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Research Article

Qin structural timbers and the First Emperor's Mausoleum (Xi'an, China)

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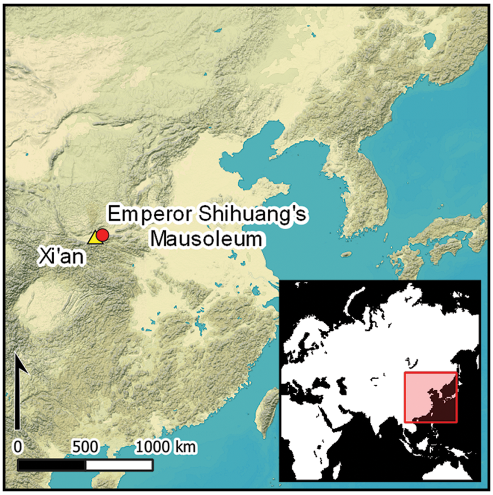

Anthracological studies of preserved wooden building materials can help reveal ancient networks of resource mobilisation. Here, the authors report on the analysis of 657 charred timbers from four ancillary pits at the UNESCO World Heritage Site of the Mausoleum of the First Qin Emperor. The frequent use of dark coniferous wood (fir, spruce and hemlock) indicates sophisticated logistical planning and labour organisation—matching historic records of Qin administrative ascendency—because these species required sourcing from across many kilometres of rugged terrain. Identification of a temporal shift towards the use of higher-elevation species points to the ecological impact of large-scale timber harvesting.

Keywords: East Asia, Shaanxi Province, Qin, archaeobotany, architecture, forest ecology, charcoal

Introduction

Wood is a vital resource and has been integral to technological, political, economic and cultural development throughout human history. While charcoal studies (anthracology) are increasingly employed in archaeology, this information contained within charcoal fragments is still underexplored, especially in terms of evidence for resource supply chains. The mausoleum of the First Qin Emperor offers a high-profile example of timber use in funerary architecture, with the diverse charred wooden elements providing an opportunity to examine wood use in early imperial China.

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Table 1. Summary of previous charcoal identification studies on building elements from the mausoleum.

			Identified taxa						
Source	Location	Type	*Abies*	*Picea*	*Tsuga*	*Keteleeria*	Ulmaceae	*Phoebe*	Total
Zhang 2002	TAP1	Unknown	3						20
	TAP2	Unknown	7	6	3		1		
Subtotal			10	6	3		1		
Wang & Zhao 2018	TAP1	Crossbeam or Square timber		18	21				39
Wang *et al.* 2009	TAP1 & 2	Crossbeam	6	3	6			1	20
		Pillar	1	1					
		Square timber	1						
		Timber for closing the entrance		1					
Subtotal			8	5	6			1	
Duan *et al.* 2001	K9901	Crossbeam		Unknown number					/
SIA & MQTA 2007	K0007	Crossbeam, pillar, or planks (unspecified)		5		6			11

The mausoleum in Xi'an, with its associated pits of terracotta warriors, belongs to Emperor Qin Shihuang (Ying Zheng 嬴政), who founded the first united and centralised empire in China *c.* 221 BC. The mausoleum complex includes an underground palace, walls, gates, ritual buildings and more than 300 ancillary pits and tombs. The world-famous Terracotta Army pits (TAPs) are just one group of ancillary pits situated beyond the outer wall of the mausoleum, with others mostly remaining unexcavated. These pits were typically composite earth-wood structures. Excavations and augur survey suggest that many were deliberately burnt and damaged. The charred wooden structures in these pits provide evidence for the use and supply of wood resources. Previous studies have reported on wood used in the mausoleum but are based on a limited number of samples (Table 1). Here, focusing on architectural timbers, we report the first systematic study of wood remains from the mausoleum, examining taxonomic composition and the co-occurrence of wood types across different pits and structural elements. Our results provide insights into wood choices, supply sources and potential resource management during the Qin Dynasty.

Figure 1. A view, looking south, of the current vegetation of Mount Li (photograph by Q.W. Zhang).

Study area

The mausoleum—in what is now Lintong District, Xi'an City, Shaanxi Province—is located on an alluvial fan 7km south of the Wei River, at the northern foot of Mount Li, which is part of the Qinling mountain range (SIA & MQTA 2000: 6; Zhang 2013: 47). The site lies in a transition zone between the semi-humid climate of temperate East Asia and the more arid climate of the interior (LCCCLC 1991: 95). It has a warm-temperate continental monsoon climate with a mean annual temperature of 13.5°C, an annual temperature range of 27.8°C and 553.5mm mean annual precipitation (LCCCLC 1991: 95). Mount Li covers an elevation range from 500–1220masl (Xue 1992). Its existing forest cover is sparse, primarily consisting of cultivated black locust (*Robinia pseudoacacia*) forests, Chinese thuja (*Platycladus orientalis*), mixed forests of these two species, a small amount of Chinese red pine (*Pinus tabulaeformis*), poplar (*Populus tomentosa*) forests, etc. (Chu 1996) (Figure 1).

Materials and methods

A total of 657 samples were collected from charred wooden building elements in TAP1, TAP2, the Stone Armour Pit (K9801) and the Pit of the Acrobats (K9901). These elements included crossbeams, pillars, square timbers, floor panels, side planks, sills and timbers for closing the pit entrance (Figures 2B & 3, Table 2). Element types were determined

