The double-domed Great Shrine of Gumbat/Balo Kale
Note on the xilotomic analysis for the wood identification

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Abstract

*This short article updates the information given in a note appeared in the Gumbat/Balo Kale excavation report (*Olivieri et al. 2014*). The new note it has been accepted in this Journal (with the courtesy of ACT/ISMEO) in recognition of its seminal importance. In fact, it is one of the first instances where modern xilotomic analysis is applied to archaeological remains of historic period in Pakistan. A study model that the Editors of this Journal hope may be replicated in future in other important sites of Greater Gandhara.*

1. Introduction

Fieldwork at Gumbat/Balo Kale (GBK I) was conducted in 2011-12 within the framework of the ACT Project (Meister 2011; Meister and Olivieri 2012; Olivieri et al. 2014; Meister, Olivieri and Vidale 2016). During the campaigns the Pakistani-Italian team conserved the monumental shrine at Gumbat [Great Shrine], excavated the terrace on which the shrine was erected, and conducted technical analysis on the wooden elements still embedded within the architectural structure of the monument. The four load bearing timber elements found in the lower inner dome of the Great Shrine of Gumbat/Balo Kale are important components of its carpentry. They are the wooden joist-like element (called element 4), the three crossed beams supporting the SE corner of the inner ceiling (labelled as elements 1, 2, 3). Samples of all the elements were taken for anatomical analysis.

2. Wood identification

In order to identify the species of the timber members, observation of macro- and microscopic features of wood has been carried out. The anatomical examination

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has been developed on four different specimens sampled one from each beam, labelled as for radiocarbon datation, and compared each other.

Fig. 1 - The terrace of GBK I seen from N. (Photo by E. Loliva).

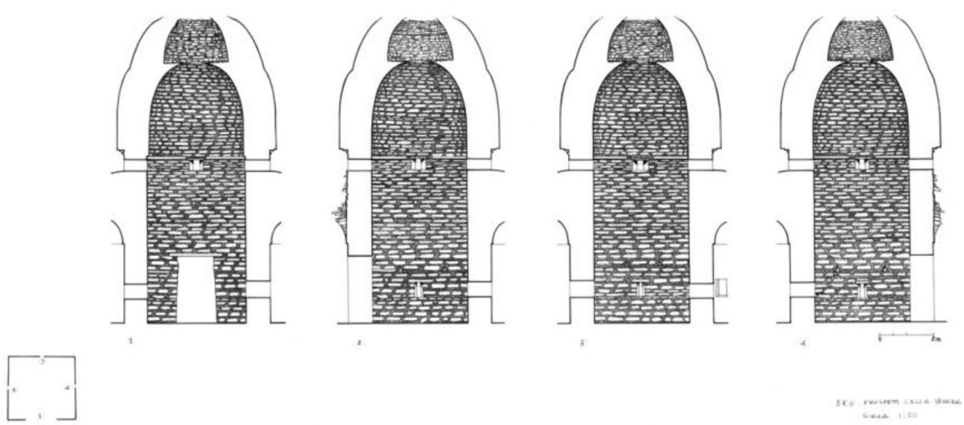

Fig. 2 - Sections of the cella of the Great Vihara (clockwise from E). (Drawings by F. Martore).

Figs. 3-4 - Conservation in progress (below: a detail of the double domes).
(Photos by F. Martore).

The wood identification was carried out with the typical methodology used in the wood anatomy science, according to the IAWA principles (www.iawa-website.org). Thin slices of wood were cut by means of a cryostat microtome and prepared to be observed to the light microscope. Through the comparison of the four specimens, no significant differences were found, disregarding the natural individual variability, therefore it can be stated that all the analysed beams belong to the species *Acacia modesta* Wall., a hardwood of Fabaceae Family, where *Acacia modesta* Wall. is the basionym of the new name *Senegalia modesta* (Wall.) P.J.H. Hurter (Dyer, 2014) .

More than 1300 species of the genus *Acacia* have been described all around the world, and twelve in Pakistan (Sheikh 1993). *A. modesta* and *A. nilotica* are very similar, from the point of view of the anatomical properties. Both are native of Pakistan, but in different habitats (Sheikh 1993). On the basis of geographical distribution, the species *A. modesta* has to be considered the most likely choice.

The main microanatomical features of diagnostic relevance are: wood diffuse-porous; vessels with simple perforation plates and shape of alternate pits polygonal; vestured pits in vessels (a particularly noteworthy character); gums and other deposits abundant in heartwood vessels; axial parenchyma vasicentric, aliform, confluent and in marginal or in seemingly marginal bands; larger rays commonly 4- to 10-seriate; all ray cells procumbent; prismatic crystals in chambered axial parenchyma cells.

The microscopic analysis by polarized light microscope showed a high bi-rifrangence of cellulose in cell walls, associated with an excellent state of preservation.

