A Brief History of Chinese Wooden Architecture

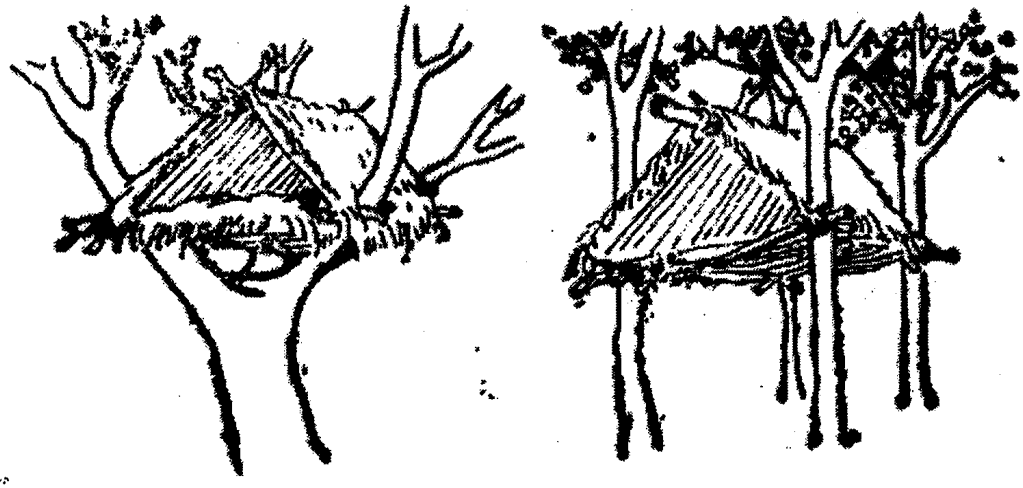
Pits to Palaces, Twigs to Temples

By Ma Bingjian

PART ONE- Origins of Chinese Wooden Architecture

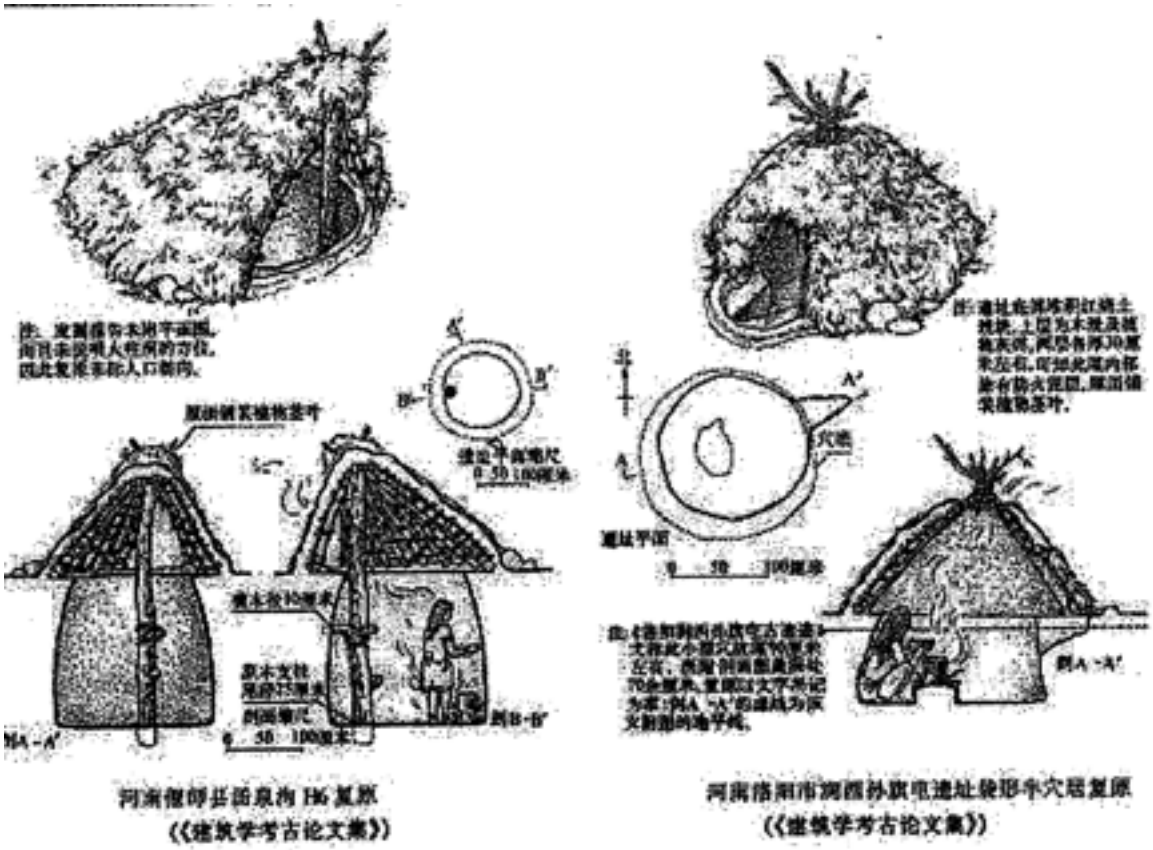
The story of China's architecture begins with shelters made by "Nest" dwellers and "Pit" dwellers. At the dawn of Chinese civilization, our ancestors took refuge in caves. They struggled to survive in a dangerous environment where they could be attacked by wild beasts, snakes and insects.

Over time, these ancestors started to move away from their cave-homes so they could make their own shelter. One group fended off danger by constructing shelters in trees. They intertwined branches and twigs to make a "nest" and were known as "Nest Dwellers".



