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Holocene peopling and sea-level changes along the northern coast of the Arabian Sea (Pakistan)

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Abstract
Surveys carried out in the provinces of Las Bela and Lower Sindh (Pakistan) have led to the discovery of many concentrations of knapped stone artefacts associated with mangrove and sea shells. The most important group of sites has been discovered along the shores of Lake Siranda (Balochistan) and on the limestone terraces that rise from the Indus Plain in Lower Sindh. The radiocarbon dates obtained from the Lake Siranda sites have shown that the ancient lagoon was seasonally settled between the last two centuries of the 8th and the end of the 5th millennium uncal BP that is from the beginning of the Neolithic to the Bronze Age. Although more research is needed, we now know the important role played by the coastal zones of Las Bela and Lower Sindh in the Holocene archaeology of the Arabian Sea, the only region of the northern coastline that has provided evidence of Neolithic and Chalcolithic settlement. The Neolithic knapped stones discovered during the surveys consist of bladelet artefacts and geometric microliths made from local cherts, while the Chalcolithic Amri Culture implements are obtained from exotic flint. Since the beginning of the Holocene the coastal zone has been affected by dramatic events among which are sea-level rise, tectonic activity, subsidence, and the advance of the Indus Delta. The present landscape shaped around the end of the Bronze Age, when arid conditions established and the Indus Civilisation declined. Unfortunately many of the coastal sites are in danger or have been destroyed by industrial development.

Keywords Arabian Sea · Balochistan · Lower Sindh · Shell middens · Radiocarbon chronology · Sea-level rise

1 Introduction

For almost two centuries shell middens have played a very important role in the study of prehistory [1–3] and Holocene coastal peopling [4–7]. During the last fifty years, shell midden studies have dramatically increased in some Arab countries, Oman and the United Arab Emirates in particular [8–16] where "*mangroves constitute a specialized and major component of a coastal ecosystem*" [17] (p. 418) the dynamic environment of which is due to several concurrent factors [18]. However, the northern coast of the Arabian Sea lacked information concerning the presence of shell middens until the 2000s when concentrations of marine shells were known only along the coast of the Makran, in Pakistani Balochistan [19], and Gujarat, in north-western India [20].

During the last twenty-five years, the present author has carried out surveys along the coasts of Las Bela and Lower Sindh [21]. The scope was to discover new archaeological sites, radiocarbon date them [22, 23], frame them into the wider picture of the prehistoric peopling of the Arab coastal zone [24], study them in relation to the Holocene sea-level rise,

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and compare the results with those already available from neighbouring countries, Oman in particular. It is well known that the northern coast of the Arabian Sea has been subject to many changes since the end of the Pleistocene. This is due to different causes [25] (p. 366), among which are marine transgression, tectonic movements, subsidence, summer monsoon winds and the advance of the Indus Delta [24, 26–30].

According to classical authors [31, 32], this coastal region of the Arabian Sea was settled by communities of fish eaters or *Ichthyophagoi*. They were described for the first time in 325 BC by the geographers of Alexander the Great [33–35]. Apart from their aspect, way of life, habitation structures, and the mangal environment they exploited [36–38], we knew nothing of the ancestors of these communities until the 1970s: where, why, when and how did they begin to settle along the coasts of Makran, Las Bela and Lower Sindh where fishing is still nowadays the most important activity [39]?

2 Methods

Apart from the research carried out by AR Khan around Karachi in the 1970s [40–42], our knowledge of the archaeology of the territory was poorly known until the beginning of the 2000s [43–46], when new surveys still in progress were initiated (Fig. 1). Their scope was to investigate the coastal zone between the Sonmiāni Lagoon and the Siranda Lake, in the west [23], and the Thatta district in Lower Sindh, in the east.

The Las Bela surveys were carried out by 2–5 persons, walking ca 6 h per day, 2 weeks each season, recording and mapping all the surface finds with a Garmin-GPS device, photographing all sites among which are shell middens, Chalcolithic and Bronze Age stone-walled villages, concentrations of knapped and ground stones, and potsherds within mangrove and marine shells concentrations. Wherever available, one fragment of *T. palustris* mangrove gastropod has systematically been sampled for radiocarbon dating. Other mangrove (*T. telescopium*) and marine species (*Anadara rhombea*) have been taken in case of a lack of *T. palustris* specimens. The typological characteristics of the knapped stone artefacts, the raw material employed for their manufacture and the radiocarbon results, have helped us to define the chrono-cultural characteristics of the sites and attribute them to the Neolithic, Chalcolithic or Bronze Age periods (Table 1). All samples were processed at the Radiocarbon Laboratory of Groningen University (CIO) in the last 25 years.

The scope of the 2011–2014 surveys carried out along the ancient shores of Lake Siranda was to check the presence of mangrove shells which had been reported by RE Snead in the 1960s along the eastern side of the *Sabkha* Depression [40] (Fig. 15) (Fig. 1, no. 1). The research led to the discovery of 76 sites among which are shell middens and concentrations of knapped stone artefacts found in association with fragments of mangrove and marine shells [47]. Lake Siranda is located in the southernmost part of the Las Bela Valley (Fig. 2).

The so-called lake is oriented north–south. Its western and southern sides are delimited by mobile dunes [39] (p. 48). Dunes separate it from the Sonmiāni (Miāni Hōr) mangrove swamp and the Arabian Sea a few kilometres farther south [49].

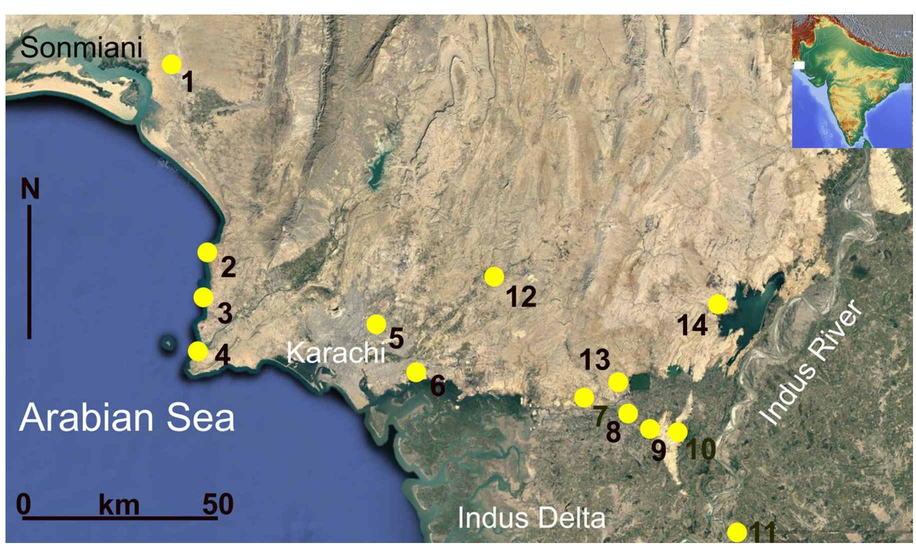

Fig. 1 Distribution map of the sites mentioned in the text: Lake Siranda (no. 1), Ras Gadani and Ras Phuari (no. 2), Bay of Daun (no. 3), Sonari (no. 4), Mulri Hills (no. 5), Rehri (no. 6), Gharo (no. 7), Tharro Hill (no. 8), Shah Hussain (no. 9), Makli Hills (no. 10), Aban Shah (no. 11), Mol and Khadeji (no. 12), Haleji (no. 13), Jhimpir (no. 14) (drawing by P. Biagi)