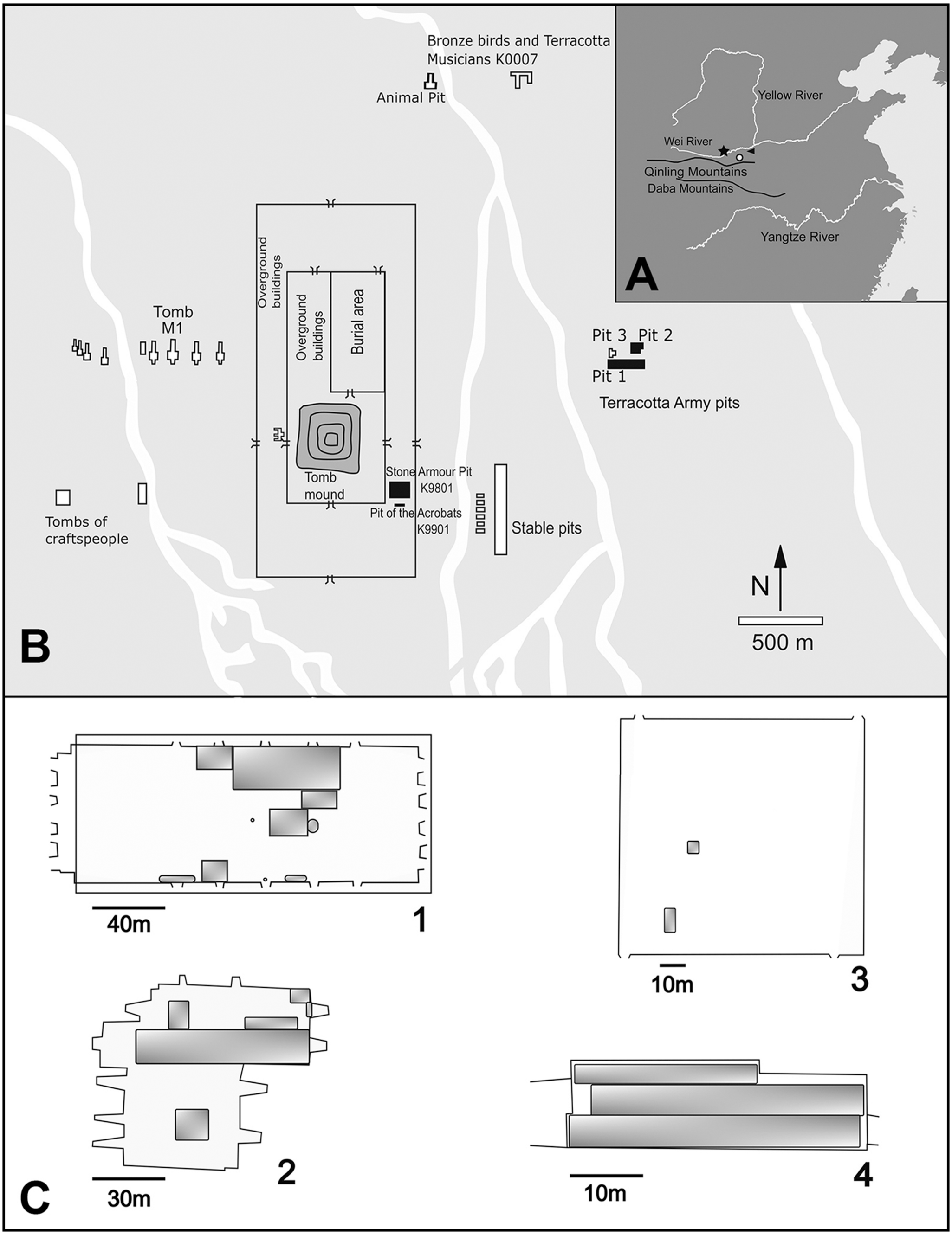

Figure 2. A) Study area showing the location of the Qin capital city of Xianyang (star), the modern city of Xi'an (circle) and the mausoleum site (triangle); B) the layout of the mausoleum (the black areas are investigated pits); C) sampling areas in each pit (1: Pit 1/TAP1, 2: Pit 2/TAP2, 3: K9801, 4: K9901) (figure by authors).

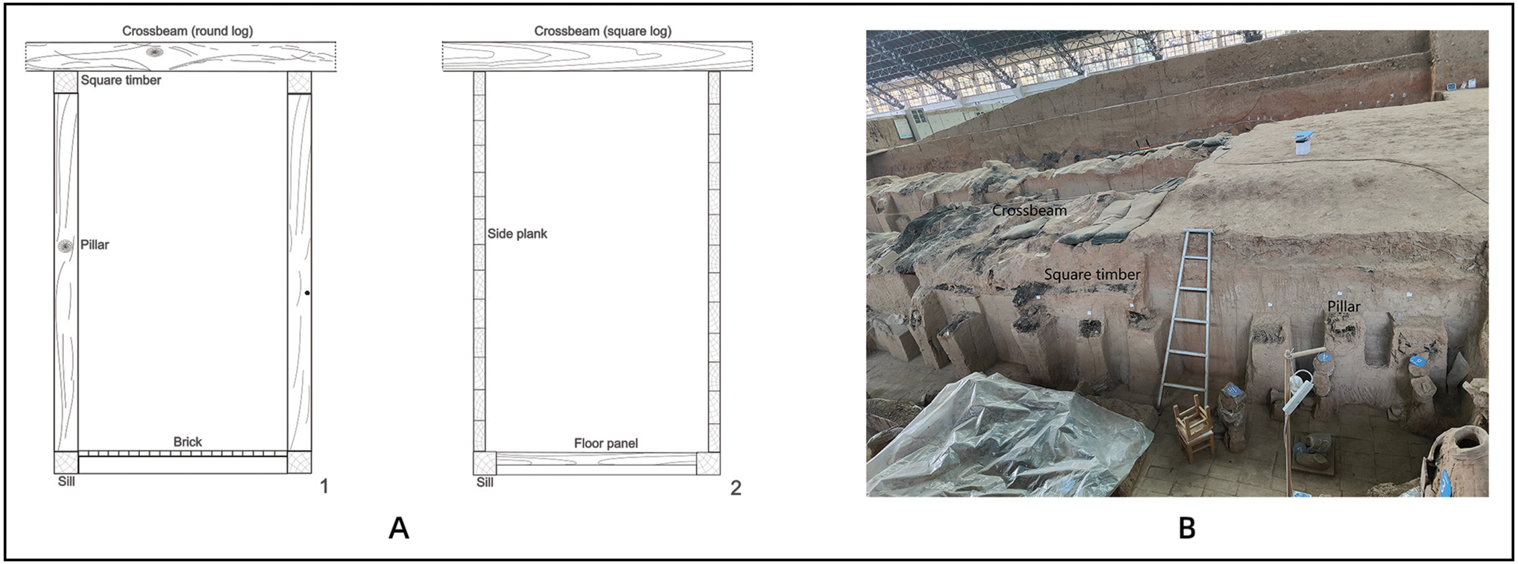

Figure 3. A) Schematic cross-sections of typical corridors showing the primary wooden frameworks (1: TAPs; 2: K9801 and K9901); B) remaining structural elements inside TAP1 (figure by authors).

Table 2. Numbers of samples of different element types in each pit.

Location	Crossbeams	Pillars	Square timbers	Floor panels	Side planks	Sills	Timbers for closing the entrance
TAP1	115	133	64	/	/	0	5
TAP2	178	8	11	/	/	0	5
K9901	35	3	/	49	6	16	0
K9801	3	0	/	21	1	4	/

based on the remaining *in situ* structures and observations of the excavation team (Figure 3B). Sampling covered eight corridors of TAP1, 14 corridors in TAP2, all three corridors in K9901 and two trial excavation units in K9801 (Figure 2C).

Both the floors and walls of K9801 and K9901 were covered with wooden panels, while the ground of TAP1/TAP2 is paved with fired bricks and the walls lack wooden coverings. All the sampled pits share the same fundamental architecture—crossbeams, pillars and sills—and three (TAP1, TAP2 & K9901) include further timbers for closing the entrance. Square timbers, however, are present only in TAP1/TAP2; the top rows of side planks in K9801 and K9901 play the same role (Figure 3A; SIA & MQTA 1988: 24–35, 2000: 54–58, 172–74; MQTA 2009: 71–97; Cao *et al.* 2013). Due to severe burning in K9801 and limited excavation of the pit, only two pillar remnants were recorded (SIA & MQTA 2000: 55), though these were not observed during sample collection.

