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The Wood Charcoals from Sheri Khan Tarakai:
A Case Study in Environmental Archaeology and Palaeoecology

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Abstract: We consider the occurrence of wood in the archaeological record, with special reference to the formation, recovery, identification, analysis and interpretation of assemblages of wood charcoals. The wood charcoals from the early village site of Sheri Khan Tarakai (c. 3800 – 2900 cal. BC) in the west of Bannu District (Khyber Pakhtunkhwa, Pakistan) are the principal focus of this paper. Twenty-six taxa of woody plants (trees and shrubs) were identified and their spatial, contextual and temporal distributions in the site are discussed. The taxa in this assemblage of wood charcoals can be associated with a diverse range of phytogeographical zones existing in the local area and broader region at the present day. Such associations might be used to model patterns of exploitation of woody taxa in, and human contacts with, various ecological and topographical zones in the past. The validity of this is discussed from a palaeoecological perspective, questioning to what extent the 'ecological present' is the principal key to understanding the 'ecological past'. It is suggested that present day distributions of plant associations in the sub-Himalayan regions of northwest Pakistan are the result of intensive human exploitation and consequent environmental degradation. Most of the woody taxa identified in the charcoals from Sheri Khan Tarakai were from habitats which, at the time the site was occupied, were either local to the site or only a few kilometres distant.

Keywords: Wood charcoals, Intra-site variation, Resource selection, Environmental Archaeology, Palaeoecology, Ecology, Sheri Khan Tarakai.

Introduction

Environmental archaeology is a well-established sub-discipline of archaeology concerned with reconstructing past human environments and human palaeoecology. This includes the selection, use and modes of acquisition of natural resources; the ecological inter-relationships of human societies and their environments; and how all this might have changed through time. These endeavours are approached through the recovery, analysis and interpretation of a range of data, principally sediments, soils, and the remains of plants and animals (including humans), from depositional contexts on archaeological sites, sometimes complemented by samples from suitable off-site contexts, such as alluvial sequences, lake-bed deposits, etc. (Harris and Thomas 1991, 93). Here we will consider the analysis and interpretation of the remains of wood resources preserved in archaeological sites.

Wood is among the earliest of natural materials used by humans, perhaps initially as expedient tools or weapons, such as twigs or branches picked up from the ground or broken from trees or bushes, and subsequently discarded. Wood became important as a fuel when humans learned to use and control fire. The woody tissues of trees, bushes, shrubs, and other plants are complex organic materials composed principally of cellulose and lignin, along with a diverse range of minor components including polysaccharides and lipids. These energy and nutrient rich compounds are a valuable food resource for a range of organisms (including bacteria, fungi and various insects), the activities of which cause the biodegradation (i.e., decay) of wood. Wood is preserved in a relatively unaltered state only in particular (often climate-related) conditions, such as intense cold (frozen), very wet (waterlogged) or very dry (desiccated); approaches to the analysis of such wood remains in archaeology have

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recently been reviewed by Cartwright (2015). Otherwise, wood can be preserved after being modified chemically in various ways, such as by replacement of organic compounds by various minerals (which is how it becomes preserved or fossilised in the geological record) or by being charred by fire. It is this latter aspect we consider here: the study of wood which, having been exposed to fire, whether deliberate (burning as fuel) or by accident, has been preserved in the archaeological record.

What remains of wood after burning depends on the degree of combustion. Complete combustion leaves wood ash and it is possible to analyse this to identify the original materials burned. Weiner (2010, 174-178) considers the problems and potential of analyzing ash, including the identification of fuel types (wood, animal dung, etc.) used in fires. Incomplete combustion, or charring, produces wood charcoal. This process is sometimes termed 'carbonization', although elemental carbon is just one of a range of chemical components in wood charcoals; see Weiner (2010, 178-185) for an outline of the principal chemical components of wood charcoals. 'Anthracology' is the sub-discipline concerned with the analysis of wood charcoals and involves specialists working in archaeology and in the environmental sciences. 'Environmental anthracology' deals with the analysis of charcoal deposited from the aerial transport and fall-out of microscopic fragments derived from fires, either natural or humanly made. For example, microscopic charcoal from lake deposits (along with pollen and other indicators) can help reconstruct forest fire historical ecology (see review by MacDonald *et al.* 1991), including distinguishing the consequences of 'natural' fires from those of human origin (e.g. Bennett, Simonson and Peglar, 1990). 'Archaeological anthracology' deals with wood charcoals recovered from archaeological contexts and it is this aspect we consider here.

One of the first studies of ancient wood from an archaeological site in Pakistan was that of Chowdhury and Ghosh (1951), who examined the remains of poorly preserved wood (not charred) from Wheeler's 1946 excavations at Harappa. They identified four woody taxa, two of which (*Ziziphus* sp. and *Dalbergia latifolia*) they suggest would have been available either locally to the site or from nearby forested areas, while the other two (*Ulmus* sp. and *Cedrus deodara*) must have come from higher hills some distance from the site. Thiébault (1988; 1989) identified wood charcoals from the site of Mehrgarh, in Baluchistan, and inferred patterns of past woody vegetation from them, including demonstrating the presence of charred wood of *Vitis* sp. (grape vine) in the assemblage. Castelletti *et al.* (1994) reported on the wood charcoals from Kot Diji and, also in Sindh, Nisbet (2010) undertook ethnobotanical studies of the wood charcoals from the firing of lime kilns. Meyer (2003) made combined ethnobotanical and archaeological analyses of present-day fuel use in different types of hearths in the Punjab at the present day and at the site of Harappa. Most recently, Lancelotti (2018) has made a valuable study of fuel use (principally animal dung and wood) at Harappa and other sites of the Indus urban period. Thomas and Cartwright (2010) reported upon the wood charcoals from the early village site of Sheri Khan Tarakai (Khyber Pakhtunkhwa) and here we re-analyse this data set, extending, refining, and revising some of our earlier interpretations.

Sheri Khan Tarakai

The Bannu Archaeological Project, directed by Farid Khan, Robert Knox and Kenneth Thomas, discovered the early village site of Sheri Khan Tarakai in 1985 (Khan, Knox and Thomas 1986). The results from the subsequent excavations have been published in full (Khan *et al.*, 2010) and only a brief outline will be given here.

The site is in the west of Bannu District (Fig. 1), at 70° 28′ 4.35″ East, 32° 50′ 32.72″ North, on part of a substantial alluvial fan formed by the Khaisor and Shaktu torrents which emerge from the hills to the west (Fig. 2). The site is situated on the left bank of the Barrai Khuarra, a minor ephemeral torrent, and is a long low mound which at the time of its discovery had been significantly damaged by bulldozing to create fields, with only a few areas left undisturbed (Fig. 3). Excavations were undertaken from 1986 onwards, with some larger trenches being in less disturbed parts of

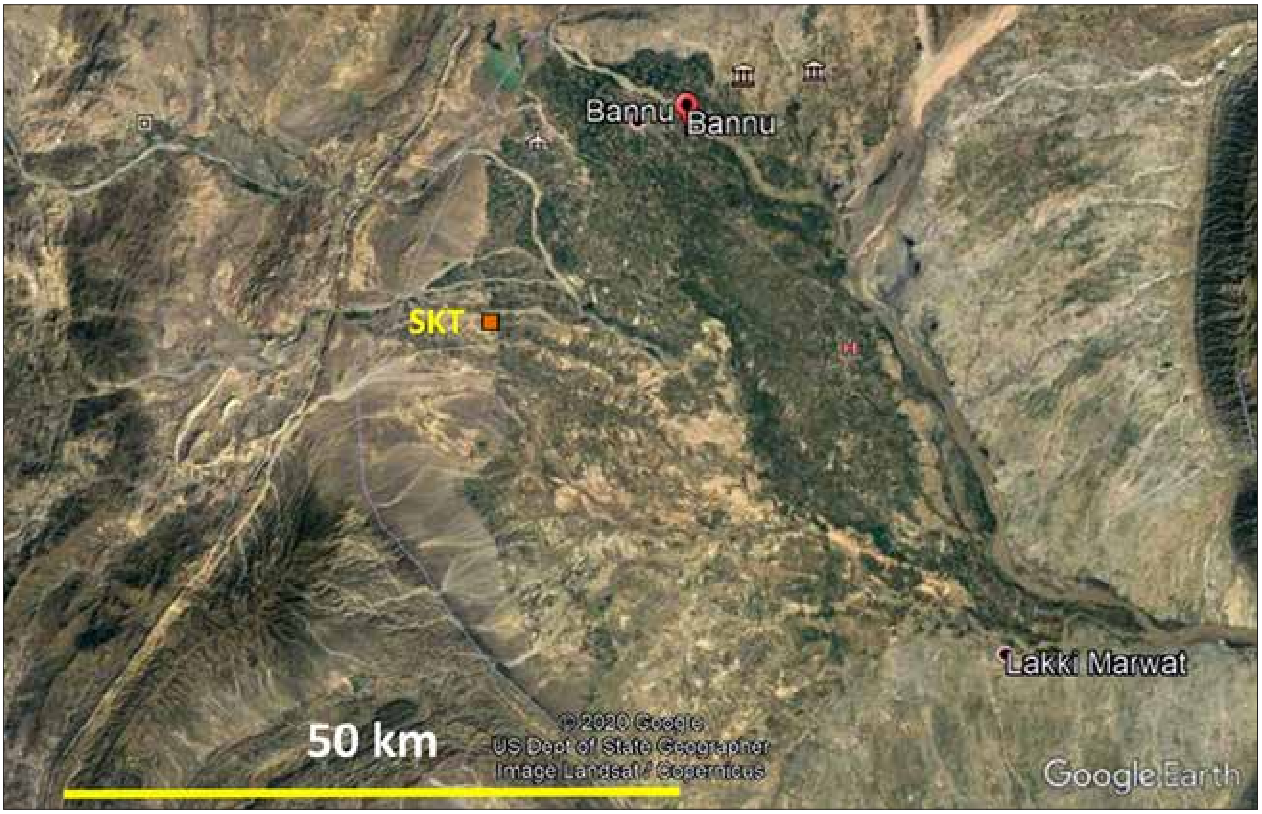


Figure 1. Google Earth™ image of the Bannu basin, north-west Pakistan, showing the locations of Bannu City and the site of Sheri Khan Tarakai

Figure 2. Google Earth™ image of the location of Sheri Khan Tarakai (circled in yellow) on the alluvial fan formed by the Shaktu and Khaisor torrents. The early village sites of Girdai (circled, above Sheri Khan Tarakai) and Ter Kala Dheri (circled, at top) are also shown. Modified from Petrie and Thomas (2012, fig. 6).

the site and others (small test pits) deployed to delimit the former extent of the ancient settlement (Fig. 3). It appears that this settlement was a small village, populated by perhaps a few hundred people living in mud walled houses, some with cobble stone footings (Fig. 4a). The range of finished pottery vessels, lithic tools and small finds, and associated production debris, indicate a diversity of on-site craft activities, including the making and firing of pottery, bone working, lithic flaking, stone grinding and bead drilling. The diverse range of terracotta figurines and the motifs depicted on many of the ceramic vessels reveal a rich iconographic tradition.