Table 1 List of the radiocarbon dates obtained from shell from the Las Bela and Lower Sindh coastal sites

Site name	Coordinates	m a.s.l	Material	Lab. Numb	$\delta^{13}C$	Uncal BP	Cal BC/AD 2σ
Lake Siranda series (SRN—Las Bela, Balochistan)							
SRN-56oto	25°29′56.3"N-66°38′56.9"E	10	*Protonibea diacanthus* fish otolith	GrM-15343	− 3.39	8260 ± 30	6816–6465
SRN-43	25°30′25.3"N-66°38′31.7"E	8	*T. palustris*	GrA-54290	− 3.55	7200 ± 35	5683–5408
SRN-27	25°30′39.9"N-66°37′39.0"E	12	*T. palustris*	GrM-24855	− 4.80	7175 ± 35	5656–5383
SRN-29Sud	25°30′24.7"N-66°37′34.8"E	8	*T. palustris*	GrM-18731	− 7.74	7130 ± 35	5622–5351
SRN-38	25°30′07.0"N-66°38′44.7"E	9	*T. palustris*	GrA-54303	− 6.58	7095 ± 35	5599–5320
SRN-56	25°29′56.3"N-66°38′56.9"E	10	*T. palustris*	GrA-57702	− 6.17	6980 ± 35	5482–5205
SRN-33	25°29′58.4"N-66°39′16.0"E	12	*T. palustris*	GrA-54291	− 6.16	6770 ± 35	5301–4971
SRN-32	25°29′59.5"N-66°39′17.1"E	12	*T. palustris*	GrA-57528	− 6.66	6630 ± 35	5177–4808
SRN-37	25°29′59.3"N-66°38′57.3"E	7	*T. palustris*	GrA-55821	− 5.87	6595 ± 45	5140–4746
SRN-29	25°30′26.8"N-66°37′35.1"E	10	*T. palustris*	GrA-54299	− 5.57	6595 ± 35	5127–4760
SRN-66	25°30′51.8"N-66°36′52.9"E	8	*T. palustris*	GrA-57703	− 5.27	6575 ± 35	5091–4730
SRN-64	25°31′18.0"N-66°36′43.2"E	13	*T. palustris*	GrA-57535	− 5.19	6515 ± 35	5020–4678
SRN-28.10	25°30′30.6"N-66°37′35.4"E	16	*T. palustris*	GrA-62260	− 4.78	6500 ± 40	5009–4654
SRN-19	25°30′53.4"N-66°37′47.2"E	4	*T. palustris*	GrM-24854	− 4.37	6465 ± 35	4964–4613
SRN-67	25°30′43.8"N-66°36′52.8"E	11	*T. palustris*	GrA-59841	− 4.75	6370 ± 60	4886–4472
SRN-39bis	25°30′08.5"N-66°38′41.2"E	9	*T. telescopium*	GrA-54298	− 4.53	6335 ± 35	4801–4461
SRN-63.2	25°32′31.1"N-66°37′09.5"E	7	*T. palustris*	GrA-57534	− 4.1	6325 ± 35	4789–4453
SRN-1	25°31′19.3"N-66°36′39.6"E	5	*T. palustris*	GrA-50325	− 6.213	6305 ± 40	4782–4437
SRN-62	25°31′28.8"N-66°36′44.4"E	5	*T. palustris*	GrA-59842	− 4.73	6230 ± 60	4712–4336
SRN-75	25°32′29"N-66°37′15"E	5	*T. palustris*	GrA-63864	− 6.8	6220 ± 40	4682–4348
SRN-40	25°30′09.9"N-66°38′40.4"E	4	*T. palustris*	GrA-55823	− 3.86	6145 ± 45	4606–4265
SRN-39	25°30′08.2"N-66°38′41.4"E	9	*T. telescopium*	GrA-55822	− 4.33	6145 ± 45	4606–4266
SRN-76	25°32′20"N-66°37′07"E	5	*T. palustris*	GrA-59840	− 3.64	6100 ± 60	4588–4211
SRN-63	25°31′19.3"N-66°36′39.4"E	6	*T. palustris*	GrA-63868	− 4.01	6055 ± 40	4500–4176
SRN-2	25°31′31.0"N-66°36′48.9"E	0	*T. palustris*	GrA-50323	− 4.638	5950 ± 40	4378–4045
SRN-1bis	25°31′19.3"N-66°36′39.6"E	5	*Anadara rhombea*	GrM-18723	− 1.54	5935 ± 30	4348–4042
SRN-22	25°30′49.5"N-66°37′43.1"E	10	*T. telescopium*	GrM-23236	− 5.07	5913 ± 26	4334–4034
SRN-21	25°30′51.2"N-66°37′44.7"E	6	*T. telescopium*	GrM-24813	− 4.09	5900 ± 26	4327–4022
SRN-31	25°30′01.1"N-66°39′19.0"E	4	*T. palustris*	GrA-55820	− 5.03	5875 ± 45	4316–3981
SRN-20	25°30′51.5"N-66°37′47.4"E	4	*T. palustris*	GrM-21242	− 4.96	5851 ± 26	4279–3966
SRN-47	25°30′39.9"N-66°38′06.3"E	10	*T. palustris*	GrA-54296	− 3.46	5800 ± 35	4241–3920
SRN-23	25°30′47.7"N-66°37′39.2"E	7	*T. palustris*	GrA-54294	− 4.67	5780 ± 30	4226–3906
SRN-42	25°30′25.1"N-66°38′32.2"E	11	*T. palustris*	GrA-54292	− 5.79	5755 ± 35	4216–3860
SRN-4	25°32′21.6"N-66°36′59.3"E	3	*T. telescopium*	GrM-24858	− 4.70	5745 ± 26	4198–3846
SRN-73	25°30′26.8"N-66°37′31.7"E	9	*T. palustris*	GrA-57707	− 3.9	5695 ± 35	4139–3779
SRN-44	25°30′21.9″N-66°38′56.9″E	2	*T. palustris*	GrA-54301	− 7.2	5690 ± 35	4138–3777

Table 1 (continued)