Not every element could be found in each pit, but each element type was sampled from at least two different pits. Each sample consisted of one fragment of charcoal, more than 4mm in length, and a judgemental sampling method was adopted, with samples collected from elements that were better preserved and the architecture more clearly identifiable and safely accessible.

Each sample was carefully broken with the aid of a scalpel to expose fresh transverse, radial and tangential longitudinal sections. A Motic BA310Met microscope was used to observe the anatomical features of each section, and a FEI Quanta 650 scanning electron microscope (SEM) was used to take representative images after a double gold-coating. The taxonomic identifications are based on anatomical features with reference to published atlases of Chinese tree species (Cheng *et al.* 1992; Itoh *et al.* 2022). A Fisher's exact test with Monte Carlo estimation was applied to test the association between taxa composition and pit/element type ($\alpha = 0.05$). A post-hoc test using pairwise tests of independence for nominal data with adjusted p-values (Holm method) was then applied to identify which pairings were statistically significantly different. Entrance-closing timbers and side planks were not included in tests for associations between taxa composition and element type for each pit/pit for each element type, due to a smaller subtotal sample size.

Results

Most samples were identifiable to the genus level, indicating that 650 specimens derived from 11 genera (Figures 4, 5, 6, 7 & Table 3). Two samples from floor panels in K9901 were identified only at the family level. Poor preservation also meant that

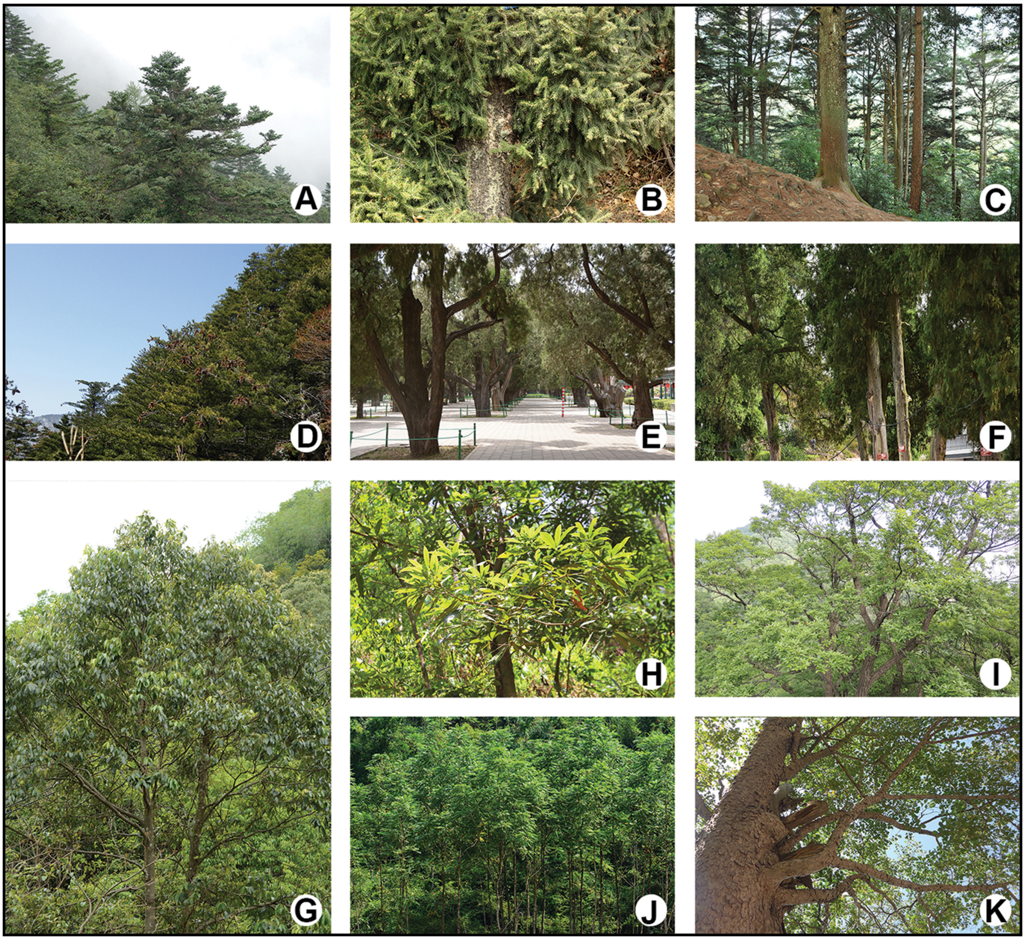

Figure 4. Identified genera: A–C) dark coniferous species: Abies, Picea *and* Tsuga*; D–F) conifers from lower elevations:* Pinus, Platycladus *and* Cupressus*; G–K) broadleaved trees:* Cinnamomum, Phoebe, Quercus, Toona *and* Ulmus *(images from the Plant Photo Bank of China with permission; photographs by G.M. Li, Z.C. Xue, Z.R. Yang, R.B. Zhu, J.W. Xi, A. Liu, Y.P. Zeng, J. Wang, Z.C. Liu, J.J. Zhou & M. Li).*

one sample from K9901 could be classified only as a diffuse-porous tree, and another four as broadleaved trees.

Overall, 94% of samples were of coniferous wood. Of this group, *Abies* (fir), *Picea* (spruce) and *Tsuga* (hemlock) account for 36%, 31% and 22%, respectively. Below we group these three taxa as 'dark coniferous species'. Yet variation across pits is apparent. About 96% of samples come from dark coniferous species in TAP1 and TAP2, with a sparse presence of *Pinus* species and broadleaved trees (Figure 8). Among samples from K9901, wood from dark coniferous species accounts for 74%, while timbers from Cupressaceae and broadleaves contribute 3% and 23%, respectively. In K9801, however, wood from Cupressaceae (including the genera *Platycladus* and *Cupressus*) accounts for the majority of samples (55%). Differences in taxa composition between the four pits were statistically significant (Fisher's exact test, $p<0.001$).

