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Exploiting mangroves: Environmental changes and human interference along the northern coast of the Arabian Sea (Pakistan) during the Holocene

By Paolo Biagi, Renato Nisbet and Tiziano Fantuzzi

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Introduction

The scope of this paper is to overview our knowledge of the prehistory of the northern coast of the Arabian Sea in Lower Sindh and Las Bela in Balochistan, define the chronology of the earliest coastal settlements, and discuss their location, characteristics, and disappearance. Coastal archaeology has greatly improved during the last 30 years[1] thanks to the interest that many archaeologists, palaeoclimatologists and geomorphologists, have paid to this unique field of research. This fact led the to the discovery of the earliest traces of coastal navigation,[2] whose archaeological evidence, in the study region, is marked by the impressive finds excavated at as-Sabiyah in Kuwait, at the westernmost edge of the Persian/Arabian Gulf.[3]

Almost nothing was known of the presence of archaeological sites along the northern coast of the Arabian Sea until the second half of the 1970s. In those years Professor A. R. Khan of the Department of Geography, Karachi University, carried out a systematic geoarchaeological survey of the entire territory around Karachi. Thanks to his discoveries at present we know that the whole area is very rich in sites of different ages, spanning a long period, from the Middle Palaeolithic to the Buddhist period.[4]

Unfortunately most of the sites discovered by Professor A. R. Khan are still unpublished, and too many of his important discoveries are unknown or unreported by most archaeologists.[5] However, our knowledge of the archaeology of the northern part of the Arabian Sea has dramatically improved following the results achieved by his surveys.

It is again thanks to the work of the aforementioned author that the Neolithic and Bronze Age shell middens of the Bay of Daun were discovered in Las Bela in 2000. The sites were systematically surveyed in 2004 and 2008.[6] Between 2000 and 2014 a few visits were paid also to Capes Gadani and Phuari,[7] Rehri, along the coastal terraces that extend east of Karachi, the Tharro Hills,[8] Balakot,[9] Pir Shah Jurio,[10] and Sonari near Cape Monze (Ras Mauri).[11]

Even more surprising is that the surveys carried out by other authors before the 1970s along the same coastline as far as Makran, did not yield any trace of the most characteristic sites of the Arabian Sea coast, namely shell middens.[12] This evidence strangely contrasts with the data available from the Sultanate of Oman since the 1960s, and more generally along the western coast of the Arabian Sea.[13]

The shell middens of the Bay of Daun were discovered in January 2000 during a short visit paid to the coast of Las Bela together with Professor A. R. Khan. The main scope of the visit was to collect complete specimens of *Terebralia palustris* mangrove shells, a few samples of which Professor Khan kept in the stores of the Museum of Prehistory and Palaeogeography, Institute of Geography, Karachi University.

Following the discovery of the Daun shell middens, the surveys were extended first to the Indus Delta, in Lower Sindh,[14] and later to the coast of Las Bela, in Balochistan.[15] Both areas yielded an impressive number of archaeological sites, mainly *Terebralia palustris* and *Telescopium telescopium* shell middens, and shell scatters both close to the seaside and well inland. A good series of AMS dates was obtained from these sites, whose scope was

1 Bailey/Parkington 1988; Erlandson/Fitzpatrick 2006; Rainbird 2007; Erlandson/Rick 2008.
2 Bjerck 2017.
3 Carter/Crawford 2010.
4 Khan 1979a.
5 Wright 2010; Coningham/Young 2015; Kenoyer 2015.
6 Biagi et al. 2012.
7 Biagi et al. 2013a.
8 Majumdar 1934; Piggott 1950; Fairservis 1975.
9 Khan 1979c, 75.
10 Khan 1979a, 3.
11 Biagi/Nisbet 2014.
12 Stein 1943; Snead 1966; 1969; Dales 1982; Besenval 1992; Dales/Lipo 1992; Hasan 2002.
13 Biagi 1988; Cleuziou 2004; Berger et al. 2005; Амирханов 2006.
14 Biagi 2010.
15 Biagi 2011; Biagi et al. 2013b.

to achieve a first reliable sequence of the prehistoric settlement and environmental changes that took place in this almost forgotten region of the north Arabian Sea coast since the beginning of the Holocene.

Current and historical mangroves in Pakistan

It is well known that mangroves represent an exceptional environment, perfectly adapted to inter-tidal habitat such as estuaries and deltas.[16] They are so strictly connected to the coast that some authors define mangroves to include the formation below the high tide mark (*tidal forests*), though other mangroves "*may occur from far below the level of the lowest to above the level of the highest tides, or on coasts where there are no tides at all*".[17] The fact that they live in areas where both fresh and saline water occur, favour the reconstruction of the coastal variations in those regions, the Indus Delta for instance, where dramatic changes in the landscape, not yet fully understood, took place during the Holocene.[18]

Many authors have pointed out the economic importance of mangroves, providing fuelwood,[19] timber, tannin and medicinal products as well as crustaceans and fish for food,[20] though no recent gatherings of the most frequent, typical molluscs have ever been mentioned,[21] as happened in prehistoric times in the Gulf and along the coasts of the Arabian Sea.[22]

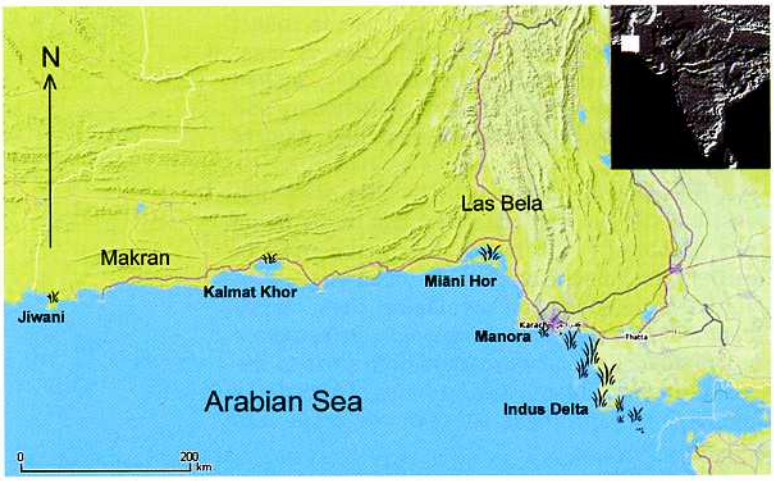

Fig. 1 Distribution map of the present mangroves along the coasts of Sindh and Balochistan (Pakistan) (topographic map OpenStreet Map: drawing by R. Nisbet)

Out of Pakistan's 1000 km coastline, roughly 300 are covered by mangroves. In the case of the Indus Delta, these tidal forests border the numerous creeks extending well inland, at a distance of 30 km or more from the coast, covering a huge territory of ca. 600,000 ha.[23] A much lesser extent have the other four mangrove areas, found at Manora (Karachi),[24] Miāni Hor,[25] Kalmat Khor and Jiwani (the last three in Balochistan), together forming only 5% of the total Pakistani mangroves endangered by increasing human pressure[26] **(Fig. 1)**.

Ancient historians have left some descriptions of mangroves at the borders of the Indian Ocean and the Gulf. Probably the earliest mention is found in Theophrastus who, in his *Historia Plantarum* (305 BC), reports from Aristobulos on the voyage by Nearchos in 325 BC from the Indus Delta to the Persian Gulf. The trees described by Alexander's admiral would apply to *Rhizophora* sp. and *Avicennia* sp.[27]. Arrian mentions of mangroves (*"These trees were on ground which was left dry by the ebb-tide; but when the water advanced they looked as if they had grown in the sea*": Arrian, Anabasis, VI.22.6)[28] in his description of Alexander's voyage are the last one together with that of Pliny's Naturalis Historia, XIII.25.51.[29] Apart from early short points in Theophrastus and Strabo, before the 13th century AD observations are reported by the botanist and physician Ibn al-Bitār along the Arabian coasts.[30]

According to B. Rollet[31] in the following three centuries no more than five or six descriptions of mangroves in the world botanical literature are found before van Rheede's *Hortus malabaricus*,[32] broadly referring to Indian Ocean mangroves. Paradoxically, Aitchison's list of Punjab and Sindh plants reports the presence of *Rhizophora* sp. at the Indus Delta, but not of *Avicennia marina*, by far more common.[33]

Even the otherwise always very well informed *Gazetteer of Sind*[34] pays no attention to the coastal vegetation between Karachi and the Indus Delta. More details were provided by A. J. Murray (1881), who described some mangrove trees (*Ceriops candoleana*) as common "*at the mouth of Indus, and in the salt-water creeks, Kurrachee, and on the coast*",[35] which is certainly an overestimation of

16 Kathiresan/Rajendran 2005; Schwadron 2013.
17 Lugo/Snedaker 1974, 43.
18 Pithawalla 1939; 1976; Wilhelmy 1968, 1986; Flam 1987, 1999; Kevran 1999.
19 Aitken 1907, 32; Hasan 2002, 10.
20 Tomlison 1986; Hogarth 1999; Ellison 2014.
21 Siddiqi 1956; Haas 1959.
22 Biagi 2008; Boivin/Fuller 2009.
23 Snedaker 1984, 256; Qureshi 1990.
24 Baillie 1890, 52-53; Campbell 1999.
25 Saifullah et al. 2002.
26 Hameed-Baloch et al. 2014.
27 Eggermont 1975.
28 Ambaglio 1994, 561.
29 McCrindle 1901; 1972.
30 Ibn al-Bitār 1987.
31 Rollet 1981.
32 van Rheede 1678-1703.
33 Aitchison 1869.
34 Hughes 1876.
35 Murray 1881, 190.

the occurrence of this species at present known as *Ceriops tagal* (Perr.) C. B. Rob., and also *Rhizophora*, *Bruguiera* and *Avicennia*. More precise indications on the location of mangroves in the Indus Delta are found in the Gazetteer of the Province of Sind, which mentions three species of mangrove trees,[36] though the first large account on Indus mangroves will appear only several years later.[37]

Balochistan mangroves have attracted attention much later, since 1980, because of their potential economic interest, and important protective programmes, while repopulation projects have been since carried out.[38] Moreover, Miāni Hor is the only area in Pakistan where the three mangrove species *Avicennia marina*, *Rhizophora mucronata* and *Ceriops tagal* occur naturally.[39]

Both Sindh and Balochistan mangroves urgently need long-term rehabilitation projects, as widely recognised by local and international authorities, in order to stop the erosion of their fragile ecosystems, whose overall extension changed from over 600,000 ha in 1932 to ca. 85,000 ha in 2005[40] mostly due to progressively increasing human pressure and pollution.[41]

Methodology

The use of Gastropods as palaeoenvironmental indicators of mangroves is well known.[42] Their exploitation is well recorded from many archaeological sites of the Gulf of Oman and Yemen along the western coast of the Arabian Sea,[43] the Persian/Arabian Gulf,[44] and the Red Sea.[45] The technique is based on the close relationship between the mangrove unique environment and a few species of molluscs (in particular *Terebralia palustris* L. and *Telescopium telescopium* L.), which feed mostly on fallen leaves of *Rhizophora* and *Avicennia*, living under the thick mangrove canopy as well as in the surrounding more open, muddy areas[46] **(Fig. 2)**.

The frequent exploitation of these molluscs as food by ancient groups led to the formation of characteristic low mounds, or sometime simply scatters of debris. The shells, which were in a few cases minutely fragmented in order to extract the edible soft tissues, are usually found concentrated in areas ranging from small spots 2-3 m diameter to very large areas, up to more than 40 m diameter (shell middens) **(Fig. 3)**. The identification of shell concentrations was generally made easier due to the barren nature of the surface. Chipped stone artefacts (mostly flint/chert) in close relationship with the shells were made using, at least in some cases, local outcrops (as, for example, at Siranda and other coastal sites in Las Bela, reddish-brown flint from Cape Gadani).[47]

The shells primarily consist of typical mangrove gastropods (*T. palustris* and *T. telescopium*) and bivalves (mostly *Anadara rhombea* Born, *Anadara* cf *uropygmelana*, *Circenita callipyga* Born, *Thais lacera* Born etc.) distinctive of both mangroves and shallow waters of the upper intertidal zone, on sandy and muddy bottoms.[48] Lists of mol-

Fig. 2 Miāni Hor, south-easternmost creek: *Rhizophora* sp. and *Avicennia* sp. mangrove forest (top), and *Telescopium telescopium* gastropods (bottom) (Photographs by P. Biagi and R. Nisbet 2012)

36 Aitken 1907, 31.
37 Blatter et al. 1929.
38 Rasool/Saifullah 2005; Amjad/Kamaruzaman 2007.
39 Baig/Iftikhar 2006, 6.
40 Damhoureyeh/Ghalib 2014.
41 Rizwi et al. 1999; Amjad et al. 2007; Hameed-Baloch et al. 2014.
42 Thomas 2015a; 2015b.
43 Biagi/Nisbet 1992; 2006; Plaziat 1995; Амирханов 1997; Amirkhanov et al. 2001; Uerpmann/Uerpmann 2003; Berger et al. 2013.
44 Choquert 1980; Feulner 2006; Hellyer/Aspinal 2006.
45 Cattani/Bökönyi 2002; Bar-Yosef Mayer/Beyn 2009, 2013; Bailey et al. 2013.
46 Vannini et al. 2008.
47 Biagi et al. 2013a Plate 1.
48 Biagi et al. 2013c.