Site name	Coordinates	m a.s.l	Material	Lab. Numb	$\delta^{13}C$	Uncal BP	Cal BC/AD 2σ
SRN-24	25°30′48.0"N-66°37′37.4"E	5	*T. telescopium*	GrA-55818	− 6.12	5665 ± 45	4108–3727
SRN-72	25°29′31.9"N-66°36′54.7"E	7	*T. palustris*	GrA-57704	− 4.67	5665 ± 35	4086–3735
SRN-25	25°30′47.1"N-66°37′35.5"E	8	*T. palustris*	GrM-23234	− 5.43	5640 ± 24	4039–3728
SRN-52	25°30′39.9"N-66°38′13.0"E	16	*T. palustris*	GrA-57701	− 5.61	5575 ± 35	3966–3651
SRN-28	25°30′32.4"N-66°37′35.9"E	9	*T. palustris*	GrA-55819	− 2.55	5440 ± 40	3854–3508
SRN-26	25°30′43.4"N-66°37′38.7"E	9	*T. telescopium*	GrM-24184	− 1.09	5219 ± 24	3603–3312
SRN-76crab	25°32′20"N-66°37′07"E	5	*Scylla serrata* mangrove crab	GrM-18730	− 4.66	5130 ± 30	3516–3162
SRN-16	25°31′39.1"N-66°35′53.9"E	7	*T. palustris*	GrA-55817	− 3.86	5065 ± 40	3469–3067
SRN-12	25°31′30.2"N-66°35′41.6"E	6	*T. telescopium*	GrM-24859	− 3.38	4735 ± 30	3011–2661
SRN-14	25°31′35.3″N-66°35′49.5″E	14	*T. palustris*	GrM-21241	− 4.11	4581 ± 24	2837–2490
SRN-13	25°31′34.4"N-66°35′48.8"E	11	*T. palustris*	GrM-21239	− 3.39	4534 ± 24	2812–2431
SRN-43oto	25°30′25.3″N-66°38′31.7″E	8	*Protonibea diacanthus* fish otolith	GrM-15342	+ 0.45	4510 ± 40	2766–2361
SRN-57	25°29′49.9"N-66°37′57.8"E	11	*T. palustris*	GrA-57533	− 0.55	4315 ± 35	2472–2122
SRN-15	25°31′34.8″N-66°35′49.5″E	16	*T. telescopium*	GrM-23238	− 3.64	4180 ± 22	2291–1952
SRN-29.1	25°30′27.3"N-66°37′35.1"E	8	*T. palustris*	GrM-18729	− 2.95	3272 ± 24	1133–817
SRN-10	25°33′41.1"N-66°35′36.5"N	8	*T. palustris*	GrA-54302	− 7.17	975 ± 25	1416–1652 AD
SRN-54oto	25°30′05.1"N-66°38′52.9"E	12	*Protonibea diacanthus* fish otolith	GrM-18722	− 0.10	724 ± 22	1647-…. AD
SRN-20oto	25°30′51.5"N-66°37′47.4"E	4	*Psicofillis tenuispinis* fish otolith	GrM-18721	− 3.21	710 ± 22	1660-…. AD
SRN-60oto	25°30′43.4"N-66°38′27.9"E	10	*Psicofillis tenuispinis* fish otolith	GrM-18728	− 2.31	690 ± 22	1684-…. AD
Daun series (Daun Bay—Las Bela, Balochistan)							
Daun-110	25°00′00.66"N-66°42′21.20"E	7	*T. palustris*	GrN-31492	− 3.44	6690 ± 40	5216–4856
Daun-111	24°00′00.17."N-66°42′25.67"E	9	*T. palustris*	GrN-31493	− 3.57	6590 ± 45	5127–4737
Daun-1	25°00′14.34"N-66°42′39.82"E	9	*T. palustris*	GrN-26368	− 3.08	6380 ± 40	4866–4506
Daun-10	25°00′12.61"N-66°42′45.14"E	8	*T. palustris*	GrN-31489	− 3.97	6305 ± 45	4786–4429
Daun-6	24°59′20.49"N-66°42′31.38"E	19	*T. palustris*	GrN-28802	+ 1.27	5370 ± 35	3762–3434
Daun-116	25°00′07.92"N-66°42′23.66"E	7	*T. palustris*	GrA-66637	− 3.52	5360 ± 40	3756–3413
Daun-5	24°59′18.46"N-66°42′28.53"E	19	*T. palustris*	GrN-28801	− 5.44	4900 ± 35	3267–2884
Daun-4	24°59′18.07"N-66°42′29.46"E	18	Ostreidae	GrN-28800	− 5.30	4800 ± 35	3114–2742
Daun-112	25°00′00.52"N-66°42′27.87"E	16	*T. palustris*	GrN-32462	− 4.95	4625 ± 30	2877–2548
Daun-102	24°59′36.54"N-66°42′21.03"E	10	*T. palustris*	GrN-32117	− 5.96	4590 ± 35	2852–2493
Daun-8	24°59′25.99"N-66°42′33.00"E	25	Mactridae	GrN-28803	− 5.16	4540 ± 35	2821–2441
Daun-105	24°59′34.64"N-66°42′21.60"E	9	*T. telescopium*	GrN-31643	− 5.09	4470 ± 40	2710–2311
Daun-104	24°59′35.01"N-66°42′21.03"E	10	*T. palustris*	GrN-32118	− 6.1	4470 ± 35	2703–2321
Daun-101	24°59′37.03"N-66°42′19.86"E	10	*T. palustris*	GrN-31490	− 5.49	4470 ± 30	2695–2329
Daun-113	25°00′03.42"N-66°42′21.20"E	7	*T. palustris*	GrN-32463	− 5.44	4455 ± 30	2670–2307
Daun-103	24°59′35.37"N-60°42′21.77"E	9	*T. palustris*	GrN-31491	− 5.37	4435 ± 40	2659–2273

Table 1 (continued)