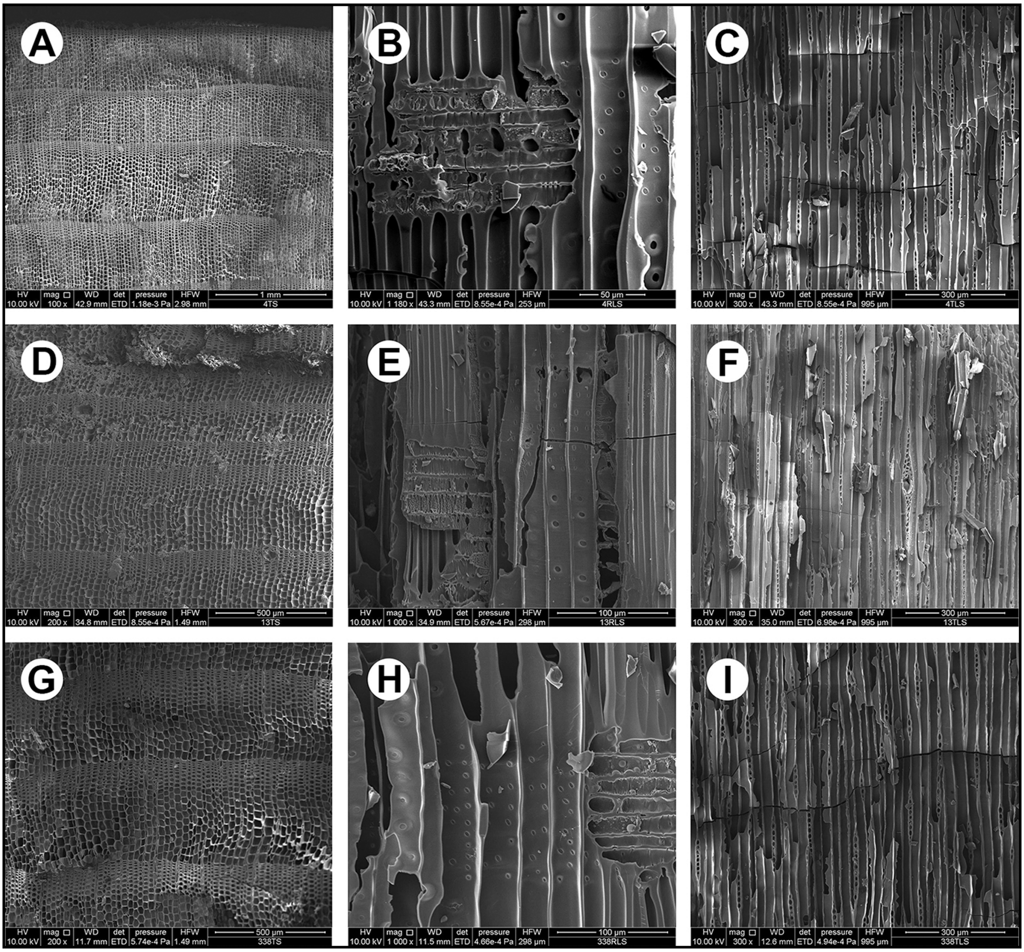

Figure 5. SEM images of anatomical features of identified samples: Abies *sp. (A–C),* Picea *sp. (D–F),* Tsuga *sp. (G–I) (figure by authors).*

While an association between element type and taxa composition was not apparent in TAP2 ($p = 0.36$) or K9901 ($p = 0.10$), some associations were apparent in TAP1 ($p = 0.02$) and K9801 ($p = 0.01$). When compared between pits, the use of different taxa was observed for crossbeams among the four pits ($p = 0.004$) and for floor panels between K9801 and K9901 ($p < 0.001$). No significant differences were seen in the use of taxa for pillars among TAP1, TAP2 and K9901 ($p = 0.29$), square timbers between TAP1 and TAP2 ($p = 0.63$) or sills between K9801 and K9901 ($p = 0.10$).

Discussion

Our results accord with previous, smaller studies (Table 1), confirming that the primary architectural timbers used in TAP1 and TAP2 came from *Abies*, *Picea* and *Tsuga* species. We also find significant variation in the type of wood used

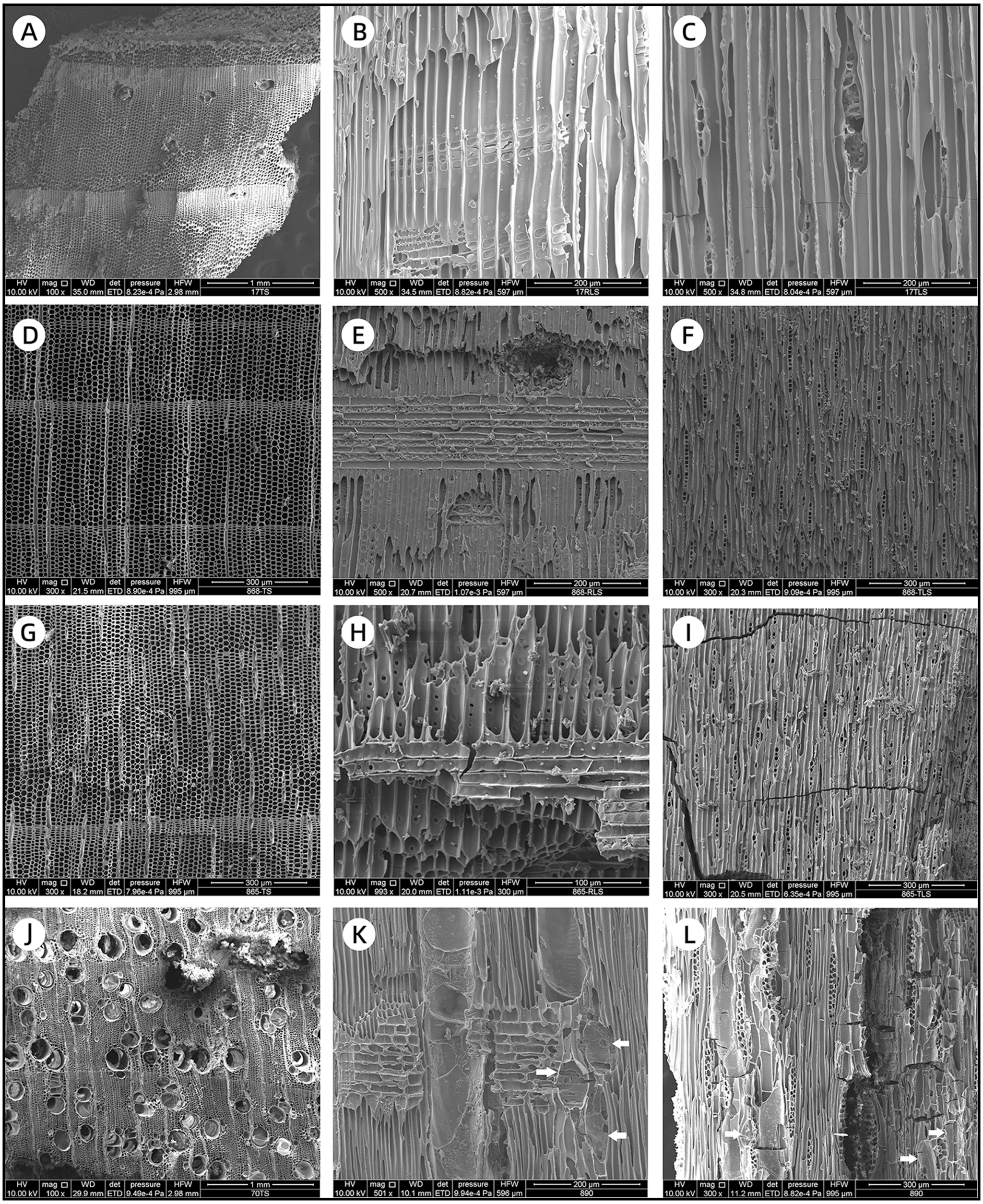

Figure 6. SEM images of anatomical features of identified samples: Pinus *sp. (A–C);* Platycladus orientalis *(D–F),* Cupressus *sp. (G–I);* Cinnamomum *sp. (J–L, arrows highlight oil cells) (figure by authors).*

between K9801/K9901 and TAP1/TAP2, as well as between K9801 and K9901 (Figure 8E).