Fig. 3 Lake Siranda: Shell midden 29 (SRN-29), main site (top), and small heap of fragmented mangrove and marine shells east of the same site (bottom) (photographs by P. Biagi 2012)

luscs found in our surveys have been provided in previous papers.[49]

Palynological evidence of palaeo-mangroves in Pakistan is very limited. Margaret McKean,[50] in her study on the ancient vegetation of Balakot[51] **(Fig. 4)** did not identify any pollen of *Avicennia* or *Rhizophora*, in spite of the proximity of the archaeological site to the well-documented Siranda mangroves during the same Bronze Age centuries. In a more recent work on a marine core off the Makran coast, Ivory and Lézine[52] described, amongst other continental vegetation associations, a well-defined curve of mangrove pollen types, with its maximum value starting from ca. the mid 6th millennium BP. The palaeoclimatic interpretation of the diagram points to humid conditions that favoured the diffusion of *Rhizophora* and freshwater algae until the following millennium, when the humid Holocene Atlantic period came to an end, and gradually more xeric vegetation indicators prevailed.

A very different picture can be drawn from the numerous, well-documented palynological sites along the western coast of the Indian Subcontinent.[53] In this latter region, under quite a different climatic regime,[54] mangroves were diffused before 40 ka cal BP and lasted until the mid-Holocene, when the

[49] Biagi et al. 2013a, 2013c.
[50] McKean 1983.
[51] Dales 1979; Shaffer 1986.
[52] Ivory/Lézine 2009.
[53] Kumaran et al. 2005.
[54] Gupta 2004.

Fig. 4 Balakot: The archaeological site (BLK-1) from the south (photograph by P. Biagi 2012)

weakening of the monsoon led gradually to drying up most of the coastal vegetation.[55]

Until now no macro-remains (fruits, charred wood etc) from palaeo-mangroves have been recognised in Pakistan, in spite of R. E. Snead's claim[56] of the presence of mangrove along the western border of Lake Siranda as late as 1890. Careful inspections carried out in the area in 2012 and 2013 did not yield any evidence of mangrove trees or faunal remains, which have totally disappeared from Siranda ca. 4500 years, following the progressive drying up of the basin during the Bronze Age.

The research area

The archaeological surveys carried out in Lower Sindh and Las Bela (Balochistan) between 2000 and 2014 led to the discovery of 17 locations with molluscs evidence of palaeo-mangroves, close to the present coastline and also far inland, from Miāni Hor (Las Bela), to the Makli Hills (Thatta, Sindh). With the present 84 radiocarbon dates from *Terebralia palustris* and *Telescopium telescopium*[57] **(Table 1)**, on which the present paper is mostly based, and 22 more from marine shells (*Purpura panama, Meretrix* sp., Ostreidae, *Lunella coronata, Turbo bruneus*, Mactridae), the project still underway furnishes the first detailed data-set for the reconstruction of the early exploitation (second half of the 9th millennium BP) of mangal resources by semi-nomadic populations. Furthermore it adds new arguments to the interpretation of the evolution of the prograding Indus Delta during the last eight millennia.

[55] Gupta et al. 2003; Yoganandan et al. 2013; Zorzi et al. 2015.
[56] Snead 1966 Fig. 21, quoting the Service of India Edition 1915.
[57] Reid et al. 2008.

Table 1 List of the radiocarbon dates from mangrove gastropods from the sites mentioned in the text. Calibrations according to the marine curve by Reimer et al. 2013

Site name	Coordinates	Altitude (m)	Material	Lab. n°	$\delta^{13}C$	Uncal BP	Cal BC 2σ	Reference
SRN-43 (Lake Siranda - Las Bela, Balochistan)	25°30'25.3"N-66°38'31.7"E	8	T. palustris	GrA-54290	-3,55	7200±35	5610-5453	Biagi 2013
SRN-38 (Lake Siranda - Las Bela, Balochistan)	25°30'07.0"N-66°38'44.7"E	9	T. palustris	GrA-54303	-6,58	7095±35	5517-5332	Biagi 2013
SRN-56 (Lake Siranda - Las Bela, Balochistan)	25°29'56.3"N-66°38'56.9"E	10	T. palustris	GrA-57702	-6,17	6980±35	5436-5229	Unpublished
SRN-33 (Lake Siranda - Las Bela, Balochistan)	25°29'58.4"N-66°39'16.0"E	12	T. palustris	GrA-54291	-6,16	6770±35	5222-4978	Biagi 2013
SRN-32 (Lake Siranda - Las Bela, Balochistan)	25°29'59.5"N-66°39'17.1"E	12	T. palustris	GrA-57528	-6,66	6630±35	5049-4796	Unpublished
SRN-37 (Lake Siranda - Las Bela, Balochistan)	25°29'59.3"N-66°38'57.3"E	7	T. palustris	GrA-55821	-5,87	6595±45	5026-4746	Biagi et al. 2013a
SRN-29 (Lake Siranda - Las Bela, Balochistan)	25°30'26.8"N-66°37'35.1"E	10	T. palustris	GrA-54299	-5,57	6595±35	5008-4764	Biagi 2013
SRN-66 (Lake Siranda - Las Bela, Balochistan)	25°30'51.8"N-66°36'52.9"E	8	T. palustris	GrA-57703	-5,27	6575±35	4984-4740	Unpublished
SRN-64 (Lake Siranda - Las Bela, Balochistan)	25°31'18.0"N-66°36'43.2"E	13	T. palustris	GrA-57535	-5,19	6515±35	4917-4683	Unpublished
SRN-28.10 (Lake Siranda - Las Bela, Balochistan)	25°30'30.6"N-66°37'35.4"E	16	T. palustris	GrA-62260	-4,78	6500±40	4914-4659	Unpublished
SRN-67 (Lake Siranda - Las Bela, Balochistan)	25°30'43.8"N-66°36'52.8"E	11	T. palustris	GrA-59841	-4,75	6370±60	4780-4461	Unpublished
SRN-39bis (Lake Siranda - Las Bela, Balochistan)	25°30'08.5"N-66°38'41.2"E	9	T. telescopium	GrA-54298	-4,53	6335±35	4696-4467	Biagi 2013
SRN-63.2 (Lake Siranda - Las Bela, Balochistan)	25°32'31.1"N-66°37'09.5"E	7	T. palustris	GrA-57534	-4,1	6325±35	4686-4456	Unpublished
SRN-1 (Lake Siranda - Las Bela, Balochistan)	25°31'19.3"N-66°36'39.6"E	5	T. palustris	GrA-50325	-6,213	6305±40	4682-4436	Biagi 2013
SRN-62 (Lake Siranda - Las Bela, Balochistan)	25°31'28.8"N-66°36'44.4"E	5	T. palustris	GrA-59842	-4,73	6230±60	4630-4328	Unpublished
SRN-75 (Lake Siranda - Las Bela, Balochistan)	25°32'29"N-66°37'15"E	5	T. palustris	GrA-63864	-6,8	6220±40	4572-4338	Unpublished

Site name	Coordinates	Altitude (m)	Material	Lab. n°	$\delta^{13}C$	Uncal BP	Cal BC 2σ	Reference
SRN-40 (Lake Siranda - Las Bela, Balochistan)	25°30'09.9"N-66°38'40.4"E	4	T. palustris	GrA-55823	-3,86	6145±45	4496-4270	Biagi et al. 2013a
SRN-39 (Lake Siranda - Las Bela, Balochistan)	25°30'08.2"N-66°38'41.4"E	9	T. telescopium	GrA-55822	-4,33	6145±45	4496-4270	Biagi et al. 2013a
SRN-76 (Lake Siranda - Las Bela, Balochistan)	25°32'20"N-66°37'07"E	5	T. palustris	GrA-59840	-3,64	6100±60	4488-4212	Unpublished
SRN-63 (Lake Siranda - Las Bela, Balochistan)	25°31'19.3"N-66°36'39.4"E	6	T. palustris	GrA-63868	-4,01	6055±40	4419-4195	Unpublished
SRN-2 (Lake Siranda - Las Bela, Balochistan)	25°31'31.0"N-66°36'48.9"E	0	T. palustris	GrA-50323	-4,638	5950±40	4306-4045	Biagi et al. 2013a
SRN-31 (Lake Siranda - Las Bela, Balochistan)	25°30'01.1"N-66°39'19.0"E	4	T. palustris	GrA-55820	-5,03	5875±45	4230-3967	Biagi et al. 2013a
SRN-47 (Lake Siranda - Las Bela, Balochistan)	25°30'39.9"N-66°38'06.3"E	10	T. palustris	GrA-54296	-3,46	5800±35	4154-3920	Biagi et al. 2013a
SRN-23 (Lake Siranda - Las Bela, Balochistan)	25°30'47.7"N-66°37'39.2"E	7	T. palustris	GrA-54294	-4,67	5780±30	4118-3900	Biagi et al. 2013a
SRN-42 (Lake Siranda - Las Bela, Balochistan)	25°30'25.1"N-66°38'32.2"E	11	T. palustris	GrA-54292	-5,79	5755±35	4070-3810	Biagi et al. 2013a
SRN-73 (Lake Siranda - Las Bela, Balochistan)	25°30'26.8"N-66°37'31.7"E	9	T. palustris	GrA-57707	-3,9	5695±35	3988-3770	Unpublished
SRN-44 (Lake Siranda - Las Bela, Balochistan)	25°30'22"N-66°38'38"E	2	T. palustris	GrA-54301	-7,2	5690±35	3982-3766	Biagi et al. 2013a
SRN-24 (Lake Siranda - Las Bela, Balochistan)	25°30'48.0"N-66°37'37.4"E	5	T. telescopium	GrA-55818	-6,12	5665±45	3970-3718	Biagi et al. 2013a
SRN-72 (Lake Siranda - Las Bela, Balochistan)	25°29'31.9"N-66°36'54.7"E	7	T. palustris	GrA-57704	-4,67	5665±35	3961-3745	Unpublished
SRN-52 (Lake Siranda - Las Bela, Balochistan)	25°30'39.9"N-66°38'13.0"E	16	T. palustris	GrA-57701	-5,61	5575±35	3894-3650	Unpublished
SRN-28 (Lake Siranda - Las Bela, Balochistan)	25°30'32.4"N-66°37'35.9"E	9	T. palustris.	GrA-55819	-2,55	5440±40	3726-3510	Biagi et al. 2013a
SRN-16 (Lake Siranda - Las Bela, Balochistan)	25°31'39.1"N-66°35'53.9"E	7	T. palustris	GrA-55817	-3,86	5065±40	3329-3023	Biagi et al. 2013a
SRN-57 (Lake Siranda - Las Bela, Balochistan)	25°31'32.0"N-66°36'48.7"E	11	T. palustris	GrA-57533	-0,55	4315±35	2326-2026	Unpublished
BLK-1 (Balakot - Las Bela, Balochistan)	25°27'22.6"N-66°42'39.7"E	27	T. palustris	GrA-55828	-3,77	4660±40	2831-2498	Biagi et al. 2013a
Daun-110 (Daun Bay- Las Bela, Balochistan)	25°00'00"N-66°42'21"E	7	T. palustris	GrN-31492	-3,44	6690±40	5176-4875	Biagi 2011
Daun-111 (Daun Bay - Las Bela, Balochistan)	24°59'59"N-66°42'25"E	9	T. palustris	GrN-31493	-3,57	6590±45	5019-4739	Biagi 2011
Daun-1 (Daun Bay - Las Bela, Balochistan)	25°00'15"N-66°42'39"E	9	T. palustris	GrN-26368	-3,08	6380±40	4762-4506	Biagi 2004
Daun-10 (Daun Bay - Las Bela, Balochistan)	25°00'13"N-66°42'45"E	8	T. palustris	GrN-31489	-3,97	6305±45	4690-4427	Biagi 2011
Daun-6 (Daun Bay - Las Bela, Balochistan)	24°59'20"N-66°42'31"E	19	T. palustris	GrN-28802	1,27	5370±35	3650-3439	Biagi 2011
Daun-116 (Daun Bay - Las Bela, Balochistan)	25°00'07.9"N-66°42'23.7"E	7	T. palustris	GrA-66637	-3,52	5360±40	3639-3384	Unpublished
Daun-5 (Daun Bay - Las Bela, Balochistan)	24°59'19"N-66°42'29"E	19	T. palustris	GrN-28801	-5,44	4900±35	3072-2860	Biagi 2004
Daun-112 (Daun Bay - Las Bela, Balochistan)	25°00'00"N-66°42'28"E	16	T. palustris	GrN-32462	-4,95	4625±30	2748-2464	Biagi 2011
Daun-102 (Daun Bay - Las Bela, Balochistan)	24°59'37"N-66°42'19"E	10	T. palustris	GrN-32117	-5,96	4590±35	2702-2431	Biagi 2011
Daun-105 (Daun Bay - Las Bela, Balochistan)	24°59'34"N-66°42'21"E	9	T. telescopium	GrN-31643	-5,09	4470±40	2546-2247	Biagi 2011
Daun-104 (Daun Bay - Las Bela, Balochistan)	24°59'37"N-66°42'19"E	10	T. palustris	GrN-32118	-6,1	4470±35	2540-2261	Biagi 2011
Daun-101 (Daun Bay - Las Bela, Balochistan)	24°59'37"N-66°42'19"E	10	T. palustris	GrN-31490	-5,49	4470±30	2528-2266	Biagi 2011