#1- Nest Dwellings

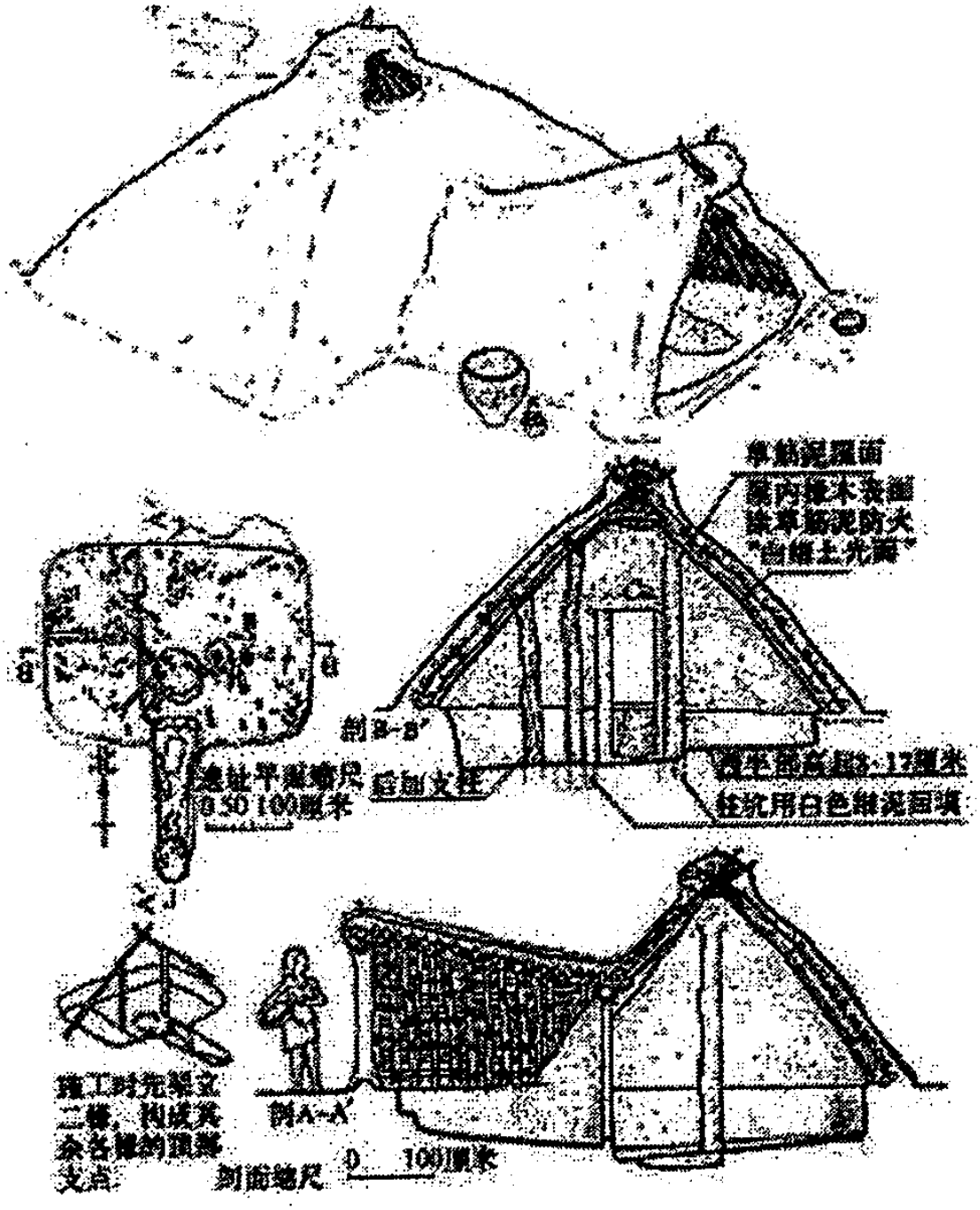
Another group picked a spot on high ground and dug a pocket-shaped pit. They stuck a wood pole into the bottom of the pit and clustered branches on top of the pole to cover the pit. In this way they could keep danger at bay and somewhat shield themselves against rain. This was the "Pit Dweller's" house.



#2- Pit Dwellings

In some ways the pit house was an improvement over cave dwelling, but it had its drawbacks as well. The early style pit dwelling was deep. Sometimes a person standing in the pit would be below ground level. Therefore it was awkward to climb in and out. Also, it was easily flooded and the roof could catch fire.

During this nascent era of architecture, pit dwelling evolved: pits became shallower and the roof was raised above ground. As floor area increased, more than one pole was set inside the pit to prop up a larger roof.