The higher frequency of *Platycladus* and *Cupressus* differentiates the timbers used in K9801, while the higher representation of broadleaved trees (23%) separates out K9901.

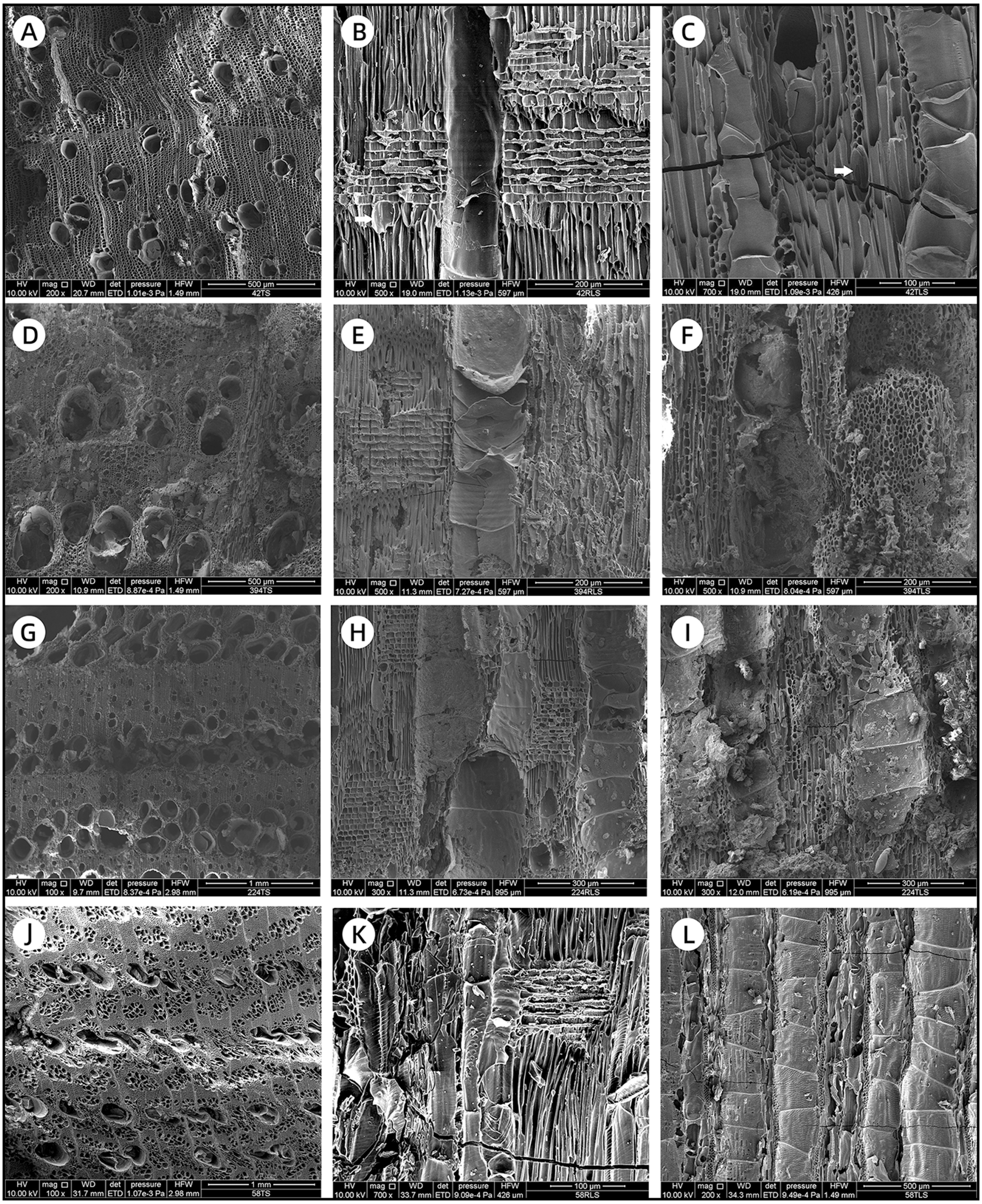

Figure 7. SEM images of anatomical features of identified samples: Phoebe *sp. (A–C, arrows highlight oil cells);* Quercus *sp. deciduous (D–F);* Toona *sp. (G–I);* Ulmus *sp. (J–L) (figure by authors).*

It should be emphasised, however, that element types are not found uniformly across pits (Table 2), so we need to consider whether these differences are representative of the pit as a whole or are caused by variations in the quantity of building element types.

If different taxa were preferred for different building elements, we would expect to find differences in the taxa used for different element types in the same pit and

Table 3. Summary of wood identification results.

Identified taxa	TAP1				TAP2				K9901					K9801			
	Crossbeam	Pillar	Square timber	Closing timber*	Crossbeam	Pillar	Square timber	Closing timber*	Crossbeam	Pillar	Floor panel	Side plank	Sill	Crossbeam	Floor panel	Side plank	Sill
Abies	35	61	24	1	73	2	5	1	10	2	15	2	4	1	3		
Picea	36	46	28	3	56	2	6	2	13		8	2	1			1	2
Tsuga	37	23	10		42	4		2	7	1	12		4	2	3		
Pinus			1		5												
*Platycladus***											1		1		13		1
Cupressus															1		1
Cupressaceae											1						
Cinnamomum	2	1	1								5	1	2				
Phoebe	2	2							1		4	1			1		
Lauraceae											1						
Quercus	2								1				2				
Toona				1	1												
Ulmus	1				1						1		1				
Diffuse-porous													1				
Broadleaved tree									3		1						
Total	115	133	64	5	178	8	11	5	35	3	49	6	16	3	21	1	4

*Timber for closing the entrance. ** Note that *Platycladus* is a monotypic genus, so all are *Platycladus orientalis*.

similarities in the taxa used for the same type of elements in different pits. Statistical testing does not indicate an association between tree taxa and element type in TAP2 and K9901. Although taxa/element associations were initially revealed for TAP1 and K9801, the adjusted p-values of post-hoc tests belie the statistical significance of differences in taxa composition between tested element types for K9801 (adjusted p-values are 0.17, 0.20 and 0.10), crossbeam versus square timber ($p_{adjusted} = 0.16$) and pillar versus square timber ($p_{adjusted} = 0.40$) for TAP1. The result of crossbeam versus pillar for TAP1 suggests a moderately significant difference in taxa composition ($p_{adjusted} = 0.04$). Comparing their taxa compositions (Figure 8A), the differences lie in the slightly unbalanced proportions of dark conifers in pillars and marginally more broadleaved trees in crossbeams. However, no evidence indicates a distinct preference for a particular dark conifer. The sparse presence of broadleaved trees in TAP1 is more likely due to accidental mix-up rather than deliberate choice. Therefore, this statistical difference is not practically meaningful.

