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Gönpa Gang—The First Application of Dendrochronological Dating to Study the Traditional Architecture of Upper Mustang (Nepal)

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Abstract: Gönpa Gang is an example of the traditional Buddhist architecture of Upper Mustang. It is also the first monument in Upper Mustang to be studied using the dendrochronological dating method. The gönpa is a two-story building of imposing size, made from simple elements of Tibetan architecture, namely masonry walls, timber posts, and beams. A total of 14 samples were collected from elements on both the ground and the first floor. The limited number of samples results from the cultural and religious character of the object under study. Only the elements consistent with the structure and the space arrangement, interpreted as original features, were examined. Microscopic observation and the analysis of the anatomical features of all 14 samples resulted in the identification of Himalayan pine (blue pine), *Pinus wallichiana* A.B. Jacks. Intra-annual density fluctuation, false rings, and missing rings were detected. From 14 samples collected in Gönpa Gang, 18 series were worked out. Thus, 15 series from 12 samples were synchronized and used for the development of the mean chronology, UMGG_m, with a total length of 160 rings. The chronology covers the period from 1524 to 1683. Examination of the Gang Gönpa wood resulted in the age determination of 13 elements. The results were compared with architectural stratification by Harrison and historical data from written sources. The timber used in the gönpa comes from the Southern Mustang area. The examined wood demonstrates a correlation with the timber used in the Upper Mustang historical buildings further north.

Keywords: dendroarchaeology; Upper Mustang; Buddhist architecture; Gönpa; *Pinus wallichiana* A.B. Jacks

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1. Introduction

Gönpa Gang is an example of the traditional Buddhist architecture of Upper Mustang. It is also the first monument in Upper Mustang to be studied using the dendrochronological dating method.

The current study presents the detailed results of research conducted in the gönpa. It focuses on the identification of tree species used in the construction, analysis of the timber, including its structure and quality, the dating of the timber, and the determination of its provenance. The results are then carefully interpreted and compared with architectural stratification by Harrison [1] and historical data from written sources [2]. Moreover, the study shows a relationship between timber from the gönpa and timber found later in other historical buildings in Upper Mustang as we continued our dendroarchaeological work in the region.

The main aim of this study was to assess the research potential of timber used in traditional local constructions and to set the direction for further dendrochronological research in the region.

1.1. Study Site—Geographic and Cultural Context

Upper Mustang is a restricted area situated in north-west Nepal, beyond the northern walls of the main Himalayan range, between the Annapurna and Dhaulagiri massifs, both rising above 8000 m a.s.l. Upper Mustang is a significant part of a large administrative district, Mustang, located in the Dhaulagiri Zone (Figure 1). Its territory extends along the river Kali Gandaki into the high Tibetan plateau, in the gorge that is one of the pathways through the natural barrier of the main Himalayan chain, acting as a link for trade and conquest, the spread of cultures and religions, and for migration and colonization [3]. The Salt Route running through Upper Mustang was the most ancient and regularly used passage through present-day Nepal [4–6].

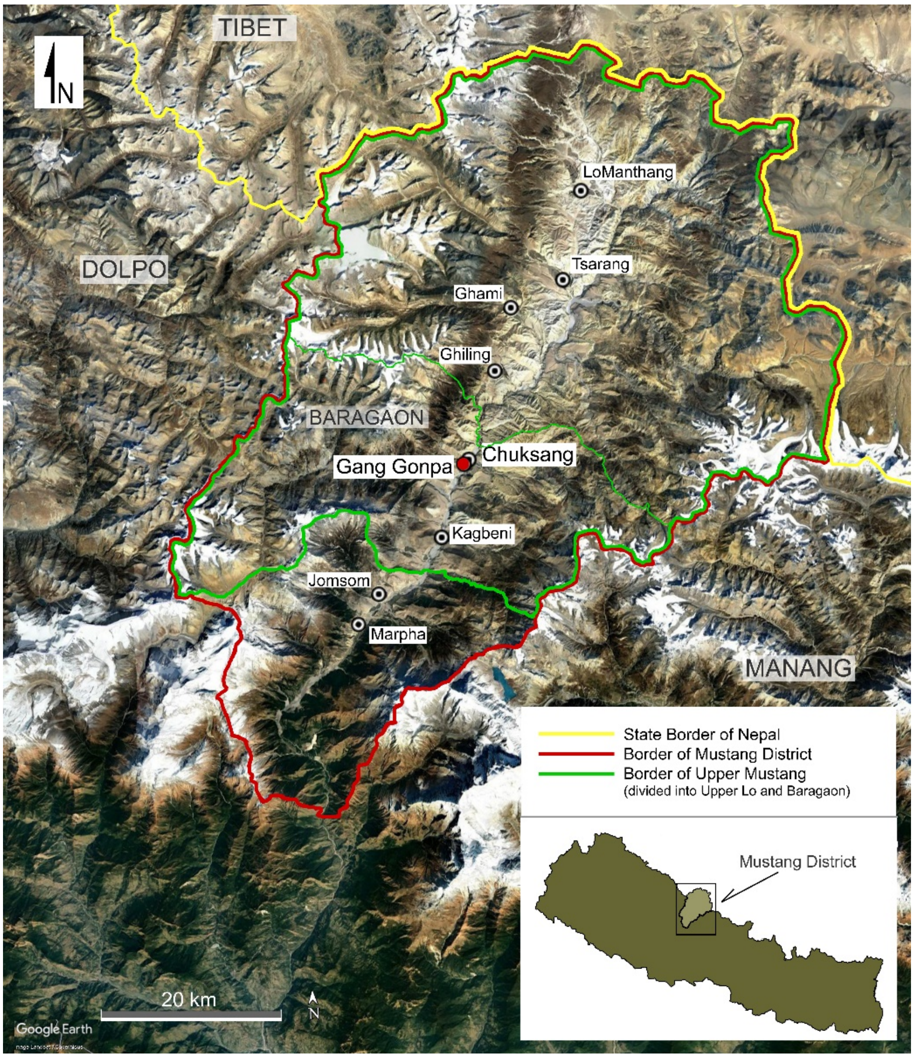

Figure 1. Location of the study area. The main settlements of the Mustang District, with the Upper Mustang restricted area (green line) including the Baragaon region. The study site, Gönpa Gang, is marked with a red dot (map prepared using Google Earth data and the scan of the map: Upper and Lower Mustang, NA518, Publisher: Himalayan Map House. Authors: Robin Boustead and Himalayan Map House).