Site name	Coordinates	m a.s.l	Material	Lab. Numb	$\delta^{13}C$	Uncal BP	Cal BC/AD 2σ
Daun-106	24°59′34.10"N-66°42′20.96"E	7	*T. palustris*	GrM-24856	− 4.94	4434 ± 29	2635–2282
Daun-119	25°00′25.44"N-66°43′06.72"E	6	*T. palustris*	GrN-31644	− 4.05	4165 ± 25	2277–1936
Daun-3	25°00′26.55"N-66°43′04.67"E	4	*T. palustris*	GrN-27945	− 4.49	4100 ± 30	2196–1857
Daun-117	25°00′07.62"N-66°42′23.05"E	7	*T. palustris*	GrN-31494	− 3.95	1440 ± 30	999–1262 AD
Gadani, Phuari series (GDN, PHR—Las Bela, Balochistan)							
GDN-0	25°06′42.4"N-66°43′13.2"E	24	*T. palustris*	GrN-26369	− 4.99	4460 ± 30	2677–2315
GDN-2	25°06′46.6"N-66°42′56.5"E	31	*P. panama*	GrA-50328	+ 1.508	1130 ± 35	1286–1508 AD
PHR-11	25°05′19.0"N-66°42′26.93"E	19	*T. palustris*	GrA-55826	− 5.09	4415 ± 40	2623–2240
PHR-4	25°05′14.4"N-66°42′38.3"E	7	*P. panama*	GrA-55824	+ 0.68	1115 ± 35	1294–1520 AD
Sonari series (SNR—Hab River mouth, Sindh)							
SNR-102	24°52′41.0"N-66°41′38.5"E	45	*Meretrix* sp.	GrA-66253	+ 0.50	6360 ± 50	4845–4465
SNR-103	24°52′41.1"N-66°41′36.7"E	32	*Meretrix* sp.	GrA-59828	+ 1.01	6180 ± 50	4657–4306
SNR-11	24°52′12.4"N-66°41′10.1"E	23	*Turbo bruneus*	GrA-59830	+ 2.11	5650 ± 60	4100–3685
SNR-1C	24°53′37.6"N-66°41′31.5"E	27	*Meretrix* sp.	GrA-36867	+ 0.13	5125 ± 35	3509–3138
SNR-1B	24°52′37.5"N-66°41′31.2"E	26	*Meretrix* sp.	GrA-59837	+ 1.30	4850 ± 60	3254–2782
SNR-1A	24°52′37.8"N-66°41′31.1"E	24	*Meretrix* sp.	GrA-59839	+ 1.30	4780 ± 60	3124–2656
SNR-101	24°52′38.7"N-66°41′46.78"E	12	*T. palustris*	GrA-62252	− 4.2	4690 ± 35	2941–2592
SNR-7	24°52′27.7"N-66°41′37.8"E	14	*T. palustris*	GrA-59832	− 2.36	4560 ± 60	2856–2429
SNR-4bis/1	24°52′39.4"N-66°41′35.2"E	27	*T. palustris*	GrA-62250	− 3.79	4520 ± 35	2781–2392
SNR-5	24°52′38.3"N-66°41′34.9"E	27	*T. telescopium*	GrA-59833	− 5.14	4470 ± 60	2752–2283
SNR-8bis	24°52′13.5"N-66°41′18.4"E	23	*Lunella coronata*	GrA-67144	+ 2.25	4450 ± 35	2661–2290
SNR-8	24°52′13.5"N-66°41′18.4"E	23	*T. palustris*	GrA-62251	− 4.38	4405 ± 35	2601–2233
SNR-3bis	24°52′38.2"N-66°41′41.4"E	9	*Lunella coronata*	GrA-67145	+ 3.42	4280 ± 35	2444–2074
Sonari	24°52′28"N-66°41′54"E	27	*T. palustris*	GrN-27054	− 4.43	4080 ± 30	2171–1821
SNR-4bis/2	24°52′38.8"N-66°41′34.6"E	24	*T. palustris*	GrA-66633	− 7.47	3995 ± 35	2056–1694
SNR-1D	24°52′37.5"N-66°41′31.7"E	27	*T. telescopium*	GrA-59835	− 4.42	3660 ± 50	1641–1273
SNR-13	24°51′45.2"N-66°40′59.0"E	31	*Meretrix* sp.	GrA-59829	+ 0.38	3520 ± 50	1468–1098
SNR-9	24°52′13.7"N-66°41′15.3"E	20	*Lunella coronata*	GrA-59831	+ 1.60	2190 ± 50	167–531 AD
SNR-3	24°52′38.2"N-66°41′41.4"E	9	*T. palustris*	GrA-62249	+ 0.94	2190 ± 30	195–501 AD
SNR-2	24°52′38.9"N-66°42′02.6"E	3	*T. telescopium*	GrA-59834	− 5.1	670 ± 50	1679-….AD
Lower Sindh series							
RHR-1 (Rehri, Karachi—Sindh)	24°49′12"N-67°13′42"E	10	*Purpura panama*	GrA-50329	+ 2.02	3225 ± 40	1090–774
RHR-3bis (Rehri, Karachi—Sindh)	24°49′12"N-67°13′42"E	10	*T. palustris*	GrA-66631	− 4.13	7045 ± 45	5558–5253
RHR-3 (Rehri, Karachi—Sindh)	24°49′12"N-67°13′42"E	10	*Purpura panama*	GrA-63865	+ 2.02	3205 ± 35	1053–760
MH-15 (Mulri Hills, Karachi—Sindh)	24°55′41"N-67°07′14"E	67	*T. palustris*	GrA-63863	− 4.01	7320 ± 40	5805–5510
MH-14 (Mulri Hills, Karachi—Sindh)	24°55′42"N-67°07′25"E	65	*T. telescopium*	GrA-63869	− 4.57	6155 ± 40	4616–4283

Table 1 (continued)