Comparisons between pits do suggest a lack of significant differences in the use of taxa for pillars, square timbers and sills, but outside of TAP1 the sample numbers for these elements are small. Crossbeams and floor panels, which demonstrate significant differences in taxa composition between pits, account for 61% of the examined samples. The post-hoc test indicates that taxa co-occurrence between TAP2 and K9901 ($p_{adjusted} = 0.02$) leads to the significant result for crossbeams, which is likely due to the higher proportion of broadleaved trees in crossbeams from K9901 (14%) than those from TAP2 (1%).

Therefore, we propose that the differences in taxa composition for investigated pits are associated with the pits themselves rather than element types. Nevertheless, the incorporation of more samples, particularly as the excavation of K9801 progresses, could help clarify our results.

The prominence of dark coniferous species

Dark coniferous species dominate the taxa used for timbers in the sampled pits. These trees grow in mountainous areas with relatively high elevations. *Abies* species, in particular, are cold- and shade-tolerant, suited to the cold and humid environments of higher-elevation areas (Fu *et al.* 1999: 44–52; Liu *et al.* 2002). Most species of this genus grow in the central Chinese mountains at 2000–4000masl, although they have also been found at lower elevations (Cheng *et al.* 1992: 22–26; Fu *et al.* 1999: 44–52; Liu *et al.* 2002). For the Qinling Mountains in general, *Abies* are distributed above 2000masl (IBBAS 1976: 5–8); on the northern slopes, for example, coniferous forest belts are found only on peaks with elevations higher than 2000masl, and *Abies* forest sub-belts occur at elevations above 2300masl (Lei 2011: 509–16; Bai *et al.* 2021). Mount Li cannot support the growth of these dark coniferous species. Caolianling (草链岭)—the highest peak of Mount Hua (华山) in the eastern part of the Qinling Mountains, approximately 55km east of the mausoleum (Figure 9A)—is a possible source of dark coniferous timber (Lei 2011: 513–14; Bai *et al.* 2021). However, it should be noted

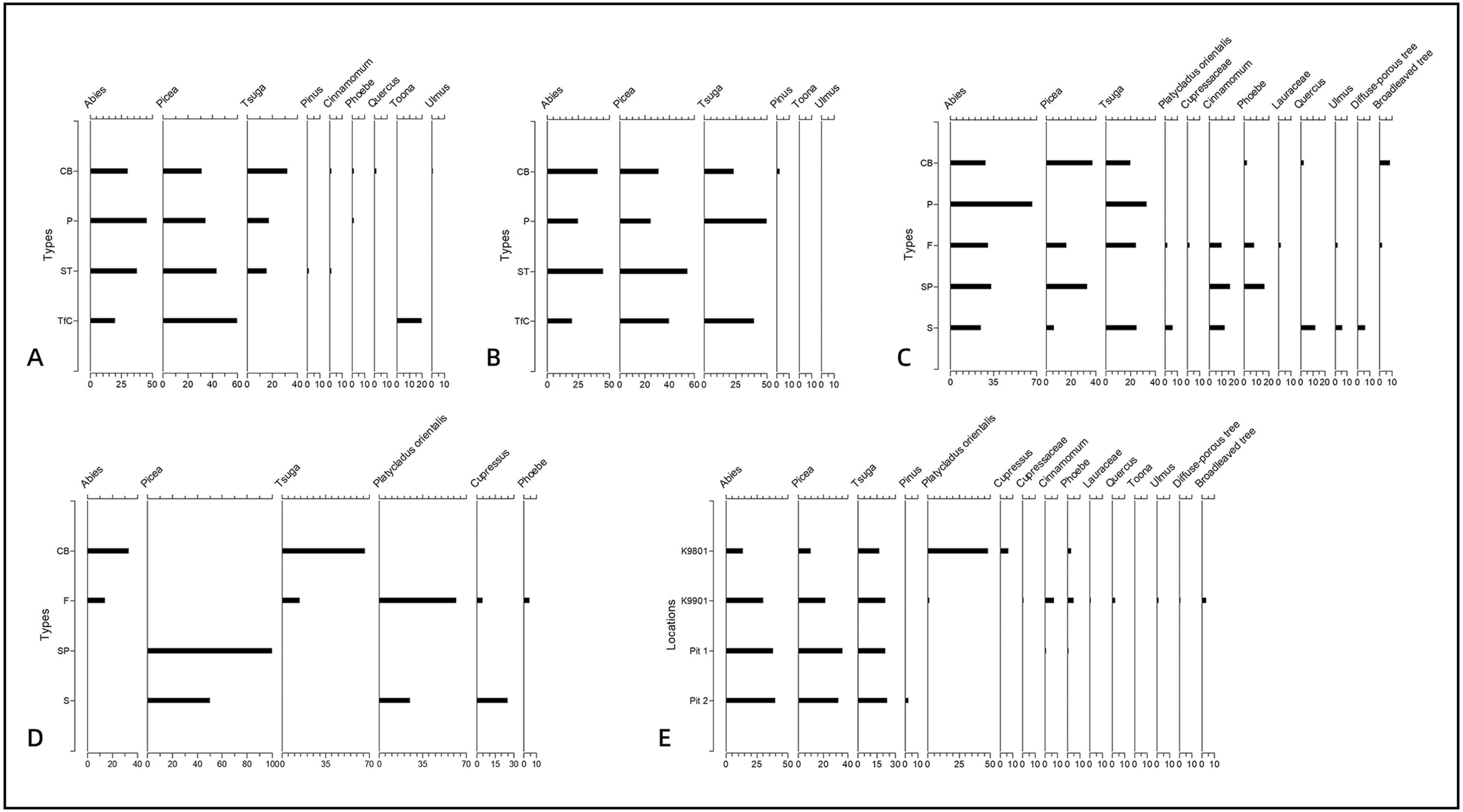

Figure 8. Percentage charcoal diagrams showing comparisons between different element types in TAP1 (A), TAP2 (B), K9901 (C) and K9801 (D), and a comparison between different pits (E) (CB: crossbeam; P: pillar; ST: square timber; TfC: timber for closing the entrance; F: floor panel; SP: side plank; S: sill) (figure by authors).