Mustang lies in the rain shadow of the Himalayas, the mountains block the monsoon which travels north-west across the Indian subcontinent from June to September each year. The climate is dry with strong winds and intense sunlight. The landscape of Upper Mustang is dominated by massive rock formations and cliffs riddled with numerous caves hollowed out by the former inhabitants of the region for housing, religious, and burial purposes [7–9]. More recent settlements of the legendary "forbidden" Kingdom of Lo are located in the valley, along the river. The capital of the region is the great walled city of Lo Manthang, funded by the first king of Lo, Ame Pal, who conquered and united the feudal estates lying in the upper reaches of the river Kali Gandaki in 1440. The history of Upper Mustang is closely related to the history of Tibet (especially with its western province of Ngari), Ladakh, and the former kingdom of Jumla, the main invader that Lo struggled with between the 16th and 18th centuries and was eventually conquered by. In 1786, the Kingdom of Lo fell under the authority of the Nepalese king [3,10–13].

Ethnically, Upper Mustang is Tibetan, settled by people moving south from the Tibetan Plateau. The dominant religion in Mustang is Tibetan Buddhism. The Sakyapa school thrived under the patronage of the kings of Lo but did not displace the older Nyingmapa school. The deeply rooted pre-Buddhist religion of Bön has adopted many of the forms of Buddhism while keeping its own pantheon of gods [3,12]. Upper Mustang is famous for its unique tangible and intangible heritage, living traditions [12], sacred landscape [14,15], and ancient structures created as an extension of the landscape, namely massive architectural features, such as forts, castles, palaces, temples, monasteries, mani walls, chörtens, and homesteads, all formed from the materials found in the region: earth, stone, and wood [3].

1.2. Gönpa Gang—From Spirituality to Construction

The term "gönpa" comes from Tibet and means a Buddhist temple inside or outside a monastery, which is also a center of study and a place of religious ceremonies. Gönpa Gang is located in the southern part of the restricted area of Upper Mustang. The region, Lower Lo, is more commonly referred to by its Nepali name of Baragaon, "Twelve Villages" [13]. It contains an enclave, Shöyul, where the pre-Tibetan language, Seke, is still spoken. The gönpa belongs to the five villages of the Shöyul: Taye, Tshug (Chuksang), Te, Tsele, and Gyaga [3]. The monument is situated on the west bank of the river Kali Gandaki (Figure 2). It is clearly visible from the village Chuksang.

Figure 2. View of Gönpa Gang from the west. In the background the Kali Gandaki river and rock formations characteristic of the Upper Mustang region are visible.

According to Tucci [10], Gönpa Gang is one of the most important in the district. However, nowadays, it is not as appreciated as other, more easily accessible gönpas situated along the main road to Lo Manthang. Despite the fact that it hides great treasures of art, Gönpa Gang is neglected and requires extensive conservation works. The main reason for this is certainly the difficulty of access to the monument, as there is no bridge across the Kali Gandaki. The name "Gönpa Gang" has been translated as Convent Ridge [16], or Promontory Monastery [17], but the proper name of the gönpa is Künzang Chöling, "All-Good Island of the Doctrine" [1]. It is a Nyingmapa temple, once a nunnery, currently under the maintenance of an old Lama.

Gönpa Gang is made from simple elements of Tibetan architecture, namely masonry walls, timber posts, and beams. The building is of imposing size. The plan of the gönpa fits into a rectangle, with approximate dimension of 20 m by 25 m. The main entrance to the building is on the eastern façade (Figure 3a). There are stone steps leading up to a small projecting masonry porch. Above the porch, there is projecting entablature supporting a balcony with a large *rabsal* window (closed with later masonry) and a two-tiered projecting canopy [1] (Figure 3b).

Figure 3. Gönpa Gang: (**a**) eastern façade; (**b**) balcony with a large *rabsal* window above the porch.

In the entrance hall, there are two square pillars with simple capitals supporting the main beam running north–south. Due to the poor shape of the gönpa, numerous secondary bearing elements were introduced to the original structure. The main beam in the entrance hall is additionally supported by four pillars added later. Two more posts stabilizing the structure were introduced to the eastern wall. Opposite the entrance, and a little off-axis, there are stone steps leading up to the assembly hall door.

The large assembly hall (*dukhang*) is entered into from the center of the east wall. The central axis from the entrance to the sanctum bisecting the large square room (15 m by 15 m) with an evenly spaced grid of pillars and beams (Figure 4). There are five main beams spanning north–south, each supported by four pillars dividing the space into bays. The central bays of the ceiling are open to the floor above, and the two central pillars rise one and a half floors into richly carved capitals and cornices. As in the entrance hall, additional posts have been introduced in the *dukhang*. They are located mainly along the south wall. There are no windows in the walls of the hall, so the only source of light is a one-bay opening in the roof, through which the light floods and reaches the hall (Figure 5). In the center of the west wall, there is a two-story-high sanctum with a colossal Maitreya statue that can be viewed and circumambulated both on the ground floor and from the upper floor. All rooms on the ground floor are richly decorated with wall paintings hidden under a thick layer of dust, oily soot, and clay stains [18,19].

Figure 4. Gönpa Gang ground floor: (**a**) assembly hall (*dukhang*); (**b**) assembly hall—a bay between the firs and the second main beams spanning north–south.