Site name	Coordinates	Altitude (m)	Material	Lab. n°	$\delta^{13}C$	Uncal BP	Cal BC 2σ	Reference
Daun-113 (Daun Bay - Las Bela, Balochistan)	25°00'03"N-66°42'22"E	7	T. palustris	GrN-32463	-5,44	4455±30	2486-2230	Biagi 2011
Daun-103 (Daun Bay - Las Bela, Balochistan)	24°59'35"N-60°42'22"E	9	T. palustris	GrN-31491	-5,37	4435±40	2475-2192	Biagi 2011
Daun-119 (Daun Bay - Las Bela, Balochistan)	25°00'25"N-66°43'06"E	6	T. palustris	GrN-31644	-4,05	4165±25	2106-1870	Biagi 2011
Daun-3 (Daun Bay - Las Bela, Balochistan)	25°00'26"N-66°43'04"E	4	T. palustris	GrN-27945	-4,49	4100±30	2010-1752	Biagi 2004
Daun-117 (Daun Bay - Las Bela, Balochistan)	25°00'07"N-66°42'22"E	7	T. palustris	GrN-31494	-3,95	1440±30	1086-1282 AD	Unpublished
GDN-0 (Cape Gadani - Las Bela, Balochistan)	25°06'42.4"N-66°43'13.2"E	24	T. palustris	GrN-26369	-4,99	4460±30	2494-2234	Biagi 2004
PHR-11 (Ras Phuari - Las Bela, Balochistan)	25°05'19.0"N-66°42'26.93"E	19	T. palustris	GrA-55826	-5,09	4415±40	2467-2186	Biagi et al. 2013b
SNR-101 (Sonari, Hab River Mouth - Sindh)	24°52'38.7"N-66°41'46.78"E	12	T. palustris	GrA-62252	-4,2	4690±35	2844-2564	Unpublished
SNR-7 (Sonari, Hab River Mouth - Sindh)	24°52'27.7"N-66°41'37.8"E	14	T. palustris	GrA-59832	-2,36	4560±60	2734-2316	Unpublished
SNR-4bis/1 (Sonari, Hab River Mouth - Sindh)	24°52'39.4"N-66°41'35.2"E	27	T. palustris	GrA-62250	-3,79	4520±35	2586-2313	Unpublished
SNR-5 (Sonari, Hab River Mouth - Sindh)	24°52'38.3"N-66°41'34.9"E	27	T. telescopium	GrA-59833	-5,14	4470±60	2566-2196	Biagi and Nisbet 2014
SNR-8 (Sonari, Hab River Mouth - Sindh)	24°52'13.5"N-66°41'18.4"E	23	T. palustris	GrA-62251	-4,38	4405±35	2452-2176	Unpublished
Sonari (Sonari, Hab River Mouth - Sindh)	24°52'28"N-66°41'54"E	27	T. palustris	GrN-27054	-4,43	4080±30	1986-1731	Biagi 2004
SNR-4bis/2 (Sonari, Hab River Mouth - Sindh)	24°52'38.8"N-66°41'34.6"E	24	T. palustris	GrA-66633	-7,47	3995±35	1879-1627	Unpublished
SNR-1D (Sonari, Hab River Mouth - Sindh)	24°52'37.5"N-66°41'31.7"E	27	T. telescopium	GrA-59835	-4,42	3660±50	1491-1204	Biagi and Nisbet 2014
SNR-3 (Sonari, Hab River Mouth - Sindh)	24°52'38.2"N-66°41'41.4"E	9	T. palustris	GrA-62249	0,94	2190±30	329-560 AD	Unpublished
SNR-2 (Sonari, Hab River Mouth - Sindh)	24°52'38.9"N-66°42'02.6"E	3	T. telescopium	GrA-59834	-5,1	670±50	1800- AD	Unpublished
PSH-1bis (Pir Shah Jurio, Hab River Mouth - Sindh)	24°55'39.1N-66°44'28.2"E	35	T. palustris	GrA-66638	-4,15	4270±35	2265-1974	Unpublished
PSH-1 (Pir Shah Jurio, Hab River Mouth - Sindh)	24°55'39.1N-66°44'28.2"E	35	T. palustris	GrN-26370	-4,38	4130±20	2035-1806	Biagi 2004
RHR-3bis (Rehri, Karachi - Sindh)	24°49'12"N-67°13'42"E	10	T. palustris	GrA-66631	-4,13	7045±45	5483-5287	Unpublished
MH-15 (Mulri Hills, Karachi - Sindh)	24°55'41"N-67°07'14"E	67	T. palustris	GrA-63863	-4,01	7320±40	5711-5524	Unpublished
MH-14 (Mulri Hills, Karachi - Sindh)	24°55'42"N-67°07'25"E	65	T. telescopium	GrA-63869	-4,57	6155±40	4504-4300	Unpublished
MH-4B (Mulri Hills, Karachi - Sindh)	24°55'47"N-67°07'57"E	65	T. palustris	GrA-66630	-5,24	6035±40	4379-4156	Unpublished
MH-18 (Mulri Hills, Karachi - Sindh)	24°54'45"N-67°06'30"E	65	T. palustris	GrA-23639	-6,6	5790±70	4211-3816	Biagi 2004
MH-17 (Mulri Hills, Karachi - Sindh)	24°54'43"N-67°07'55"E	65	T. palustris	GrA-66634	-3,98	5530±40	3850-3617	Unpublished
Garo-1 (Bhambor - Sindh)	24°45'36.3"N-67°33'17.4"E	31	T. telescopium	GrA-59844	-3,64	6320±60	4726-4408	Unpublished
THR-3 (Tharro Hills, Gujo - Sindh)	24°43'46"N-67°45'07"E	13	T. palustris	GrA-47084	-5,15	5555±35	3876-3635	Biagi 2011
Beri (Gujo - Sindh)	24°43'00"N-67°45'09"E	7	T. palustris	GrN-32166	-6,9	5960±50	4320-4041	Biagi 2010
JSH-1bis (Shah Husein, Gujo - Sindh)	24°42'26.0"N-67°48'38.3"E	12	T. telescopium	GrA-66636	-4,79	5800±40	4165-3910	Unpublished
JSH-2 (Shah Husein, Gujo - Sindh)	24°42'26"N-67°48'39"E	19	T. telescopium	GrA-45181	-3,21	4245±40	2230-1926	Biagi 2010

Site name	Coordinates	Altitude (m)	Material	Lab. n°	$\delta^{13}C$	Uncal BP	Cal BC 2σ	Reference
JSH-10 (Shah Husein, Gujo - Sindh)	24°42'09.8"N-67°48'28.1"E	14	T. telescopium	GrA-62255	-5,18	2715±30	339-78	Unpublished
KKT-2 (Kalan Kot, Thatta - Sindh)	24°42'17.3"N-67°52'23.5"E	22	T. palustris	GrN-32464	-5,5	6320±45	4700-4442	Biagi 2011
MKL-10 (Makli Hills, Thatta - Sindh)	24°37'40.6"N-67°51'41.2"E	25	T. telescopium	GrA-62256	-7,02	6140±40	4486-4274	Unpublished
MKL-1 (Makli Hills Thatta -Sindh)	24°36'52.5"N-67°51'36.5"E	24	T. palustris	GrA-50330	-3,929	5750±40	4074-3796	Unpublished
KKT-4 (Kalan Kot, Thatta - Sindh)	24°42'15.3"N-67°52'15.7"E	27	T. telescopium	GrA-59843	-7,03	5460±60	3788-3498	Unpublished
KKT-3 (Kalan Kot, Thatta - Sindh)	24°41'54.8"N-67°52'40.4"E	32	T. telescopium	GrA-50324	-5,01	5270±40	3579-3336	Unpublished
OBS-1 (Aban Shah, Thatta - Sindh)	24°22'17.8"N-67°58'20.6"E	8	T. palustris	GrA-47082	-9,17	3790±35	1616-1398	Biagi 2011
KRM-13 (Kot Raja Manjera, Jerrack - Sindh)	25°01'21"N-68°12'37"E	45	T. palustris	GrA-47083	-6,17	4635±35	2771-2469	Biagi 2011

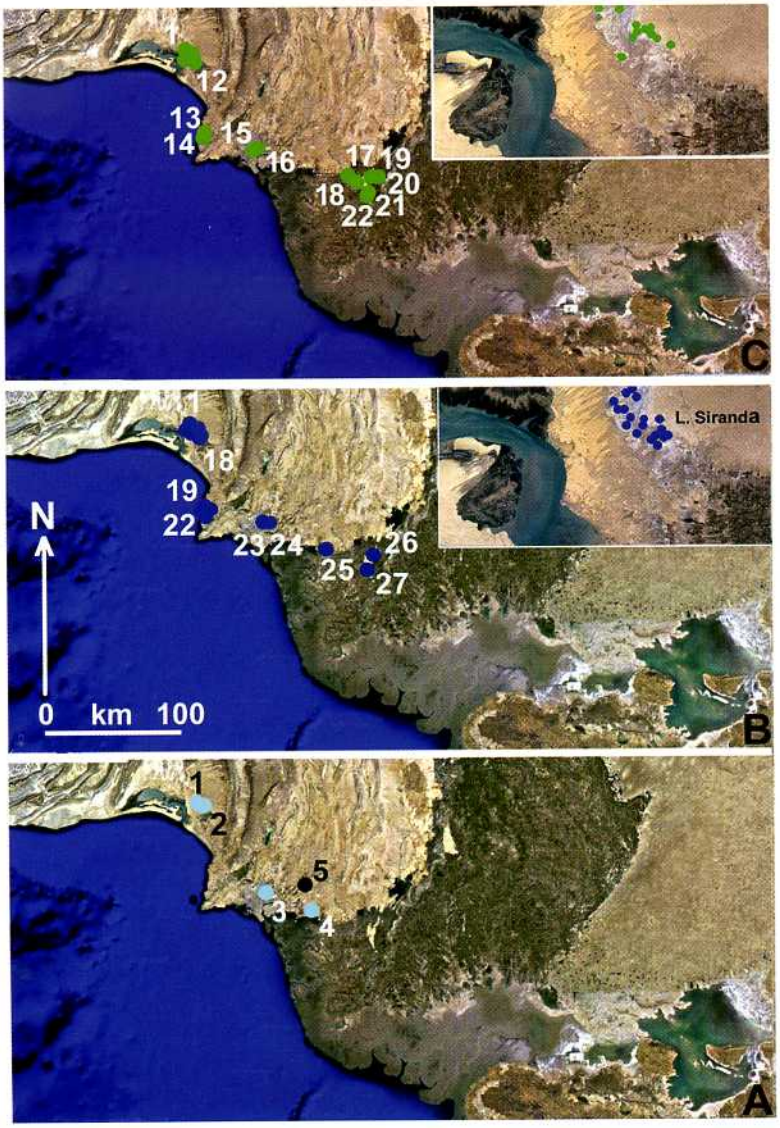

Fig. 5 Distribution map of the radiocarbon-dated shell middens and shell scatters in the study area: A) 8th millennium BP (light blue): SRN-43 (1), SRN-38 (2), MH-15 (3), RHR-3bis (4); 9th millennium BP: KDJ-1 (5) (black); B) 7th millennium BP (blue): SRN-56, SRN-33, SRN-32, SRN-37, SRN-29, SRN-66, SRN-64,SRN-28.10, SRN-67, SRN-39bis, SRN-63.2, SRN-1, SRN-62, SRN-75, SRN-40, SRN-39, SRN-76, SRN-60 (1-18), Daun-110, Daun-111, Daun-1, Daun-10 (19-22), MH-14 (23), MH-4B (24), GARO-1 (25), KKT-2 (26), MKL-10 (27); C) 6th millennium BP (green): SRN-2, SRN-31, SRN-47, SRN-23, SRN-42, SRN-73, SRN-44, SRN-24, SRN-72, SRN-52, SRN-28, SRN-16 (1-12), Daun-6 (13), Daun-116 (14), MH-18 (15), MH-17 (16), THR-3 (17), Beri (18), JSH-1bis (19), MKL-1 (20), KKT-4 (21), and KKT-3 (22) (drawings by R. Nisbet and P. Biagi)

The surveyed region spans from the shallow depression of Siranda (Las Bela district, Balochistan), the high coastline between Cape Gadani and the mouth of the Hab River, to the flats of the Indus Delta with some remnants of the pre-deltaic Eocene limestone reliefs, the Makli Hills, south of Thatta, and Aban Shah in the lower Delta plain.[58] Moreover, the research carried out along the limestone mesas of the western side of the Indus, between Ongar, Meting and Jhimpir, while resulting in the discovery of many archaeological sites from the Lower Palaeolithic to Historical times,[59] yielded evidence of Bronze Age *T. palustris* shells at Kot Raja Manjera, near Jerruck (Jhirak).[60] This is, at the moment, the northernmost point from which mangrove shells have been found, some 150 km as the crow flies from the present Indus mouth **(Fig. 5 and 6)**.