Twenty-one radiocarbon dates make Sheri Khan Tarakai one of the most comprehensively dated sites in South Asia (Khan *et al.*, 2010, 344). The relative and absolute chronological evidence indicate occupation was principally from the late fifth to the early third millennium BC. It is not clear if this occupation was continuous, but the most reliable radiocarbon dates suggest the main period of occupation at the site occurred between *c.*3800 and 2900 cal. BC.

The inhabitants of Sheri Khan Tarakai deployed a range of subsistence strategies, including the cultivation of barley and wheat, the management of domestic sheep, goat and cattle, the collection of a range of wild plant and wood species, and the hunting of wild animals. The abundance of grinding artefacts at the site and the presence of rachis internodes and chaff in some deposits suggest that grain processing took place on site. Few young domestic animals appear to have been slaughtered at the site; the fact that most lived on into adulthood suggests that they were primarily used as a source of meat, and possibly to provide secondary products such as wool, milk, work, and dung.

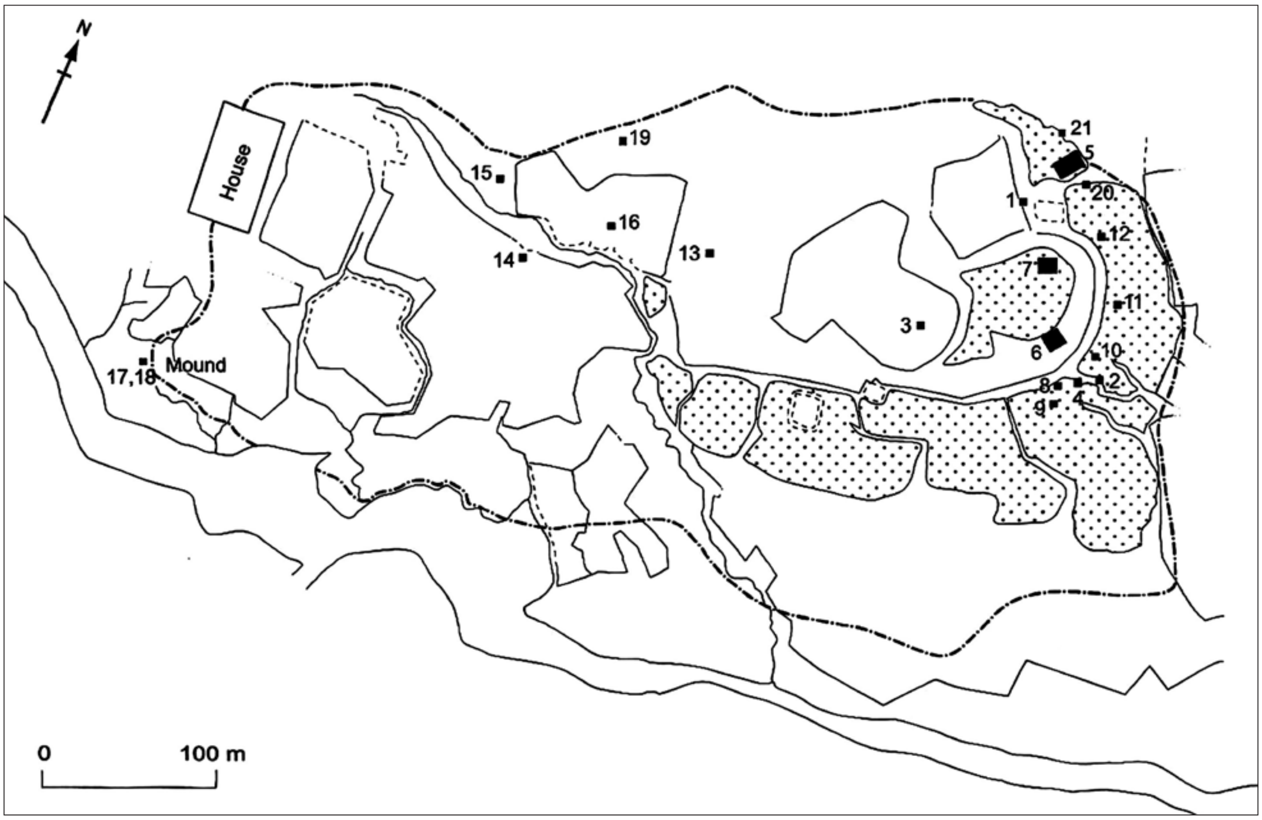


Figure 3. Topographical plan of the site of Sheri Khan Tarakai on the left bank of the Barrai Khuarra torrent, showing the locations of the excavation trenches and test pits. The site has been extensively damaged by recent land use, but the stippled areas have undisturbed archaeological deposits. Modified from Khan et al. (2010, fig. 4.6).

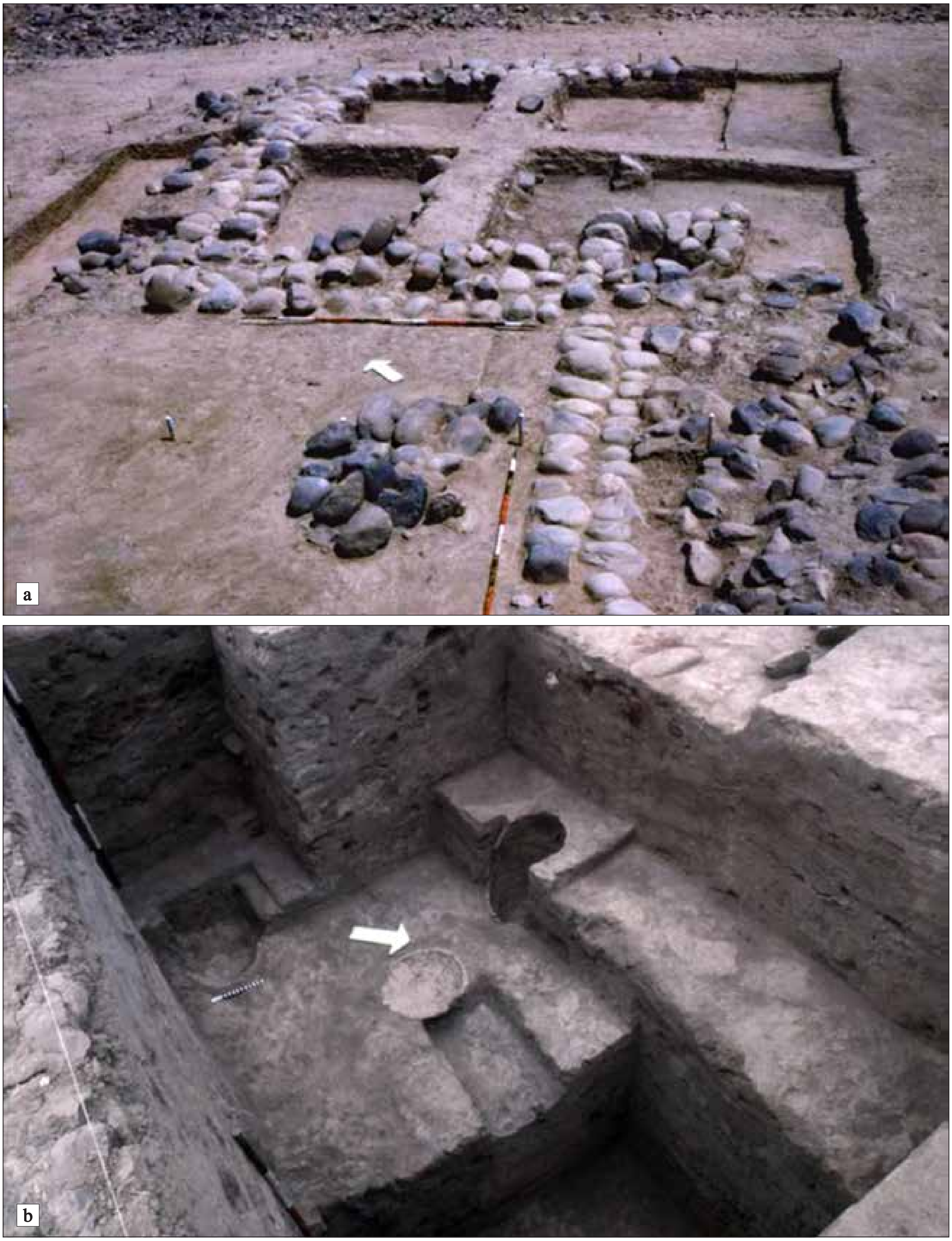


Figure 4. Sheri Khan Tarakai excavations. a: 'House A', Trench 7, during excavation. b: Floor levels and clay 'bins' in Trench 6, Area A. Modified from Khan et al. (2010, figs. 4.22 and 4.27 respectively).

The settlement's location would have allowed use of the run-off from the ephemeral torrents that flowed from the hills of Waziristan (Figs. 1, 2) and the inhabitants probably engaged in some type of floodwater farming (Petrie and Thomas 2012). Storage structures (Fig. 4b) imply occupation throughout the year, but there is evidence that a proportion of the population engaged in some form of transhumant pastoralism or had links (possibly through trade or exchange) with other mobile groups of people.

Methods

Recovery of bioarchaeological materials, with special reference to wood charcoals

The excavations at Sheri Khan Tarakai produced an abundance of biological data, including archaeobotanical remains (wood charcoals, charred grains, seeds and fruits) and zooarchaeological remains (mammals, birds, reptiles, amphibians, fish and molluscs), as detailed by Thomas and Cartwright (2010). Recovery was by three methods: directly during excavation, by on-site dry sieving of all excavated deposits, and by flotation combined with wet sieving of bulk samples of deposit. It is important not to rely on only one method, because different methods of recovery (direct during excavation, dry or wet sieving, or flotation) can yield variable results (Thomas and Zapata 2018).

Wood charcoals from Sheri Khan Tarakai were recovered by all these methods. Direct recovery during excavation is probably the best way to obtain samples of wood charcoals for subsequent analysis, whether radiocarbon dating or microscopic identification of the biological taxa present. There is less damage to the fragile charcoals and contamination is less likely if recovered and packaged directly, which is especially important if destined for the radiocarbon dating laboratory. On-site dry sieving down to 0.5 mm mesh size of all excavated deposits is essential for the recovery of small artefacts and biological remains such as small bones. Fragile wood charcoal specimens can suffer damage by the mechanical process of sieving and relatively fewer useful pieces of charcoal were recovered by this means. Flotation of bulk samples of deposit, taken before the remainder of those deposits went through the dry sieving procedure, is an excellent way to recover many types of biological remains, including charred grains and seeds, wood charcoals, and the shells of land and freshwater molluscs. Different flotation methods can produce slightly varied results, as can variation between the matrices (clays, silts, sands, etc.) of the bulk samples being processed in this way (Wagner 1982). Material that does not float passes through a 0.5 mm mesh and is dried and sorted, although in the case of Sheri Khan Tarakai very little wood charcoal was recovered by this wet sieving procedure.