Figure 5. Gönpa Gang ground floor: (**a**); the central bays of the ceiling open to the first floor; (**b**) a one-bay opening in the roof—the source of light for both the *dukhang* on the ground floor and the gallery above the *dukhang*.

The large room above the *dukhang* is accessed from a stone staircase, through a door in the southeast corner of the room (Figure 6a). The organization of the space corresponds to the division of the assembly hall below. It forms a wide gallery overlooking the central space of the *dukhang*. The original rhythm of pillars, however, is disturbed by a few irregularly spaced posts added later. The gallery is very well lit, as one of the ceiling bays is entirely open to the sky (Figures 5b and 6b). A second door in the east wall leads to the main reception room [1] above the entrance hall of the gönpa. The ceiling is supported by two original square pillars and two added posts.

Figure 6. Gönpa Gang first floor: (**a**) southern bay of the gallery above *dukhang*; (**b**) eastern bay of the gallery above *dukhang*.

There are two doors in the western wall of the *dukhang* gallery placed to the north and south of the central open space. The doors lead to the back space divided into two communicated rooms. In the south room, there are two square posts supporting a long beam. The north room, with a single north window has one square pillar in the middle. Both rooms provide access to the upper part of the sanctum with the Maitreya statue and to the circumambulatory gallery.

The south wing adjacent to the main body of the gönpa is probably a later extension [1]. There are two principal rooms on the first floor, with some further subdivision of the space. The southeast room has an imposing interior, with four square pillars and capitals and a central lantern roof light.

1.3. Dendrochronology, Dendroarchaeology and Dendroprovenance—The Methods Applied to Historical Objects in Upper Mustang

Dendrochronology is a scientific method that deals with the dating and study of the annual tree rings in wood and shrubs. Dendroarchaeology, a subdiscipline of dendrochronology, was defined by Hollstein [20] as a "system of scientific methods used to determine the exact time span of a period during which timber has been felled, transported, processed, and used for construction" [21]. Today, dendrochronology is a well-established method used to date and analyze a wide range of wooden objects, commonly used in several heritage science disciplines, including cultural history, archaeology, fine arts, timber trading, historical buildings, and construction [22]. It is the most accurate known dating method, however it can only be successfully applied when several requirements are met. The object under study needs to be made from wood species that produce distinct tree rings with annual resolution [23,24]. Another restriction is the number of preserved rings, with at least 50 rings needed to avoid accidental cross-matching [25]. Moreover, to use the method, appropriate regional and supraregional reference tree-ring chronologies of the same species or other species with similar growth responses to environmental conditions, against which the newly developed chronology can be dated, are needed [26]. The existence of appropriate reference chronologies, together with knowledge of wood anatomy, are key factors when determining the possible origin of the wood, through a technique called dendroprovenancing [24,27]. The interpretation of the results of dendrochronological dating of historical wood requires great caution since the last preserved, dated tree ring does not necessary correspond to the date of the construction of the object under study. Only the presence of bark and/or a waney edge allows us to determine the exact year when the tree was cut or died. Otherwise, the only date that can be given is a terminus post quem, or earliest possible felling date [25].

In Nepal, the application of dendrochronology to study historical objects is still rare. This method is widely used for climate and environment research [28] conducted on species with high dendrochronological potential, mainly *Abies spectabilis* (D.Don) Mixb., *Tsunga dumosa* (D.Don) Eichler, *Pinus wallichiana* A.B.Jacks, and *Pinus roxburghii* Sarg. [29].

The first dendroarchaeological research in Nepal was carried out under the auspices of the Nepal-German Project in High Mountain Archaeology by Burghard Schmidt in 1989 and then between 1993 and 1997. Schmidt developed a well replicated master chronology for Southern Mustang, extending from 1997 back to 1324 and a chronology for Manang (Figure 1) covering the period from 1697 to 1996 [30–34]. The first version of the Southern Mustang master chronology was developed on the basis of data derived from living trees and timber collected in Mukinath monastery, workshops in Thini and houses in Marpha and Thini [30]. Further samples were obtained from castles, houses, and monasteries of Jarkot, Kagbeni, and Lupra [31]. For the Manang chronology, Schmidt et al. used timber collected in a castle of Ngawal and a monastery in Braga. It was shown that it is possible to correlate the chronology from Manang with the Southern Mustang master chronology [31] and that the historical wood samples cross-date well with overlapping chronologies from living trees [30].

Another person who dealt with historical wood in Nepal is Achim Bräuning, who worked in the Dolpo region (Figure 1) in 2004 and developed the chronologies of East Himalayan fir (1665–1998), birch (1655–1998), and Himalayan pine (1556–1998) extended with data derived from timber found in Samling Gönpa and successfully used to date wood found in the abandoned village of ancient Pö [35,36].

Since that time, no systematic study of historical tree-ring series had been carried out until works in Gönpa Gang started, initiating a project entitled "Wood in the architecture and the art of Upper Mustang/Nepal. Dendrochronological research and conservation problems", the main aim of which was to develop the Upper Mustang master chronology [37].

2. Materials and Methods

2.1. Material and Sample Collection

Dendrochronological works in Gönpa Gang were initiated in 2015. After a visual examination of timber elements preserved in the structures, a total of 14 samples were collected, most of which were samples from the large timbers in the support system. The very limited number of samples results from the specificity of the study site and the character of the object under study. While working in the restricted area, in a building that for local society is still a place of religious significance and an element of unique identity and cherished traditions, sampling requires not only permission from the Department of Archeology in Kathmandu, but also the favor of the local people and the approval of the maintainer of the temple, in this case, the old Lama. The number of collected samples is therefore the result of negotiation, respect for the owners' decisions, and mutual understanding.