Before the construction of dams and barrages along its course,[61] the Delta shoreline advanced at an average rate of ca. 45 m/year, with maxima of 150 m/year at the mouth of active channels.[62] The importance of recognising the complex history of

58 Blanford 1880.
59 Starnini/Biagi 2011.
60 Khan 1979a, 6, 1979c, 71-72; Cousens 1998, 87; Biagi 2010.
61 Pithawalla 1939; Panhwar 1964; Rahman 1988.
62 Hayter 1960; Giosan et al. 2006.

the coastline changes in the millennia,[63] in relationship with the prehistoric human presence, is easily understood. Several calculations have been made also regarding the rate of rising of the alluvial plain in the Delta area. According to H. T. Lambrick[64] a rise of 20 to 30 cm a century is quite a realistic figure, and the central part of the plain would have increased for ca. 9 m in the last 5,000 years. More recent estimates[65] display offshore sedimentation rates of 50 cm/year at the mouth of the active channel, in the Indus canyon, and huge quantities of sediments, calculated in terms of 250 megatonne per year, were supplied by the river prior to modern damming.[66]

Mangroves and radiocarbon dates

As reported above, the 2000-2014 surveys carried out along the Las Bela coast and the Indus Delta led to the discovery of dozens of prehistoric sites. The research was coupled with a wide programme of radiocarbon dating made mainly on mangrove, but also marine shells, whose scope was to define the chronology of the prehistoric exploitation of the coastal forests. Furthermore carbon isotopes are an excellent way to understand the changing landscape of the Indus Delta, one of the most active coastlines of the world.[67]

The description of the aforementioned changes are based on radiocarbon dates mainly obtained from the apex of one single specimen of adult, decoloured, mangrove Gastropod weighing 5 to 10 grams, collected from the centre of each site. *T. palustris* was preferably selected or, in its absence, *T. telescopium* (see **Table 1**). They all were dated at Groningen University Isotope Laboratory: GrA- in the case of AMS dates from one individual, and more specimens of the same species in the case of ordinary dates (GrN-) processed before 2004. The dates throughout the text are given as uncal BP unless otherwise stated.

Three main large areas have been considered: 1) the Siranda basin, at present a sabkha-like saline depression, some 15 km long and 4 km wide, whose south-western side lies 5 km from the Sonmiani Lagoon (Miāni Hor) and ca. 15 km from the present sea-shore; 2) the coast between Cape Gadani and the mouth of the Hab River that marks the boundary between Balochistan and Sindh, with its long low-lying shores (like partially at Daun) and some headlands of solid massive rocks (f.i. at Gadani, Phuari, Daun and Sonari); and 3) the Indus Delta, corresponding in our survey to the coast from Karachi to Aban Shah, south of Thatta in longitude, and Gharo-Makli Hills (Thatta) to Kot Raja Manjera (Jerruck) in latitude **(Fig. 7)**.

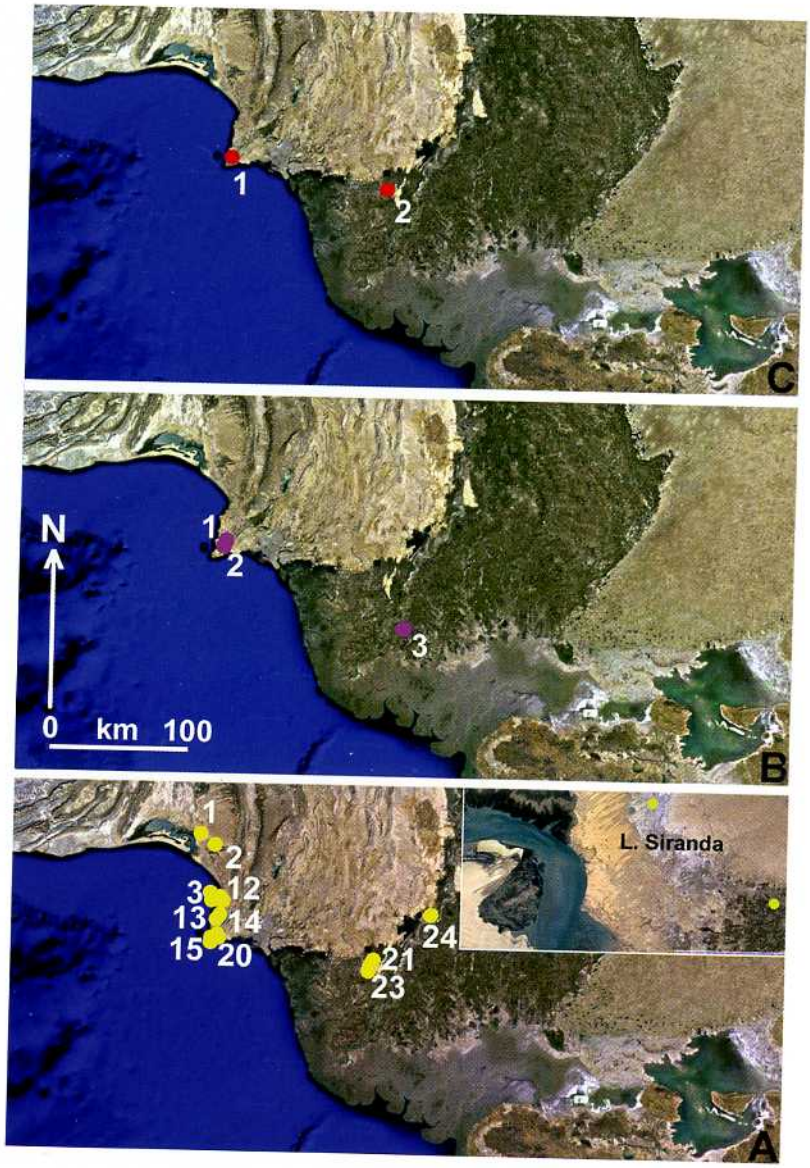

Fig. 6 Distribution map of the radiocarbon-dated shell middens and shell scatters in the study area: A) 5th millennium BP (yellow): SRN-57 (1), BLK-1 (2), Daun-5, Daun-112, Daun-102, Daun-105, Daun-104, Daun-101, Daun-113, Daun-103, Daun-119, Daun-3 (3-12), GDO-0 (13), PHR-11 (14), SNR-101, SNR-7, SNR-4bis/1, SNR-5, SNR-8, Sonari (15-20), PSH-1bis (21), PSH-1 (22), JSH-2 (23), KRM-13 (24); B) 4th millennium BP (violet): SNR-4bis/2 (1), SNR-1D (2), OBS-1 (3); C) 3rd millennium BP (red): SNR-3 (1), and JSH-10 (2) (drawings by R. Nisbet and P. Biagi)

63 East et al. 2015.
64 Lambrick 1986.
65 Inam et al. 2007.
66 Clift/Giosan 2014; Clift et al. 2014.
67 Wells/Coleman 1984; Meadows/Meadows 1999; Shuaib/Tariq Shuaib 1999.

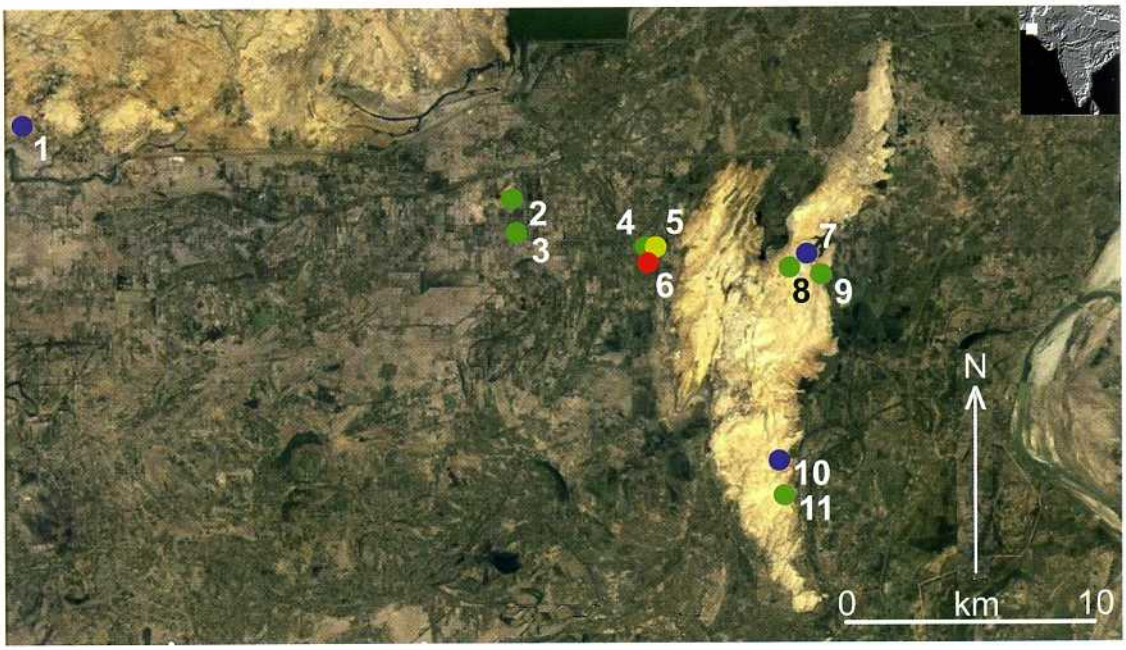

Fig. 7 Distribution map of the radiocarbon-dated sites from mangrove specimens from Bhambor, in the west, to the Makli Hills, in the east. Garo-1 (1), THR-3 (2), Beri (3), JSH-1bis (4), JSH-2 (5), JSH-10 (6), KKT-2 (7), KKT-4 (8), KKT-3 (9), MKL-10 (10), and MKL-1 (11) (drawing by P. Biagi)

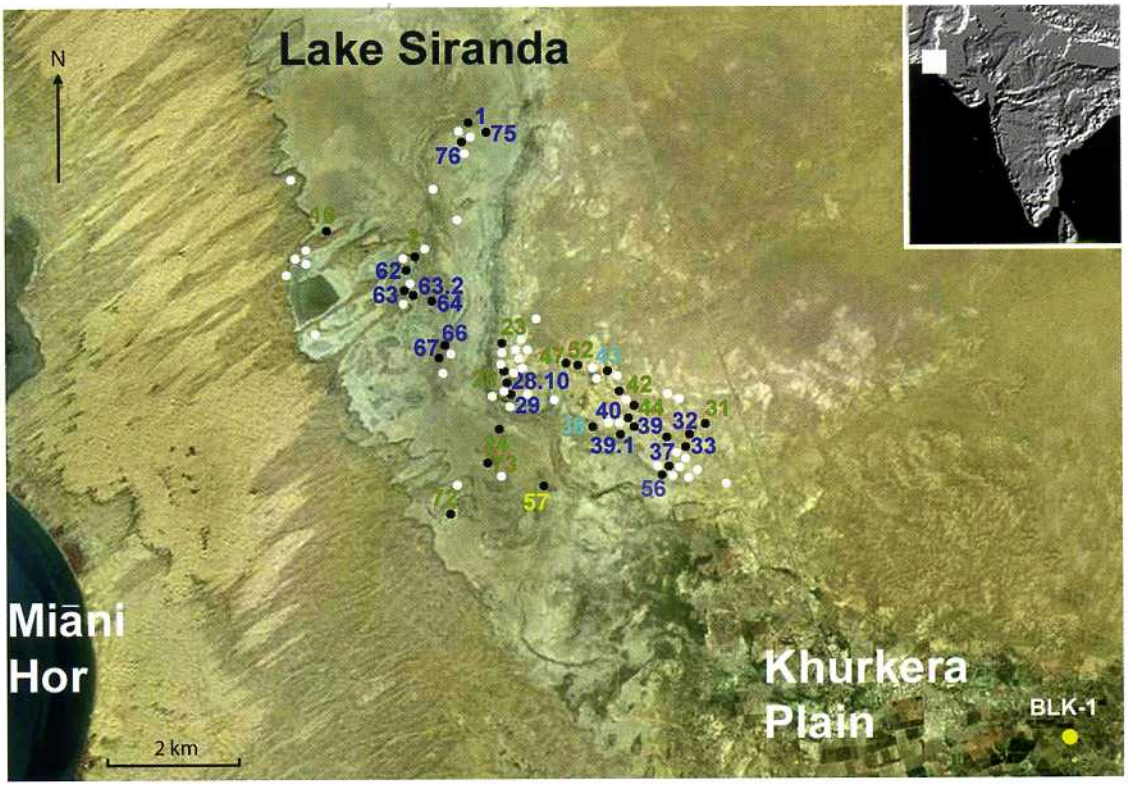

Fig. 8 Lake Siranda: Distribution map of the archaeological sites, mainly shell middens, discovered during the 2010-2014 surveys. 8th millennium BP (light blue), 7th millennium BP (blue), 6th millennium BP (green), 5th millennium BP (yellow), white dots represent undated sites, Balakot (BLK- 1) (drawing by R. Nisbet)