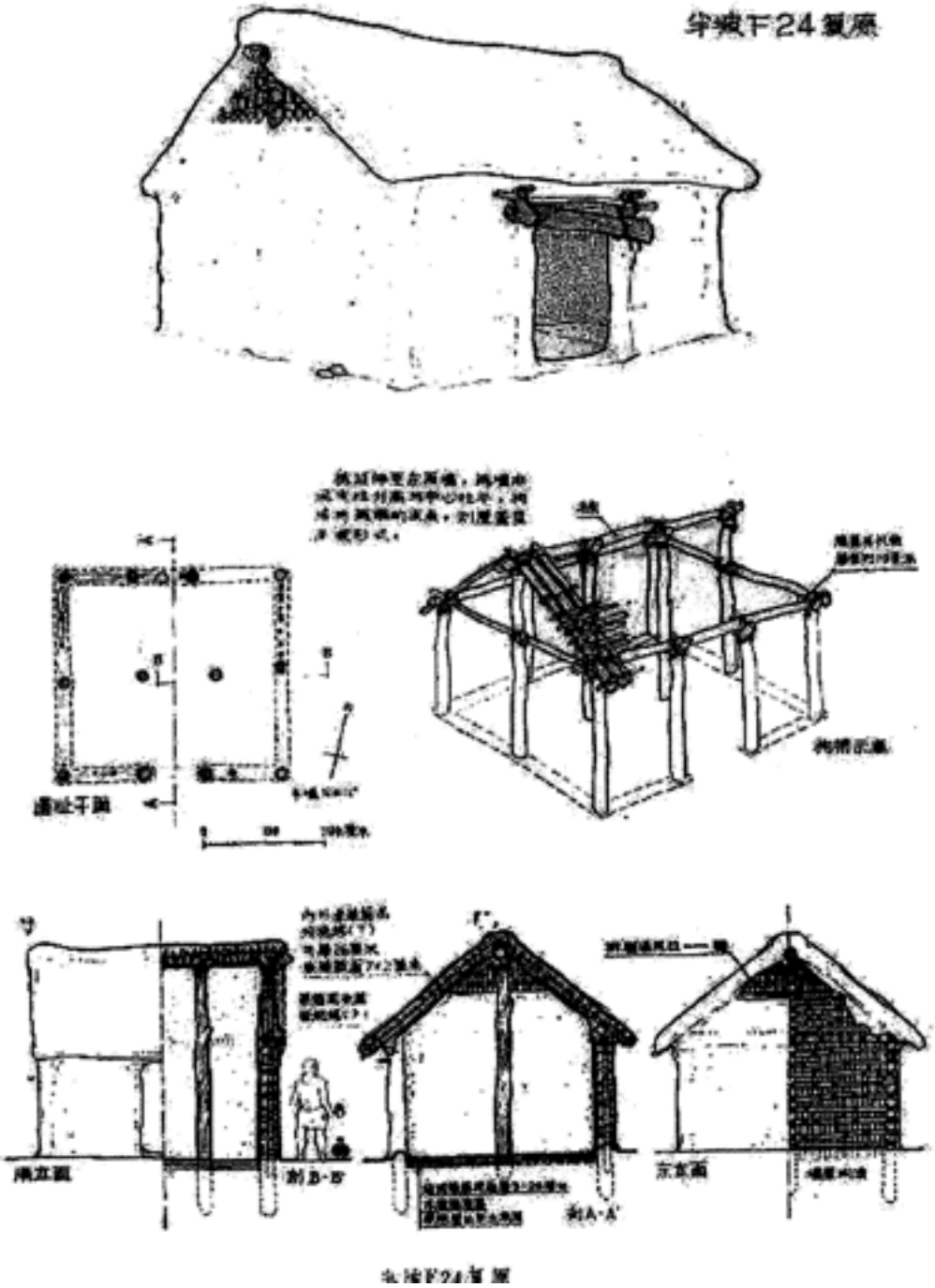


半坡F41复原

(引自姜寨遗址论文集)

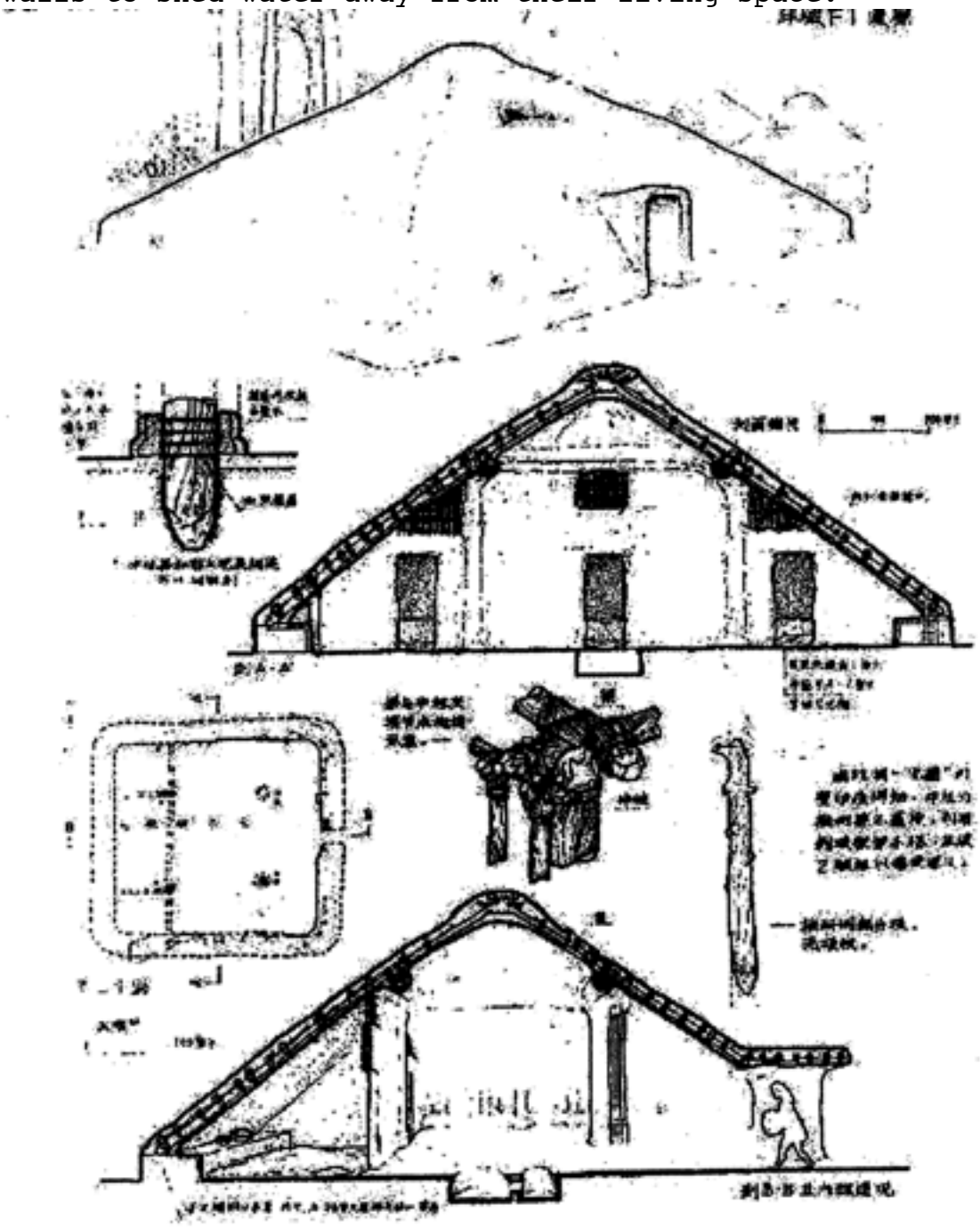
#3- Evolution of Pit Dwellings

Pit Dwellers gradually moved up and out of the earth. They inhabited larger spaces in shallower pits. Looking at the restored Ban-Po Archeological Site in Xian, we can see that early in the New Stone Age, these shelter-makers took an evolutionary step forward when they started living on the ground surface.