Due to these limitations, sampling in the gönpa required a thought-out strategy and careful selection of elements to obtain maximum information from the minimal number of timber samples taken from different parts of the building. Only the elements consistent with the structure and the space arrangement, interpreted as original features, were examined. Five samples were collected from the ground floor. Specifically, one was taken from the pillar in the entrance hall, and four were taken from main pillars of *dukhang*. Nine samples were collected from the first floor, including two in the southern wing. Two beams and one pillar were cored in the gallery, while in the reception room in the east wing, one sample was taken from a pillar. In the separate western space, two samples were taken from the pillars and one was taken from the beam (Figure 7).

Figure 7. Plans of the ground floor and the first floor of the gönpa. The sampled elements are marked in red and labeled.

All the samples were collected in the least invasive manner possible—with incremental borers. They were to be used both for wood identification and for dendrochronological research. One additional sample for wood identification was taken from the outermost part of the element no. UMGG10 (Figure 7). Detailed information on the examined elements is provided in Table 1.

Table 1. Core samples collected in Gönpa Gang—basic information.

Sample No.	Location of the Element	Function of the Element	Size of the Element (cm)	
			Cross Section	Height/Length
UMGG01	Ground floor, assembly hall	Pillar	Ø 29	230
UMGG02	Ground floor, assembly hall	Pillar	Ø 30	223
UMGG03	Ground floor, assembly hall	Pillar	Ø 24	240
UMGG04	Ground floor, assembly hall	Pillar	Ø 26	235
UMGG05	Ground floor, entrance hall	Pillar	23 × 21	280
UMGG06	First floor, gallery	Pillar	14 × 15	166
UMGG07	First floor, gallery	Beam	14 × 15	98
UMGG08	First floor, gallery	Beam	15 × 15	278
UMGG09	First floor, west space, south room	Pillar	14 × 15	188
UMGG10	First floor, west space, north room	Pillar	14 × 17	177
UMGG11	First floor, southern wing	Pillar	14 × 15	203
UMGG12	First floor, southern wing	Beam	13 × 17	66
UMGG13	First floor, west space, south room	Beam	16 × 17	910
UMGG14	First floor, reception room	Pillar	17 × 17	194

2.2. *Wood Identification*

The first step when working with historical wood is tree species identification. The identification of wood used in Gönpa Gang was based on observation of microscopic slices representing transverse (cross), radial, and tangential sections of wood. The microscopic slides were prepared using microtome GSL 1 (Production: Schenkung Dapples, Zürich).

Subsequently, they were bleached using Eau de Javelle (in order to remove the cell contents and dark-stained cell wall components) and stained with Safranin solution to create good contrast for microscopic observation. The stained micro-sections were embedded in Euparal resin, dried, stabilized, and then studied under a biological microscope, OLYMPUS BX53, in transmitted light, at magnifications of 40×, 100×, and 200× [38]. The wood structure of the studied species was analyzed to determine characteristic features [39–41] and compared with the reference material from known tree species occurring in the Himalayas [41,42].

2.3. Samples Preparation, Measurements and Statistical Analysis

The preparation, measurement, and further analyses of samples followed traditional dendrochronological methods [43–45]: all samples collected in the gönpa were properly prepared with the use of progressively finer grade abrasive paper to obtain tree-rings and xylem cells clearly visible under magnification. Subsequently, the samples were analyzed to determine if the bark and/or waney edge was present [25], and to detect growth anomalies, such as missing rings, frost rings, radial cracks, and reaction wood [46]. Moreover, the presence of intra-annual density fluctuation (IADF)/false rings was verified [47], and the number of rings to the pith was estimated.

The tree-ring widths were measured to 0.01 mm using Time Series Analysis and Presentation (TSAP) software [48] and LINTAB measuring table. The measured series were synchronized based on both statistical evaluation and the visual cross-matching. Then, a mean chronology was developed and attempts at cross-dating against existing reference chronologies were made. Cross-dating was performed with the use of TSAPWin, and its results were evaluated based on the following parameters: (1) Glk (Gleichläufigkeit) showing the coefficient of correlation of year-to-year changes in ring widths [49]; (2) t-values that are sensitive to extreme values, such as marker years (both TVBP calculated according to Baillie and Picher [50] and TVH calculated according to Hollstein [51] were taken into account); and (3) the cross-dating index (CDI), which combines parameters 1 and 2 [48]. The common interval expressed by the number of overlapping years (OVL) was also considered.

Chronologies used as references are: Southern Mustang master chronology (conifers) covering the period from 1324 to 1997 by Schmidt et.al. [31], Dolpo pine chronology, covering the period from 1556 to 1998, by Bräuning [35], and mean chronologies developed from timber collected in historical buildings in Upper Mustang in 2018 [37].

3. Results

3.1. Wood Identification

Microscopic observation and the analysis of the anatomical features of all 14 samples resulted in the identification of Himalayan pine (blue pine), *Pinus wallichiana* A.B. Jacks.

This species is characterized by well-defined growth rings, while the transition from early to late wood is gradual. The axial tracheids are of square, rectangular or polygonal sections. Intercellular spaces (between two or more tracheids) can occur. Vertical resin canals are visible on the cross section and they are present mainly in the late wood (Figures 8a,b and 9a), while they can sometimes be found within the early wood, usually solitarily. Epithelial cells are very thin-walled and there are usually four cells per canal. Axial parenchyma was not observed. In tangential sections, uniseriate and fusiform rays are visible (Figure 8c). Rays are heterogeneous, consisting of parenchymatous cells, ray tracheids, and epithelial cells of resin canals. The height of uniseriate rays is mostly 1–16 cells. Ray parenchyma cells are ovular in tangential view. In the radial section, ray tracheids are present in one or two rows at the margins of rays, and the inner surface of walls is usually smooth. Cross field pits are large and window-like (fenestriform) with fine borders (Figure 8d). Usually, there is one pit in the cross field. Two pits rarely occur.