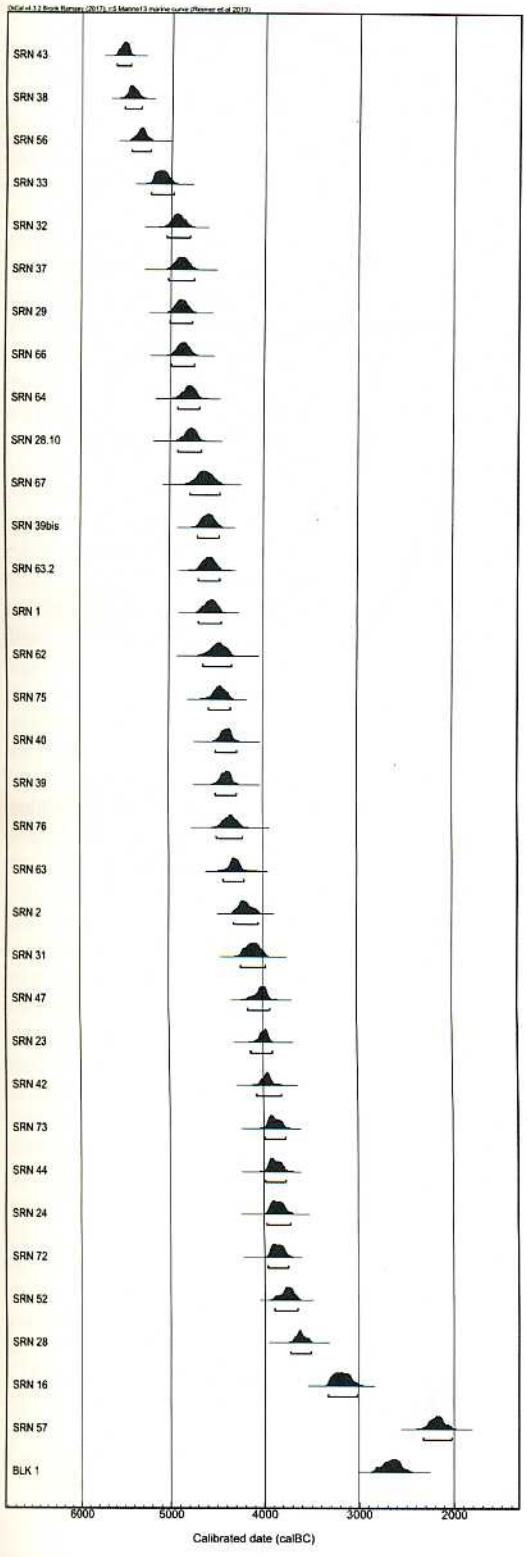

Fig. 9 Lake Siranda: Plot of the calibrated dates obtained from mangrove gastropods from the shell middens, and the Chalcolithic/ Bronze Age site of Balakot (BLK-1) (Las Bela, Balochistan) (scatterplot by T. Fantuzzi)

1) Siranda palaeo-lagoon

At present a detailed sequence in the use of palaeo-mangroves is known from Lake Siranda.[68] The early morphological history of the basin is still poorly understood.[69] It is accepted by the authors that it was formerly part of the present Sonmiani Lagoon (Miāni Hor), sharing with it its dominant environmental aspects and that it "*functioned as a tidal lagoon in the not-too-distant past*" **(Fig. 8)**.[70] According to the above author Siranda was formerly connected to Sonmiani Lagoon from which it was later separated by sand dune formations, eventually stabilised by vegetation.[71]

The 33 radiocarbon dates so far obtained from the area **(Fig. 9)** show that the first exploitation of mangroves started ca. one century after the radiocarbon result obtained from the Mulri Hills, east of Karachi (MH-15, GrA-63863: 7320±40 BP), and lasted for the entire 7th and 6th millennia BP. The earliest dates, spanning from the last centuries of the 8th and the middle of the 7th millennium BP, come from sites located along the south-eastern side of the basin, some of which yielded chipped stone assemblages with geometric microliths obtained mainly from Gadani reddish-brown flint **(Fig. 10)**. Just after the mid 7th millennium BP the sites spread toward north-east, at the inner sides of the depression. After this period the shell middens seem to

68 Minchin 1907: 9; Hughes-Buller 1908: 96.
69 Biagi et al. 2013b.
70 Snead 1966, 60.
71 Snead 1969, 34.

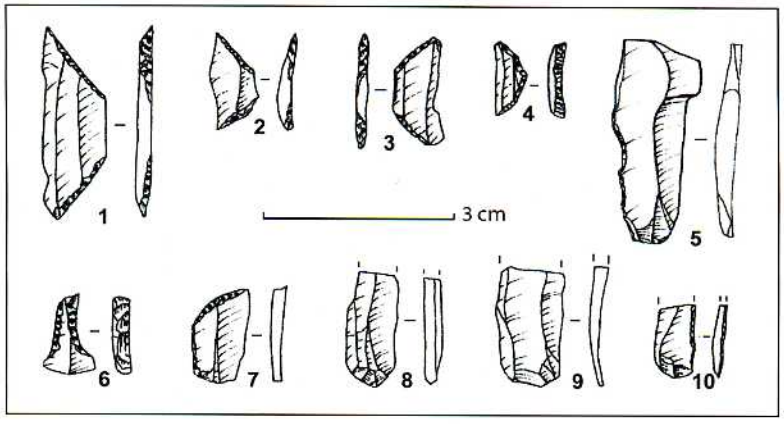

Fig. 10 Lake Siranda: chipped stone tools of Gadani reddish-brown flint from shell midden SRN-29: trapezoidal geometrics (1–3), lunate (4), backed bladelets (5, 10), micro-drill (6), truncation (7) and unretouched bladelets (8, 9) (from Biagi et al. 2013b fig. 6)

disappear from the northern part of the palaeo-lagoon, and are found again at its south-western corner.

Quite rapid shift of sites to its southern margin took place between the end of the 6th and the end of the 5th millennium BP, showing the progressive desiccation of the ancient lagoon, which would have lost its connections with the sea probably by the end of the 5th millennium BP, when the sea-level started to decrease.[72] The more recent shell midden found at Siranda yielded a date of 4315±35 BP (SRN-57, GrA-57533), which is three centuries more recent than that obtained from a *T. palustris* specimen collected from the surface of Balakot, ca. 10 km to the south-east (BLK-1, GrA-55828: 4660±40 BP). The stratified Chalcolithic/Bronze Age mound of Balakot **(Fig. 4)** developed during the last phases of exploitation of the Siranda palaeo-mangrove, as shown by many *Terebralia palustris* shells retrieved from the Bronze Age occupation layers.[73] In effect they are very common to the Bronze Age Indus period settlement, where they represent 67% of the total shell assemblage, while their presence reaches only 18% in the Chalcolithic layers.

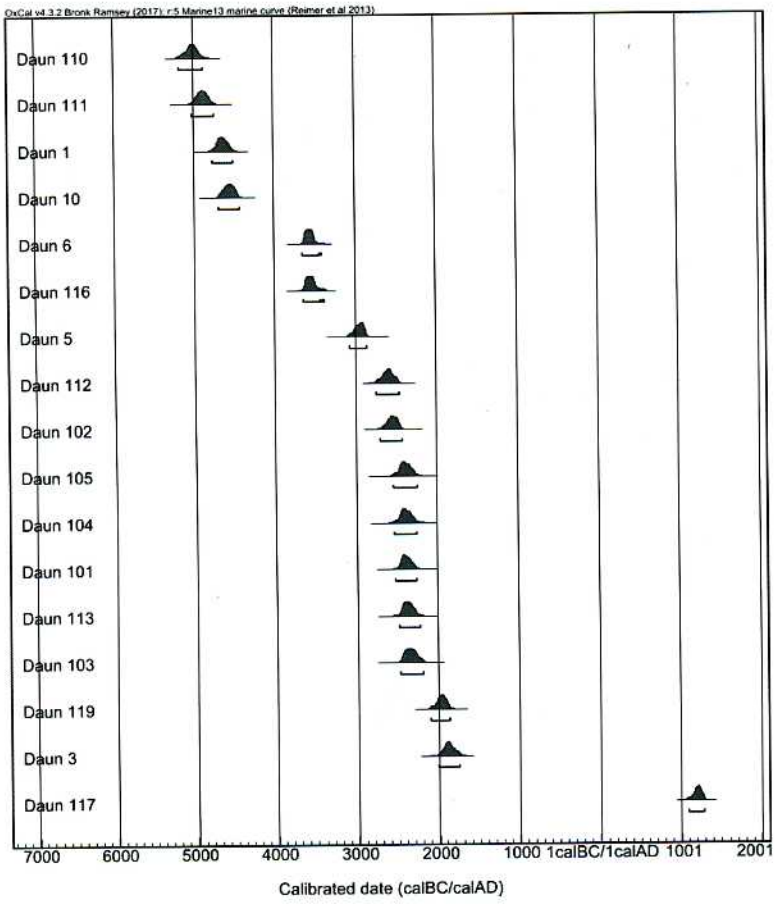

Fig. 11 Daun: Plot of the calibrated dates obtained from mangrove gastropods from the shell middens (scatterplot by T. Fantuzzi)

[72] Gupta 1972: 360.
[73] Dales 1974; Meadow 1979: Fig. 6.

2) The Balochistan coast between Cape Gadani and the Hab River mouth

South of Sonmiani Lagoon the coast forms a long, low sandy strip, interrupted only by two rocky headlands at Gadani and Phuari. The first belongs to the Bela Ophiolite, a sequence of basaltic pillow-lavas, inter-flow sedimentary rocks (chert, argillite and limestone) mostly of Upper Cretaceous age[74] emerging as the western part of Mor Range, and the Parh limestone formation (Upper Cretaceous), a unit of the Pab Range.

Ras Gadani is separated from Ras Phuari, some 3.5 km to the south, by a sand strip that runs in a NNE-SSW direction, in the centre of which is a small, seasonal stream called Kunari Dhora, which flows into the Arabian Sea. The Bela Ophiolithes outcrop runs along the coast, south of the mouth of the Kunari Dhora as far as Ras Phuari. Two almost identical dates from Gadani (GDN-0, GrN-26369: 4460±30 BP) and Ras Phuari (PHR-11, GrA-55826: 4415±40 BP) prove the existence of mangroves probably at the mouth of the mentioned small streams, around the middle of the 5th millennium BP, a time when Siranda palaeo-lagoon had already transformed into a saline depression, fed only by monsoon rains and seasonal rivers.[75]

Further south, the shell middens of Daun Bay lie partly along the sand beach around and south of the bay, some 4-10 m above the maximum level reached by the tide, partly on the top of the Pleistocene marine terrace (16-20 m) extending south of a small headland.[76] Their distance from the present shoreline varies from 60 to 700 m. Most sites consist of heaps or scatters of fragmented *Terebralia palustris* gastropods,[77] although other mangrove and marine species are represented, among which are *Telescopium telescopium* and *Anadara uropygmelana*.

The radiocarbon results from the Daun sites indicate that the exploitation of the mangrove resources was not "continuous" **(Fig. 11)**. It took place mainly during two distinct periods of the middle of the 7th and the 5rd millennium BP respectively,[78] thus pointing to the existence of coastal forests at the same time as at Siranda. The first cluster of Daun dates, belonging to the Neolithic, shows a

[74] Blanford 1880; Vredenburg 1909; Sarwar 1992.
[75] Minchin 1907; Biagi et al. 2013b.
[76] Snead 1966, 47; 1967; 1969, 38; Snead/Frishman 1968, 1673.
[77] Biagi 2004; Biagi/Franco 2008; Biagi et al. 2012.
[78] Biagi et al. 2012.

$\delta^{13}C$ ratio ranging from -3.44 to -3.97, which is compatible with a mixed marine mangrove ecosystem. A more recent sporadic episode of exploitation, which took place during the Chalcolithic (Daun-6, GrN-28802: 5370±35 BP and Daun-116: GrA-66637: 5360±40 BP), shows in one case a dramatic increase to +1.27 (GrN-28802), possibly an indicator of environmental stress. The samples obtained from the second main cycle of exploitation of Daun Bay, as well as Capes Gadani and Phuari, show once again lower $\delta^{13}C$ (-4.49 to -6.10) that are typical of a healthy mangrove ecosystem with mixed marine and freshwater. However, a much more recent result obtained from one single *T. palustris* sample shows that mangroves were still growing immediately south of the bay in historical times (Daun-117, GrN-31494: 1440±30 BP).

At the southern mouth of the Hab River the southernmost extension of Pab Range rises with its Jhill limestone unit, a member of the Miocene Gaj Formation.[79] On the top of a saddle 30-40 m high located near the village of Sonari, ca. 7 km north-east of Ras Mauri (Cape Monze) **(Fig. 12)**, local prehistoric fishermen living in rectangular stone structures **(Fig. 13)** collected mangrove Gastropods in a tidal forest certainly growing along the estuary of the Hab River **(Fig. 14)**, at least since the early 4th millennium BP.[80] Similar dates were obtained from the Bronze Age Indus Civilisation small settlement of Pir Shah Jurio (PSH-1, GrN-26370: 4130±20 BP; PSH-1bis, GrA-66638: 4270±35 BP) located on a protruding terrace along the left, eastern bank of the Hab River, surrounded by alluvium, some 6.5 km north-east of its mouth[81] **(Fig. 15)**. The last two results from Sonari (SNR-3, GrA-62249: 2190±30 BP and SNR-2, GrA-59834: 670±50 BP), and one from Daun (Daun-117, GrN-31494: 1440±30 BP) are so far the only historical dates available for the Pakistani palaeo-mangroves **(Fig. 16)**.