Seventy samples of wood charcoals were obtained at Sheri Khan Tarakai, 16 directly during excavation and 54 by flotation. On–site flotation was not possible because of a lack of water and samples were transported to Bannu city, where (KDT) carried out the flotation procedure in the project's house, using equipment constructed from materials purchased in the Bannu bazaar (with the exception of the standardized 1.0 mm and 0.5 mm nylon meshes, which were brought from London). Fig. 5 shows the basic flotation set up, involving a large plastic waste bin, standard meshes supported

Figure 5. Flotation equipment for the recovery of charred plant remains from samples of deposits from the site of Sheri Khan Tarakai. Key: 1: Fresh clean water supply; 2: Flotation 'tank'; 3: Overflow pipe carrying floated material away from the 'tank'; 4: Nest of sieves (mesh sizes 1.0 and 0.5 mm) collecting the floated material; 5: Pipe carrying away used water and fine sediments to drainage system.

in wooden frames, plastic hosepipes and bowls. Samples were processed separately and material that floated was collected on a nest of 0.5 and 1.0 mm meshes. Residues in the waste bins were sorted for any other remains, including micro artefacts. In addition to plant remains, small bones and the shells of land and freshwater molluscs were recovered, either in the floated material or in the residues. The rather fragile drainage system in Bannu city at that time imposed a further constraint on the procedure: all waste residues were taken out of town for disposal on fields or in drainage channels. Had water supplies been adequate, on-site flotation would have been the preferred option. In a subsequent excavation by the Bannu Archaeological Project at the site of Lewan, clean sediment-free ground water pumped from a tube well enabled large volumes of deposits to be processed by flotation on site (Fig. 6) and all waste residues were dumped onto the surface of an adjacent field.

The floated charred material recovered from each sample was dried and carefully packaged for transportation from Bannu to London. Samples were sorted (by KDT) at the Institute of Archaeology, University College London, using a low power incident–light microscope. All fragments of cereals, seeds and fruits were retained for examination by KDT, and the remaining wood charcoals were examined by CRC at the British Museum, using optical and scanning electron microscopy.

Identifying the wood charcoals

Cartwright and Parkington (1997) give a comprehensive account of the methods used and the underlying principles. Charring can modify the anatomical features in wood in various ways and to varying degrees (Braadpart and Poole 2008; Leme, Cartwright and Gasson 2010; Gasson, Cartwright and Leme 2017; Tamburini *et al.* 2020), depending, among other factors, on the woody taxon, the type of fire and the degree of exposure to it. Despite this, microscopic features of the original wood anatomy can persist in wood charcoals (Figs. 7, 8) and enable identification to at least genus level and sometimes to specific levels. The charcoal from Sheri Khan Tarakai was identified by standard techniques of optical microscopy using reflected (incident) light on a Leica Aristomet microscope with dark-field, interference contrast and polarizing capabilities, and a range of magnifications from x50 to x1000. Selected specimens of various charcoal taxa were imaged using the Hitachi S–3700N variable pressure scanning electron microscope and Hitachi S–4800 field emission scanning electron microscope (Figs. 7, 8). Each charcoal fragment was fractured to show transverse, radial longitudinal and tangential longitudinal planar sections for identification. Detailed anatomical comparisons were made with reference specimens of woody taxa and computer databases (Wheeler *et al.* 1986). Further details of the principles of scanning electron microscopy applied to archaeological wood charcoals can be found in Cartwright (2013).

Nomenclature follows that of Nasir, Ali and Stewart (1982) and Hoch (2009), unless stated otherwise. In recent years, and for a variety of reasons, there has been instability in nomenclature affecting a range of taxa in the animal and plant kingdoms. In our case, this involves the recent change of genus-level nomenclature for species once included in the genus *Acacia*, a name now restricted to species native to Australia. The interested reader may consult Orchard and Maslin (2003) for the origins of this change, the excellent review of the ensuing dispute by Carruthers and Robin (2010), and a potential resolution proposed by Miller, Seigler and Mishler (2014). Thomas and Cartwright (2010) named some wood charcoal specimens from Sheri Khan Tarakai as *Acacia* sp. because there were insufficient diagnostic characteristics to enable determinations to any species within this genus. We are no longer able to use this generic name in a formal way (by citing it in italicized script), so here we use the general term 'Acacia' for all specimens we previously named *Acacia* sp. We retain the use of *Acacia*, and of named species such as *Acacia modesta* (syn. *Senegalia modesta*), where earlier authors have used it and we are drawing upon their work.

Figure 6. Flotation equipment for the on-site recovery of charred plant remains as used at the multi-phase protohistoric site of Lewan, Bannu District.

(a) Location of the flotation set-up near drainage gully;

(b) Sieve of mesh size 0.5 mm which fits into the flotation 'tank', the large blue bucket;

(c) Overflow pipe from the flotation bucket carries the floated material on to the collection sieve;

(d) Fine muslin cloth on the collection sieve traps all floated material > 0.5 mm. The cloth is then carefully gathered up by its corners and tied with string to form a loose 'bag', an identification label is attached, and the bag hung up to dry. On no account attempt to move the bag until it and its contents are completely dry and always handle the bag very gently, holding it only by the string tie.

Quantification of the charcoal assemblages

Counting the number of charcoal pieces of each taxon merely gives an index of fragmentation. In consequence, the relative proportions of different types of charcoal were determined by percentage by weight (mass, in grams) of each taxon identified (Table 1) and by percentage ubiquity, which is the frequency of occurrence of each taxon in the seventy samples analysed (Table 2).

Results

A high diversity of twenty-six taxa were identified in the total wood charcoal assemblage (Tables 1, 2), although five taxa dominate with the remainder being represented either by small quantities (by mass) of material or being present in only one or two samples, and therefore of low ubiquity. Figures 7 and 8 show scanning electron microscope images of a range of selected charcoal taxa identified in the assemblages from Sheri Khan Tarakai, organised according to their occurrence in present-day environmental zones: those 'local' to the site (Fig. 7) and those associated with more 'distant' environments (Fig. 8).

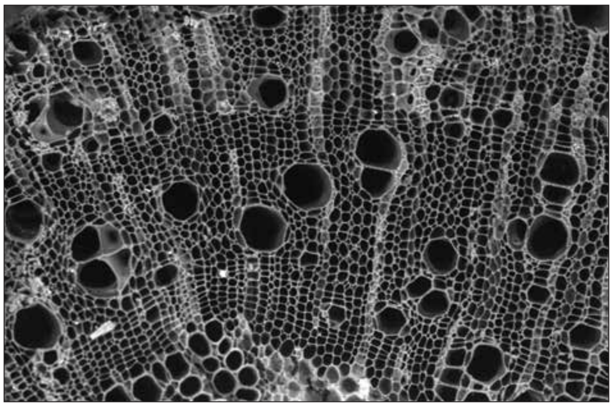
For details of the taxa identified, see Cartwright and Thomas (2010, 309-311) who also consider the species of trees or shrubs they might represent, and the plant 'communities' with which they are associated at the present day. Their analysis draws upon various published sources, principal among which are those by Nasir, Rafiq and Roberts (1995), Champion, Seth and Khattak (1966), Hoch (2009), Negi and Naithani (1995), Ahmad, Sabir and Lodhi (2005), Bahri–Sahloul *et al.* (2009), Champion and Seth (1968), Ahmad, Sabir and Zubair (2006), and Sahni (1990). These sources also under-pin much of what we present and discuss here.

Table 1. Relative abundance (by mass) of taxa in the total wood charcoal assemblage from Sheri Khan Tarakai.

Taxon	Mass (g)	Percentage by mass
Tamarix	337	31.7
Pistacia	151	14.2
Quercus	138	13.0
'Acacia'	124	11.7
Ziziphus	82	7.7
Celtis	57	5.4
Cassia	23	2.2
Salvadora	23	2.2
Populus	19	1.8
Prosopis	16	1.5
Crataegus	14	1.3
Morus	12	1.1
Prunus	8	0.7
Elaeagnus	7	0.7
Capparis	7	0.7
Olea	6	0.6
Rhamnus	6	0.6
Vitex	6	0.6
Sorbus	5	0.5
Ficus	4	0.4
Juglans	4	0.4
Pinus	4	0.4
Salix	4	0.4
Calligonum	2	0.2
Dodonaea	2	0.2
Suaeda	1	0.1
Total mass (gm)	1062	

Table 2. Ubiquity (%) of occurrence of wood charcoal taxa in the seventy samples analysed. For convenience of layout, in this and subsequent tables, taxa are cited by generic names (Table 1 gives the full names).

