *Geología del Uruguay*. Departamento de Publicaciones de la Universidad
666 de la República, Montevideo, 469 p.
- 667 Bossi, J., Ferrando, L., Fernández, A., Elizalde, G., Morales, H., Ledesma, J. J., ... &
668 Montaña, J. 1975. Carta Geológica del Uruguay (1: 1000.000). *Dirección de Suelos
669 y Fertilizantes, Ministerio de Agronomía y Piscadería*. Montevideo, Uruguay.
- 670 Conolly, J., & Lake, M. 2006. *Geographical Information Systems in Archaeology*.
671 (Cambridge Manuals in Archaeology). Cambridge: Cambridge University Press.
672 <https://doi.org/10.1017/CBO9780511807459>.
- 673 Dillehay, Tom. D. 2008. Profiles in Pleistocene History. In Silverman, H., Isbell, W.H.
674 (Eds.). *The handbook of South American archaeology*. Springer, New York, NY.
675 pp. 29-43. https://doi.org/10.1007/978-0-387-74907-5_2.
- 676 Erlandson, J.M. 2001. The archaeology of aquatic adaptations: paradigms for a New
677 Millennium. *Journal of Archaeological Research*, 9(4): 287-350.
678 <https://doi.org/10.1023/A:1013062712695>.
- 679 Fábrega-Álvarez, P., & Parcero-Oubiña, C. 2007. Proposals for an archaeological
680 analysis of pathways and movement. *Archeologia e calcolatori*, 18, 121-140.
681 <http://hdl.handle.net/10261/18229>.
- 682 Figuerero Torres, M. J., & Izeta, A. D. 2013. *El uso de Sistemas de Información
683 Geográfica (SIG) en arqueología sudamericana*. British Archaeological Reports

- 684 S2497 South American Archaeology Series 18, Oxford.
685 <http://sedici.unlp.edu.ar/handle/10915/27415>.
- 686 Flegenheimer, Nora. 2004. Las ocupaciones de la transición Pleistoceno-Holoceno: Una
687 visión sobre las investigaciones en los últimos 20 años en la región pampeana. *Actas*
688 *del X Congreso Nacional de Arqueología Uruguaya* (26-29).
- 689 Flegenheimer, Nora, Cristina Bayón, Miguel Valente, Jorge Baeza, and Jorge Femenías.
690 2003 Long distance tool stone transport in the Argentine Pampas. *Quaternary*
691 *International* 109–110:49–64. [https://doi.org/10.1016/S1040-6182\(02\)00202-1](https://doi.org/10.1016/S1040-6182(02)00202-1).
- 692 Flegenheimer, Nora, Laura L Miotti, and Natalia Mazzia. 2013. Rethinking early objects
693 and landscape in the Southern Cone: fishtail point concentrations in the Pampas and
694 Northern Patagonia. In K. E. Graf, C. V. Ketron, & M. R. Waters (Eds.),
695 *Paleoamerican Odyssey*, 359–376. College Station, TX: Center for the Study of the
696 First Americans.
- 697 Flegenheimer, N., Mazzia, N., & Weitzel, C. 2015. Landscape and rocks in the east-
698 central portion of the Tandilia range (Buenos Aires Province,
699 Argentina). *PaleoAmerica*, 1(2),163-180.
700 <https://doi.org/10.1179/2055556315Z.00000000017>.
- 701 Garrasino, C. F. 1989. La Cuenca Chaco-Paranense Argentina. Sus tendencias evolutivas
702 y algunas posibilidades exploratorias. *Boletín de Informaciones Petroleras*, 6(18),
703 2-17.
- 704 Gianotti, C. 2014. Procedimientos para el análisis de la movilidad prehistórica entre los
705 constructores de cerritos mediante el uso de tecnologías geoespaciales. *Revista del*
706 *Museo de Antropología* 7(2): 271–284.
707 <https://doi.org/10.31048/1852.4826.v7.n2.9177>.
- 708 Goso H. 1965. *El Cenozoico en el Uruguay*. Instituto Geológico del Uruguay. Informe
709 interno. 36pp.
- 710 Goso, C. 1999. *Análise estratigráfica do Grupo Paysandú (Cretáceo) na Bacia do Litoral*
711 *Uruguai*. Doctoral Thesis, IGCE-UNESP, Rio Claro, 184pp.