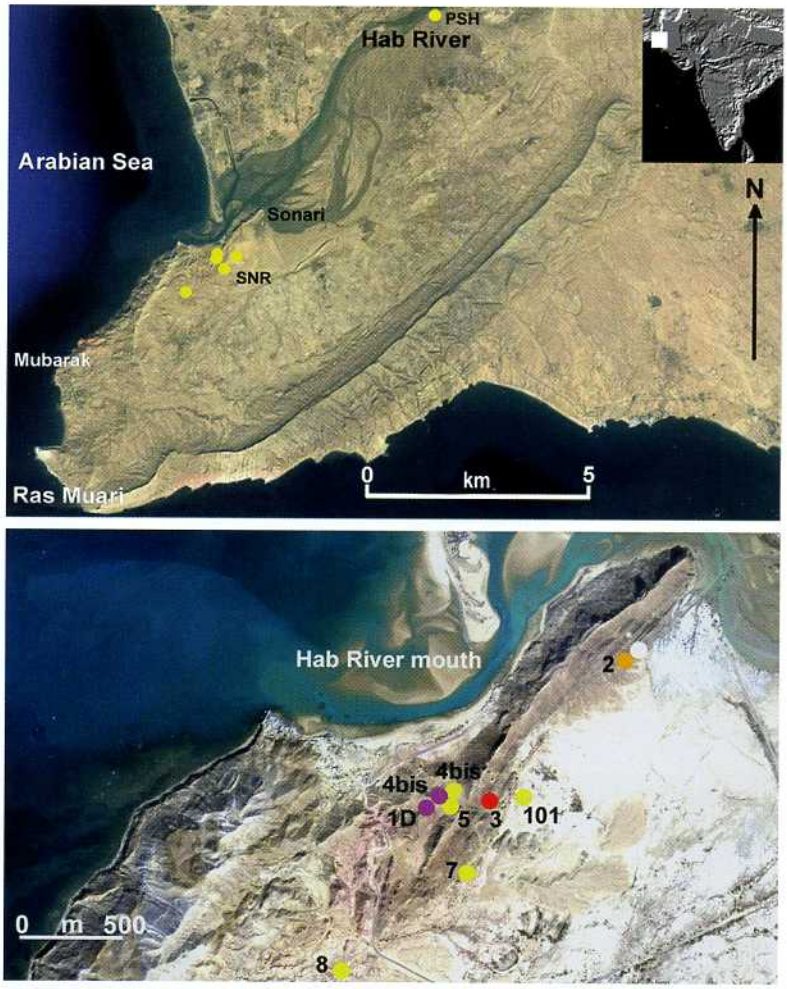

Fig. 12 Sonari: Distribution map of the 5th millennium BP sites radiocarbon-dated from mangrove gastropods: PSH is Pir Shah Jurio (top); distribution map of the 5th millennium BP (yellow), 4th millennium BP (violet), 3rd millennium BP (red), and Historical period (ochre). The white dot is a group of Islamic tombs (bottom) (drawings by P. Biagi)

[79] Blanford 1880; Naseem et al. 1996.
[80] Biagi/Nisbet 2014.
[81] Fairservis 1993 Fig. 9.1.

Fig. 13 Pir Shah Jurio: the mature Indus Civilisation site (top), and *Terebralia palustris* specimens from the surface of the same site (bottom) (photographs by P. Biagi 2014)

Fig. 14 Sonari: location of the radiocarbon-dated Bronze Age fishermen site SNR-1, in the centre of the saddle (top), and rectangular stone structures filled with marine and mangrove shells from the same site (bottom) (photographs by P. Biagi 2013)

Fig. 15 Sonari: The Hab River mouth from the south, with the location of the Islamic cemetery (ochre dot) (photograph by P. Biagi 2013)

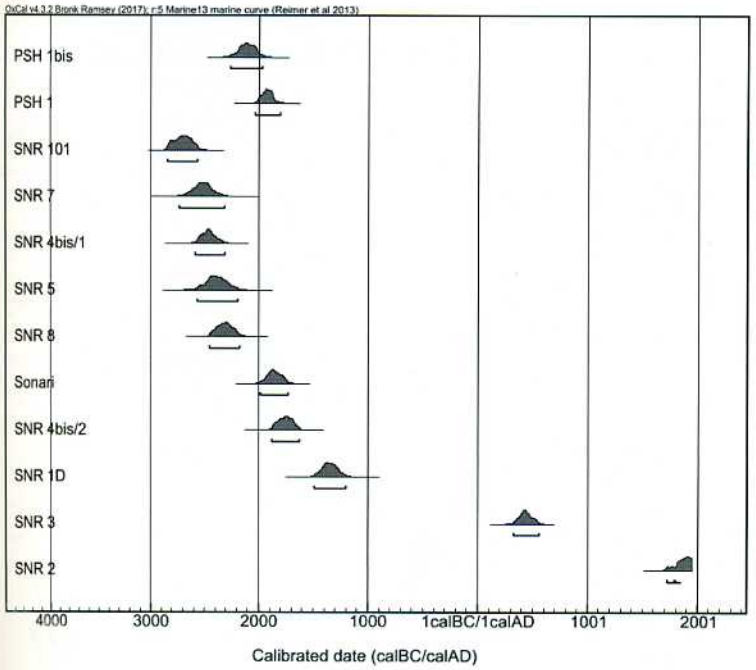

Fig. 16 Sonari: Plot of the calibrates dates obtained from mangrove gastropods (scatterplot by T. Fantuzzi)

3) The Indus Delta

The date from the Mulri Hills, at the eastern outskirts of Karachi (MH-15, GrA-63863: 7320±40 BP), is the oldest radiocarbon result available to date from mangrove gastropods showing the presence of mangroves along the seaside of present-day Pakistan. The Mulri Hills are a unique location in the entire study region. Their surface was literally covered with Late (Upper) Palaeolithic and Mesolithic sites until the 1980s. The hills are rich in freshwater that gushes out of roughly east-west oriented faults, from which originate small streams that flow southward down into the Malir River and soon after the Ghizri Creek west of Rehri, and Kadiro Creek.[82] Given the inland position of the hills ca. 70 m high[83] it is probable that the *T. palustris* shells were collected from mangroves that flourished along the coast ca. 8 km to the south, where they still survive (Manora Island and surrounding areas) or along the mouth of the Malir River at Ghizri Creek and further south, or east at Kadiro Creek[84] **(Fig. 17)**. It is important to point out that a date similar to the oldest so far available from the Mulri Hills (MH-15, GrA-63863: 7320±40 BP) comes from a *T. palustris* scatter found at Rehri, a location facing the latter aforementioned creek (RHR-3bis, GrA-66631: 7045±40 BP) **(Fig. 18)**. However, according to Professor A. R. Khan the whole coastal area around Karachi has been subjected to at least three phases of uplift during the Holocene, with the formation of a series of raised beaches and marine terraces (at 6-7 m, 9-12 m and over 15 m respectively).[85] How effective these tectonic processes were instrumental in causing changes to the coastal mangroves is still to be understood, as they resulted in the seaward advance of the shoreline.

Moving eastward, the first AMS-dated occurrence of *Telescopium telescopium* is known from Gharo (Garo-1, GrA-59844: 6320±60 BP). Located on a limestone terrace, at an altitude of ca. 30 m, the site is 4-5 km from the ruins of the 8th-13th century AD Gharo Creek outpost of Bhambor,[86] at present along the shore of an active channel of the Indus River and close to the actual mangrove.

A consistent number of radiocarbon dates has been obtained west and south of Thatta, one of the ancient capitals of Sindh. The shell middens are located some 30 km from the present western coastline, and more than 80 km from the mouth of the main Indus channel, in the south. Almost all the samples come from the top or, less frequently, the side of isolated tracts of calcareous and sandstone hillocks, rising from the alluvial plain between 10 and 30 m, at an elevation of 15-40 m above the sea level. These features were undoubtedly surrounded by the sea before the advance of the Delta, forming

82 Khan 1979b; Biagi 2003-2004, 2017.
83 Zaidi et al. 1999.
84 Snedaker 1984; Kazi 1999.
85 Khan 1979a, 19-21.
86 Majumdar 1934, 19; Cousens 1998, 64; Felici et al. 2016.

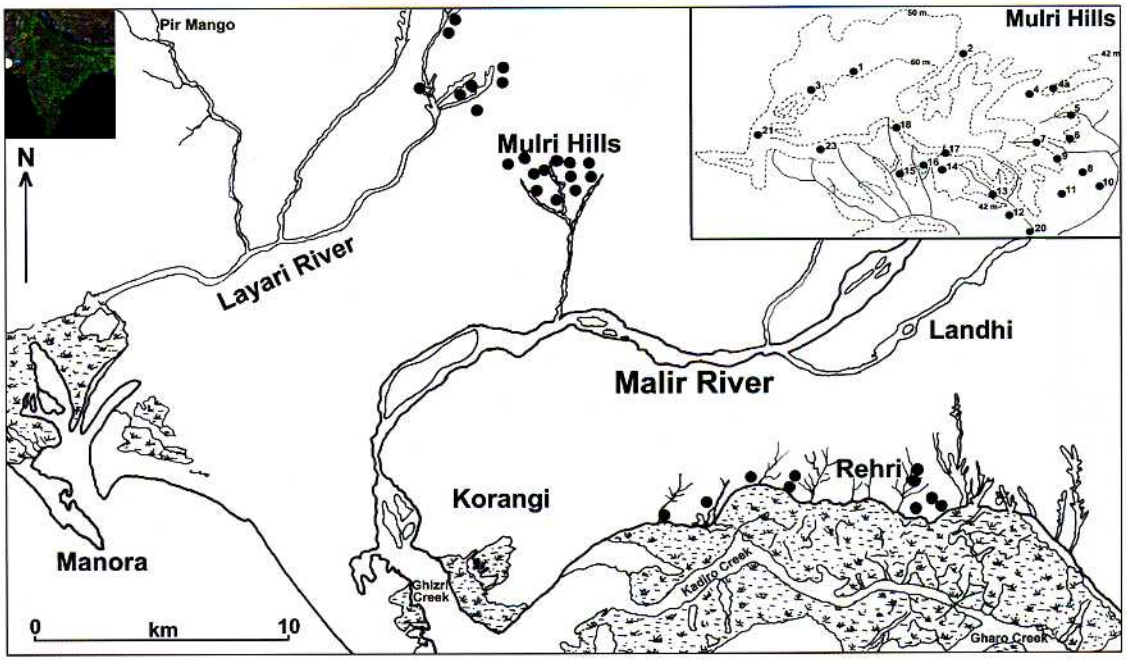

Fig. 17 Mulri Hills: Distribution map of the sites at the eastern outskirts of Karachi. The other black dots show the location of some archaeological sites discovered by Professor A. R Khan in the late 1970s (drawing by P. Biagi)

an archipelago which could be easily reached from the coast even in historical times. Arrian's account on Nearchos journey mentions some "isles" when the fleet reached the sea. The more evident of these elevations are the Makli Hills, running north-south with the ruins of an impressive fortress known as Kalan Kot (8th to 18th century according to Cousens),[87] close to which the earliest date for the area has been obtained (KKT-2, GrN-32464: 6320±45 BP) **(Fig. 19-21)**.

The results yielded by nine sites show the presence and exploitation of mangroves since the mid 8th to the end of the 6th millennium BP. There are, however, interesting exceptions from Shah Husein (JSH-1bis, GrA-66636: 5800±40 BP; JSH-2, GrA-45181: 4245±40 BP and JSH-10, GrA-62255: 2715±30 BP), an isolated rocky cliff ca. 13 km west-southwest from Thatta, from which we have evidence of several mangrove shell scatters as well as chipped stone artefacts **(Fig. 22)**. The latter date shows that a mangrove environment lasted locally probably as late as the Hellenistic period, along one or more creeks connecting the site to the seaside over a period of four millennia.

Some 13 km west of Thatta, and 3 south-west of Gujo, another limestone terrace is well known in the archaeological literature as a fortified Amri Culture site, from the surface of which thousands of chipped stone tools have been retrieved.[88] The site, known as Tharro Hills, is located at the south-eastern edge of the terrace. It is surrounded by two parallel, semi-circular stone walls **(Fig. 23)**. During the intensive survey carried out in January 2008,[89] many specialised areas were recorded, 41 of which yielded characteristic Amri chipped stone tools, among which are bladelets with semi-abrupt retouch, truncations and typical elongated scalene triangles[90] **(Fig. 24)**, and a few characteristic painted potsherds. Two radiocarbon dates were obtained from samples of Ostreidae (THR-1, GrN-27053: 5240±40 BP) and *T. palustris* (THR-3, GrA-47084: 5555±35 BP) respectively recovered from a well-defined spot of shells located along the southern edge of the inner wall, confirming once again attribution of the site to the Chalcolithic.