Taxon	Samples in which present	Ubiquity %
Tamarix	62	88.6
Pistacia	34	48.6
'Acacia'	29	41.4
Quercus	21	30.0
Ziziphus	20	28.6
Celtis	11	15.7
Cassia	7	10.0
Salvadora	6	8.6
Crataegus	5	7.1
Prosopis	4	5.7
Capparis	3	4.3
Populus	3	4.3
Morus	2	2.9
Olea	2	2.9
Vitex	2	2.9
Calligonum	1	1.4
Dodonaea	1	1.4
Elaeagnus	1	1.4
Ficus	1	1.4
Juglans	1	1.4
Pinus	1	1.4
Prunus	1	1.4
Rhamnus	1	1.4
Salix	1	1.4
Sorbus	1	1.4
Suaeda	1	1.4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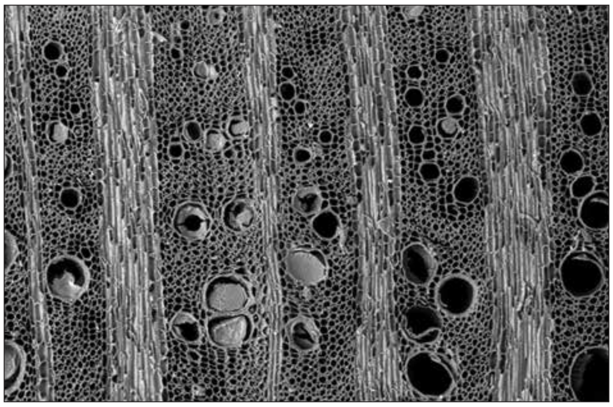
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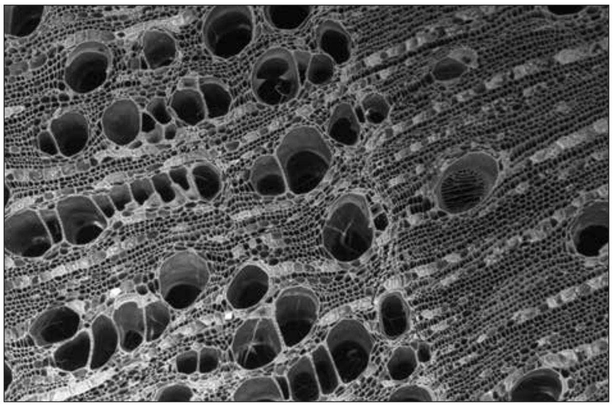
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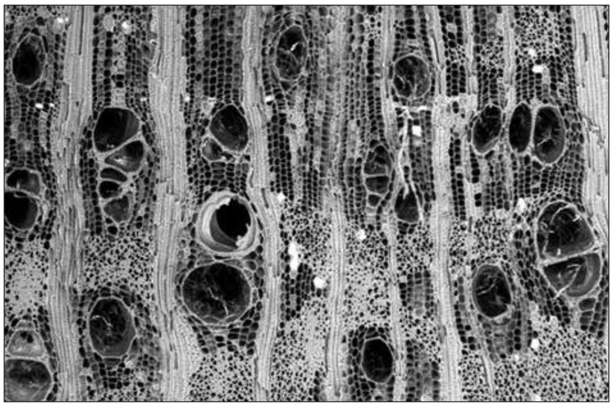
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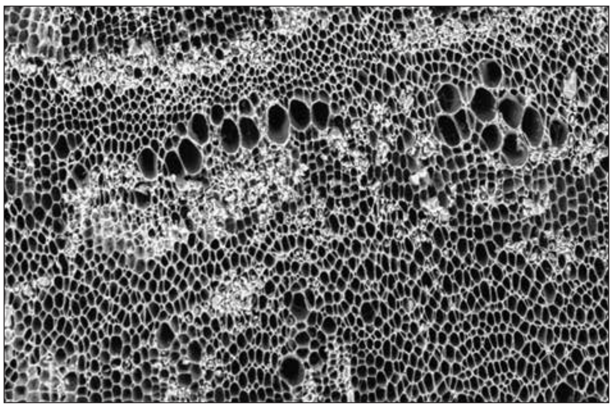
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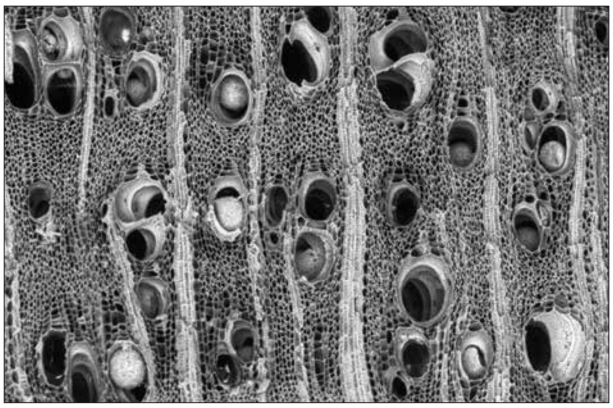
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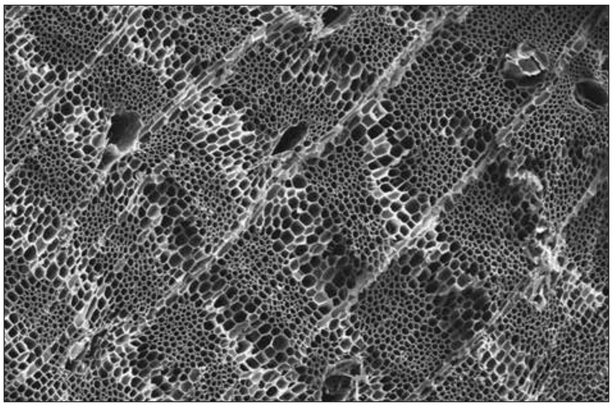
Figure 7. Sheri Khan Tarakai. Transverse sections of selected wood charcoal taxa representative of present-day local dry thorn forest habitats. Modified from Thomas and Cartwright (2010, fig. 8.2).
All images produced by C.R. Cartwright (copyright: The Trustees of the British Museum)

(a) *Cassia* sp. charcoal viewed in the Hitachi S–3700N variable pressure scanning electron microscope (VP–SEM)
(b) *Tamarix aphylla* charcoal viewed in the VP–SEM
(c) *Ziziphus* sp. charcoal viewed in the VP–SEM
(d) '*Acacia*' sp. charcoal viewed in the VP–SEM
(e) *Suaeda* sp. charcoal viewed in the VP–SEM
(f) *Capparis* sp. charcoal viewed in the VP–SEM



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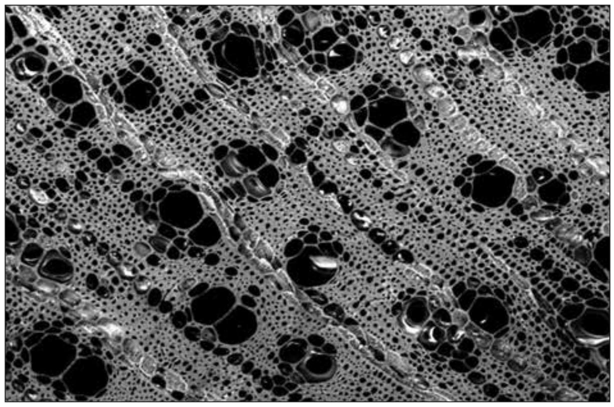

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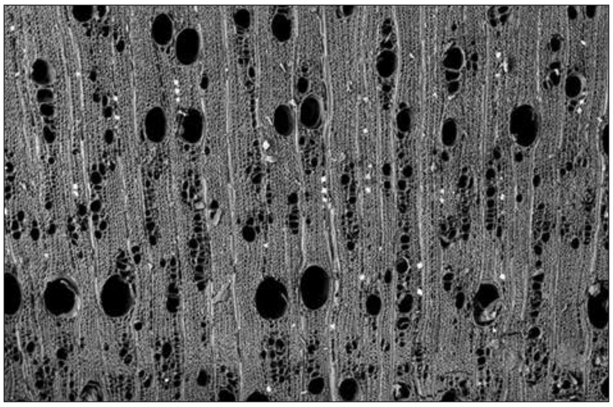

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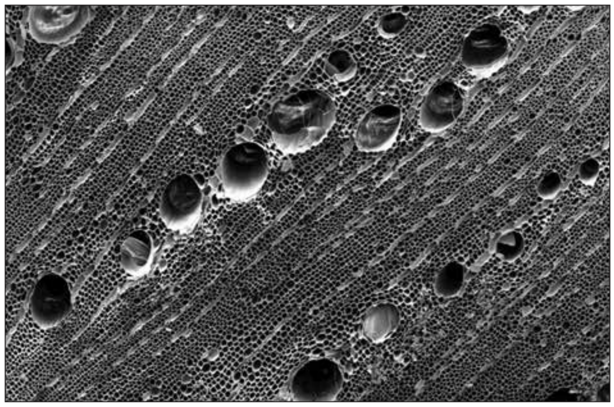

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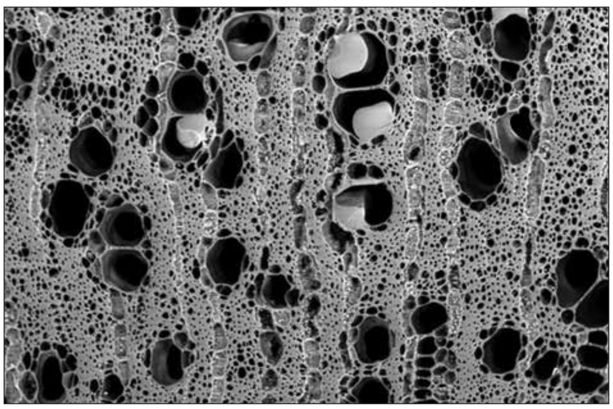

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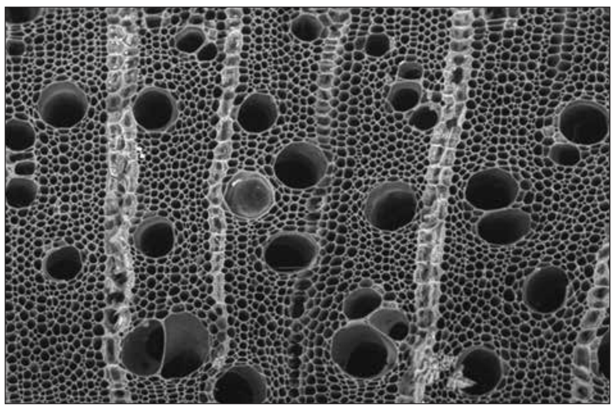

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Figure 8. Sheri Khan Tarakai. Transverse sections of selected wood charcoal taxa representative of the present-day plant associations of more distant hill zones. Modified from Thomas and Cartwright (2010, fig. 8.3).
All images produced by C.R. Cartwright (copyright: The Trustees of the British Museum).

(a) *Ficus* sp. charcoal viewed in the Hitachi S–4800 field emission scanning electron microscope (FE–SEM)
(b) *Olea cf. ferruginea* charcoal viewed in the VP–SEM
(c) *Pistacia chinensis ssp. integerrima* charcoal viewed in the VP–SEM
(d) *Quercus cf. baloot* charcoal viewed in the FE–SEM
(e) *Dodonaea* sp. charcoal viewed in the VP–SEM
(f) *Vitex cf. negundo* charcoal viewed in the VP–SEM.

Analysis of the wood charcoals data

Variation between trenches

Trench 6 (Fig. 4) was the one most extensively excavated and therefore the principal focus for the sampling and recovery of wood charcoal remains. Trench 13 was excavated to a shallow depth and produced relatively fewer samples, while Trenches 5, 7, 8, 9 and 10 produced only single samples of wood charcoals. Fig. 9 shows the distinct relationship between the numbers of samples from each trench and the diversity of woody taxa present.

There is variation in the representation of different taxa in the excavated trenches (Fig. 10), which, unsurprisingly, corresponds broadly to the overall ubiquity of the taxa (Table 2).

Variation between phases

Only for Trench 6 can we investigate any changes in the diversity and representation of woody taxa over time. Table 3 shows the number of samples processed from each of the three principal stratigraphic phases (*Early SKT*, *Middle SKT* and *Late SKT*) identified in Trench 6, along with the numbers (and proportions) of samples in each phase in which a particular taxon was found. The *Middle SKT Phase* is represented by only 9 samples, so the results from this phase should be treated with caution; the *Early SKT Phase* is represented by 28 samples and the *Late SKT Phase* by 16 samples. *Tamarix aphylla* is the most abundant taxon in each phase, but there is variation between phases in the next most frequent taxa. Most notable is the low representation of *Quercus* cf. *baloot* in the *Early SKT Phase* (at 14%) compared with the *Middle* and *Late SKT Phases* (at 67% and 50%, respectively), the late phase also including *Pinus* sp. Another interesting difference between the *Early* and *Late SKT Phases* (Table 3) is the lower relative frequency in the later phase of some taxa, such as *Ziziphus* sp. and *Cassia* sp., from 'local' plant associations although other 'local' taxa do not differ significantly between these phases. The proportion of possibly non–local taxa in the *Early SKT Phase* is 41% compared to 53% in the *Late SKT Phase* with, as noted above, *Quercus* and *Pinus* being more frequent in the later phase. Although such geographically 'distant'

Table 3. Distribution of woody taxa by stratigraphic phase in Trench 6 of Sheri Khan Tarakai. The total number of samples from each phase is at the head of each column. The abundance of each taxon is by the numbers of samples in which they are present and by percentage ubiquity (in brackets) in each column. The bottom row gives the numbers of taxa that are 'local' to Sheri Khan Tarakai in modern times (see Table 7) and their percentage of the total taxa in each phase.