Site name	Coordinates	m a.s.l	Material	Lab. Numb	$\delta^{13}C$	Uncal BP	Cal BC/AD 2σ
MH-4B (Mulri Hills, Karachi—Sindh)	24°55′47"N-67°07′57"E	65	*T. palustris*	GrA-66630	− 5.24	6035 ± 40	4483–4158
MH-18 (Mulri Hills, Karachi—Sindh)	24°54′45"N-67°06′30"E	65	*T. palustris*	GrA-23639	− 6.6	5790 ± 70	4277–3846
MH-17 (Mulri Hills, Karachi—Sindh)	24°54′43"N-67°07′55"E	65	*T. palustris*	GrA-66634	− 3.98	5530 ± 40	3942–3627
Garo-1 (Bhambor—Sindh)	24°45′36.3"N-67°33′17.4"E	31	*T. telescopium*	GrA-59844	− 3.64	6320 ± 60	4826–4425
Garo-3 (Bhambor—Sindh)	24°45′35.96"N-67°33′18.63"E	25	*T. telescopium*	GrM-30576	− 2.84	5838 ± 30	4263–3952
Garo-8 (Bhambor—Sindh)	24°45′41.86"N-67°33′55.96"E	35	*Anadara rhombea*	GrM-30577	− 2.50	5230 ± 30	3614–3322
THR-2 (Tharro Hill, Gujo—Sindh)	24°43′27.1"N-67°44′44.8"E	10	Ostreidae	GrN-32119	− 0.11	6910 ± 60	5461–5086
THR-3 (Tharro Hill, Gujo—Sindh)	24°43′46"N-67°45′07"E	13	*T. telescopium*	GrA-47084	− 5.15	5555 ± 35	3950–3641
THR-1 (Tharro Hill, Gujo—Sindh)	24°43′46"N-67°45′07"E	13	Ostreidae	GrN-27053	− 0.64	5240 ± 40	3624–3320
Beri-1 (Gujo—Sindh)	24°43′00.03"N-67°45′09.48"E	7	*T. palustris*	GrN-32166	− 6.9	5960 ± 50	4411–4047
Beri-1crab (Gujo—Sindh)	24°42′59.88"N-67°45′09.48"E	7	*Scylla serrata* mangrove crab	GrM-30757	− 4.14	7485 ± 35	5969–5675
JSH-1bis (Shah Hussain, Gujo—Sindh)	24°42′26.00"N-67°48′38.33"E	12	*T. telescopium*	GrA-66636	− 4.79	5800 ± 40	4246–3915
JSH-2 (Shah Hussain, Gujo—Sindh)	24°42′26.39"N-67°48′39.02"E	12	*T. telescopium*	GrA-45181	− 3.21	4245 ± 40	2411–2021
JSH-1 (Shah Hussain, Gujo—Sindh)	24°42′26.00"N-67°48′38.33"E	12	Ostreidae	GrA-45180	− 2.34	5325 ± 40	3699–3373
JSH-10 (Shah Hussain, Gujo—Sindh)	24°42′09.8"N-67°48′28.1"E	11	*T. telescopium*	GrA-62255	− 5.18	2715 ± 30	462–142
MKL-10 (Makli Hills, Thatta—Sindh)	24°37′40.6"N-67°51′41.2"E	17	*T. telescopium*	GrA-62256	− 7.02	6140 ± 40	4597–4271
MKL-1 (Makli Hills Thatta—Sindh)	24°36′52.5"N-67°51′36.5"E	22	*T. palustris*	GrA-50330	− 3.929	5750 ± 40	4211–3842
KKT-2 (Kalan Kot, Thatta—Sindh)	24°42′17.28"N-67°52′23.39"E	22	*T. palustris*	GrN-32464	− 5.5	6320 ± 45	4799–4441
KKT-6 (Kalan Kot, Thatta—Sindh)	24°42′01.1"N-67°52′43.6"E	21	*T. telescopium*	GrM-33794	− 5.71	5505 ± 40	3931–3602
KKT-4 (Kalan Kot, Thatta—Sindh)	24°42′15.3"N-67°52′15.7"E	26	*T. telescopium*	GrA-59843	− 7.03	5460 ± 60	3907–3521
KKT-5 (Kalan Kot, Thatta—Sindh)	24°42′11.41"N-67°52′15.23"E	26	*T. telescopium*	GrM-29973	− 5.02	5415 ± 27	3798–3500
KKT-3 (Kalan Kot, Thatta—Sindh)	24°41′55.89"N-67°52′40.63"E	22	*T. telescopium*	GrA-50324	− 5.01	5270 ± 40	3641–3342
OBS-1 (Aban Shah, Thatta—Sindh)	24°22′18.22"N-67°58′21.346"E	8	*T. palustris*	GrA-47082	− 9.17	3790 ± 35	1788–1450
OBS-1bis (Aban Shah, Thatta—Sindh)	24°22′18.22"N-67°58′21.346"E	8	*Meretrix chione*	GrA.66632	+ 0.29	1960 ± 30	445–713 AD
KDJ-1 (Kadeji Gorge, Karachi—Sindh)	25°02′15.7"N-67°25′12.5"E	112	Marine bivalve fr unidentified	GrA-63862	− 4.44	8275 ± 45	6888–6466
KDJ-3 (Kadeji Gorge, Karachi—Sindh)	25°02′29.31"N-67°27′33.30"E	115	Marine bivalve fr unidentified	GrM-31995	− 4.21	1654 ± 23	763–1039 AD
Mol-34 (Mol River, Karachi—Sindh)	24°02′47.86"N-67°24′34.64"E	123	Marine bivalve fr unidentified	GrM-32754	− 3.44	6276 ± 29	4729–4404
Mol-7 (Mol River, Karachi—Sindh)	25°02′34.19"N-67°24′41.43"E	119	Marine bivalve fr unidentified	GrM-32753	− 0.91	1824 ± 20	614–861 AD
Mol-21 (Mol River, Karachi—Sindh)	25°02′52.59"N-67°24′39.64"E	126	Marine bivalve fr unidentified	GrM-32754	− 6.79	˃40,000	
Mol-24 (Mol River, Karachi—Sindh)	25°02′52.71"N-67°24′35.09"E	123	Marine gastropod fr unidentified	GrM-32755	− 2.76	3354 ± 20	1235–919
HLJ-22 (Haleji, Thatta—Sindh)	24°49′34.4"N-67°43′59.1"E	24	*T. telescopium*	GrM-32746	− 6.74	6254 ± 24	4706–4392
HLJ-39 (Haleji, Thatta—Sindh)	24°49′36.2"N-67°43′59.2"E	26	Ostreidae	GrM-33799	− 1.96	7150 ± 45	5642–5351
HLJ-41 (Haleji, Thatta—Sindh)	24°49′35.9"N-67°43′59.5"E	26	Ostreidae	GrM-32748	− 2.40	7215 ± 27	5695–5436
HLJ-67 (Haleji, Thatta—Sindh)	24°49′36.6"N-67°43′58.2"E	26	Ostreidae	GrM-32749	− 3.25	7237 ± 26	5709–5461
KRM-13 (Kot Raja Manjera, Jerrack—Sindh)	25°01′20.58"N-68°12′36.69"E	45	*T. palustris*	GrA-47083	− 6.17	4635 ± 35	2771–2469

Calibrations according to the OxCal 4.4 Marine 20 curve [90]

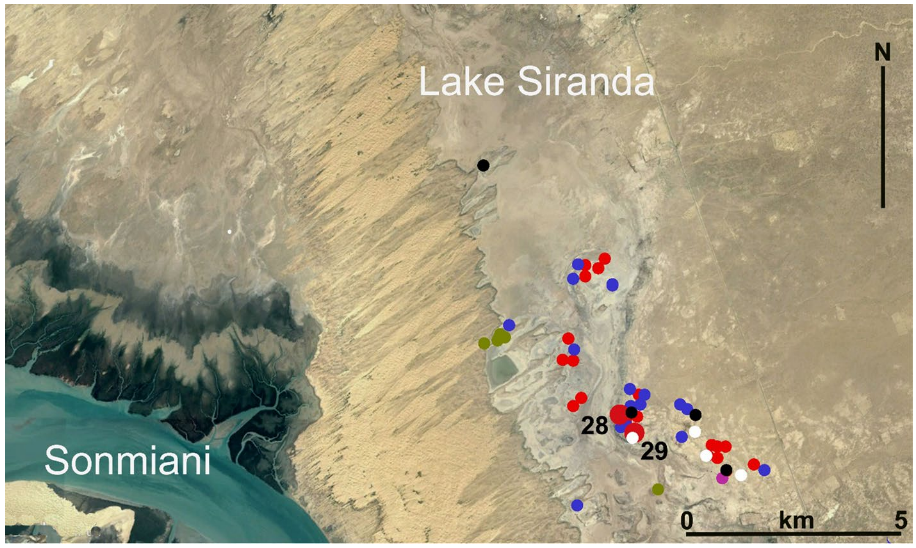

Fig. 2 Siranda Lake: Distribution map of the radiocarbon dated sites: 9th millennium BP (violet dot), 8th millennium BP (white dots), 7th millennium BP (red dots), 6th millennium BP (blue dots), 5th millennium BP (green dots), historic dates (black dots) (drawing by P. Biagi)

During the winter and summer monsoon seasons, the depression is fed by sparse rains [49] (p. 18) and the Watto River that flows from the north [41] (Fig. 13). According to a report written at the beginning of the last century, "*when full ….. is 9 miles long and 2 miles broad*" [48] (p. 19). So far, 45 Siranda sites have been radiocarbon dated mainly from *T. palustris* or *T. telescopium* mangrove shells, but also *Anadara rhombea* (1), 1 *Scylla serrata* mangrove crab (1) claw, and fish otoliths (6) (Table 1).

Concerning the Las Bela coast, other groups of shell middens have been discovered and radiocarbon-dated at Ras Gadani, Ras Phuari [50] (Fig. 1, no. 2), and along the small Bay of Daun [21, 51] (Fig. 1, no. 3). The available data suggest that this part of the Arabian Sea coast [52] (p. 136) was unpopulated during the Early Holocene until the last centuries of the 8th millennium uncal BP. The same has been suggested for the entire coast of the Arabian Peninsula [53].