#4- Development of Ground-Level Dwellings

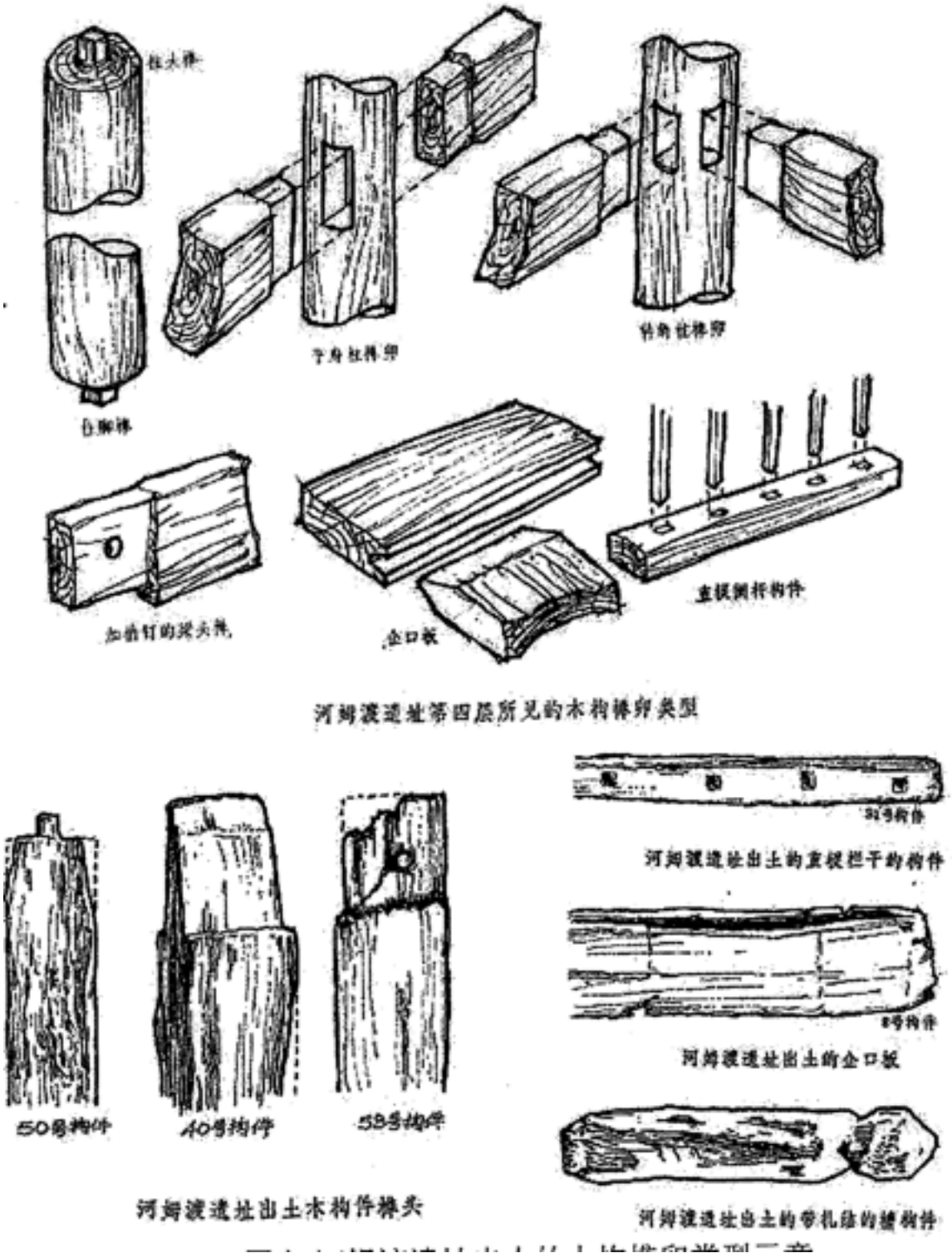
These newer generations of Pit Dwellers fashioned branch and stick wooden structures that enclosed a ground-level living space with a roof. Living on the ground instead of inside a pit, they solved the problem of flooding, but they still could not avoid moisture and dampness. They came up with the idea of sloping the roof down toward the outside walls to shed water away from their living space.



#5- Low Walls Protect Against Rain and Seepage

A new idea- making a “wood frame” to enclose space and support a roof- slowly took hold over the course of many centuries. When shelter-makers used rattan and vines to lash together branches, they took the first rudimentary step in creating wooden architecture. They cobbled together a framework strong enough to support a roof. By sloping the branches and leaves of the rudimentary roof and extending them beyond the perimeter walls to make eaves, they were able to protect vulnerable mud walls from rain.

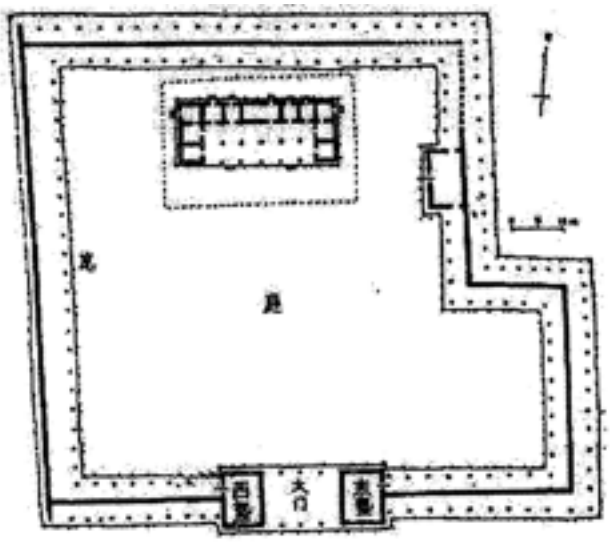
Over the course of countless years, shelter-makers morphed into carpenters. They picked up stone tools such as shovels, sickles and axes and used them as woodworking tools. They shaped wood to their needs, and at some point they learned to carve mortises and hew tenons. They also fashioned a wide variety of other joints. They were now able to connect together various wooden parts into a unified whole by using joinery. The advent of joinery made vine-lashing obsolete. Joinery connections proved to be stronger and more durable than lashed connections. And significantly, they could use with larger pieces of wood to build bigger structures.