Taxon	Early SKT Phase (N = 28 samples)	Middle SKT Phase (N = 9 samples)	Late SKT Phase (N = 16 samples)
Tamarix	24 (86%)	9 (100%)	13 (81%)
Pistacia	16 (57%)	4 (44%)	10 (63%)
Quercus	4 (14%)	6 (67%)	8 (50%)
'Acacia'	12 (43%)	1 (11%)	10 (63%)
Ziziphus	9 (32%)	5 (56%)	4 (25%)
Celtis	4 (14%)	2 (22%)	3 (19%)
Cassia	6 (21%)	1 (11%)	–
Salvadora	3 (11%)	2 (22%)	2 (13%)
Populus	–	2 (22%)	1 (6%)
Prosopis	1 (4%)	1 (11%)	2 (13%)
Crataegus	3 (11%)	–	2 (13%)
Morus	1 (4%)	–	1 (6%)
Elaeagnus	1 (4%)	–	–
Capparis	2 (7%)	–	1 (6%)
Olea	1 (4%)	1 (11%)	–
Rhamnus	–	–	1 (6%)
Vitex	1 (4%)	–	–
Sorbus	1 (4%)	–	–
Ficus	–	–	1 (6%)
Pinus	–	–	1 (6%)
Salix	–	1 (11%)	–
Calligonum	–	1 (11%)	–
Dodonaea	–	1 (11%)	–
Suaeda	1 (4%)	–	–
Number of taxa	17	14	15
Number of 'local' taxa	10 (59%)	10 (71%)	7 (47%)

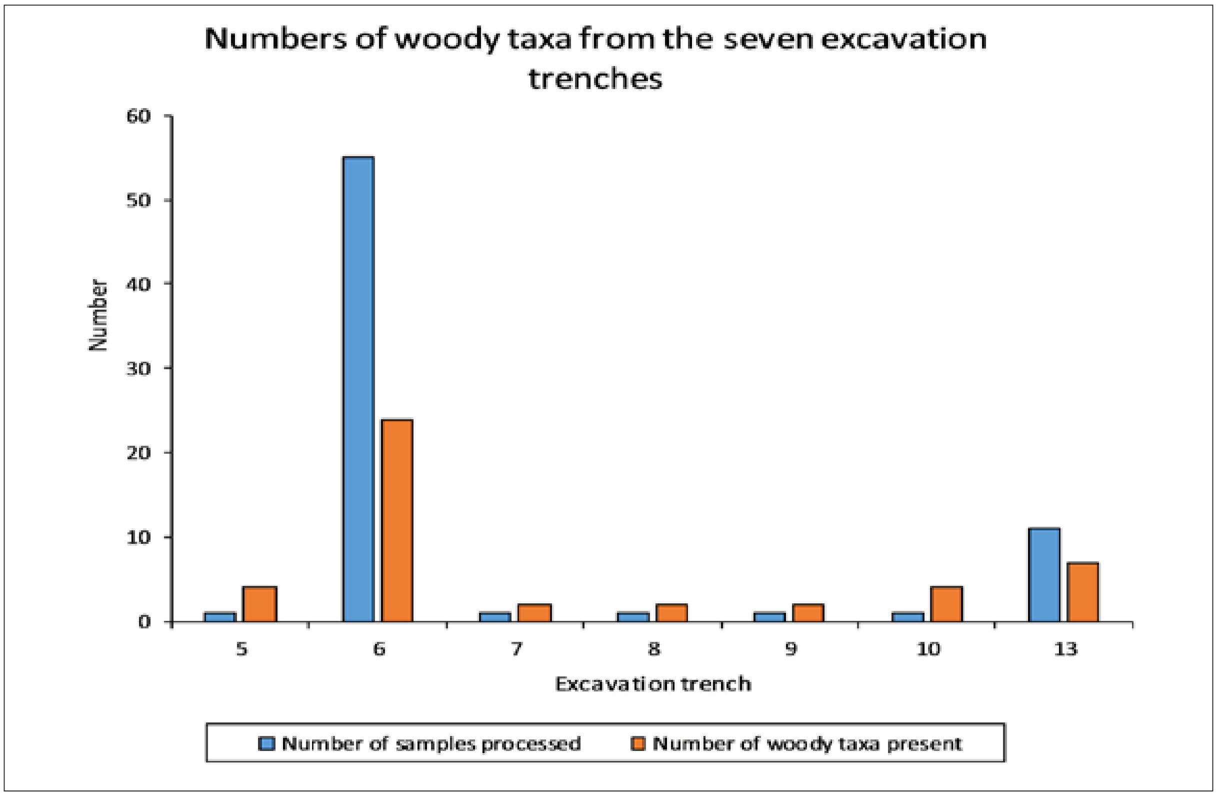

Figure 9. Numbers of woody taxa recovered from samples of the deposits of the seven principal excavation trenches.

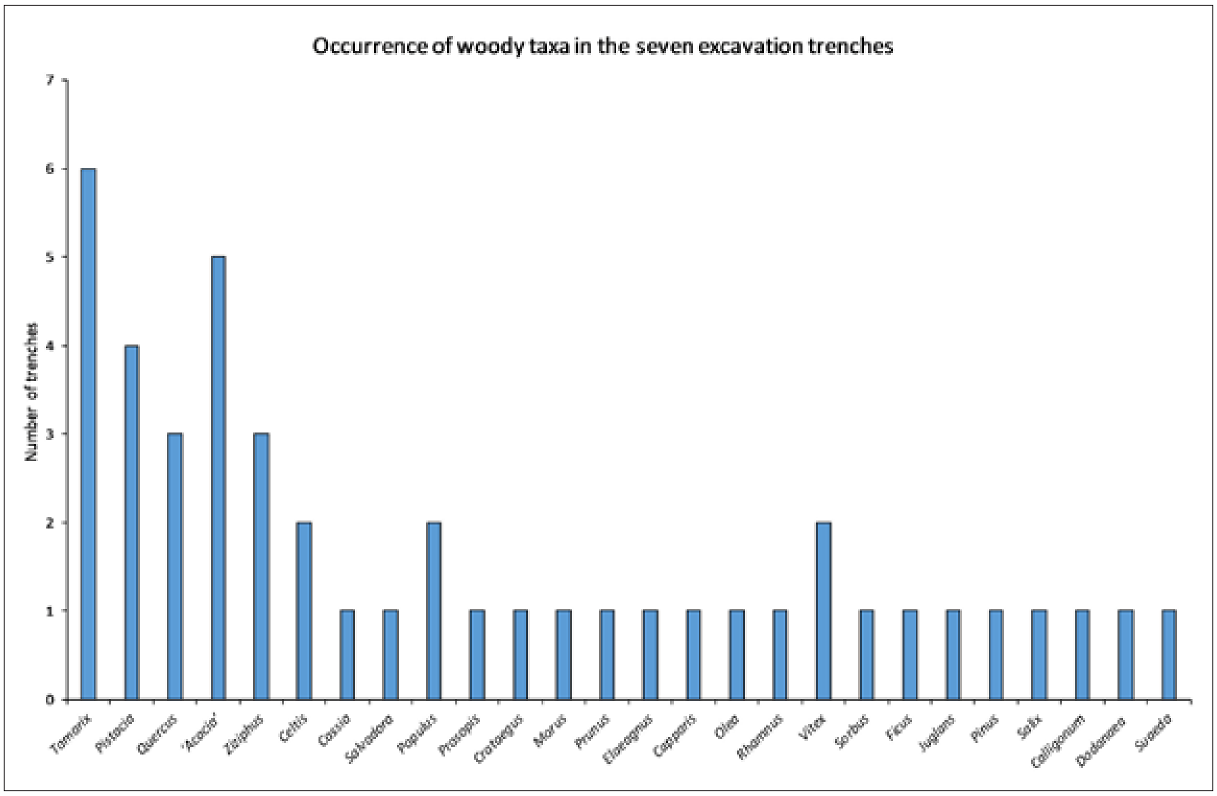

Figure 10. Occurrence of woody taxa in the assemblages from the seven principal excavation trenches.

taxa are fewer in the *Early SKT Phase*, there is nevertheless a strong presence in this phase of taxa from phytogeographical zones that, based on present-day distributions, could have been some distance away from the site (see Discussion for a critical evaluation of this hypothesis).

Variation between contexts

The main types of contexts from which samples came are floor deposits, hearths, pit fills and general ashy fills, the latter probably associated with collapse and levelling activities, or with the large–scale ashy pit fills of the latest stratigraphic phase in Trench 6. Ideally, a contextual analysis of the distribution and abundance of woody plant taxa would involve context types within and between stratigraphic phases. Here the numbers of samples make such an analysis impossible and only inter–context variation is analysed. Table 4 shows the diversity of woody taxa in samples from the different types of context. The highest numbers of taxa are in samples from hearths (although only five samples fall into this contextual category), varying from 4 to 6 taxa, with a mean of 4.6 taxa. Pits yield the lowest numbers of taxa, although there is a wide spread of data, ranging from one taxon (in most pits) to 6 taxa, with a mean of 2.2 taxa. Where only a single taxon is present in a pit sample, it is either *Tamarix* (in most cases) or 'Acacia'. Floor and ashy fill deposits have wider ranges in the numbers of taxa present.

The distribution of different woody taxa according to context is shown in Fig. 11. *Tamarix* is abundantly represented in all categories, although *Pistacia* is the most frequent taxon in hearths, being present in all five samples. Setting the small number of hearth samples aside, *Quercus* is much more frequently associated with floor (59%) than with pit (22%) or ashy fill (13%) deposits. In these three principal context types, there is a long tail of taxa with low frequencies below a ubiquity level of around 20%. This is especially noticeable for ashy fill contexts, which probably arises in part from the larger number of samples from such contexts (N = 30), as well as from the diversity of formation processes which produced this category of context.

If we consider only the top–ranked taxa from each of the principal contexts, i.e. those with a ubiquity ranking of 20% or higher (as detailed in Table 5), floors have the greatest range of such taxa (6) and pit fills the least (4), with ashy fills falling between. While 'local' taxa account for half of the principal taxa in floor and pit fill contexts, they account for 80% of those from ashy fill contexts (Table 5). Ashy fill contexts are likely to derive from the reworking of destroyed structures, such as houses or other roofed-over buildings, in which locally derived woody materials were used for various structural purposes.