- 712 Goso Aguilar, C. A., & Perea Negreira, D. 2003. *El Cretácico post-basáltico de la*
713 *Cuenca Litoral del Río Uruguay: geología y paleontología* (No. 551.76 (899)
714 CUE).
- 715 Herrera, K., Pelegrin, J., Gayo, E., Santoro, C. 2019. Circulation of Objects and Raw
716 Material in the Atacama Desert, Northern Chile by the End of the Pleistocene.
717 *Paleoamerica* 5 (4):335-348. <https://doi.org/10.1080/20555563.2019.1697999>.
- 718 Hermo, D., Terranova, E. 2012. Formal Variability in Fishtail Projectile Points of Amigo
719 Oeste Archaeological Site, Somuncurá Plateau (Río Negro, Argentina). In
720 *Southbound: Late Pleistocene Peopling of Latin America*, edited by Laura Miotti,
721 Mónica Salemme, Nora Flegenheimer, and Ted Goebel, pp. 121-125. Center for the
722 Study of the First Americans, Texas A&M University, College Station.
- 723 Hermo, D., Miotti, L., Terranova, E. 2022. Exploring Technological Choices in Fishtail
724 Points from Southern Contexts: A Comparative Overview. *PaleoAmerica* 8 (1):79-
725 84. <https://doi.org/10.1080/20555563.2021.2000090>.
- 726 Hogg, A. G., Heaton, T. J., Hua, Q., Palmer, J. G., Turney, C. S., Southon, J., ... &
727 Wacker, L. 2020. SHCal20 Southern Hemisphere calibration, 0–55,000 years cal
728 BP. *Radiocarbon*, 62(4), 759-778. <https://doi.org/10.1017/RDC.2020.59>.
- 729 Inda, H., del Puerto, L., Bracco, R., Castiñeira, C., Capdepon, I., Gascue, A., & Baeza,
730 J. 2011. *Relación hombre-ambiente para la costa estuarina y oceánica de Uruguay*
731 *durante el Holoceno*. Ediciones Universitarias.
- 732 Kelly, Robert L. 1983. Hunter-Gatherer Mobility Strategies. *Journal of anthropological*
733 *research*, 39(3): 277-306. <https://doi.org/10.1086/jar.39.3.3629672>.

- 734 Kelly, Robert L. 1988. The Tree Sides of a Biface. *American Antiquity*, 53(4): 717-734.
735 <https://doi.org/10.2307/281115>.
- 736 Lambert, R. 1939. Memoria explicativa del mapa geológico de los terrenos sedimentarios
737 y de las rocas efusivas del Departamento de Durazno. Boletín del Instituto
738 Geológico del Uruguay 25b: 1-37.
- 739 Lambert, R. 1940. Memoria explicativa de un mapa geológico de reconocimiento del
740 Departamento de Paysandú y los alrededores de Salto. Boletín del Instituto
741 Geológico del Uruguay 27: 1-41.
- 742 Lohse, Jon C. 2021 When Is a Mesoamerican? Pleistocene Origins of the Mesoamerican
743 Tradition. In *Preceramic Mesoamerica*, edited by Lohse, Jon
744 C., Borejsza, Aleksander, and Joyce, Arthur A., pp. 1–36. Routledge, London.
- 745 López Mazz, J.M. 2017. Silcrete procurement system in Uruguayan prehistory. *Journal*
746 *of Archaeological Science: Reports*, 15: 561-569.
747 <https://doi.org/10.1016/j.jasrep.2017.08.009>.
- 748 Loponte, D., Tchilinguirian, P., & Silvestre, R. S. 2011. Caracterización de afloramientos
749 de calizas silicificadas de la provincia de Entre Ríos (Argentina) y su vinculación
750 con los circuitos de abastecimiento prehispánico. *Avances y perspectivas en la*
751 *arqueología del Nordeste*, 145-156.
- 752 Loyola, R., Cartagena, I., Núñez, L., López, P. 2018. Moving into an arid landscape: Lithic
753 technologies of the Pleistocene-Holocene transition in the high-altitude basins of
754 Imilac and Punta Negra, Atacama Desert. *Quaternary International* 473: 203-224.
- 755 Magnín, Lucía A. 2012. *Distribuciones arqueológicas en la Meseta Central de Santa*
756 *Cruz* (Doctoral dissertation, Facultad de Ciencias Naturales y Museo).