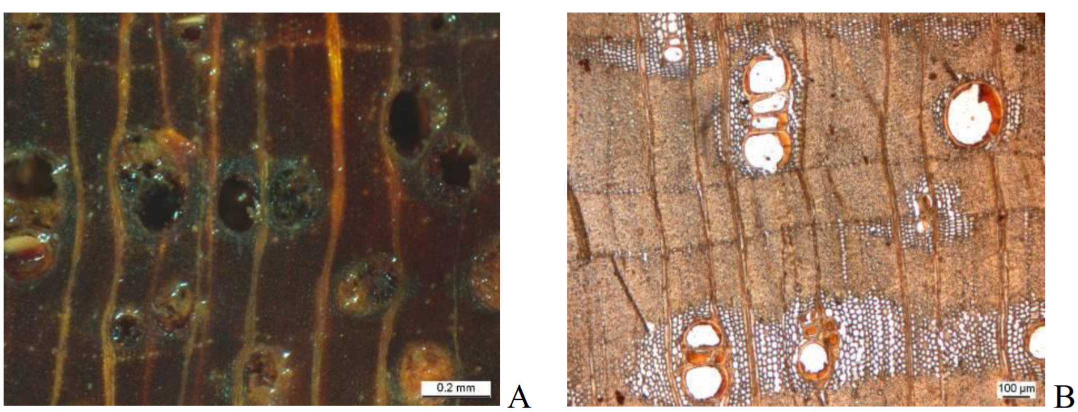

Fig. 5 - Cross section. A: element 4, stereomicroscopy. B: element 3, transmitted light microscopy. (Photos by GG).

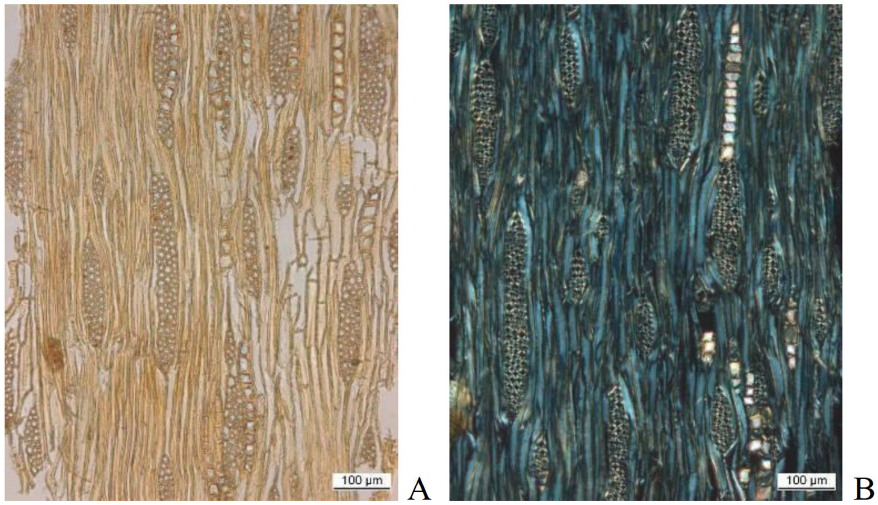

Fig. 6 - Tangential section: element 4, light microscopy. A: normal transmitted light. B: polarized light, that highlights the presence of crystals chains in axial parenchyma. (Photos by GG).

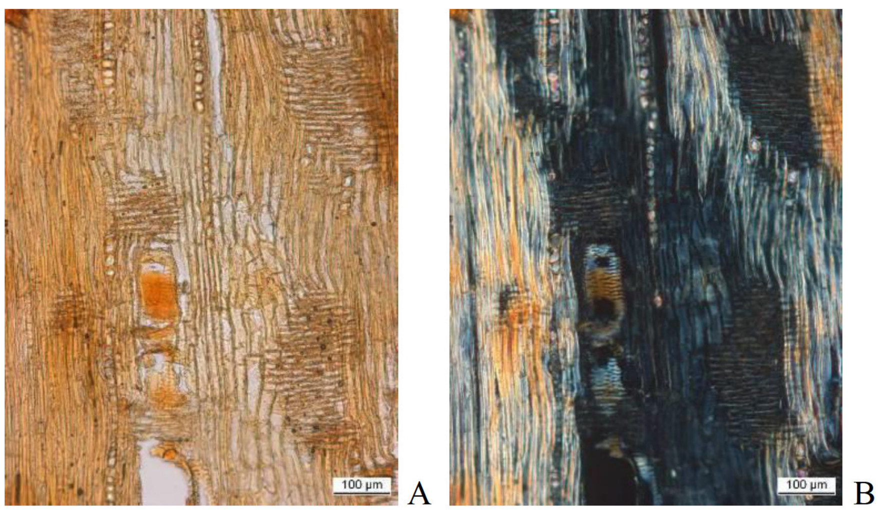

Fig. 7 - Radial section: element 4, light microscopy. A: normal transmitted light. B: polarized light. (Photos by GG).