Table 4. Comparison of the diversity of woody taxa between the different categories of contexts. At the head of the columns are the numbers of samples from that category of context. Those in the body of the table are the numbers of samples containing the number of taxa specified in the first column. The mean numbers of taxa in each type of context are in the bottom row.

Number of taxa	Floors (N = 17)	Hearths (N = 5)	Pits (N = 18)	Ashy fills (N = 30)
1	–	–	9	1
2	3	–	3	6
3	7	–	1	16
4	2	3	4	3
5	1	1	–	2
6	2	1	1	2
7	2	–	–	–
Mean	3.9	4.6	2.2	3.2

Table 5. Rank ordering of taxa with a ubiquity greater than 20% (see Figure 11) in the samples from the principal categories of excavated contexts. The bottom row shows the proportions of taxa that are 'local' to Sheri Khan Tarakai in modern times (see Table 7).

Rank order	Floors (N=17)	Pit fills (N=18)	Ashy fills (N=30)
1st	*Tamarix*	*Tamarix*	*Tamarix*
2nd	*Pistacia*	'Acacia'	*Pistacia*
3rd	*Quercus*	*Pistacia*	'Acacia'
4th	'Acacia'	*Quercus*	*Ziziphus*
5th	*Celtis*	-	*Cassia*
6th	*Ziziphus*	-	-
Local taxa	50%	50%	80%

Discussion

The selection and use of woody plants

Table 6 summarizes some of the principal present-day uses of various woody species and their products in Pakistan. Unsurprisingly, most taxa have important uses as fuel wood, timbers for building and for making a range of artefacts. Such uses also probably account for their occurrence in the archaeological wood charcoal assemblages, either from intentional burning of fuel or from becoming charred in accidental blazes. Many of these taxa also provide leafy food (browse or fodder) for animals and fruits or nuts for human consumption, and some might have been valued for their medicinal properties. Such uses would not necessitate the bringing of wood to a site, while some would require taking animals to the places where the trees or bushes are growing for them to feed upon foliage, seedlings, saplings, or fallen fruits and nuts.

Environmental and phytogeographical implications of the assemblage

There is very little direct evidence concerning the past ecology and vegetation of the Bannu region. Using the taxa represented in the wood charcoals assemblage from Sheri Khan Tarakai and their principal ecological and plant community associations at the present day, groups of associated woody taxa in the assemblage can be sorted into discrete zones within the region and further afield. Certain indicator species, diagnostic of local environmental factors such as salinity in the soil, phreatic conditions, and so on, or components of particular communities that today appear to be restricted to certain altitudinal zones, have been carefully evaluated. A tentative model of the principal phytogeographical zones that might be distinguished among the woody taxa from Sheri Khan Tarakai is given in Table 7. The taxa are arranged in order, from those that probably represent the local vegetation zones that

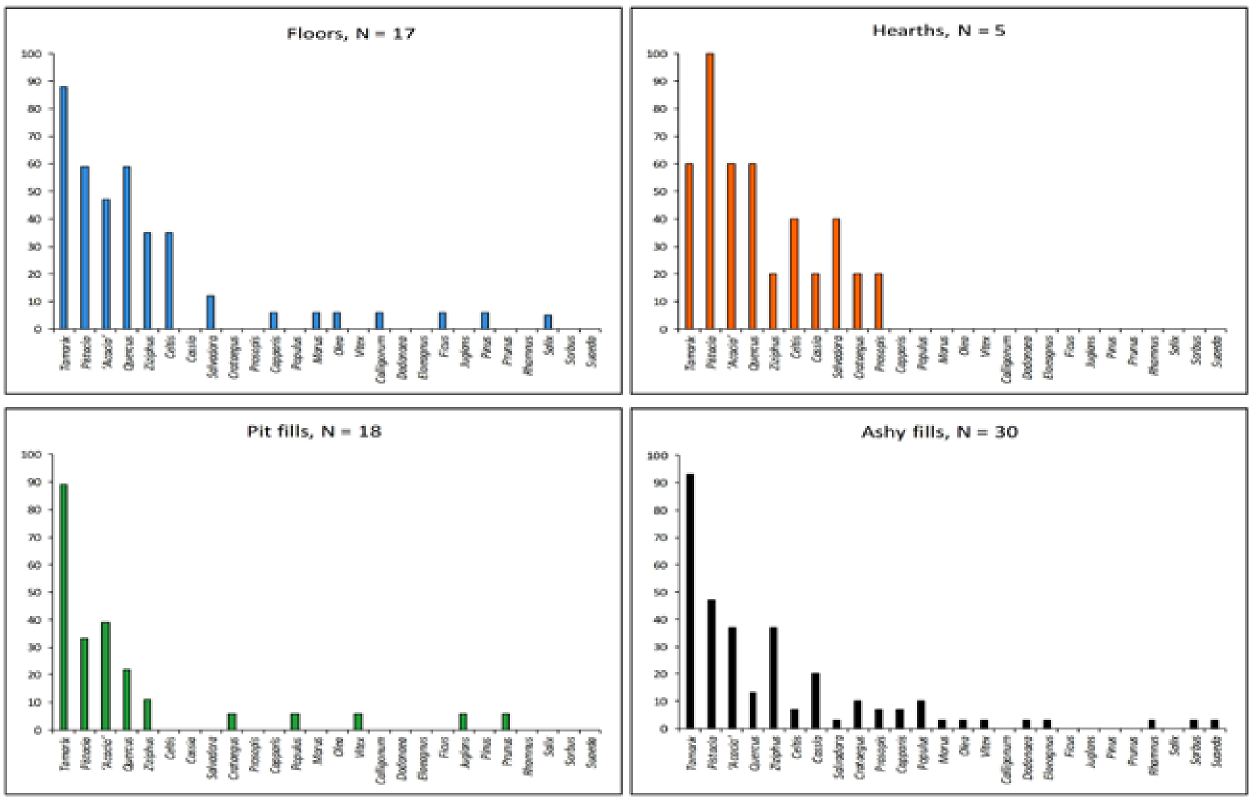

Figure 11. Distribution of woody taxa according to context type. Percentage occurrence of taxa in all the samples for each category of context.

were relatively close to the site, to those from other plant communities and localities increasingly further away, particularly the distinctive altitudinal zones of the lower dry broad–leaved forests, the higher dry broad–leaved forests and the sub–montane dry evergreen forests. Most interestingly, at least twelve taxa were being obtained from the lower and higher hills, and even from the supposed sub–montane zone, including those with high ubiquity in the assemblage such as *Pistacia chinensis* ssp. *integerrima*, *Quercus* cf. *baloot* and *Celtis eriocarpa*, as well as *Pinus*. These results suggest that the altitudinal plant communities attested in the recent past in Pakistan (as, for example, discussed by Champion, Seth and Khattak 1966) can be broadly detected in, or inferred from, the wood charcoal assemblages of the fourth millennium BC. This is, of course, a positivist interpretation based on assumptions of: (i) uniformity in vegetation zonation and the composition of 'communities' over at least the last 5 or 6 millennia, and (ii) the primacy of modern ecological data over palaeoecological data, with the latter being fitted into models based upon the former. An alternative view is that the charcoal assemblage is giving us information about a fourth millennium BC palaeoecology that differed from that of recent times. This idea calls for the following brief digression into the structure of modern ecological science.

The ecological and palaeoecological contexts of this research

Despite differences in intellectual history and methodologies, palaeoecology and present-day (neo-) ecology are now considered as complementary partners in a more inclusive science of ecology (Rull 2010; Bjune *et al.* 2015). Palaeoecologists are ecologists working on a wider range of time scales, but with lower spatial and temporal precision (and often lower taxonomic precision) than neo-ecologists. Environmental archaeology or its specifically ecological endeavour, human palaeoecology, constitutes another branch of ecology (Briggs *et al.* 2006) which employs a diverse range of data from archaeological sites. There are problems and challenges of integrating palaeoecological (including archaeological) data with other types

Table 6. Possible principal uses of the woody taxa in the charcoal assemblage from Sheri Khan Tarakai.

Taxon	Fuel as wood or charcoal	Timber for building	Artefacts made of wood	Bark or pods for tanning	Fruit or nuts for humans	Fruit or nuts for animals	Animal browse	Animal fodder	Fibres for mats, baskets	Medicinal	Ritual or symbolic
Tamarix	x	x	x	x			x				
Pistacia		x	x	x?	x?	x?				x	
'Acacia'	x	x	x	x	x	x	x	x		x	
Quercus	x	x	x	x	x	x	x			x	
Ziziphus	x	x	x		x	x	x			x	x
Celtis	x	x	x					x			
Cassia	x									x	
Salvadora	x	x	x		x					x	
Crataegus	x		x		x					x	
Prosopis	x	x	x	x	x	x	x	x			
Capparis	x	x	x		x					x	
Populus	x	x	x	x?				x			
Morus	x	x	x		x						
Olea	x	x?	x?		x					x?	
Vitex										x	
Calligonum	x	x					x				
Dodonaea			x				x				
Elaeagnus	x	x	x	x	x	x		x		x	
Ficus	x	x	x		x	x				x	
Juglans	x	x	x		x					x	
Pinus	x	x	x		x					x	
Prunus	x		x	x	x		x?				
Rhamnus							x			x?	
Salix	x	x	x					x	x	x	
Sorbus	x?	x?	x	x	x				x		
Suaeda							x	x			
% of taxa	81%	73%	81%	35%	62%	30%	35%	23%	8%	58%	4%

of ecological data (Peng *et al.* 2011), but the importance of doing so is increasingly being appreciated, especially in biological conservation and environmental management, where the longer-term perspectives offered by palaeoecology and environmental archaeology are invaluable (Birks 2012; Gillson and Marchant 2014). A major objective of our work on the wood charcoals from Sheri Khan Tarakai is the insight they may give on past environments and how people in the past interacted with them. As discussed above, the charcoal taxa can be 'sorted' into sub-assemblages to match certain components within present-day plant communities. In classical neo-ecology, these communities can be envisaged as arising through processes of ecological succession, commencing at the end of the last glacial period (the beginning of the Holocene) and leading to increasingly more stable and long-lasting associations between species that can be observed today. How might the history and composition of such 'communities' be perceived from a palaeoecological perspective?

Table 7. Environmental and topographic zones of the taxa represented in the wood charcoal assemblage from Sheri Khan Tarakai, listed according to their likely proximity to the site during its occupation. For convenience of layout, taxa are cited by generic names (Table 1 gives the full names).