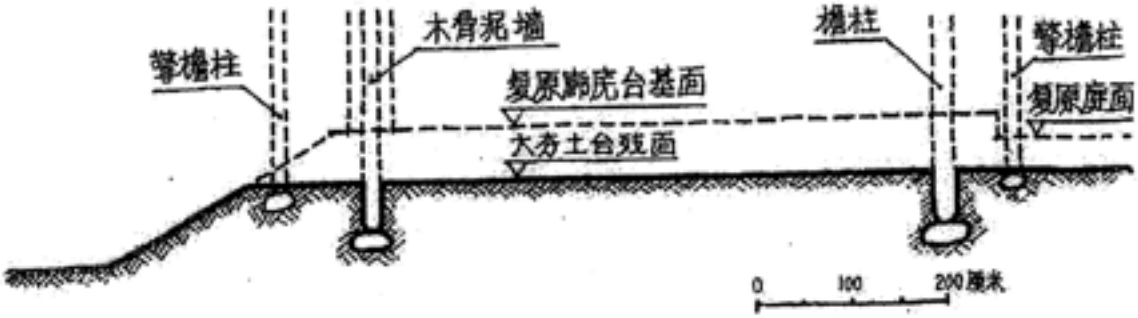
#6- Early Wood Joinery from Hemudu Excavation Site

Three to four thousand years ago during the Xia and Shang Dynasties, builders took a significant step in creating a distinctly Chinese architectural style- they started

constructing rammed-earth raised platforms. A platform functions as an elevated foundation for the structure and also serves as the floor. One might say it keeps the building “high and dry”. Evidence from Xia and Shang sites in Erli Toutsun, Yensi County, Henan, reveals rammed-earth building platforms that are about one meter in height above ground level.