- 757 Martín, F.M., Todisco, D., Rodel, J., Prevosti, F.J., San Roman, M., Morello, F., Stern,
758 C., Borrero, L.A., 2019. The cave at the end of the world. Cueva del medio and the
759 early colonization of southern South America. In *People and Culture in Ice Age*
760 *Americas: New Dimensions in Paleoamerican Archaeology*, edited by Suárez, R.,
761 Ardelan, C. pp. 1–12. University of Utah Press,
- 762 Martínez, S., Veroslavsky, G., & Veroslavsky, G. 2004. Registros continentales no
763 depositacionales del Terciario Temprano. *Cuencas Sedimentarias del Uruguay:*
764 *Montevideo, Uruguay, DIRAC*, 63-82.
- 765 Martínez, S., Veroslavsky, G., & Cabrera, F. 2015. Calizas del Queguay: Un enfoque
766 hacia la arqueología. *Revista de Antropología del Museo de Entre Ríos*, 1(2):01-10.
767 <https://ramer.ar/revista/index.php/ramer/article/view/96>.
- 768 Massone, M. 2004. *Los Cazadores Después del Hielo*. Dirección de Bibliotecas, Archivos
769 y Museos. Santiago.
- 770 Méndez, C., Nuevo Delaunay, A., Seguel, R., Maldonado, A., Murillo, I., Jackson, D.,
771 Fernández, M. 2018. Late Pleistocene to early Holocene high-quality quartz crystal
772 procurement from the Valiente quarry workshop site (32° S, Chile, South America).
773 *PLoS ONE*, 13(11). <https://doi.org/10.1371/journal.pone.0208062>.
- 774 Miotti, Laura L. 2010. Cuevas y abrigos rocosos: nudos de las redes sociales entre
775 cazadores recolectores del macizo del deseado, patagonia extra-andina. In J. C.
776 Giménez López, C. Serrano Sánchez, A. González González, & F. J. Aguilar
777 Arellano (Eds.), *III simposio internacional El Hombre temprano en América* (pp.
778 146-174). México D.F.: Instituto Nacional de Antropología e Historia, Instituto de
779 Investigaciones Antropológicas, UNAM.
- 780 Miotti, Laura L, and Mónica C Salemme. 2004. Poblamiento, movilidad y territorios entre
781 las sociedades cazadoras-recolectoras de Patagonia. *Complutum* 15:177–206.

- 782 Miotti, L., Terranova, E. 2015. A Hill Full of Points in Terra Incognita from Patagonia:
783 Notes and Reflections for Discussing the Way and Tempo of Initial Peopling.
784 *PaleoAmerica* 1(2): [doi: 10.1179/1055556315Z](https://doi.org/10.1179/1055556315Z).
- 785 Nami, H.G. 2007. Research in the middle Negro river basin (Uruguay) and the
786 paleoindian occupation of the southern cone. *Current Anthropology*, 48(1), 164-
787 176. <https://doi.org/10.1086/510465>.
- 788 Nami, H. G. 2017. Silcrete as a valuable resource for stone tool manufacture and its use
789 by Paleo-American hunter–gatherers in southeastern South America. *Journal of*
790 *Archaeological Science: Reports*, 15: 539-560.
791 <https://doi.org/10.1016/j.jasrep.2016.05.003>.
- 792 Núñez, L.; Varela, J.; Casamiquela, R.; Schippacasse, V.; Niemeyer, H.; Villagran, C.
793 1994 Cuenca de Taguatagua en Chile: el ambiente del Pleistoceno superior y
794 ocupaciones humanas. *Revista Chilena de Historia Natural* 64 (4):503-519.
- 795 Politis, G. 1991 Fishtail Projectile Points in the Southern Cone of South America: An
796 Overview. In *Clovis: Origins and Adaptations*, edited by R. Bonnicksen y K.
797 Turnmire, pp. 287-301. Center for the Study of the First Americans. Oregon
798 University Press. Corvallis.
- 799 Politis, Gustavo, P Messineo, and C Kaufmann. 2004. El poblamiento temprano de las
800 llanuras pampeanas de Argentina y Uruguay. *Complutum* 15:207–224.