TAXON	1: Local dry plains/ desert thorn vegetation	2: Local riverine vegetation	3: Local anthropic vegetation including planted & managed	4: Distant foothills: dry sub–tropical broad–leaved forest	5: Distant foothills: dry sub–tropical evergreen forest	6: Distant upper hills: dry sub–tropical broad–leaved forest	7: Distant upper hills: dry sub–tropical evergreen forest
'Acacia'	■						
Prosopis	■						
Suaeda	■						
Calligonum	■		■				
Tamarix	■	■					
Salvadora	■	■					
Ziziphus	■		■	■			
Capparis	■		■	■			
Populus		■					
Salix		■					
Morus			■				
Vitex			■	■			
Elaeagnus			■	■			
Cassia			■	■			
Dodonaea				■			
Celtis				■		■	
Pistacia				■		■	
Ficus				■		■	
Rhamnus				■		■	
Olea					■	■	
Crataegus						■	
Prunus						■	
Sorbus						■	
Juglans						■	■
Quercus						■	■
Pinus							■

Plant 'communities' in the Holocene palaeoecological record

Recent studies of palaeoecological metadata, mainly of pollen assemblages, have shown that biomes and communities are dynamic entities that have changed in distribution, composition, and structure over time. The consequence of such studies is that successional processes should be considered to be less deterministic than previously thought, with important roles for contingency and for a diversity of pathways leading to the assembly and development of biological communities. For example, Huntley (1990) applied multivariate classification to trans-European pollen data from some 500 sites (mostly lakes) over the last 13,000 yr. The resulting clusters, mapped at millennial intervals, show the changing vegetation of Europe since the last glacial and the impermanence of the assemblages of species that neo-ecologists have hitherto considered to be stable climax communities. In a similar analysis, Williams *et al.* (2004) reviewed late-Quaternary vegetation history for northern and eastern North America across levels of ecological organization from individual taxa to biomes and discussed the biome maps generated from the pollen data from over 700 sites (again, mostly lakes). Shifts in plant taxon distributions involved individualistic changes in population abundances and ranges, and included large east–west shifts in addition to the northward redistribution of most taxa. In both these studies it is clear the dominant patterns of plant associations change through time, reflecting changes in palaeoenvironmental conditions and in the alignment of major environmental gradients. For Pakistan and many other regions of the world we do not yet have such comprehensive palaeoecological data sets, but the lessons from them are clear and there is no reason to suppose their general implications do not apply more widely.

The Sheri Khan Tarakai wood charcoals from a palaeoecological perspective

Returning to the wood charcoals data from Sheri Khan Tarakai, a major question is: can they provide palaeoecological information that is independent of neo-ecological assumptions about plant communities, their distribution and composition? Further analyses of the data might provide clues. We have seen (Table 7) that the taxa present in the assemblage are also to be found in a range of present-day plant associations, some local to the site and others further away. We have re-organised these data into three main present-day categories: groups of taxa local to the site, those present in the foothills and those to be found in the upper hills (Fig. 12). Some 60% of the taxa, by mass and ubiquity index, fall into the local group, with the other two groups each having 20%. A progressive fall-off curve of abundance against distance would accord with expectations, and this does apply to the local category compared with the two others. However, the 'foothills' and 'distant hills' categories have identical representation, suggesting that a simple distance model is not valid and that these groups of taxa, or some of the taxa in them, might have been closer to Sheri Khan Tarakai than their modern distributions suggest. If we break these categories down into the taxa within each of them (Figs. 13a–c), we see that the foothills category (Fig. 13b) is dominated by *Celtis* and *Pistacia* (although, as shown in Table 7 column 6, these taxa can extend into the distant hills zone), and the distant hills category (Fig. 13c) is dominated by *Quercus* c.f. *baloot*. Some of the charcoal fragments of *Quercus* c.f. *baloot* from Sheri Khan Tarakai that were selected for radiocarbon dating were of twiggy wood. If the oak trees had indeed been restricted to the 'distant hills', quite why small twigs of this oak were collected and brought to the site is puzzling. Unless, of course, the dry oak forests were a lot less distant than today: a possibility we consider next.

The ecological status of Quercus baloot and associated taxa

Various authorities have recorded aspects of the ecology and vertical range of *Quercus baloot,* which we summarise here. Negi and Naithani (1995) describe *Q. baloot* as a small evergreen tree or large shrub (2.5–8 m tall) of dry temperate forest habitats, often today found in steep or rocky terrain. It, along with taxa such as *Pistacia* and *Olea*, indicates former Mediterranean–type forest vegetation, although *Olea* is also found below the oak zone (Champion, Seth and Khattak 1966). Beg (1975, 33) notes it as a component of dry temperate evergreen oak forests, with Mediterranean-type climate out of range of the southwest monsoon. It occurs from 1220 – 2130 m asl in Kurram Agency northeast across to Jammu and Kashmir, alongside taxa including *Cedrus deodara* and *Pinus* species. According to Oaks of the World (2020), it can be found at altitudes from 1000 to 3000 m on all types of soils. Ahmed *et al.* (2010) found *Quercus* baloot at two locations between 1415m to 1580m, as a co-dominant species with *Olea ferruginea*. The Flora of Pakistan (2011) records it as present in dry valleys from 1800-3000 m, being gregarious and often associated with pine. The distribution includes Kurram Agency, above Parachinar at c. 2000 m, where it is 'very common'. Stewart (1972, 189) also notes that *Q. baloot* is gregarious in dry inner valleys 1200-2600 m asl, including Kurram. We note here that Parachinar is some 120 km north of the location of Sheri Khan Tarakai.

In a detailed study of dry oak (*Q. baloot*) forests in Pakistan, the forest botanists A.R. Beg and M.H. Khan note that these once occurred over a large area but have largely been destroyed by felling, lopping for timber or fuel, and/or to open-up land for cultivation or use as rangelands (Beg and Khan 1980, 109). They make a key observation: obliteration, especially of the lower limits (our emphasis), makes it difficult to determine the true biogeographical distribution of this forest type. Khan *et al.* (2010) also observed that trees of *Quercus baloot* and *Quercus dilatata* were at risk of elimination due to a range of anthropogenic factors, either through direct cutting down or lopping of branches, or from overgrazing leading to environmental degradation, such as soil erosion creating bare rock surfaces.

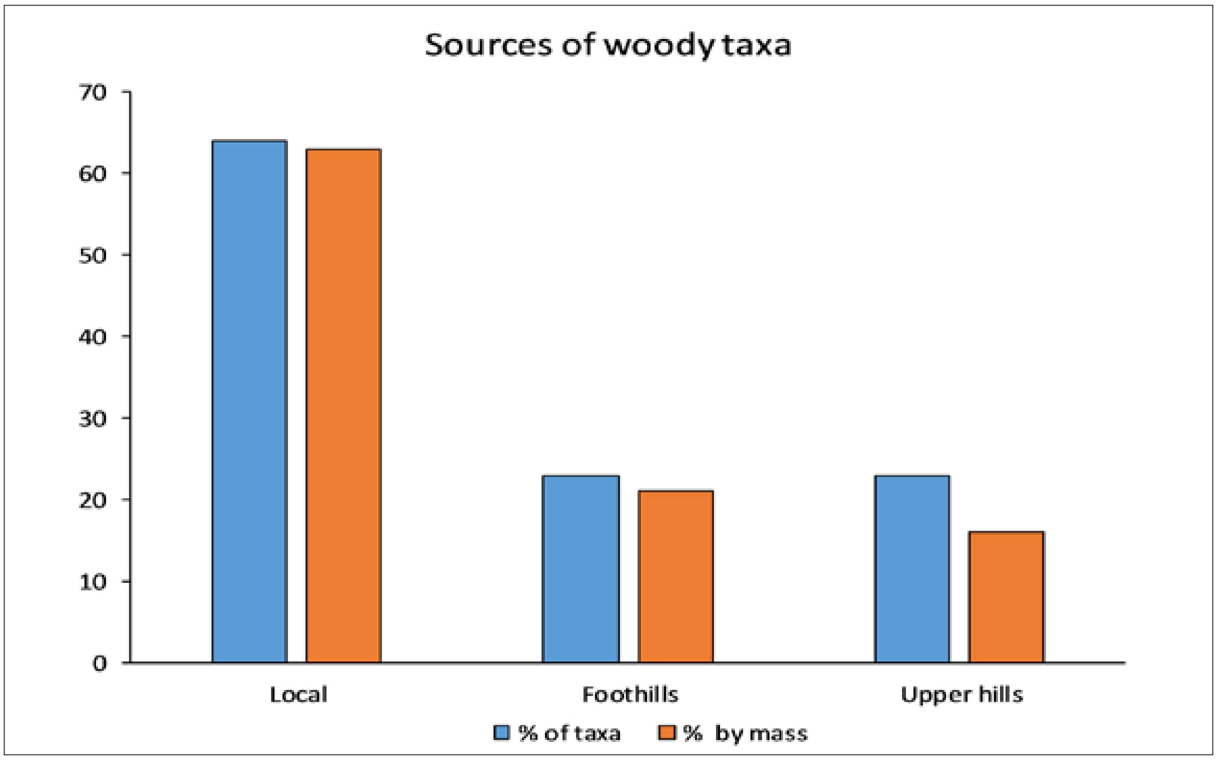

Figure 12. Possible sources of woody taxa in relation to present-day topographic and associated environmental parameters, based upon Table 7: 'local' (combining columns 1 to 3 in Table 7), those from the 'foothills' (columns 4 and 5) and those from the 'upper hills' (columns 6 and 7). To avoid duplication of taxon counts, taxa occurring in both the 'local' and 'foothills' groups are assigned to the 'local' group; similarly, taxa occurring in both the 'foothills' and 'distant hills' groups are assigned to the foothills group. See text for further discussion.