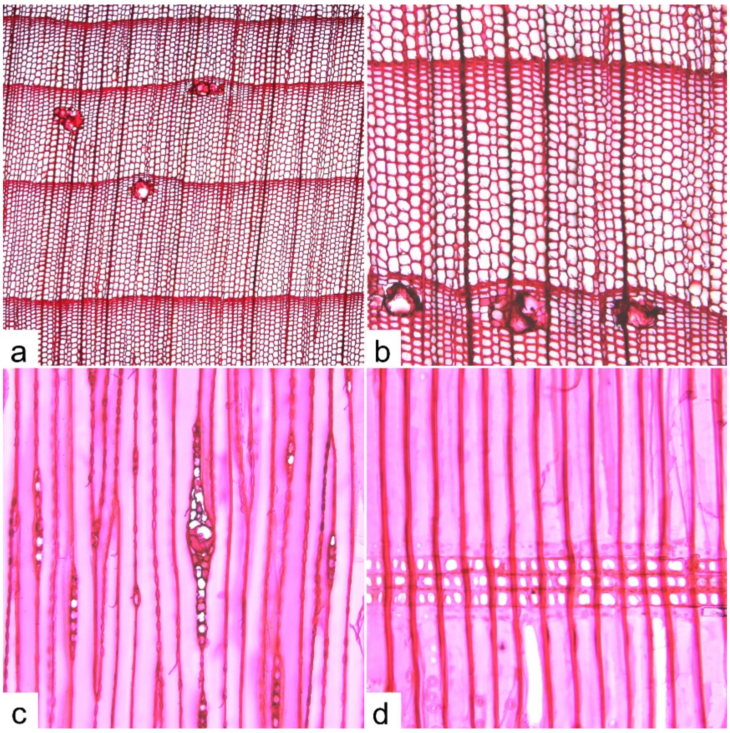

Figure 8. Himalayan pine—*Pinus wallichiana* A.B. Jacks—used as a timber in Gönpa Gang. Element no. UMGG10. Microscopic slides: (**a**) cross section in which the well-defined growth rings and the gradual transition from early to latewood is visible; (**b**) cross section—three resin canals located in the latewood are visible; (**c**) tangential section—uniseriate and fusiform rays are visible; (**d**) radial section—a heterogeneous ray with window-like pits in cross fields is visible.

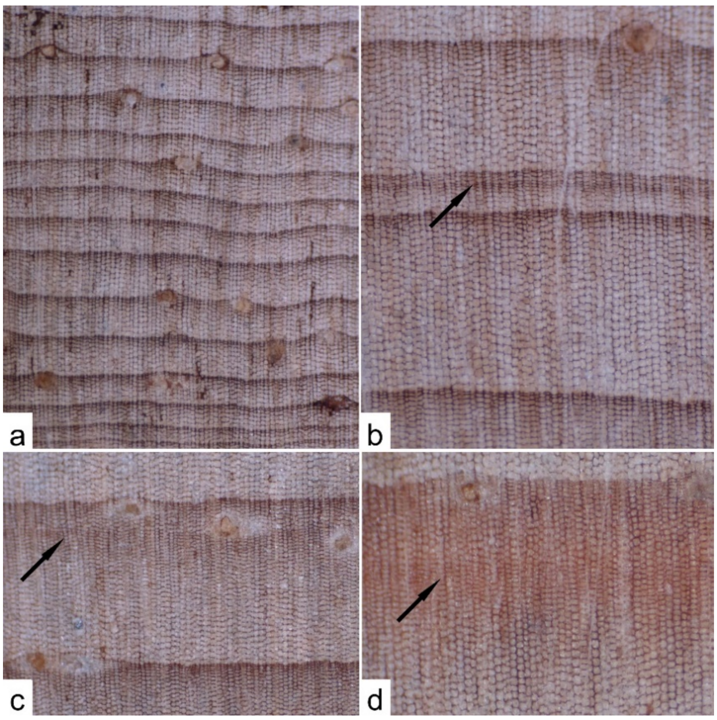

Figure 9. Growth characteristics and growth anomalies observed in the timber from Gönpa Gang: (**a**) arrangement of the resin canals, mainly in the latewood; (**b**) false ring (intra-annual density fluctuation—IADF) detected within the 41st ring of sample no. UMGG09; (**c**) IADF detected in the 15th ring of sample no. UMGG06; (**d**) IADF detected in the 38th ring in sample no. UMGG10.

3.2. Wood Characteristics and Cross-Matching

The number of rings preserved in all samples collected in Gönpa Gang varies from 29 to 151. Four cores are long enough to be measured on both sides of the pith. Five elements contain less than 50 rings (see Table 2). This means that to carry out secure dendrochronological analysis for some of the samples, statistical evaluation needs to be supported by careful visual cross-matching.

Table 2. Characteristics of wood and structure of samples collected in Gönpa Gang. 1 * for number of rings means that the outermost ring present in the sample is not fully preserved and therefore has not been measured. Distance to the pith was estimated based on curvature, using a geometric pith locator.

Sample No.	Number of Rings	Presence of Bark and/or Waney Edge	Distance to the Pith(No. of Rings)	Growth Anomalies	
				Missing Rings	Intra-Annual Density Fluctuation (IADF)/False Rings
UMGG01	151	close to the bark	5	-	-
UMGG02	112 + 1 *	close to the bark	11	-	-
UMGG03	140	close to the bark	15	+	-
UMGG04	123	close to the bark	5	-	-
UMGG05	29	no	4	-	+
UMGG06	46 + 1 *	no	2	-	+
UMGG07	72	no	1	-	-
UMGG08	37	no	4	-	+
UMGG09	94	no	2	-	+
UMGG10	45	no	3	-	+
UMGG11	88 + 1 *	no	5	-	+
UMGG12	38 + 1 *	no	1	-	-
UMGG13	68	no	2	-	-
UMGG14	104	no	10	-	-

None of the cores from the gönpa contain bark and/or a waney edge. However, with the samples taken from the main pillars in the assembly hall (UMGG01-UMGG04), it is possible that the last preserved ring is very close to the bark, as pillars are made of full trunks and some very narrow rings were most probably removed accidentally while preparing the timber. Since the pith was not present in the cores collected in the gönpa, a geometric pith locator was fitted to the innermost rings, to estimate the number of missing rings up to the pith (Table 2) and thus obtain more information about the age of the trees [52,53].