South of the Tharro Hills another Chalcolithic site was discovered at the top of a small limestone terrace rising from the Indus alluvium, locally called Beri.[91] A *Terebralia palustris* shell sample was collected from the surface of this site, later radiocarbon-dated to 5960±50 BP (Beri-1, GrN-32166)

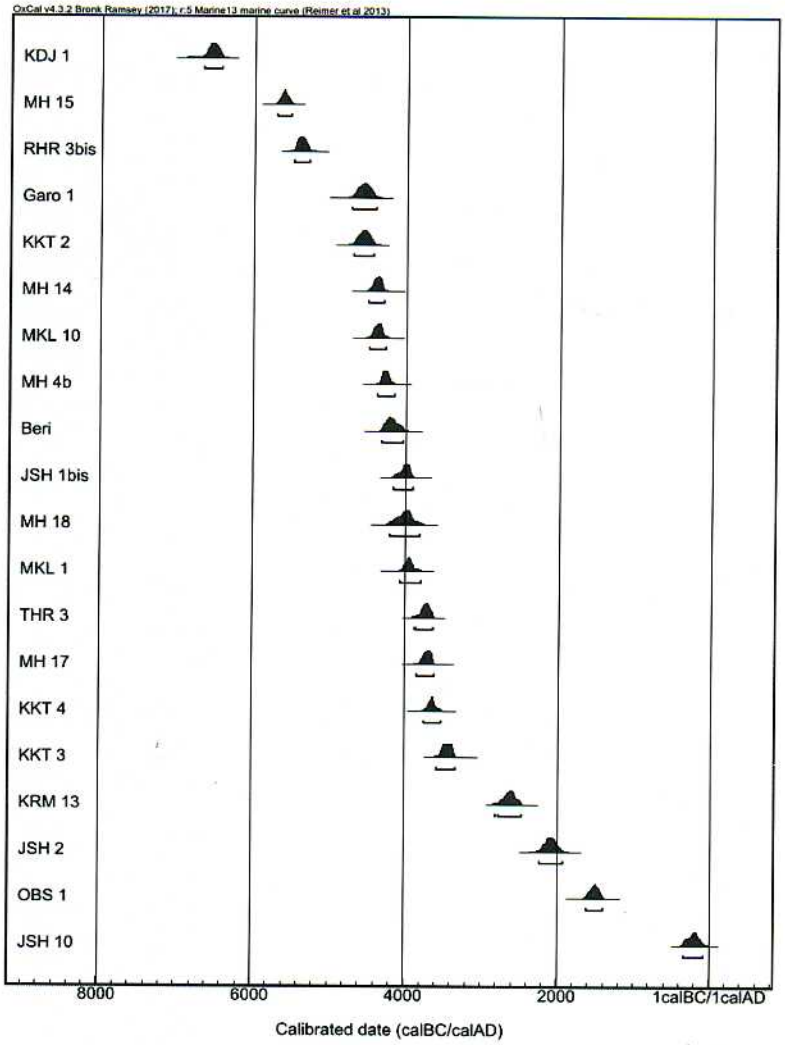

Fig. 18 Indus Delta: Plot of the calibrated dates obtained from mangrove gastropods from the shell middens (scatterplot by T. Fantuzzi)

The only dated site on the left bank of Indus is an isolated rocky hill known as Aban Shah **(Fig. 25)**. The site lies some 70 km north of the present Arabian Sea shore. The date (ABS-1, GrA-47082: 3790±35 BP) provides evidence of a local mangrove still growing after the end of the Bronze Age. It shows that 1) the progress of the coastline has been relatively slow (20 km/3500 years) in comparison with other points of the Delta; 2) the presence of mangroves surrounding the site during the early 4th millennium BP would exclude it as the island "*out in the sea*" of the 4th century BC reported by Arrian, erroneously considered by H. T. Lambrick[92] the islet on which Alexander landed, before sailing back to Pattala.[93]

87 Cousens 1998.
88 Majumdar 1934; Piggott 1950; Khan 1979a, 5; Biagi 2005.
89 Biagi/Franco 2008.
90 Biagi 2005.
91 Biagi 2010, 9.
92 Lambrick 1986, 113.
93 see Eggermont 1975 Map 2.

Fig. 19 Makli Hills: The site of Kalan Kot 2 (KKT-2) (top), and the eastern edge of the hills, along the central part of the terrace looking at the Indus alluvial plain (bottom) (photographs by P. Biagi 2011)

Fig. 20 Makli Hills: The site of Kalan Kot 4 (KKT-4) (top), and fragments of *Telescopium telescopium* mangrove gastropods on its surface (bottom) (photographs by P. Biagi 2012)

Fig. 21 Makli Hills: The site of MKL-10 (blue spot) (top), and fragments of marine shells on its surface (bottom) (photographs by P. Biagi 2013)

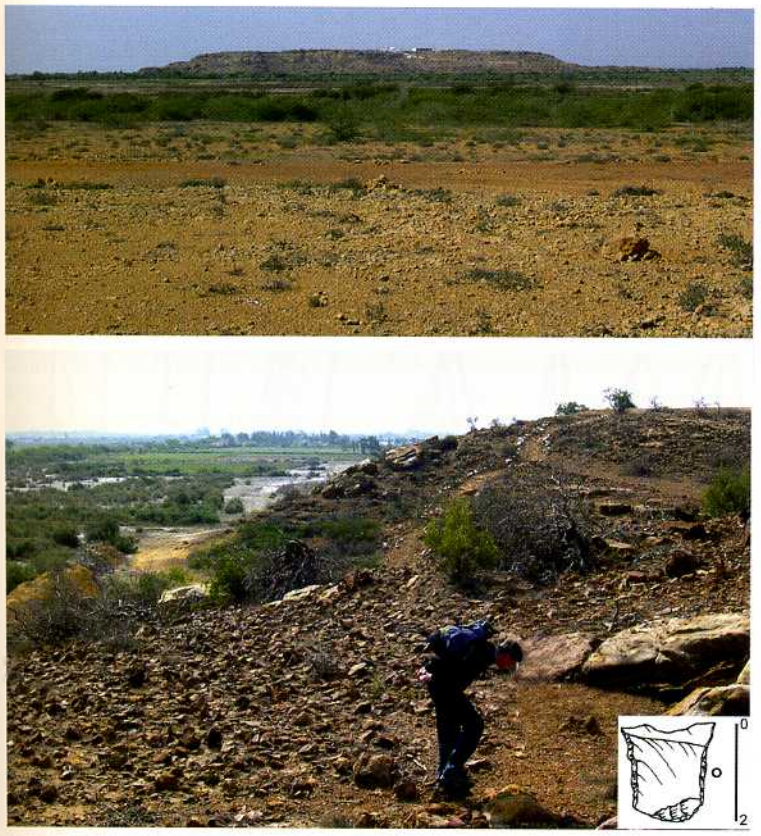

Fig. 22 Shah Husein: The hill from north-west (top), and the radiocarbon-dated site of JSH-1bis from which one trapezoidal arrowhead of *fleche trenchant* type has been recovered (bottom) (photographs by P. Biagi 2009)

Fig. 23 Tharro Hills: Location of the fortified Amri Culture site (red square), the radiocarbon-dated Chalcolithic (THR-3: green dot) and Neolithic (THR-2: blue dot) sites (top), and the fortified Amri Culture site from the east (bottom) (from Biagi and Franco 2008 Fig. 7, with modifications; photograph by P. Biagi 2009)

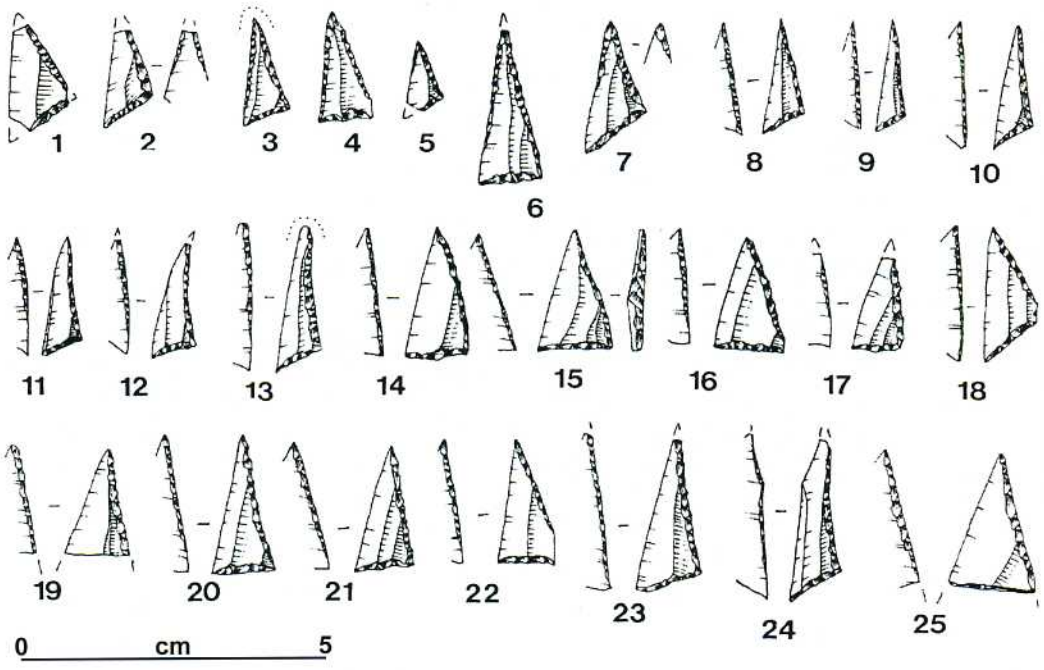

Fig. 24 Tharro Hills: characteristic long triangles of the Chalcolithic Amri culture (from Biagi 2005 Fig. 7 with modifications)

Fig. 25 Aban Shah: A view of some hillocks from the highest limestone terrace (photograph by P. Biagi 2011)

In this chronological frame, the most intriguing date obtained from our survey in the Delta area comes from an inland site located on a flat-topped limestone mesa (45-47 m asl) of the Kirthar formation, called Kot Raja Manjera. The site is famous for its Buddhist stupa and other archaeological remains attributed to the 5th century AD **(Fig. 26)**. The terrace is roughly east-west oriented, along the south-western bank of an ancient meander of the Indus, which at present flows some 5 km to the east. Kot Raja Manjera is a fortified Amri Culture Chalcolithic settlement. From its surface also a few Bronze Age potsherds were collected as well as many chipped stone tools among which are small drills for bead manufacture.[94] A few marine shells were recovered as well as one *T. palustris* specimen, which was AMS-dated to 4635±35 BP (KRM-13, GrA-47083). Close to the terrace the river forms a semicircular bend that in prehistoric times lapped the limestone formation on which the village of Lakho Pir is located.[95]

According to the above results we have to admit that 1,000-1,500 years after the exploitation of the mangroves in Thatta region the same was still happening around a site ca. 60 km northward. In fact Kot Raja Manjera yielded the northernmost finding of a mangrove shell within the entire Indus Delta region.

Calibration problems

The problems related with the calibration of radiocarbon results of both mangrove and marine specimens from shell middens excavated along the shores of the Oman Peninsula Arabian Sea coasts have already been discussed in several papers with contrasting results.[96] In the case of Las Bela and Sindh, the nearest data as to deep-water upwelling and/or oceanic reservoir that might affect the calibration of the radiocarbon dates from the study area come from a sea core off the Makran coast[97] some 300 km north-west of Port Okha in Gujarat.[98] This value, chosen to calibrate the dates presented in **Table 1,** should be treated with caution, as both local and diachronic variations in the ΔR that have proven to be relevant in modern age samples[99] might be unrecognisable on the basis of the available data.

Moreover, as the $\delta^{13}C$ values show **(Table 1)**, the samples presented in this paper come from mangrove environments, from which we cannot exclude the presence of old carbon caused by variations of the percentage of fresh vs. marine water, hard water effects, and organic litter composition. However, their percentage is very low off the Las Bela coast.[100]

94 Khan 1979c, 72.
95 Biagi 2010 Fig. 14.
96 Uerpmann 1991; Biagi 1994; Saliège et al. 2005; Zazzo et al. 2012; 2016.
97 56KA: von Rad et al. 1999; Saliège et al. 2005 Fig. 1.
98 229±27 ^{14}C years: Reimer/Reimer 2001.
99 Dutta et al. 2001.
100 Stewart/Pilkey 1966 Fig. 9.