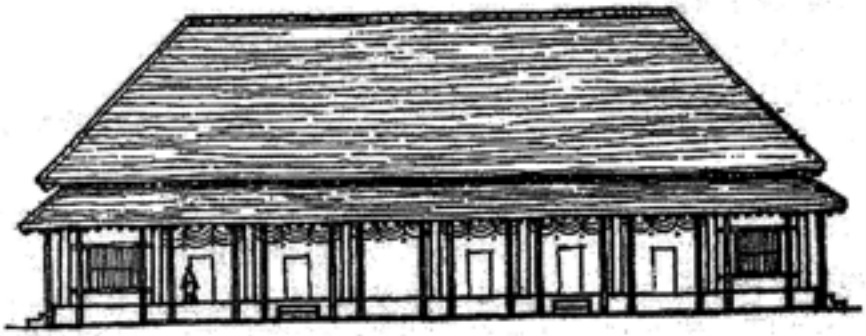
河南偃师二里头建筑复原平面之一



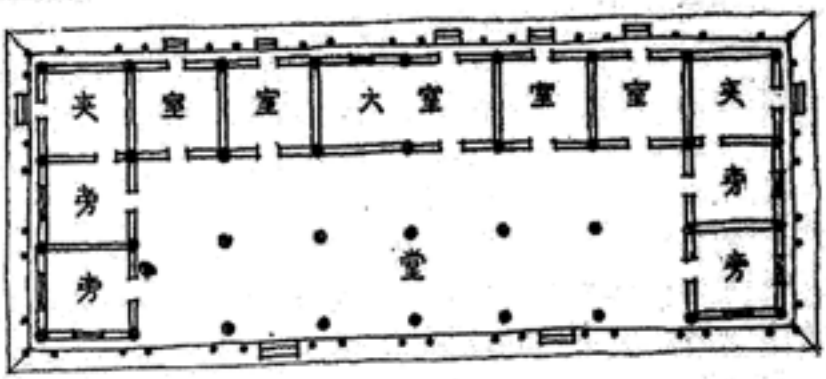
大夯土台南部横剖面示意图

横剖面图

侧立面图

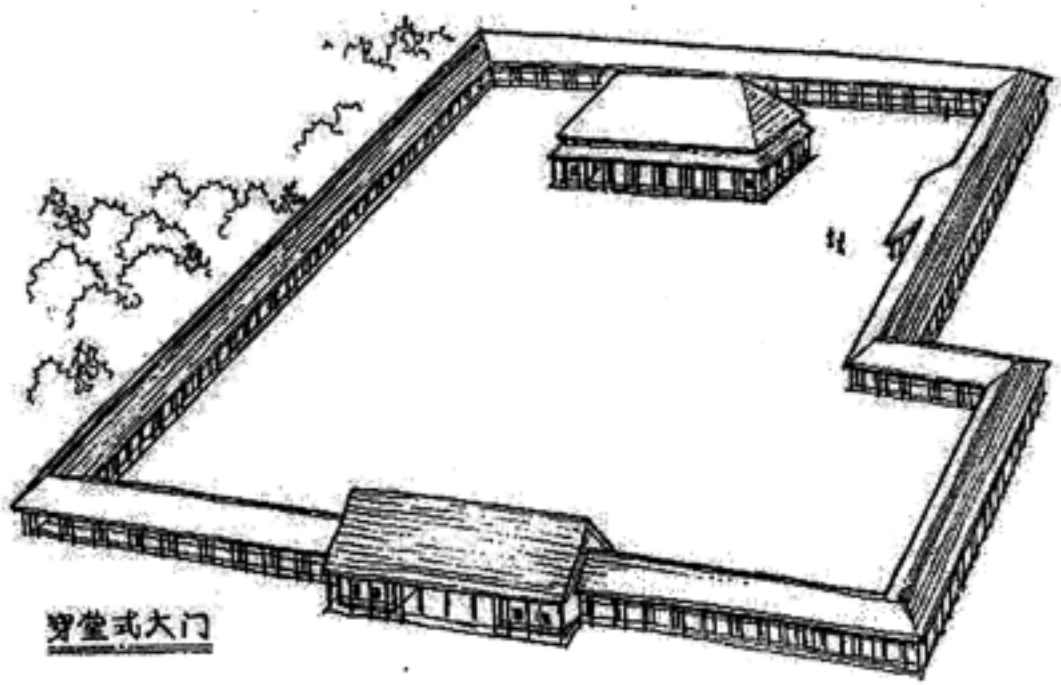


正立面图



平面图

河南偃师二里头遗址主体殿堂复原设想之一



河南偃师二里头建筑复原鸟瞰图

#7- Reconstruction Drawings Based on Excavations at Erlitou, Henan

Even though the roots of Chinese architecture trace back to both “Pit” and “Nest” dwellers, we have no surviving archeological evidence of “Nest” architecture. We only have a few descriptive phrases from ancient literature.

However, there are many excavated sites where “Pit” dwellers lived. Architectural historians have analyzed “Pit” sites and have learned about the evolution of pit culture from literary descriptions as well as from site restoration work. From their research, they describe how man-made shelter progressed from “Pit Dweller” to “Half Pit Dweller” i.e. the pit is half as deep as earlier pits, to “Ground Dweller” to “Mud Wall House Dweller” to “House on Raised Platform Dweller”.

This evolution of shelter shows that our ancestors progressively adapted to their environment by making new choices about protecting themselves. Historians now

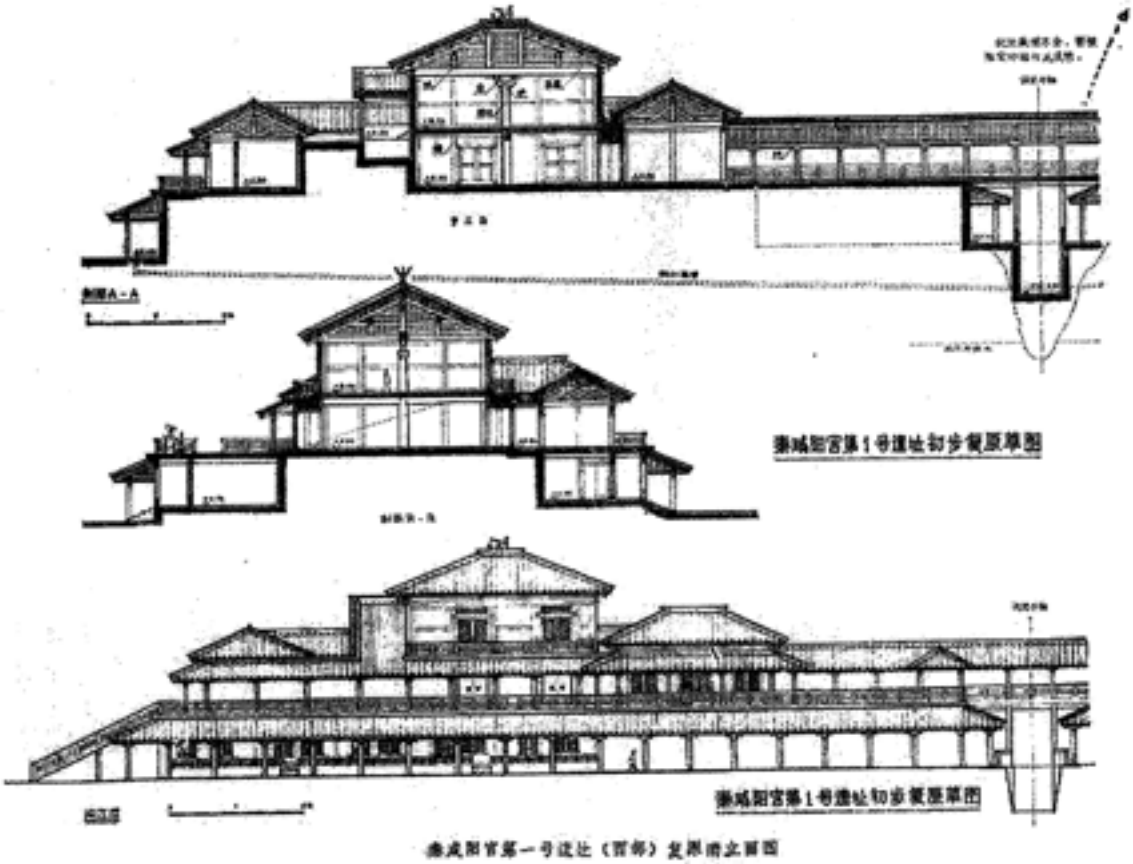
consider the “House on Raised Platform” stage as the first step in defining a distinct style of Chinese architecture.

Builders passed another significant milestone in achieving a well-defined system of architecture when they began constructing houses with load-bearing wooden house-frames. Wood posts in the frame support a heavy roof that consists of beams, purlins, struts, king posts, ridge, rafters, wood sheathing, clay bedding and clay tiles. (Mud, adobe, plaster, stone or brick is used to fill the spaces between posts but the in-fill wall does not support the roof.)

From this point- building a wood frame on a raised foundation- Chinese architecture blossomed. Since wood is a strong and abundant material, easy to work and shape, builders, who were not yet called architects, could design buildings to meet aesthetic as well as practical criteria. They learned how to construct houses with bigger, heavier and more durable roofs. What is now universally recognized as the “Chinese style roof”, which curves upward at its corners like a bird’s wings, is the ultimate expression of architectural freedom.