The timber used in the assembly hall is of the best quality. It was derived from long-lived trees (more than 156 years old), while timber used in the entrance hall and some of the wood used on the first floor represent fast growing, young trees.

The intra-annual density fluctuation detected in a few samples (Table 2) mostly occurs within juvenile wood, formed during the first 20–30 years of the tree's life [44,54] (Figure 9c,d). Moreover, one missing ring was detected in sample no. UMGG03, and one false ring (IADF) was found in sample no. UMGG09 (Figure 9b).

From the 14 samples collected in Gönpa Gang, 18 series were worked out. Since cores no. UMGG02, UMGG03, UMGG06, and UMGG13 contain a sufficient number of rings on both sides of the pith, two sequences were measured for each of them. Hence, 15 series from 12 samples were synchronized and used for the development of the mean chronology, UMGG_m, with a total length of 160 rings (Figure 10). The samples not included in the mean chronology are: sample no. UMGG05, containing 29 rings, which is not sufficient for reliable synchronization, and sample no. UMGG13, containing 68 rings.

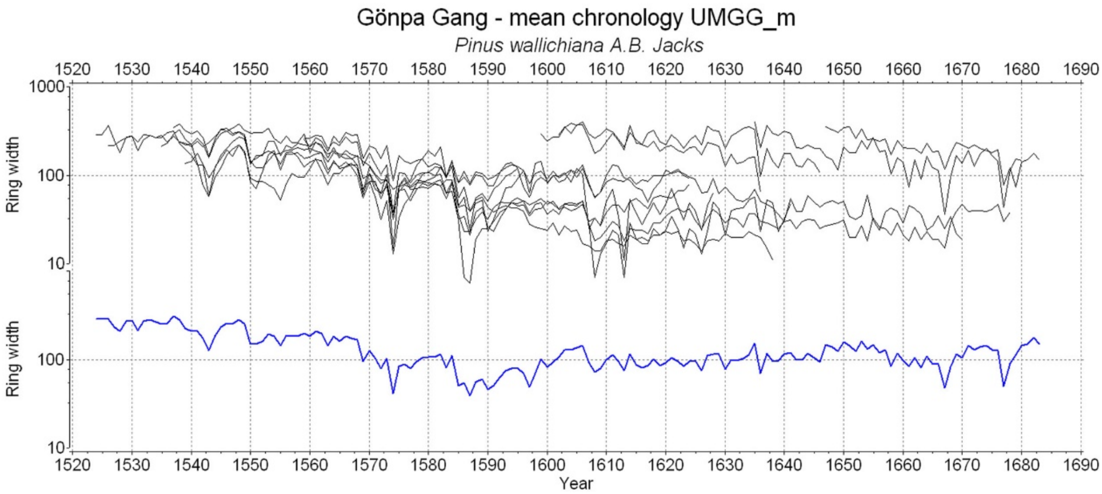

Figure 10. The development of the mean chronology UMGG_m from sequences: UMGG01, UMGG02A, UMGG02B, UMGG03A, UMGG03B, UMGG04, UMGG06A, UMGG06B, UMGG07, UMGG08, UMGG09, UMGG10, UMGG11, UMGG12, UMGG14 (upper section) and the developed chronology (blue curve). All graphs are shown in logarithmic scale. (TSAP-Win [48]).

3.3. Cross Dating and Dendroprovenance

For the cross-dating of the newly developed chronology, UMGG_m, three different reference chronologies were used (Table 3). The first one is Southern Mustang master chronology (SM_Schmidt) by Schmidt et al. [30,31]. The level of agreement is very high both for the chronology UMGG_m (Table 3) and for single, dated series (Table 4). The dated chronology UMGG_m covers the period from 1524 to 1683 (Figure 11). The samples that could not be dated using SM_Schmidt reference chronology are UMGG01 and UMGG05. Sample UMGG01 was, however, synchronized with chronology UMGG_m, and the last ring was dated back to 1680. Sample UMGG05, which contains only 29 rings, could not be dated or synchronized using statistical evaluation. Attempts at visual cross-matching with chronology UMGG_m were made, and the possible position between 1623 and 1651 was found. Still, the series is too short to consider this result as reliable. Moreover, the series represents juvenile wood (between the 5th and 33rd year of the tree's life), so the tree-ring pattern can be irregular and most likely reflects mainly tree-specific variation [44,54].

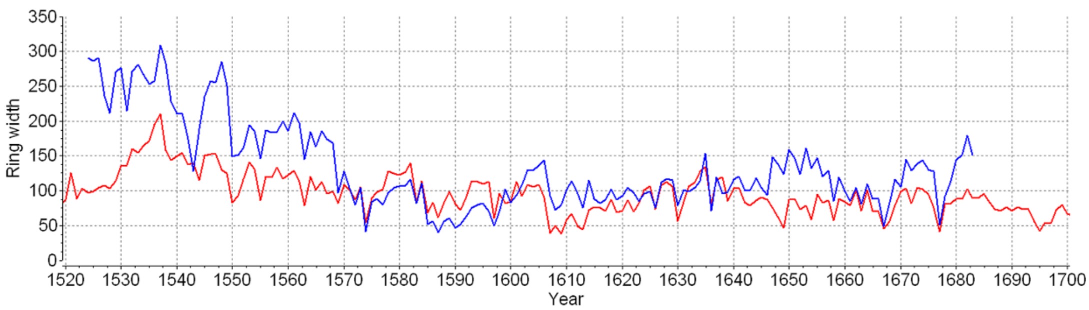

Figure 11. Visual cross-matching of the chronology representing timber from Gönpa Gang: UMGG_m (blue curve) with the Southern Mustang master chronology SM_Schmidt [30,31] in red. Only the overlapping period of the two chronologies is presented here. (TSAP-Win [48]).