- 801 Prates, L., Rivero, D., Perez, I., 2022. Changes in Projectile Design and Size of Prey
802 Reveal the Central Role of Fishtail Points in Megafauna Hunting in South America.
803 *Nature Scientific Reports* 12(1): 1-13. [https://doi.org/10.1038/s41598-022-21287-](https://doi.org/10.1038/s41598-022-21287-0)
804 [0](https://doi.org/10.1038/s41598-022-21287-0).
- 805 Preciozzi, F.; Spoturno, J.; Heinzen, W. y R. Rossi. 1985. *Carta Geológica del Uruguay*
806 *a escala 1:500.000 y Memoria explicativa*. Editado por Dirección General de
807 Minería y Geología. Montevideo.
- 808 Rademaker, Kurt, Gregory Hodgins, Katherine Moore, Sonia Zarrillo, Christopher
809 Miller, Gordon R. M. Bromley, Peter Leach, David A. Reid, Willy Yépez Álvarez,
810 and Daniel H. Sandweiss. 2014. Paleoindian settlement of the high-altitude
811 Peruvian Andes. *Science* 346 (6208):466–469.
- 812 Skarbun, F., Frank, A. D. 2011. Organización espacial intrasitio durante el pleistoceno
813 final en la meseta central de Santa Cruz. *Relaciones de la Sociedad Argentina de*
814 *Antropología*, 36. <http://suquia.ffyh.unc.edu.ar/handle/suquia/7802>.
- 815 Skarbun, F., Cueto, M. E., Frank, A. D., & Paunero, R. S. 2021. Tecnología lítica de las
816 primeras sociedades del extremo sur de Sudamérica. *Latin American Antiquity*,
817 33(3): 1-21. <https://doi.org/10.1017/laq.2021.50>.
- 818 Suárez, R. 2000. Paleoindian Occupations in Uruguay. *Current Research in the*
819 *Pleistocene*: 78-80.
- 820 Suárez, R. 2010. *Arqueología prehistórica en la localidad arroyo Catalán Chico:*
821 *investigaciones pasadas, replanteo y avances recientes*. Ediciones Universitarias.
- 822 Suárez, R. 2011a. *Arqueología durante la Transición Pleistoceno Holoceno:*
823 *componentes paleoindios, organización de la tecnología y movilidad de los*
824 *primeros americanos en Uruguay*. BAR International Series 2220. Oxford.
825 England.
- 826 Suárez, R. 2011b. Movilidad, acceso y uso de ágata traslúcida por los cazadores-
827 recolectores tempranos durante la transición Pleistoceno-Holoceno en el Norte de
828 Uruguay (ca. 11,000-8500 AP). *Latin American Antiquity* 22(3): 359-384.
829 <https://doi.org/10.7183/1045-6635.22.3.359>.

- 830 Suárez, R. 2015. The Paleoamerican occupation of the plains of Uruguay: Technology,
831 adaptations, and mobility. *PaleoAmerica*, 1(1): 88–104.
832 <https://doi.org/10.1179/2055556314Z.00000000010>.
- 833 Suárez, R. 2017. The human colonization of the southeast plains of South America;
834 climatic conditions, technological innovations and the peopling of Uruguay and
835 south of Brazil. *Quaternary International* 431, 181-193.
836 <https://doi.org/10.1016/j.quaint.2016.02.018>.
- 837 Suárez, R. 2018. The Peopling of Southeastern South America: Cultural Diversity,
838 Paleoenvironmental Conditions, and Lithic Technological Organization During the
839 Late Pleistocene and Early Holocene. *Lithic Technological Organization and
840 Paleoenvironmental Change* (pp. 281-300). Springer, Cham.
841 https://doi.org/10.1007/978-3-319-64407-3_13.
- 842 Suárez, R. 2019. High resolution AMS 14C dates for late Pleistocene Fishtail technology
843 from the Tigre site, Uruguay river basin, South America. *Quaternary Science
844 Reviews*, 213, 155-161. <https://doi.org/10.1016/j.quascirev.2019.04.009>.
- 845 Suárez, R., & Piñeiro, G. 2002. La cantera taller del Arroyo Catalán Chico: Nuevos
846 aportes a un viejo problema de la Arqueología uruguaya. *Del Mar a los Salitrales.