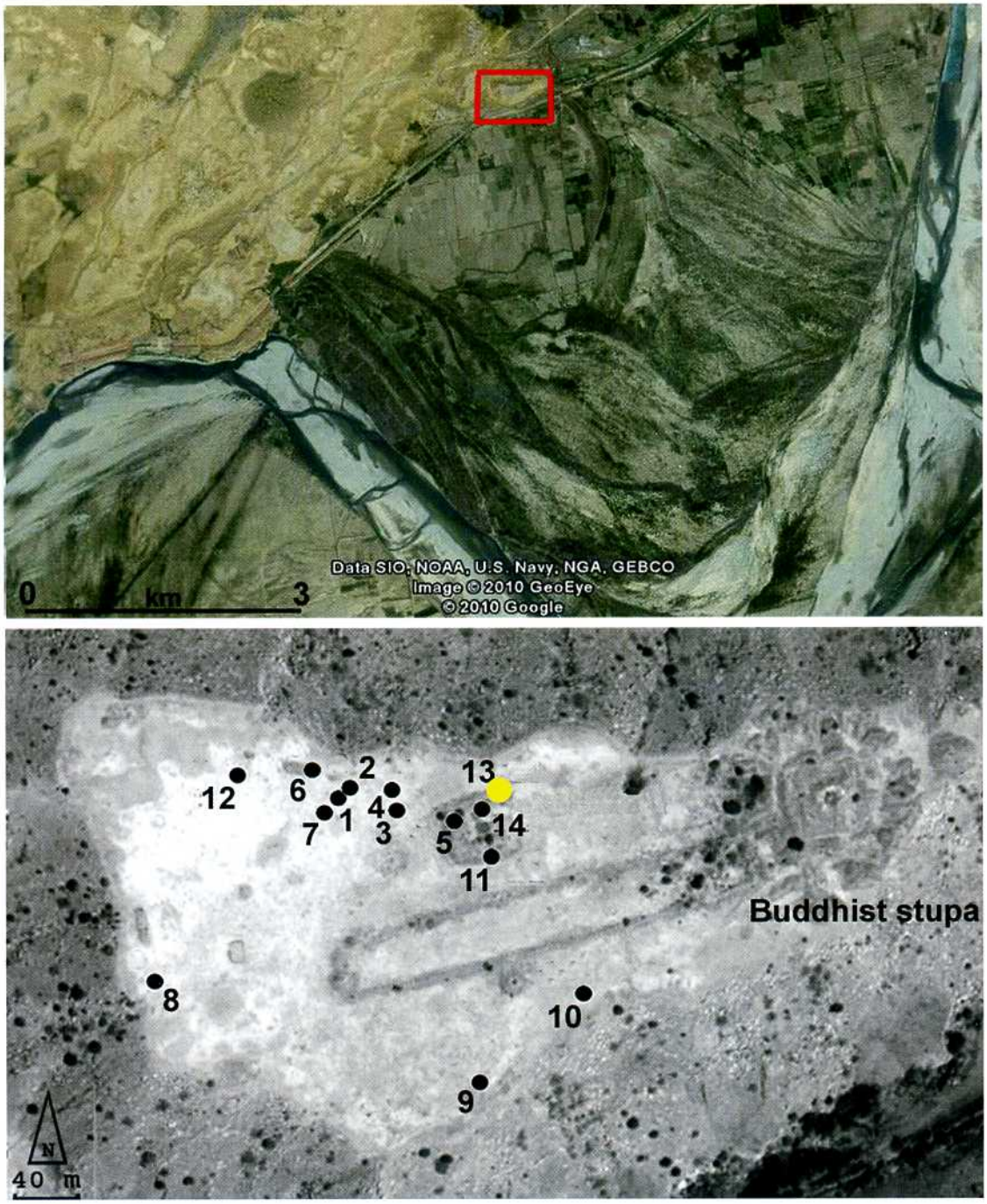

Fig. 26 Kot Raja Manjera: Site location (red square) and point 13 (yellow dot) from which one *Terebralia palustris* fragment was radiocarbon-dated (GrA-47083) (top). The other black dots show concentrations of Chalcolithic and Bronze Age finds (bottom) (drawing by P. Biagi and R. Nisbet)

Discussion

Leaving apart the 9th millennium BP date obtained from the Kadeji River marine bivalve discussed below (KDJ-1), according to the aforementioned results, around the end of the 8th millennium BP there is evidence of mangroves at or near the mouth of a few rivers in the Sonmiani and Karachi areas, which were exploited by the earliest Holocene inhabitants of the northern coast of the Arabian Sea. These data can be compared with those obtained from the earliest shell middens of the coasts of Oman,[101] and more generally the entire coastline of the Arabian Peninsula, from which we have a reasonable set of dates confirming that the territory began to be settled roughly during this period.[102] According to the available radiocarbon results from mangrove shells, between the 7th and 6th millennia BP the coast of the Indus Delta was located along an arc running from Manora-Ghizri Creek, in the west, to Thatta-Makli Hills, in the east. It seems, therefore, that the western sector of the Delta, from Karachi to Bhambor-Gharo developed at that time, and later seaward accretion occurred in a minor extension.[103] In contrast, the central part of the Delta, south of Thatta, has been subjected to a much larger advance even in historic times, though it is not possible, on the basis of our data, to establish the dynamics in the course and position of the palaeo-channels.[104]

With regard to the last two millennia, since the 18th century AD many authors have tried to reconstruct the road followed by Nearchos fleet in its journey back to Mesopotamia, in relationship with the location of the ancient seashore, generally using as a source the itineraries handed down by Greek and Roman historians.[105] According to H.R. Haig[106] the head of the Delta would be situated at the latitude of Thatta in Hellenistic times, which well agrees with the radiocarbon data. A similar opinion is shared by T.H. Lambrick[107] yet suggesting that the western coast of the Delta was not far from the Makli Hills and Pir Patho (Thatta) in Alexander's times. This hypothesis is not consistent with both the radiocarbon dates, and the reconstruction by P. H. L. Eggermont,[108] though his interpretation of Aban Shah hillock as *"the island in the sea"*[109] is not confirmed by our *T. palustris* date (OBS-1, GrA-47082: 3790±35 BP). In contrast it points to the presence of mangroves in the area at least one thousand years before Alexander's retreat from India.

According to D.A. Holmes, deltaic morphologies are found as inland as to 55 km north-east of Hyderabad in historical times, *"suggesting a very high rate of alluvial aggradation and delta advancement"*.[110] Similarly the reconstruction proposed by L. Flam,[111] which is mostly based on aerial photography and the distribution of archaeological sites in the Delta, suggests that the 6th-5th millennium BP coast was probably located somewhere between Hyderabad and Thatta,[112] an hypothesis that would better fit with our dates, and could also explain such an early date as that from Kot Raja Manjera (KRM-13, GrA-47083: 4635±35 BP).

Conclusion

The results obtained from the 2000-2014 surveys carried out along the coast of Lower Sindh and Las Bela in Balochistan, have shown the great archaeological potential of the area for the study of the prehistory of the two territories. The discovery of an impressive number of sites, and their radiocarbon dating, has shown that the earliest settlements of the coastal strip are to be referred to the last centuries of the 8th millennium BP. Furthermore the data retrieved from our research has shown that

1. Early Neolithic settlements are not exclusively limited to the regions of the interior of Pakistani Balochistan[113] as often suggested.[114] According to both the new radiocarbon results, and the analysis of the lithic assemblages recovered from the Siranda shell middens, among which are geometric microliths obtained from Gadani reddish-brown flint **(Fig. 10)**, Neolithic sites undoubtedly existed along the ancient coastline. Our results show that they are more or less contemporary, or slightly more recent, to the earliest occupation of Mehrgarh in the Kachi Plain,[115] though the radiocarbon chronology of the aceramic Neolithic occupation of this site is very controversial.[116] This fact open new perspective to the interpretation of the Neolithic archaeology of Balochistan at present known from a far too small number of sites.[117]
2. Movements along the northern coast of the Arabian Sea began at least around the beginning

[101] Berger et al. 2013; Zazzo et al. 2016.
[102] Boivin/Fuller 2009.
[103] Tremenheere 1867.
[104] Wilhelmy 1968.
[105] Eggermont 1975; Kevran 1995; Baynham 2005; Biagi 2017.
[106] Haig 1894.
[107] Lambrick 1986, 113.
[108] Eggermont 1975.
[109] Eggermont 1975 Map. 2.
[110] Holmes 1968, 369.
[111] Flam 1999.
[112] Flam 1999, 65.
[113] Fairservis 1956; Jarrige 2004.
[114] See also Possehl 2003 Fig. 2.5.
[115] for a comparison see Petrie et al. 2010 Table 2.1.
[116] Jarrige/Lechevallier 1980; Jarrige et al. 1995, 555; Lechevallier 2003, 15, note 4.
[117] Fairservis 1956; Shaffer 1978; Petrie et al. 2010.

of the 7th millennium BP. A scatter of oyster shells discovered along the southern edge of the Tharro Hills yielded a date of 6910±60 BP (THR-2, GrN: 32119). It can be compared with some of the most ancient results from Lake Siranda (see **Fig. 9**: SRN-56, GrA-57702: 6980±35 BP and SRN-33, GrA-54291: 6770±35 BP respectively), while the Makli Hills were first settled during the second half of the same millennium (KKT-2, GrN-32464: 6320±45 BP, and MKL-10, GrA-62256: 6140±40 BP) **(Fig. 20 and 21)**. This would suggest that navigation along the northern coast of the Arabian Sea had already started in this period, if not already a few centuries before,

3. The Indus Delta "islands" were undoubtedly exploited since the Late Neolithic and Chalcolithic periods as shown by the presence of Amri Culture sites, like the Tharro Hills, and the radiocarbon results from Beri and the Makli Hills **(Fig. 18)**. The same sites do not seem to have been settled during the Bronze Age Mature Indus Civilization. This fact is intriguing, since we know that during the mid 3rd millennium BC, Indus sailors and traders systematically moved across the Arabian Sea to reach the coasts of the Arabian Peninsula, where Indus outposts are known since a few decades,[118]

4. The series of radiocarbon dates obtained from shells provide excellent arguments for a preliminary reconstruction of the Holocene history of the mangroves along the coasts of Las Bela, and the variation of the profile of the Indus Delta during the same period. In this region mangroves followed the millennial built-up of the land at least since the 6th millennium BP. Unfortunately at present no dates are available for the earliest formation of the Delta, undoubtedly pre-Holocene,[119] whose apex several authors would set dozens km north to Hyderabad. The advance of the Delta coast during the last millennium could by no means hinder the use of the river for sailing northward, though the number of 5,000 boats moving from the ancient port of Debal (al-Daybul, most probably Bhambor[120]) at the time of Sultan Feroz Shah Tughluq invasion of Sindh (1365-1367 AD)[121] might be exaggerated by the ancient geographers. According H. G. Raverty, near Thatta the river was so large that from a side of the river "*the land around could not be distinguished*"[122] and therefore "*a great part of the delta south of* [Thatta] *has been formed since these events happened*".[123]

5. The new radiocarbon results **(Table 1)** show that mangroves flourished during the mid-Holocene along the northern coast of the Arabian Sea. For still unknown reasons they were no longer exploited after the 5th millennium BP at Siranda, or much later, around the end of 3rd millennium BP at Sonari, and very rarely even in historical times (Daun and Sonari). At the present state of the research it is impossible to say whether this fact is related to their disappearance, as a consequence of eco-climatic changes, as should be the case for Lake Siranda, or cultural reasons. The data achieved from fieldwork show that all the palaeo-mangroves so far recorded at Las Bela (Siranda, Gadani, Phuari and Daun), as well as those still flourishing one or two centuries ago at the mouth of the Hab River (SNR-2, GrA-59834: 670±50 BP) have now totally disappeared. However, most of the radiocarbon dates fall into a period comprised between two dramatic climatic changes. The first took place during the second half of the 9th millennium BP, following a sudden reduction of precipitations all over this part of the Indian Subcontinent,[124] while the second, a more drastic drought, occurred around 4200 BP,[125] and most probably contributed to the decline of the Indus Civilization.[126] This last climatic crisis seems well represented in the sharp fall of occurrences in the distribution map between the 4th and 3rd millennium BP **(Fig. 8 and 9)**.

6. A new radiocarbon result from a site re-discovered along the southern bank of the Kadeji River at its confluence with the Mol, suggests that mangroves were already present somewhere along the coast already during the second half of the 9th millennium BP (KDJ-1, GrA-63862: 8275±45 BP) **(Fig. 5A-5)**. Though the assay was obtained from a fragment of marine bivalve, its negative $\delta^{13}C$ value of -4,44, perfectly fits into the general picture of a mangrove environment.[127] This fact would indicate that already during the Mesolithic period, the area surrounding the Malir River, was partly covered with mangroves, which were exploited by groups of last hunter-gatherers.

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[118] Charpentier 1996; Méry 1996; 2000; Ray 2003; Ratnagar 2004.
[119] Clift et al. 2014, 185
[120] Pathan 1978, 417.
[121] Panhwar 1983, 32.
[122] Raverty 1895, 126.
[123] Raverty 1895, 126, note 235.
[124] Staubwasser et al. 2002.
[125] Staubwasser et al. 2003; Dixit et al. 2014.
[126] Gangal et al. 2010.
[127] Biagi 2018

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Paolo Biagi
Department of Asian and North African Studies
Ca' Foscari University
Ca' Cappello, San Polo 2035
I-30125 Venezia, Italia
Email: pavelius@unive.it

Renato Nisbet
Department of Asian and North African Studies
Ca' Foscari University
Ca' Cappello, San Polo 2035
I-30125 Venezia, Italia
Email: renato.nisbet@unive.it

Tiziano Fantuzzi
Department of Humanities
Ca' Foscari University
Palazzo Malcanton-Marcorà
Dorsoduro 3484/D
I-30123 Venezia, Italia
Email: tiziano.fantuzzi@gmail.com

Summary

The research carried out between 2000 and 2014 along the north Arabian Sea coast of Lower Sindh and Las Bela in Balochistan (Pakistan) has shown that the two regions started to be settled, in and around mangroves, during the last three centuries of the 9th millennium BP. The sites discovered during fieldwork are represented by shell middens, shell scatters and fishermen villages, the presence of which was almost unknown until the beginning of the 2000s. Many of the sites were sampled for conventional and AMS radiocarbon dating from mangrove gastropods, and more rarely marine shells. So far 105 sites have been AMS (GrA-) or conventionally (GrN-) radiocarbon-dated, 84 of which from *Terebralia palustris* or *Telescopium telescopium* adult specimens. This paper describes the results so far obtained from three well-defined macro areas (Lake Siranda, the coastline between Cape Gadani and the Hab River mouth, and the Indus Delta) where this research methodology has been applied. The results contribute to the study of the archaeology of the coastal area of present-day Pakistan, the definition of the sea-shore variations that took place since the middle of the Atlantic period, the disappearance and exploitation of ancient mangroves, and the modes of advance of the Indus Delta up to Historic times. Furthermore it contributes to the study of the early navigation along the northern coast of the Arabian Sea inhabited by different groups of fish-eaters (ichthyophagoi).