Table 3. Cross-dating results of the developed chronology, UMGG_m, against the reference chronologies. The parameters used for the statistical evaluation of the cross-dating results were: the Gleichläufigkeit (Glk) score, showing the level of agreement between consecutive ring width slopes; GSL: signature Glk (statistical significance of Glk * = 95.0%, ** = 99.0%, *** = 99.9%); T-values: TVBP and TVH, sensitive to extreme values, such as marker years; and CDI—Cross-Dating Index, which uses the GLS value and t-values to determine the quality of the series match.

Developed Chronology (Length of the Chronology)	Reference Chronology Code	Region	Years AD of the Reference Chronology (No. of Years)	TVBP/TVH	CDI	Glk/GSL	No. of Overlapping Years	Cross-Dating Results
UMGG_m (160)	SM_Schmidt [30,31]	Southern Mustang (Nepal)	1376–1993 (618)	13.0/14.7	105	75/***	160	1524–1683
	Dolpo4c7 [35]	Dolpo (Nepal)	1556–1998 (443)	6.5/7.7	37	60/*	128	
	THTSKP_m [37]	Upper Mustang Palaces Tsarang and Thinggar (Nepal)	1523–1916 (394)	13.1/12.1	101	78/***	160	

Table 4. Cross-dating results of the sequences representing samples collected in Gang Gönpa, against the Southern Mustang master chronology. The parameters used for the statistical evaluation of the cross-dating results were: Gleichläufigkeit (Glk) score; GSL; T-values: TVBP and TVH and CDI. (statistical significance of Glk ** = 99.0%, *** = 99.9%).

Sample No.	Serie's Length	TVBP/TVH	Glk/GSL	CDI	Time Span
UMGG01	151	not dated			
UMGG02	112	4.3/4.8	63/**	28	1559–1670
UMGG03	140	9.0/8.0	69/***	59	1539–1678
UMGG04	123	4.2/4.4	69/***	30	1526–1648
UMGG05	29	not dated			
UMGG06	46	9.6/10.4	81/***	81	1635–1680
UMGG07	72	7.7/7.5	69/***	52	1524–1595
UMGG08	37	4.0/5.5	76/***	36	1647–1683
UMGG09	94	12.2/12.3	74/***	91	1535–1628
UMGG10	45	6.5/6.3	75/***	48	1602–1646
UMGG11	88	7.5/8.4	72/***	58	1537–1624
UMGG12	38	6.2/3.4	70/**	34	1599–1636
UMGG13	68	4.6/4.9	72/***	34	1742–1809
UMGG14	104	11.0/8.5	75/***	73	1538–1641

Since the samples UMGG02, UMGG06, UMGG11, and UMGG12 contain one outermost unmeasured ring (Table 2), one year needs to be added to the dated series to obtain the final results of dating of the elements.

The cross-dating results of the mean chronology UMGG_m against Dolpo4c7 chronology developed by Bräuning [35] are the same from 1524 to 1683. However, the agreement between chronologies is much lower than in the case of the SM_Schmidt chronology (Table 3). Moreover, when considering a single series, only four samples could be dated using the Dolpo chronology.

The UMGG_m chronology was additionally compared with data derived from historical buildings in Upper Lo examined in 2018, within Gmińska-Nowak's Project [37]. The timber from the 16th and 17th century was found in Thinggar Palace and in Tsarang Palace. The results of cross matching the UMGG_m chronology with a mean chronology representing the two palaces are as strong as the correlation with the Southern Mustang master chronology (Table 3, Figure 12). This shows that the source of timber used in all three constructions was the same, the forests of Southern Mustang.

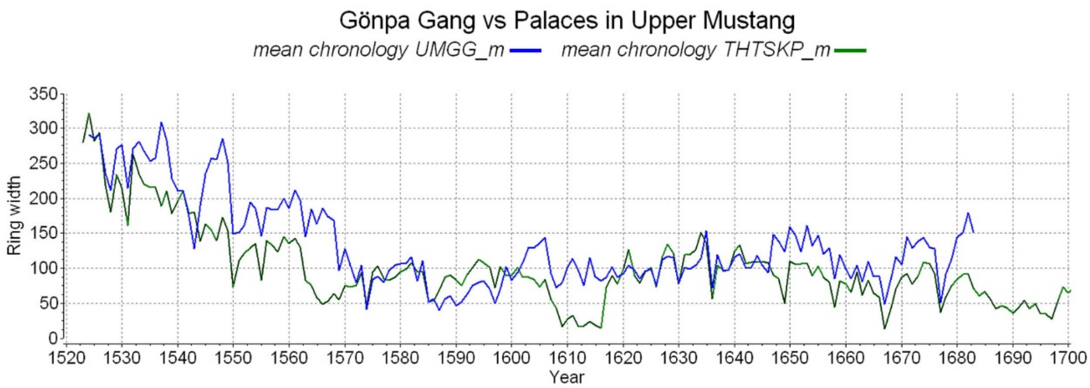

Figure 12. Visual cross-matching of the chronology representing timber from Gönpa Gang: UMGG_m (blue curve) with the chronology developed from timber found in Tsarang Palace and Thinggar Palace in Upper Mustang [37] in green. Only the overlapping period of the two chronologies is presented here. (TSAP-Win [48]).