847 Diez mil años de Historia Pampeana en el Umbral del Tercer Milenio*, D.
848 MAZZANTI, M. BERÓN Y F. OLIVA (Org.), Mar del Plata, 263-279.
- 849 Suárez, R., & López, J.M. 2003. Archaeology of the Pleistocene/Holocene transition in
850 Uruguay: An overview. *Quaternary International* 109-110. Pág. 65-76
851 [https://doi.org/10.1016/S1040-6182\(02\)00203-3](https://doi.org/10.1016/S1040-6182(02)00203-3)
- 852 Suárez, R., G. Piñeiro, and F. Barceló. 2018. Living on the river edge: The Tigre site
853 (K87) new data and implications for the initial colonization of the Uruguay River
854 basin. *Quaternary International*, 473: 242-260.
855 <https://doi.org/10.1016/j.quaint.2017.08.024>.
- 856 Suárez, R., & Cardillo, M. 2019. Life history or stylistic variation? A geometric
857 morphometric method for evaluation of Fishtail point variability. *Journal of
858 Archaeological Science: Reports*, 27, 101997.
859 <https://doi.org/10.1016/j.jasrep.2019.101997>.
- 860 Suárez, R., Volarich, J., & Melián, J. 2023. The initial peopling of South American Plains:
861 An overview on Late Pleistocene and Early Holocene settlers in
862 Uruguay. *L'Anthropologie*, 103-120.
- 863 Tobler, W. 1993. Three presentations on geographical analysis and modeling. Non-
864 Isotropic Modeling Speculations on the Geometry of Geography Global Spatial
865 Analysis. *National Center for Geographic Information and Analysis (NCGIA)
866 technical report*, 93(1).
- 867 Tófaló, O. 1986. Depósitos clásticos y carbonáticos del Cretácico Superior, Formación
868 Puerto Yerúa, Entre Ríos. In *Reunión Argentina de Sedimentología. 1* (pp. 201-
869 204).
- 870 Tófaló, O.R., P. J. Pazos., L. Sánchez, H. de Santa Ana y S. Alonso. 2001. Caracterización
871 micromorfológica de calcretes, Calizas del Queguay, departamento Paysandú,
872 Uruguay. *11º Congreso Latinoamericano y 3er Uruguayo de Geología, Actas CD-
873 Rom*. Montevideo.
- 874 Tófaló, O. & Pazos, P., 2002. Caracterización de calcretes de la Formación Puerto Yerúa
875 (Cretácico), en base a su micromorfología (Entre Ríos, Argentina). *Revista de la
876 Asociación Argentina de Sedimentología*, 9 (2), 127–134.
- 877 Tófaló, O., & Morrás, H. J. 2009. Evidencias paleoclimáticas en duricostras, paleosuelos
878 y sedimentitas silicoclásticas del Cenozoico de Uruguay. *Revista de la Asociación
879 Geológica Argentina*, 65(4), 674-686.

- 880 Tófalo, O, & Pazos, P. J. 2010. Paleoclimatic implications (Late Cretaceous–Paleogene)
881 from micromorphology of calcretes, palustrine limestones and silcretes, southern
882 Paraná Basin, Uruguay. *Journal of South American Earth Sciences*, 29(3), 665-675.
- 883 Veroslavsky, G., & Martínez, S. A. 1996. Registros no depositacionales del paleoceno-
884 eoceno del Uruguay: Nuevo enfoque para viejos problemas. *Revista Universidade*
885 *Guarulhos. Geociências*, 1(3), 32-41.
- 886 Veroslavsky, G., Martinez, S., & De Santa Ana, H. 1997. Calcretas de aguas subterráneas
887 y pedogénicas: génesis de los depósitos carbonáticos de la Cuenca de Santa Lucía,
888 sur del Uruguay (Cretácico Superior?-Paleógeno). *Revista de la Asociación*
889 *Argentina de Sedimentología*, 4(1), 25-35.
- 890 Veroslavsky, G. y H. de Santa Ana. 2009. Calizas del Queguay: génesis y potencial
891 económico. In *Cuencas sedimentarias de Uruguay: geología, paleontología y*
892 *recursos naturales - Cenozoico (2a. Ed.)*, edited by G. Veroslavsky, M. Ubilla y S.