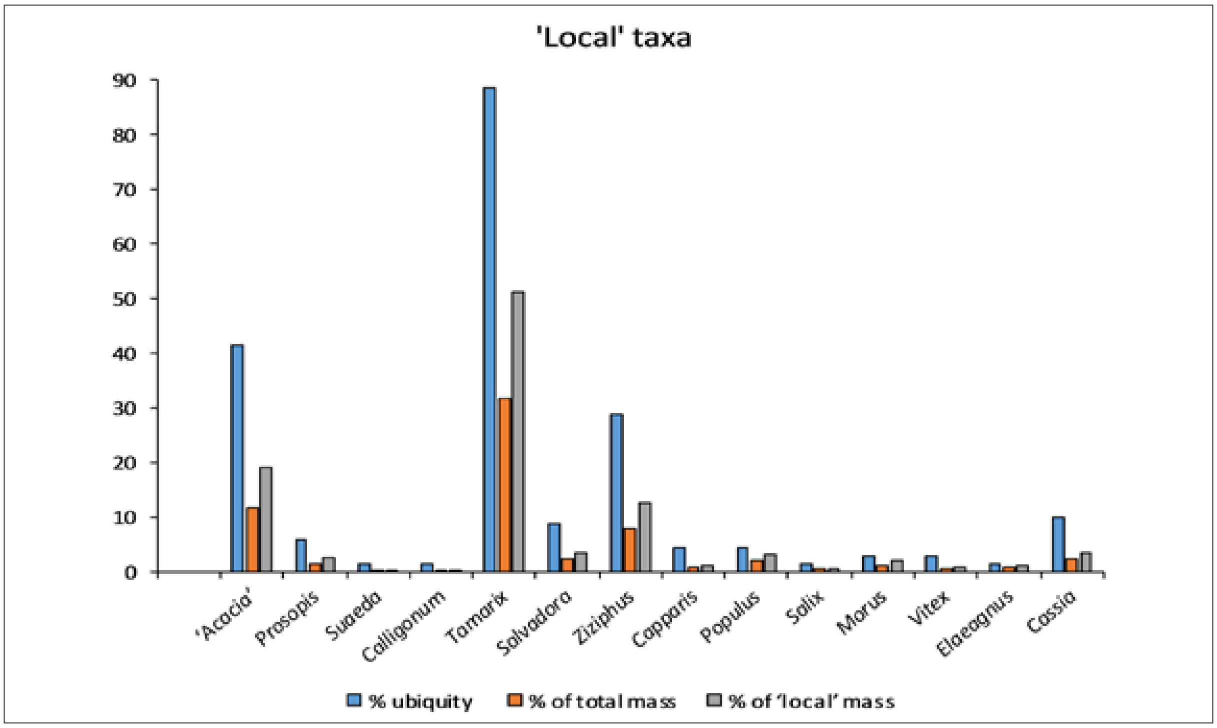

Figure 13a. Frequencies of 'local' woody taxa as percentage ubiquity across all samples (see Table 2), percentages of the total mass of charcoal from the site (see Table 1), and percentages of the total mass of charcoal within the category 'local taxa'.

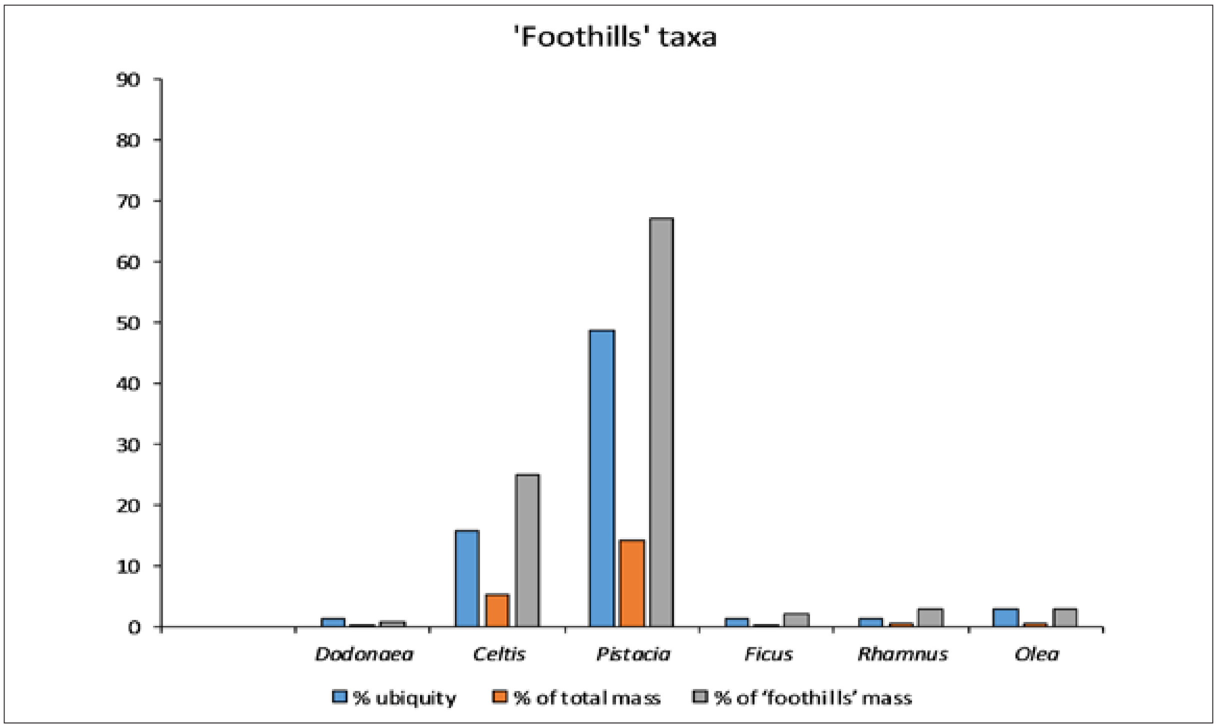

Figure 13b. Frequencies of 'foothills' woody taxa as percentage ubiquity across all samples (see Table 2), percentages of the total mass of charcoal from the site (see Table 1), and percentages of the total mass of charcoal within the category 'foothills taxa'.

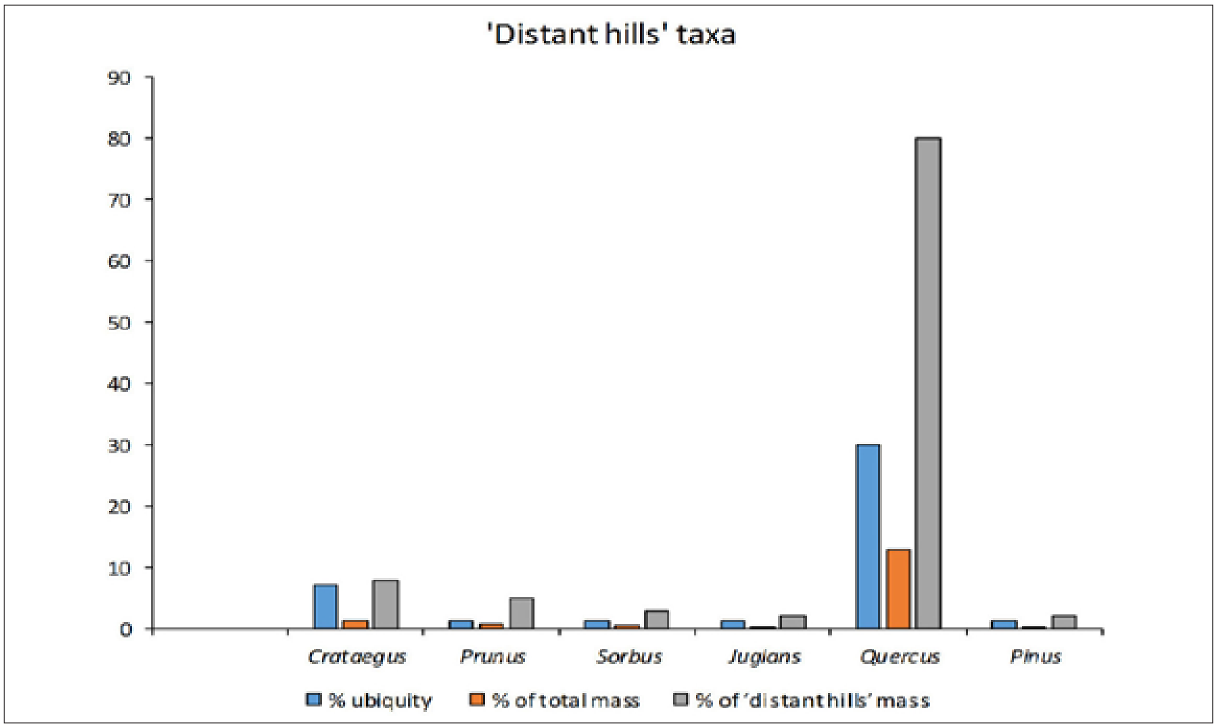

Figure 13c. Frequencies of 'distant hills' woody taxa as percentage ubiquity across all samples (see Table 2), percentages of the total mass of charcoal from the site (see Table 1), and percentages of the total mass of charcoal within the category 'distant' hills taxa'.

Beg and Khan (1980, 119) suggest that dry oak forests once occurred at 900-2550 m asl or even lower, but have been replaced by a scrub of *Reptonia*, *Olea* and *Acacia* (among other taxa) growing as a zone below what remains of the once-extensive dry oak forests. They suggest *Reptonia* scrub to be a reliable indicator of the former oak/pine belt that occurred widely in the region, including in North and South Waziristan immediately to the west of Bannu District. Thus, the former oak (*Q. baloot*) and *chir* pine (*P. roxburghii*) zone, along with other associated woody taxa, could once have extended down to about 600-1350 m asl.

Using the altitudinal ranges suggested by Beg and Khan (1980) for the past zones of dry oak forests (900-2550 m asl) or oak/pine forests (600-1350 m asl), for the former altitudinal range there are hills in Waziristan at 1000 m asl, about 25 km west of the site of Sheri Khan Tarakai. For the latter range of altitudes, hills at 600 m asl are to be found less than 10 km west of the site. Still a long way, perhaps, over which to transport twigs of oak, along with all the other wood resources that could be obtained, but far less than the distances of 120 km or more based on the present-day distribution of such plant associations.

Conclusions

The wood charcoals assemblage recovered from the site of Sheri Khan Tarakai is very diverse, comprising 26 taxa of trees and shrubs. We have sought to analyse the assemblage in terms of how these woody resources were used on the site and to what extent they can inform about past environments around the site and its broader region, including human exploitation of such environments. Based upon their present-day distributions, many of the woody taxa would have been available from habitats 'local' to the site, but significant numbers of taxa are to be found, today, in plant associations at varying distances from the location of the site (more than 120 km in some cases). Following a discussion of the relationships between present day ecology and palaeoecology (including environmental archaeology), we suggest it is unlikely that the 'ecological present' can provide wholly adequate analogues for the 'ecological past'. Human impact in the forest zones in the recent past and continuing today, have dramatically altered the composition and zonal distribution of many associations of woody plants. These impacts have modified distributions, especially at lower altitudes. After a critical evaluation of the ecology and distribution of the dry oak forests and oak/pine forests, we suggest that such habitats with their rich array of woody taxa (many of which are represented in the archaeological assemblage) were much closer to the site, possibly some 10 km or less, than today.

We hope to have shown that wood charcoals from archaeological sites, although less aesthetically appealing than pottery or figurines, can nevertheless provide a great deal of information about the human past. Moreover, that wood charcoals are among a range of evidence used in environmental archaeology to investigate human palaeoecology, to assess the impact of human activities on their environments, and to provide a long-term perspective on current environmental problems.

Acknowledgements

We write this paper in memory of our dear friend and colleague the late Professor Farid Khan, and his brother the late Mr Feroze Khan; without their support our work in Bannu District would not have been possible. We thank Dr A.R. Beg of the Pakistan Forest Institute, Peshawar, and Professor Jehan Dar Shah of the Department of Botany, Islamia College, Peshawar, for valuable information and stimulating discussions. Our colleagues in the Bannu Archaeological Project, in particular Dr Cameron Petrie and Mr J. Robert Knox, have given us unfailing and enthusiastic support. We are grateful to the three reviewers of our manuscript for their positive comments and to the editor, Professor Ibrahim Shah, for his encouragement and guidance.

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