4. Discussion

Himalayan pine, *Pinus wallichiana* A.B. Jacks, is a large evergreen tree which is naturally distributed in South Asia from Afghanistan to Bhutan at altitudes ranging from 1800 to 3900 m a.s.l. In Nepal, it occurs between 1800 to 3600 m a.s.l. and can occasionally be found up to 4400 m a.s.l. Himalayan pine is the second most studied species in Nepal [29]. Due to its clear annual rings and its wide geographical coverage, it has shown potential for multiple aspects of dendrochronological studies [55,56]. Although false rings and missing rings can provoke some problems during cross-dating [57], *Pinus wallichiana* is widely used for climate-related studies [29], while dendroachaelogical research reveals its potential for heritage-related studies [30–37].

The use of Himalayan pine as a timber for structural elements in Gönpa Gang is not an exceptional situation. The species has already been found in many traditional structures in Upper Mustang, Southern Mustang, and the neighboring areas (Manang, Dolpo). Himalayan pine was used in the most important buildings of Lo Manthang, including Thupchen Gönpa, Jampa Lakhang, and King Place. Moreover, it was used in Tsarang Palace and Thinggar Palce, as well as in Ghar Gönpa in Lo Gekhar [37]. *Pinus wallichana* was also found in the fortress in Lupra [58] and in several structures in Lower Mustang examined by Schmidt et al. [31–34].

Dendrochronological research carried out in Gönpa Gang allowed to estimate the age of 13 out of 14 examined elements. Since no bark and/or waney edges were preserved in the samples, it was not possible to determine the exact year when the trees were cut. The only date that can be given for each element is a terminus post quem, or earliest possible felling date [25].

The timber used in the gönpa is of imposing size. The largest elements are pillars in the main assembly hall, made of solid trunks with an average diameter of 28 cm and a height of 2.50 or 4 m (in the case of pillars reaching the gallery above the *dukhang*) and pillars in the entrance hall with the height of 2.80 m and a rectangular cross-section of 21 cm $\times$ 23 cm. Timber used on the first floor is smaller. The height of all pillars is adapted to the height of the rooms and usually does not exceed 2 m. The longitudinal beams are of various length, reaching up to 10 m. All elements are shaped, and the average section size is 14 $\times$ 17 cm.

According to Ramble [2], almost everything that is known about the history of Gönpa Gang and the convent is based on written sources kept in the village Chuksang. These sources include documents in the Chuksang community archive, concerned with the convent, the convent archive itself, and the autobiography of the founder of the gönpa, Kunzang Longyang.

The original construction period is known from the autobiography of the founder, who suggests that the gönpa was built between 1684 and 1695. Further deductions regarding the sequence of building operations based on the examination of the structure were made by Harrison [1].

According to Harrison [1], the *dukhang* was the first part of the gönpa built, constructed together with the attached western sanctum. The four samples from the pillars of the *dukhang* were dated back to 1648, 1671, 1678, and 1680 terminus post quem. The minimum age of the trees used to build the pillars was 124, 128, 155, and 156 years. The results confirm that the initial construction phase could have started in 1684. Some of the outermost rings were removed from the trunks, but most likely very few are missing. The timber from the first floor collected in the rooms above the *dukhang* was dated back to 1681, 1595, and 1683 (elements in the gallery) and 1628, 1648 and 1809 (elements in the separate western rooms). Only the element from the western room, the longitudinal beam, turned out to be a replaced/later element, introduced into the structure after 1809. The other dated timbers (terminus post quem) come from the time before the suggested original construction period (1684–1695), so they can be considered as consistent with information from written sources.

In his study, Harrison suggests that the entrance hall could have been added to the main body of the gönpa later, as there are butt joints between its rammed earth walls and those of the *dukhang* east wall, and the central axis of the entrance pillars is a little south of the *dukhang* door axis. Unfortunately, the sample taken from the pillar in the entrance hall was not dated. The element was made of material that differs substantially from the timber used in the *dukhang*. It comes from young, fast-growing trees, but this is not a satisfactory premise to separate the construction phase. Moreover, a separate construction phase cannot be inferred from the dating of the sample taken in the reception room above the entrance hall. The pillar (made of a trunk of minimum age of 114 years) was dated to 1641 terminus post quem, and the number of missing outermost rings could not be determined.

According to Harrison, the entire south wing of Gönpa Gang is a later extension. Both floor and roof levels are lower than in the main building. The walls are built in stone, and it can be seen in the ground floor rooms that the north–south cross walls lean against the battered and originally external south wall of the *dukhang*. This hypothesis cannot be confirmed using the results of dendrochronological research based on a limited number of samples. The two examined elements were dated to 1625 and 1637 terminus post quem. They are both shaped into a rectangular section and an unknown number of the outermost rings were removed.

5. Conclusions

The dendrochronological research carried out in Gönpa Gang is of paramount importance for the development of dendroarchaeological research in Upper Mustang. As it was the first monument in Upper Mustang successfully dated using dendrochronological methods, it justified and simplified similar activities at other sites in the restricted area. The data derived from the timber found in the gönpa became a key component of the first Upper Mustang master chronology [37].

Examination of the Gang Gönpa wood resulted in the age determination of 13 out of 14 elements. When it comes to interpreting the expansion phases of the building, these results can only be used to a limited extent, but in the context of the dating of the facility, the results are consistent with information from ancient written sources. Significant information obtained on the basis of these studies concerns the provenance of the wood, which comes from the less arid Southern Mustang area. Moreover, the examined timber demonstrates the correlation with the timber used in the Upper Mustang historical buildings further north.

The research carried out in Gönpa Gang is also important on another plane. The gönpa is a unique historic building, but at the moment, due to its state of preservation, it is seriously threatened with collapse and, in the long term, will vanish from the cultural landscape of Upper Mustang. All activities focusing on this object, including scientific research, can be used to call attention to the importance of this building. The better this object is recognized, the easier it will be to prepare a full conservation program. The more attention we draw to the object, the easier it is to raise funds for the conservation and protection of this extraordinary heritage.

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