Lower Sindh is one of the provinces of Pakistan where careful investigations could greatly improve the archaeology of the Indian Subcontinent. The complexity of the Sindhi landscape has been stressed by several authors [27, 39, 54–56]. A seminal volume on the geology of the region [57] reports the presence of "*rocky outcrops*" rising from the Indus alluvium all of which have been surveyed and yielded evidence of prehistoric settlement [24]. Professor AR Khan of Karachi University was the first to survey a territory of ca 40 kms radius around Karachi in the 1970s. He was also the first to report the discovery of marine shells "*60 miles inland and at a height of more than 1,100 feet*" [40] (p. 18). Unfortunately, most of the sites discovered then have already been destroyed by industrial development.

3 Materials

3.1 Las Bela

Most of the Siranda shell middens consist of thin deposits or surface concentrations of discoloured fragments of *T. telescopium*, *T. palustris* and marine shell species. The only exceptions are SRN-28 and SRN-29 which are located along the eastern shore of the lake. SRN-28 is a thin, almost circular midden ca 30 m in diameter. It is surrounded by 13 heaps of mangrove shells, 2 to 3 m in diameter each (Fig. 3).

The site was most probably settled in different Neolithic periods. This is confirmed by two radiocarbon dates (SRN-28.10: GrA-62260, 6500 ± 40 BP, and SRN-28: GrA-55819, 5440 ± 40 BP both on *T. palustris* (see Table 1) and the presence of different types of geometric microliths. SRN-29 is an impressive shell mound, which is clearly visible from a great distance. It is surrounded by several smaller shell middens and heaps over a very wide area (Fig. 4).

Neolithic knapped stone artefacts and one copper vessel have been retrieved from different areas of the site (SRN-29Sud: GrM-18731, 7130 ± 35 BP, SRN-29: GrA-54299, 6595 ± 35 BP, and SRN-29.1: GrM-18729, 3272 ± 24 uncal BP, all on *T. palustris*: see Table 1). None of the Siranda middens has ever been excavated. The sites do not show the presence of habitation structures, graves, human and animal bones, hearths and charcoals. Two Neolithic (SRN-19 and 29), four Chalcolithic (SRN-12, 13, 16 and 52) and one Bronze Age (SRN-15) sites have yielded ceramic potsherds.

Fig. 3 Siranda Lake: General view of Site SRN-28 taken from SRN-29 (top), with *T. telescopium* fragments on the site's surface (bottom) (photographs by P. Biagi, 2013)

The percentage and state of fragmentation of the Siranda mangrove shells varies site by site, though *T. telescopium* always prevails over *T. palustris* [58, 59]. Other common species are *Anadara rhombea* and *Thais* marine shells. Three typical net weights, obtained from bilaterally notched beach pebbles, have been recorded from SRN-62, 64 and 73. They suggest that the Siranda Neolithic communities practised some sea fishing on a small scale.

The radiocarbon dates and the techno-typological characteristics of the knapped stone artefacts show that the Neolithic shell middens were settled between the last two centuries of the 8th and the entire 7th millennium uncal BP (Fig. 2). The lithic assemblages of this period are represented by microlithic bladelet artefacts which were obtained almost exclusively from dark reddish-brown Ras Gadani chert, whose outcrops are located ca 50 km south of the Siranda Lake [60, 61]. The tools consist of prismatic and subconical microlithic cores with one prepared platform from which parallel-sided microbladelets have been detached, microlithic isosceles trapezes, micro-drills, retouched and unretouched microbladelets [47].

The 6th millennium BP Chalcolithic sites have yielded knapped stone artefacts made from Gadani and other varieties of black and whitish chert. Although the location of these chert sources is unknown, we can exclude that the Siranda Chalcolithic communities ever exploited any of the well-known sources of Lower and Upper Sindh [62]. We know that limestone and conglomerate deposits containing knappable cherts do exist [63], although the provenance of Lake Siranda Chalcolithic artefacts is still undefined.

Fig. 4 Siranda Lake: General view of Site SRN-29 (top), with *T. telescopium* and *T. palustris* fragments on the site's surface (bottom) (photographs by P. Biagi, 2013)

Most of the Chalcolithic bladelets were detached by pressure technique to obtain blanks with straight, parallel sides and trapezoidal or more rarely triangular cross-sections. The tools are represented by semi-abrupt retouched bladelets and truncation and one lunate [47]. These artefacts can be compared with those of the Amri phase which flourished in Sindh during this period [64–66], and the knapped stone artefacts from the Chalcolithic layers of Mehrgarh in Balochistan [67, 68]. These important lithic industries have never been taken into great consideration, although they show unique techno-typological characteristics which clearly distinguish them from those of the Neolithic and Bronze Age periods of Pakistan.

3.2 Lower Sindh and the Indus Delta

Moving along the coast from west to east, the Bronze Age settlement of Sonari plays a very important role in the archaeology of the study area. Sonari is the only fisher-gatherer settlement of this period so far discovered along the northern coast of the Arabian Sea. The site is well-sheltered inside a wide saddle that opens at the top of the limestone terrace facing the Hub River mouth a few kilometres north of Ras Muari (or Cape Monze, Sindh) (Fig. 1, no. 4). The site cannot be seen from both the Arabian Sea and the plain that extends east of the limestone ridge. It consists of a few small, rectangular stone structures, east–west and north–south oriented, whose floors are covered with fragments of hundreds of *Meretrix* bivalves. The presence of several net sinkers made from beach pebbles, other ground stone implements, and marine and mangrove shells, shows that fishing and shell gathering were the most important activities practised by the inhabitants of the site, which has been radiocarbon dated to the 5th millennium uncal BP by mangrove and marine shells. The site yielded a few locally made ceramic potsherds [69].

Apart from Sonari, many concentrations of knapped stone artefacts, mangrove and marine shells have been discovered and radiocarbon dated along the coast of Lower Sindh during the last two decades [23, 70]. Recently, surveys have been extended to the confluence of the Mol and the Khadeji Rivers, ca 30 km north of the present coastline (Fig. 1, n. 12). Here concentrations of knapped stone artefacts have been recovered in association with a few marine and mangrove shells. One fragment of a large marine bivalve from the Khadeji Valley site KDJ-1 has been radiocarbon dated to 8275 ± 45 BP (GrA-63862) [71, 72]. The result shows that groups of Holocene hunter-gatherers were active in the territory already during the second half of the 9th millennium BP. This discovery shows that they exploited the Arabian Sea mangal environment, and moved towards the interior following the terraces of the most important watercourses, most probably the Malir River banks [40] (p. 18).

Chalcolithic *T. telescopium* shell middens have been collected from the surface of the Makli Hills and Shah Hussain, south of Thatta [23, 24] (Fig. 1, no. 9 and 10). However, the only stone-walled settlement of this period with evidence of exploitation of marine resources is Tharro Hill near Gujo [73] (p. 20) (Fig. 1, n. 8). The site has been attributed to the Chalcolithic Amri phase [66] due to the recovery of characteristic painted potsherds with geometric motifs, typical knapped stone artefacts, and two radiocarbon dates obtained from marine and mangrove shells. A small concentration of oyster shells discovered along the southern edge of the Tharro terrace has been radiocarbon dated to the Neolithic period (GrN-32119: 6910 ± 60 BP). Neolithic mangrove shell fragments have been collected and dated also from the Mulri Hills (Fig. 1, n. 5), in the eastern suburbs of Karachi, Rehri (Fig. 1, n. 6), a village facing the Gharo Creek, and the limestone terraces around the village of Gharo [70] (Fig. 1, n. 7).