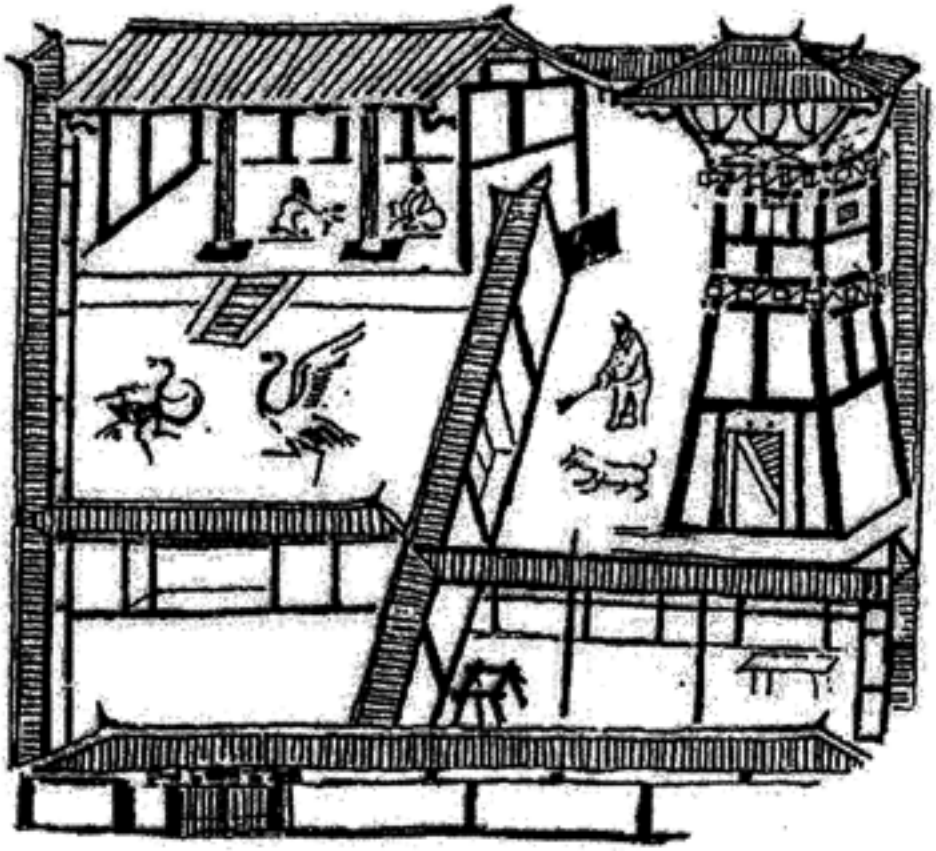
PART TWO- The Special Characteristics of Chinese Wooden Architecture

The adolescence of Chinese wooden architecture spanned many thousands of years. Already 20-30 centuries ago, Chinese architecture had developed into a recognizable style, and by 700-600 B.C. during the Spring-and-Autumn and Warring States periods, these styles were maturing. In the third and second centuries B.C. in the Chin and Han Dynasties, written records tell of many almost-unimaginably grand timber-framed palaces. They were considerably larger than anything existing today. Architecture was flourishing.



#8- Theoretical Reconstruction of Qin Dynasty Palace at Xianyang

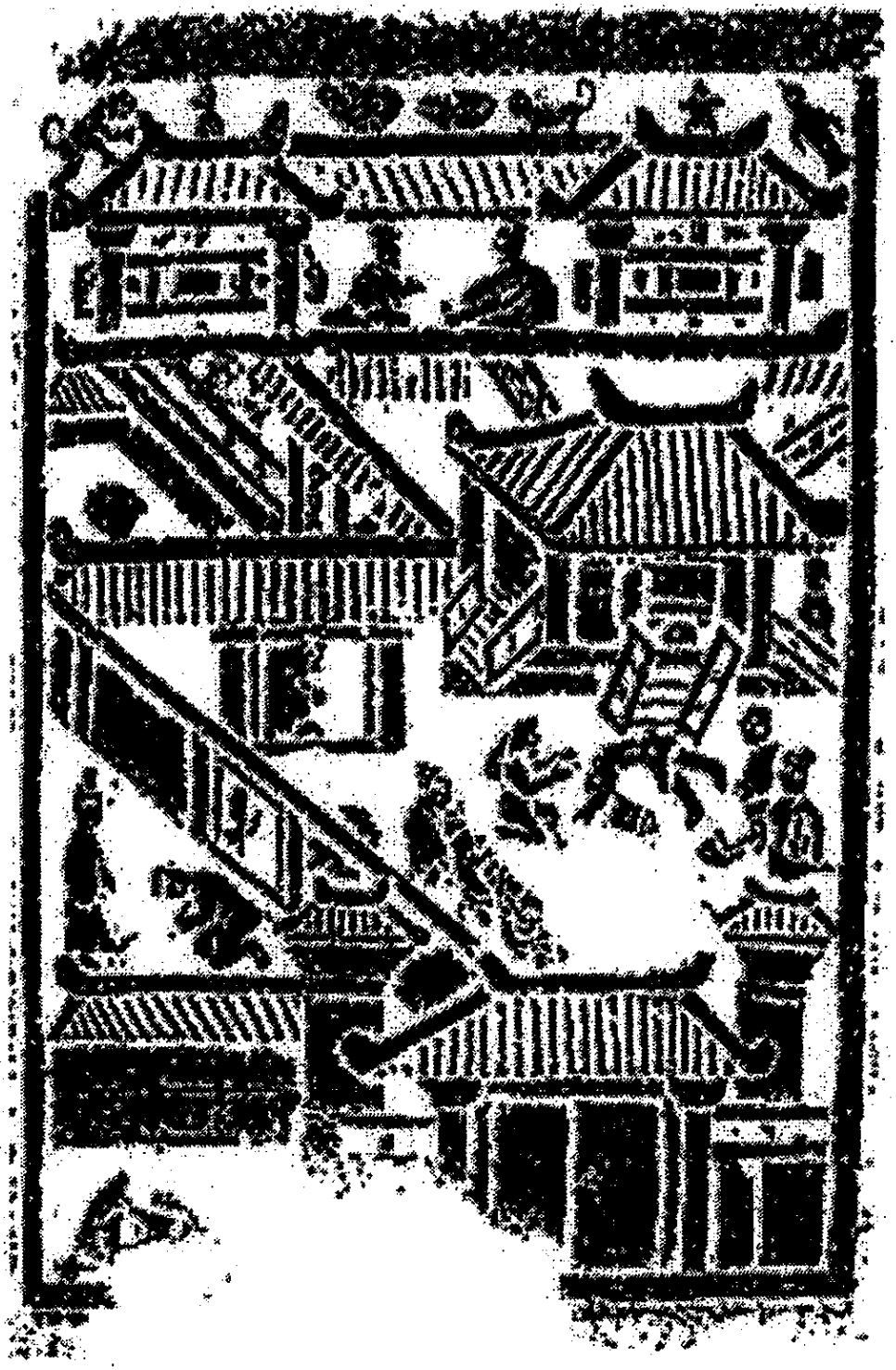
From excavated Han dynasty paintings on stone and brick, we can see many depictions of Han architecture.