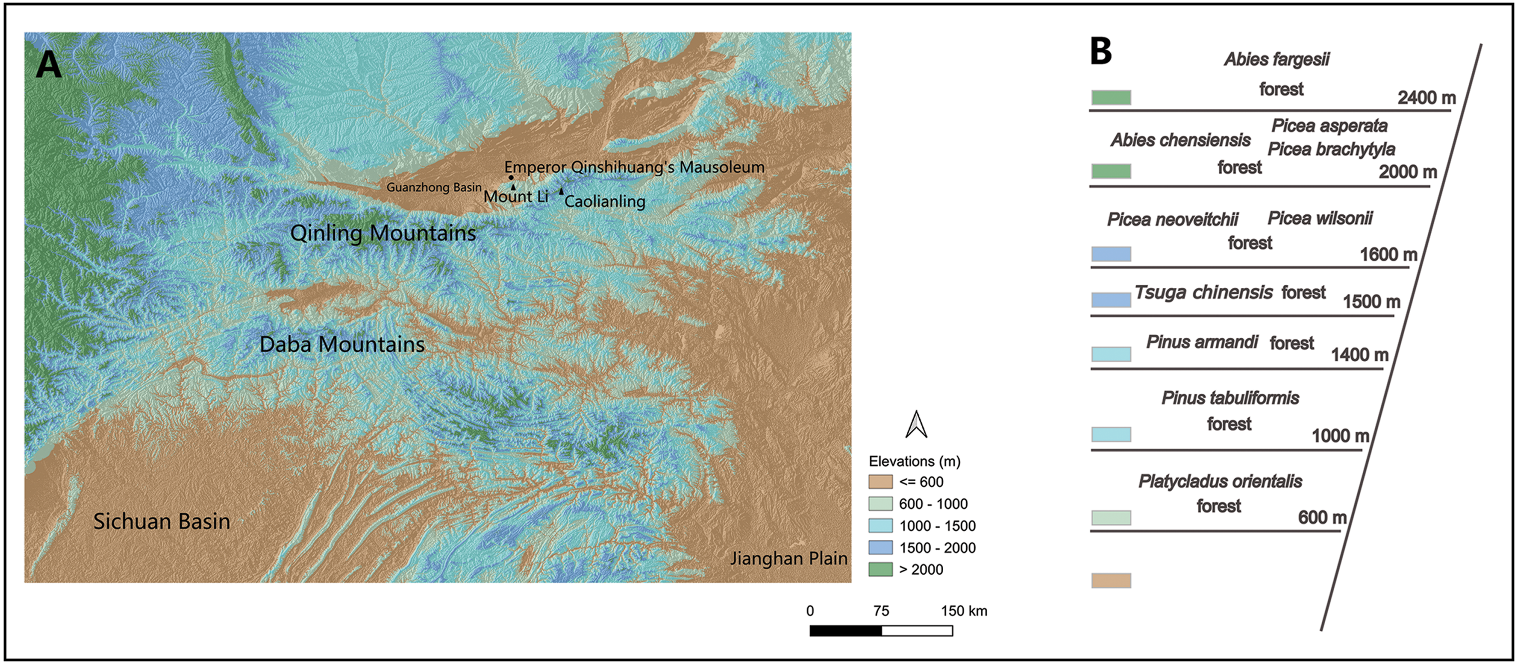

Figure 9. A) Digital Elevation Model (DEM) of the study area; B) schematic vertical distribution of relevant species in Shaanxi (referring to Lei et al. *2011: 246–67; the elevation value indicates the common lower line of the corresponding species' elevation range) (figure by authors).*

that the direct distance substantially underestimates the reality of transport logistics. More distant sources might have also been exploited.

The source(s) of timbers used in the mausoleum remains uncertain. The Han historian Sima Qian (*c.* 145–86 BC), in his biography of Qin Shihuang, '*Shiji*' (史记• 秦始皇本纪; Han 2010: 559), claimed that the timber came from *Shu* (modern Sichuan) and *Jing* (central and southern Hubei), both located south of the Qinling Mountains. Without excluding the possibility of these more distant origins, a source in the Qinling Mountains is supported by the taxonomic identification of our samples. Forming a boundary between northern and southern China, the Qinling Mountains span almost 800km east to west and nearly 200km north to south (Li *et al.* 2018, 2020). While Mount Li can be excluded as a source for most timbers, it remains unclear if the observed taxa could have been harvested from the northern slopes of the Qinling alone, particularly given the presence of a few subtropical species more common on its southern slopes. In the construction of the four sampled pits alone, the volume of wood required is estimated at 14 300m^3. Given the size of the mausoleum, much of which remains incompletely excavated, and the number of ancillary facilities, the logistical planning and resource mobilisation involved in its construction are difficult to comprehend.

Even before unification, the Qin state had developed an efficient logistical system to mobilise resources for its frequent military campaigns. This was supported by rigorous administrative and legal processes and an organised transport network (Wang 2013: 16–19; Sun 2023). The logistics were manifested in how effectively supplies from the Ba Shu region to the south (Sichuan and Chongqing) contributed to the Qin military victories in more distant regions (Gan 2009). After unification, the logistical system was further strengthened under the centralised bureaucratic autocracy. Transport routes were upgraded, creating a crisscrossing national network (Liao 1999: 97–98; Wang 2013: 24–31). Yet, many sections of the Shu Roads through the Qinling and Daba mountains, which enabled movement from the Qin capital Xianyang and the mausoleum to the *Shu* region, were narrow plank roads (Liao 1999: 97; Wang 2013: 27). The feasibility of transporting huge bulky logs along these routes therefore needs to be considered. Wuguan Road, linking Guanzhong and the *Jing* region, was wider, containing fewer plank sections and covering gentler mountainous terrain (Wang 2015: 1–8), making it a more viable transport route. Timber may also have been transported by waterways (Menzies 1984: 640–41; Xie 2022), but water systems to the north and south of the Qinling Mountains are not naturally connected. Water-borne transport of timber from the south could have proceeded through canals and sea shipping routes, but the associated cost would likely have been prohibitive.

Records on bamboo slips in the Qin period, and in other texts, indicate the roles of various officials and legislation in supplying timber for both national and local projects (Xie 2022) and outline the specialised supply of wood used for weapons, such as the crossbows (Chen 2015).

With regard to other resources used in the mausoleum, the clay for the statues and tiles was likely sourced nearby, while the stone used for armour in K9801 was probably from the Beishan Mountains, about 50–60km away (Zhao 2006; Li & Li 2015; Quinn *et al.* 2017). Although the exact source of copper ore used in the crafting of the bronze water birds discovered in the ancillary pit K0007 (see Figure 2B) has not been determined, it is thought to be related to the Qinling Mountains ores (Shao *et al.* 2015). These potential sources reveal an indicative resourcing radius for the mausoleum that overlaps with a possible timber source in the Qinling Mountains supported by our identification results.

A temporal shift in taxa composition?

The pits at the mausoleum are unlikely to have been constructed simultaneously; with previous archaeological work inferring parts of the sequence of their construction, we can ask whether wood choice or availability changed over time. TAP1 and TAP2 are adjacent on the eastern edge of the overall complex, while K9801 and K9901 are also next to each other, but much closer to the mausoleum centre, between the inner and outer complex walls (Figure 2B). The physical proximity of the two pits in each pair is matched by consistencies in structure: construction of K9801 and K9901 relied on similar element types, while architectural similarities are also seen between TAP1 and TAP2. Excavations suggest that K9901 was built slightly later than K9801 (Duan *et al.* 2001), as some stone armour pieces were found in the backfilled soil of K9901. In contrast, the TAPs are thought to have been hastily completed sometime later, during the closing stages of the mausoleum project (Zhang 2010).