The countryside of Sindh is punctuated by many shallow salt basins, called "*dhandhs*". They show "*evidence of the former sea communicating the interior…. After a huge inundation of the area, they lose their aloofness from one another and are joined together for the time being. Later on, when the flood waters subside, they regain their individuality and aridity and grow in salinity*" [55] (p. 310–311). Their archaeological importance has been pointed out by the discovery of concentrations of microlithic knapped stone artefacts along the limestone terrace located west of the Kheenjar Lake (Fig. 1, n. 14) near Jhimpir [74] and west of the Haleji Lake (Fig. 1, n. 13).

The December 2022 surveys were conducted along and around two low limestone terraces located ca 1000–1500 m west of the Haleji freshwater reservoir [75]. Before the 1930s, Haleji was a *dhandh*, a "*fine sheet of water, also fed by hill torrents, but its size is chiefly regulated by the amount of rainfall*" [76] (p. 291). The surveys led to the recovery of many concentrations of knapped stone artefacts often associated with oyster shells and, in one case, *T. telescopium* fragments. So far, only four Haleji sites have been radiocarbon-dated (Fig. 5).

The results show that the concentrations of microlithic knapped stone artefacts and oyster shells (Fig. 6) discovered on the top of the terrace belong to the last three centuries of the 8th millennium BP (see Table 1, HLJ-39, 41 and 67), while the concentration of *T. telescopium* shell fragments located along at the north-easternmost slope of the same terrace is roughly one millennium later (HLJ-22: GrM-32746, 6254 ± 24 uncal BP) (Fig. 7).

4 Discussion

More than 150 radiocarbon dates have been obtained from shell sites and concentrations discovered along the coasts of Las Bela and Lower Sindh (Table 1). The results have contributed to the interpretation of Holocene coastal changes, chronology and location of the ancient mangrove ecosystems and their related archaeological sites. During this period the present arid conditions were established and the Bronze Age Indus Civilization began to fractionate and decline around the end of the 5th millennium BP [77–79]. This event took place when several mangrove environments started to disappear and their distribution reached that of the present [17] (p. 429).

The discovery and radiocarbon dating of shell sites has contributed to the interpretation of some aspects of the Neolithic coastal peopling of which almost nothing was known until the 2000s [80, 81]. This is the period during which the earliest maritime movements took place along the northern coast of the Arabian Sea and the small islands located close to the ancient coast were settled for the first time [24].

The new Haleji radiocarbon dates suggest that important changes took place along the coast of Lower Sindh during the last three centuries of the 8th millennium BP when the first shell middens were established. This happened during a

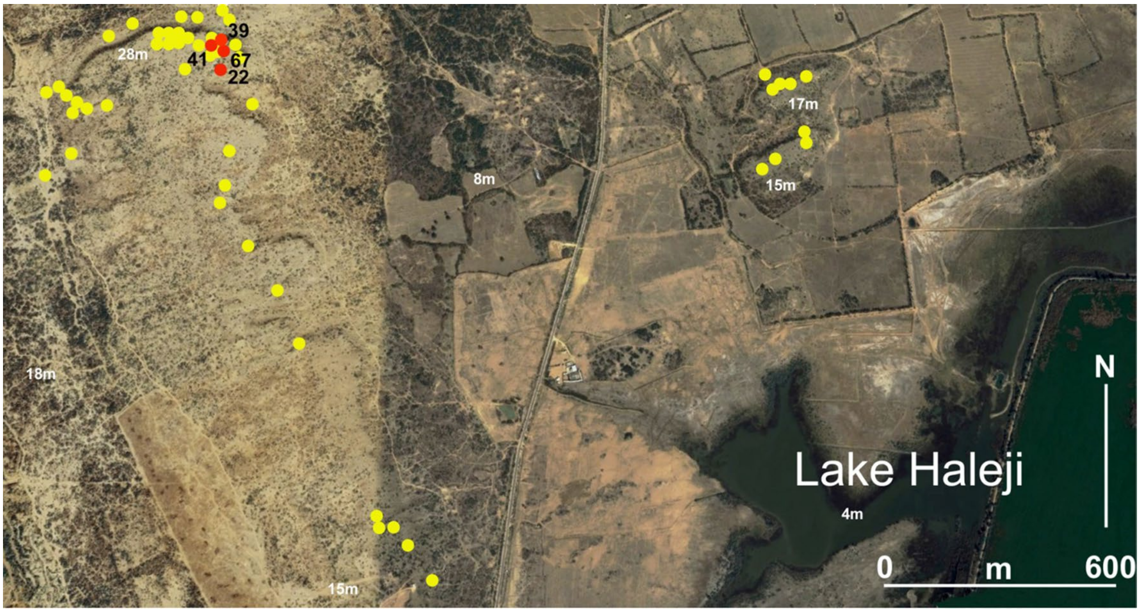

Fig. 5 Haleji: distribution map of the concentrations of knapped stone artefacts and shells discovered in December 2022 on the terraces west of the Haleji Lake (yellow dots) and the radiocarbon-dated sites (red dots) (drawing by P. Biagi)

humid climatic period of increased monsoon precipitations [82], sediment transport [83] and advance of the Indus Delta [84]. During the same period, mangrove ecosystems flourished in many areas of the northern coastline of the Arabian Sea. This is the case for Lake Siranda where the oldest shell midden (SRN-43) has been radiocarbon-dated to 7200 ± 35 BP (GrA-54290). This result is similar to those obtained from the Haleji sites of Lower Sindh (HLJ-39, 41, 67: Table 1). The location of the shell middens along the eastern shore of Lake Siranda (Fig. 2) can be compared to that of the Ja'alan coast in Oman. In both areas, the Neolithic shell middens are located along the coast of ancient shallow lagoons a few kilometres inside the present coastline where mangrove swamps flourished during a period of humidity and ample freshwater supply [14] (Fig. 13).

The Neolithic Lake Siranda and Haleji sites are the first to be discovered along the northern coast of the Arabian Sea. Their cultural attribution is still undefined. The lithic inventory consists of geometric microliths among which are lunates and isosceles trapezes obtained from microbladelet blanks detached by indirect percussion, many of which were hafted inside wooden sticks or show traces of impact. Small drills for piercing hard materials are also common. Moreover, a few ceramic potsherds have been recovered from two Siranda sites (SRN-19 and 29). The general impression is that the middens were seasonally settled for gathering mangrove shells, though hunting and fishing were practised on a small scale. This is confirmed by traceological analysis of the knapped stone artefacts (Mazzucco pers. comm. 2023) and the presence of a few fishing implements. Unfortunately, given the limited territory surveyed during the last decades, we still do not know where the base camps are located.