893 Martínez S., pp 269-296. DIRAC, Facultad de Ciencias, Montevideo, Uruguay.
- 894 Waters, M. R., Amorosi, T., & Stafford, T. W. 2015. Redating Fell's cave, Chile and the
895 chronological placement of the Fishtail projectile point. *American Antiquity*, 80(2):
896 376-386. <https://doi.org/10.7183/0002-7316.80.2.376>.
- 897 Weitzel, C., Mazzia, N., & Flegenheimer, N. 2018. Assessing Fishtail points distribution
898 in the southern Cone. *Quaternary International*, 473, 161-172.
- 899 Wheatley, D., & Gillings, M. 2000. Vision, perception and GIS: developing enriched
900 approaches to the study of archaeological visibility. *Nato Asi Series a Life*
901 *Sciences*, 321: 1-27.

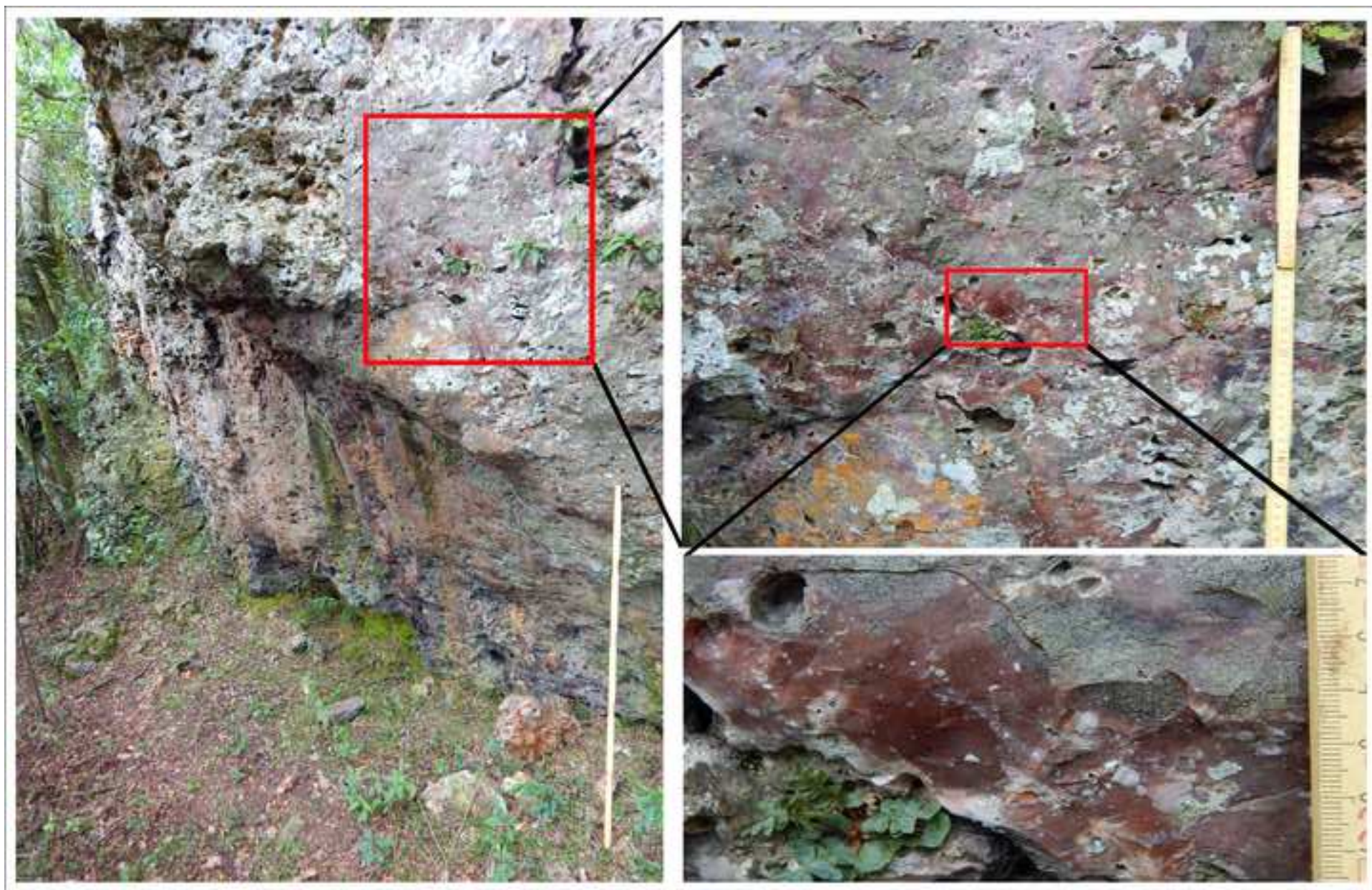




Figure 7

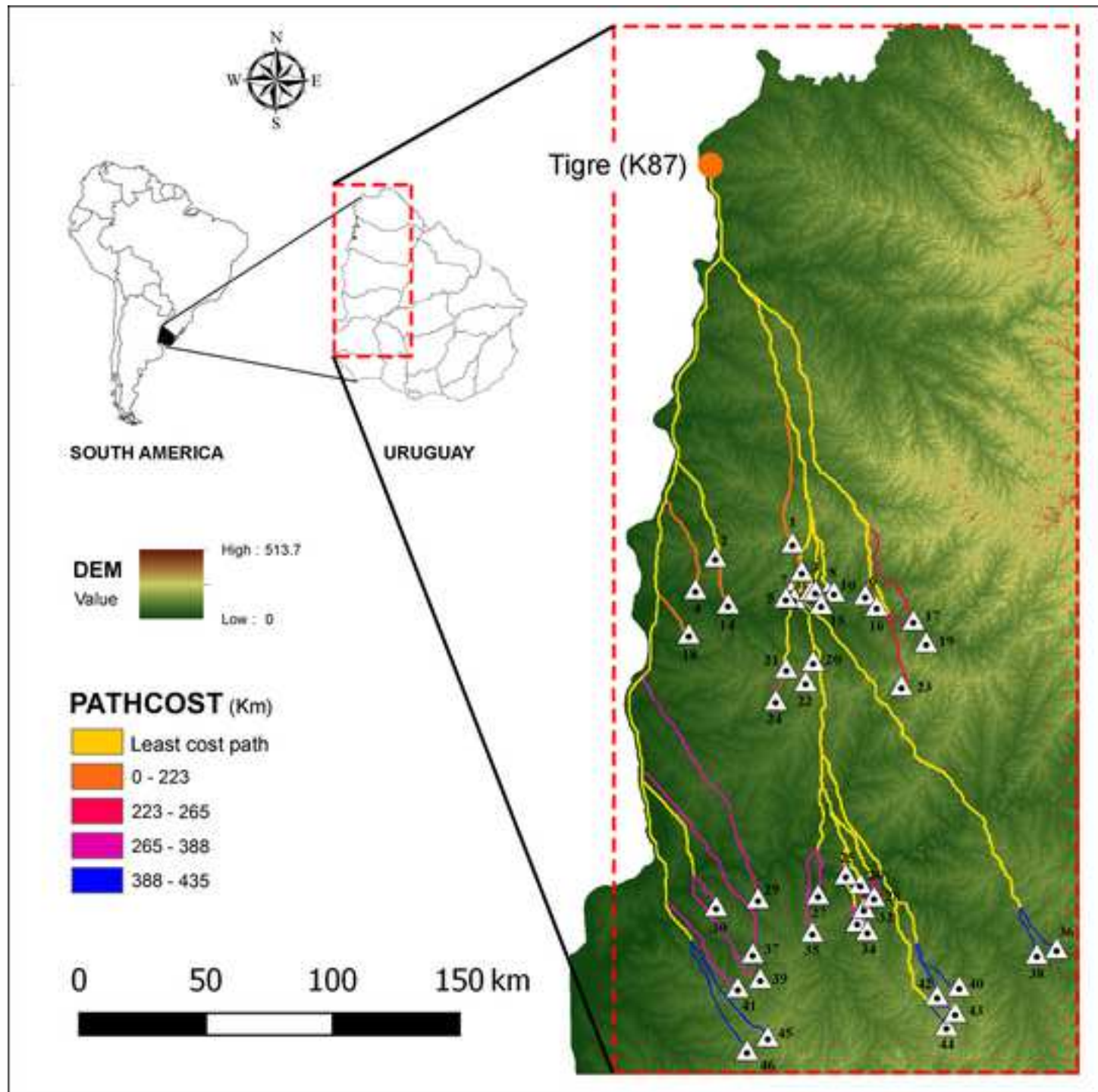


Figure 8

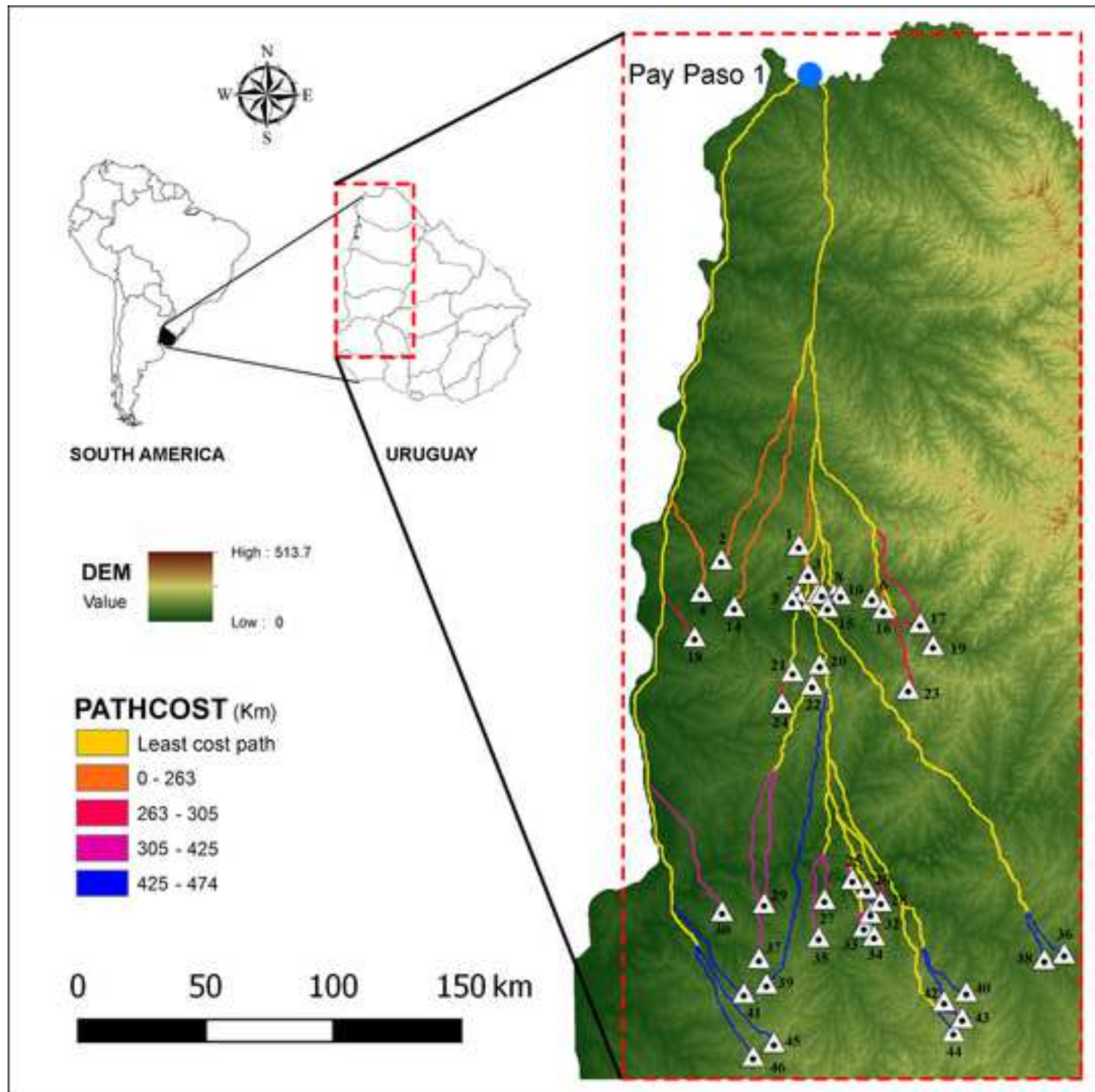


Figure 9