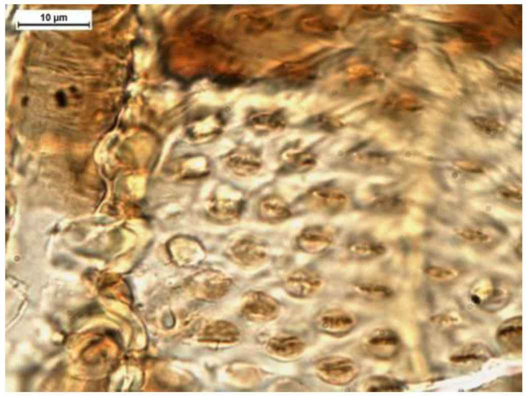

Fig. 8 - Vestured pits visible on longitudinal section (element 3). Transmitted light microscopy at high magnification. (Photo by GDG and GS).

Density of the specimens

As an additional diagnostic element, the density of some specimens was determined. Due to the irregular shape, the volume of each specimen was measured through the buoyant force (according to the Archimedes' principle). Both for the measure of the load of the specimens and of the force generated by the distilled water moved by the body in it immersed, an analytic balance was used. Results showed a density very similar to the value coming from literature.

Description	Density [kg/m³]
Element n. 1	971
Element n. 2	995
Element n. 3	970
Element n. 4	1003
Reference density (mean value of the species)	
Sheikh 1993	960
Pearson & Brown 1932	993

Wood density at 12% of moisture content

Properties of the species

Common names for *A. modesta* are Phulai and Palosa, depending on the geographic area. As Sheikh wrote, this species is native to Pakistan, Afghanistan, and India. Nizami (2012) indicated that *A. modesta* is one of the two dominant species in the subtropical broadleaved evergreen forest of Kherimurat and Sohawa with a medium stem density close to 190 trees on one hectare.
In Pakistan it is found below 1200 m in the foothill ranges of the Himalayas, Salt Range, Sulaiman Hills, Balochistan, and Kirthar Range and it is also found in the plains close to these mountains. A schematic representation of the growth area is reported in the next *ad hoc* drawing.

Fig. 9 - Map of the natural growth area in Pakistan of *Acacia modesta* Wall. Red dot: site of Gumbat. (Drawings by GS and GDG).

A. modesta is a deciduous, thorny moderate-size tree, 3 to 9 m tall. Diameters up to 2 m have been recorded (Sheikh 1993).
The wood was historically described by Pearson and Brown (1932) as '*light russet with a faint greenish cast, ageing to dark brown, often with darker streaks somewhat lustrous fairly even and straightgrained, medium-textured. It is a strong and extremely hard wood. Certainly the hardest acacia timber examined durable, even in exposed positions, and in contact with water'*. In a more recent description, its properties are summarized as follows: close-grained wood with heartwood sharply distinct from the white sapwood, heartwood is dark brown with typical black streaks (Sheikh 1993). Wood specimens, mechanically

extracted from the beams, exhibit greasy and blackened surfaces, caused by the repeated exposition to the carbon black originated by bonfires lit inside the dome during its long-life history. Despite the age and exposition conditions, wood shows a very good preservation state so that, a few millimeters under the surfaces, the original natural colour can be observed (figure below).

Figs. 10-11- Particular of the sampling point from beam 4, on the SE corner. (Photos by E. Loliva, processed by GG).

3. Conclusions

This plant has been recognized a significant ethnobotanical value: extraction of leaves, as well as extract oil and gums are used in popular medicine for different purposes (Yaseen et al. 2015). Foliage is used as fodder, fencing/hedge plant and locally as timber: because of its hardness and resistance, it is used in the manufacture of ploughs and other agricultural tool, but also as roof beams and in the frame of doors (lintels) (Faiz Ul Haq et al. 2010; Sher et al. 2012). Many authors described as relevant the use as fire wood (Faiz Ul Haq et al. 2010; Tahir et al. 2010; Groninger 2012; Sher et al. 2012).

The wood is very heavy, with an average density close to 1000 kg/m³ (960 kg/m³ Sheikh 1993, and 993 kg/m³ Pearson and Brown 1932). The same authors agreed considering the wood as heavy, hard and very strong, durable even in exposed positions and in contact with water (meaning the heartwood only). The characteristics listed above, combined with the particular colour (described as '*decorative wood'* by Pearson and Brown 1932) and the potential growth dimensions of the trunk, are all favourable reasons for the use as structural timber in the studied building (see the data, partly coeval with Gumbat, collected at Ahichchhatra, Srivastava 2004). As demonstrated by the data collected, the specimens have the mean value typical of the species and they do not indicate any sign of mass lost, notwithstanding the exceptionally long service life.

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