The *Abies*, *Picea* and *Tsuga* genera are collectively referred to as *sōng* (松), meaning pine, in Chinese. Similarly, conifers from the Cupressaceae (cypress) family are called *baǐ* (柏). Both pine and cypress woods were used widely in ancient China for funerary and architectural purposes, influenced by and reinforcing the 'Pine and Cypress Culture', a common theme in Chinese philosophy, literature, art and beyond (Li 2005: 2–3). The *Sub-Commentary on the Book of Rites* (礼记正义, *Liji Zhengyi,* a later examination (Eastern Han and Tang period) of the *Liji* (礼记, Book of Rites), a compilation of the first century BC of texts thought to originally pre-date the Qin Dynasty; Lu 2008: 337), states that cypress should be used for the burial chambers of both *Tianzi* (天子, the Son of the Heaven) and *Dafu* (大夫, officers), while pine should be used for *Zhuhou* (诸侯, vassal rulers). Thus, it is unclear whether there was a precise hierarchical distinction between the coniferous woods, though both pine and cypress were regarded as symbols of nobility, tenacity and longevity. Referring to two Qin tombs that are generally recognised as exhibiting features of the highest rank, the primary wooden chamber of Vassal Lord Jing of the Qin State was predominantly composed of *Platycladus orientalis* (An *et al.* 1990). Similarly, the wooden chamber of the Qin State Mausoleum at Shenheyuan was constructed using wood from *Abies*, *Picea*, *Tsuga* and *Pinus* species (Wang 2009). It seems unlikely, then, that the Qin viewed cypress and pine as substantially different in terms of grade, and thus the differences in wood composition used in the construction of K9801 and K9901 versus TAP1 and TAP2 were probably not symbolic.

Platycladus orientalis is widely distributed in temperate coniferous forests below 1500masl (ECFC 1978: 321–23). *Platycladus* forest grows on the northern slopes of the Qinling Mountains in the low altitude zone, ranging from 500–1300masl (Zhu 1978). Some species of *Cupressus* also grow at elevations below 2000masl (ECFC 1978: 336). Dark conifers *Abies*, *Picea* and *Tsuga*, by contrast, form the primary components of the subalpine evergreen coniferous forests at altitudes in excess of 2500masl (Lei 2011: 246; Bai *et al.* 2021). The situation is similar for dark conifers in Sichuan (LCCCSP 1996: 291–95). Hence, the change in the primary taxa used—from conifers growing at lower elevations earlier in the sequence of mausoleum construction (K9801), to predominantly dark coniferous species later in the sequence (TAP1 and TAP2)—might reflect a shift in the location of timber extraction, with more timbers from higher elevations being used in the later pits.

Timbers must be seasoned for a period of time before being used in construction. This ensures that moisture, which might otherwise cause deformation and decay, is removed from the wood. The wood from *Abies* species has a low natural resistance to decay (Cheng *et al.* 1992: 23–27), thus the low frequency of fungal hyphae inside tracheids (water-conducting cells) and the largely intact tracheid walls observed in the wood samples collected from the mausoleum indicate that the wood was probably seasoned before use. Timbers harvested from lower elevations could therefore be used earlier in construction as they could be both collected and seasoned sooner than higher-elevation timbers. Consequently, and considering only the predominant woods used, K9801 appears to have been built first, followed by K9901 and finally the TAPs. Crossbeams also differ between K9801/K9901 and the TAPs, being mostly square logs in the former and round logs in the latter (SIA & MQTA 1988: 34, 2000: 56 & 172; MQTA 2009: 73). Square logs require more preparation, so the change in crossbeam shape may suggest that the construction of the TAPs was hurried. Although we cannot extrapolate our results to include the many unexcavated pits that lie between K9801/K9901 and TAP1/TAP2, a temporal shift towards higher-altitude timber and reduced time investment is apparent.

The extensive use of higher-altitude species suggests that lower and middle mountainous areas were no longer able to meet supply requirements. This, in turn, implies that the construction of the mausoleum, and other anthropogenic activities, affected conifer woodlands and timber supply, forcing a shift to increasingly distant and higher-elevation sources. It also seems to suggest a centralised timber-harvesting strategy that could relate to ease of access in specific mountainous areas.

Unanswered questions

While we can plot a possible shift in wood exploitation over the course of the mausoleum project—from Cupressaceae growing at lower elevations to dark coniferous species on the higher slopes—there is a notable absence of true pine (*Pinus* sp.). Many species of *Pinus* grow at similar elevations to Cupressaceae, ranging up towards the dark conifers (Figure 9B), but only one sample from TAP1 and five from TAP2 are *Pinus*. Wood from this genus has been commonly exploited for millennia (Wang 2022), so its near absence suggests deliberate avoidance for an unexplained reason or unavailability. Why was *Pinus* wood not used more in the architectural features of the mausoleum?

A few samples from TAP1 (n = 12) and TAP2 (n = 2) were identified as broadleaved trees; given that wood from these trees was also found in wooden chariots and weapon parts (to be published separately), it is possible that some timbers were mixed up during the seasoning and storage stage. However, around 23% of the building elements in K9901 (n = 25) were from broadleaved trees, making their appearance purely due to a mix-up in storage unlikely. Some other reason for their significant presence in this pit must be sought.

Finally, why was so much *Tsuga* (hemlock) used? This genus is found in rainy, humid and cloudy mountainous areas with mild climates, acidic soils and good drainage. It is especially common in subtropical and tropical mountains south of the Qinling Mountains, with a dense distribution in south-western China and a scattered presence in eastern China (Liu & Qiu 1980). In Shaanxi, hemlock forests are usually small, with hemlock more often mixed into the broadleaf forest zone or the spruce forest subzone as a minor component (Lei 2011: 252). It is unclear, therefore, why *Tsuga* timbers are found in substantial numbers in these pits. Is it possible that anthropogenic activities, along with the drying and cooling trend of the later Holocene (Dong *et al.* 2022), reduced the geographic distribution of hemlock forests since the mausoleum was constructed? Or was some wood sourced from more distant south-western China, where hemlocks were more common?

Conclusions

This article offers the first systematic study of wood remains from the First Qin Emperor's mausoleum, where excavated pits were constructed with mainly coniferous wood. These timbers were not harvested from the nearby Mount Li, but rather indicate that sophisticated logistical planning and resource mobilisation allowed their collection from more distant mountains. Timber use varied over time, with a shift from lower-elevation cypresses to the increasing use of higher-elevation dark conifers. This suggests an intense and concentrated anthropogenic impact on the ecology of mountainous areas—an impact that may continue to affect species distributions today.

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