The radiocarbon dating of shell sites has been crucial also for the study of the Chalcolithic Amri phase, an important period of which very little is known. It is now becoming clear that the coast of Sindh and its related islands, Tharro Hill for example [71], played a very important role in the economic strategy of the Amri phase. Thanks to the data collected during the 2020–2022 surveys and a new series of radiocarbon dates, we can attribute the Chalcolithic shell middens discovered along the coast of Lower Sindh, Kalan Kot in the Makli Hills (Thatta) for example [24], to the 6th millennium BP Amri phase [64]. Though we still know very little about Amri, its origin and disappearance [68], several Amri fortified settlements and shell middens, have been discovered close to the coastline and on small islands, suggesting that the subsistence economy of the sites of this aspect was partly oriented toward the sea.

Very few Bronze Age sites are known along the coast of Sindh which does not have any evidence of Kot Diji sites. Their discovery is important for the interpretation of the origin and spread of the Mature Indus Civilisation which developed around the middle of the 3rd millennium cal BC. What are the relationships between the three archaeological aspects of Amri, Kot Diji and the Mature Indus? [85]. The new surveys and systematic radiocarbon dating of the coastal shell sites have contributed to the study of the prehistory of Las Bela and Lower Sindh, which has drastically improved during the last two decades.

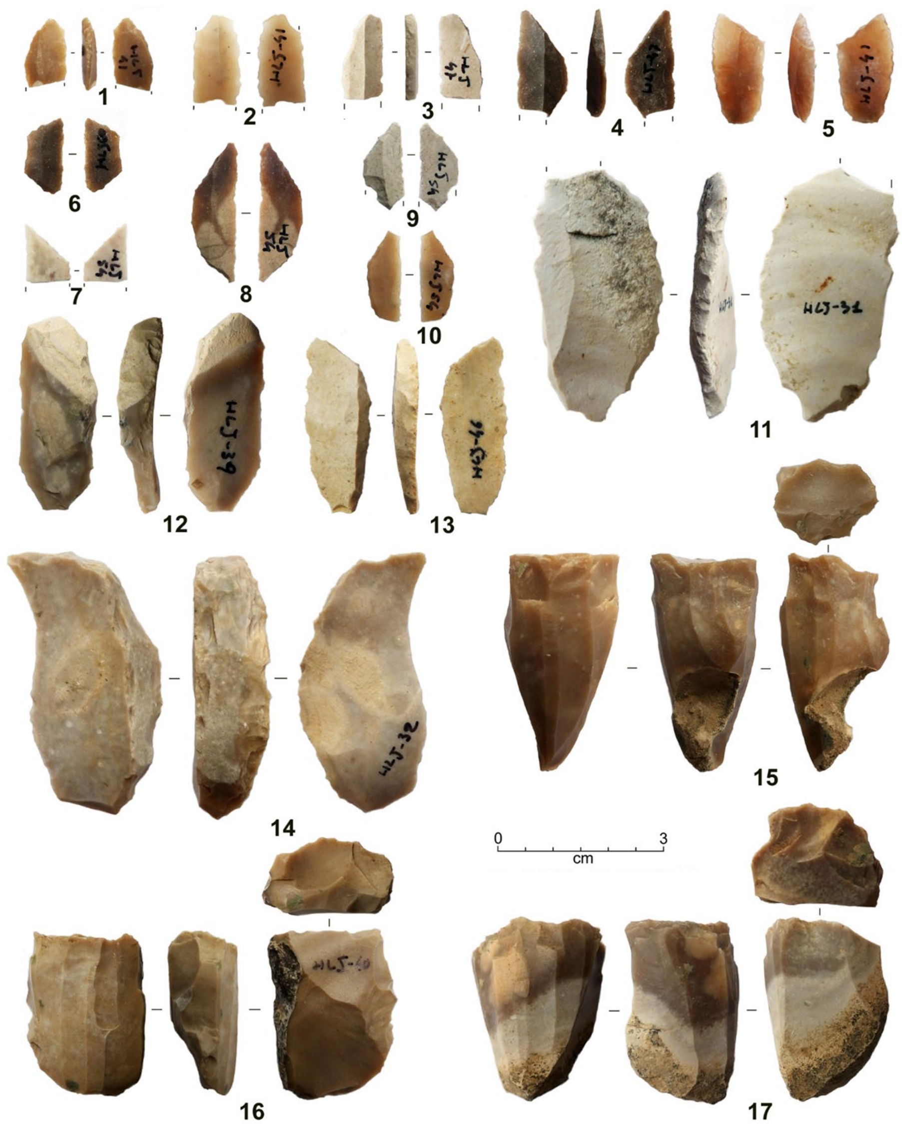

Fig. 6 Haleji: knapped stone artefacts from different sites: abrupt-retouched tools (no. 1–13), crested flake (no. 14), cores (no. 15–17) (photographs by E. Starnini)

Our present view is based on more data that favour the interpretation of settlement chronology and location in relation to the distribution of the mangrove ecosystems, the establishment of the present coastline, impressive environmental changes, early maritime movements, first island settling, decreasing number of mangal ecosystems and the advance of the Indus Delta.

Unfortunately, many of the sites described in this paper and those discovered by Professor AR Khan in the 1970s, have been destroyed or damaged during the last thirty years due to population growth, industrial development and uncontrolled expansion of residential centres.

5 Conclusion

Recently, *T. palustris* shell middens and knapped stone artefacts have been discovered in Khadir Island (Gujarat, India) [86], not far from the Bronze Age Indus metropolis of Dholavira [87]. This discovery shows that Neolithic shell middens, radiocarbon-dated to the second half of the 7th millennium BP, are present also in other regions of the northern coast of the Arabian Sea. Research currently underway in the Rann of Katchchh should tell us if there is any relationship between these sites and those of the coast of Lower Sindh. The discovery of shell middens in this region of western India is very important because the Late Pleistocene and Holocene events that led to the present environmental conditions have been studied in detail in Gujarat, especially concerning tectonic, fluvial and monsoon activities [88].

Fig. 7 Haleji: Site HLJ-22 along the slope in the centre of the image (top), and site HLJ-39 with knapped stone artefacts (black dots) and oyster shell fragments on its surface (red dots) (bottom) (photographs by P. Biagi, 2022)

Research into the Early and Middle Holocene peopling of the northern Arabian Sea coast should be extended to the Makran (Balochistan) [89] and the limestone terraces that border the artificial Haleji and Kalri Lakes in Sindh, which mark the coastline of the Hellenistic period [36] (map 2). As reported above, AR Khan surveyed this region in the 1970s. He described the tectonic processes that affected the territory around the beginning of the Holocene and reported the presence of three series of raised beaches and marine terraces each of which is characterised by different archaeological artefacts from the Upper Paleolithic to the Chalcolithic [40] (p.19).

The shell sites discovered along the shores of Lake Siranda show that the landscape of Las Bela changed drastically between the beginning of the Neolithic and the Bronze Age when the lagoon was no longer connected to the Arabian Sea for various reasons including river aggradation and accumulation of aeolian sediments along its shores [48]. The events that took place in Las Bela during this period, can be compared with those of the coast of Oman [14, 15], while the situation in Sindh is still under study.

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Author contributions The author Paolo Biagi confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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Declarations

Competing interests The authors declare no competing interests.

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