四川成都市出土东汉住宅画象砖（拳窝）

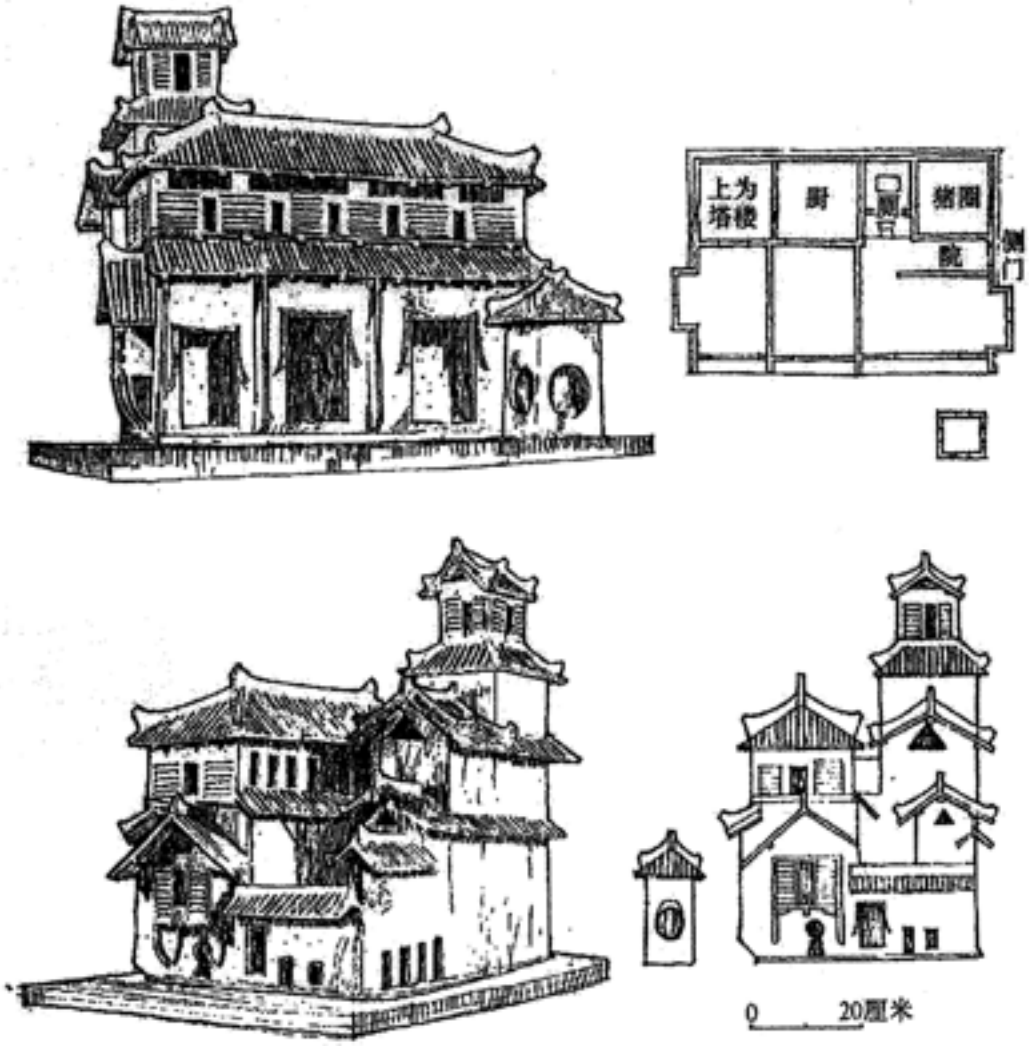
（《文物参考资料》1954 年 9 期）

-Eastern Han Period Painted Brick Picture of House in Chengdu, Sichuan



山东曲阜市旧县村汉画像石中之大型住宅形象

-Han Painted Stone Image of Large Living Compound from Shandong

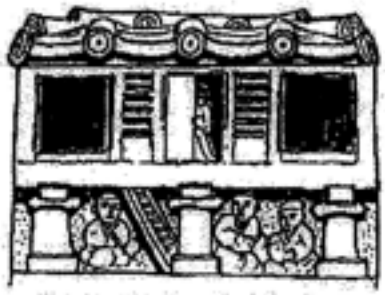


湖北云梦县癞痢墩一号墓出土釉陶楼屋

（《考古》1984 年 7 期）

-Excavated Pottery Multi-Story Buildings from Hubei

•江苏睢宁县双沟画象石中之楼及廊庑
(《中国古代建筑史》)



•四川芦山县出土汉代石刻干阑建筑
(《文物》1987年10期)

•广州市红花岗29东汉木椁墓出土陶屋
(《文物参考资料》1956年5期)

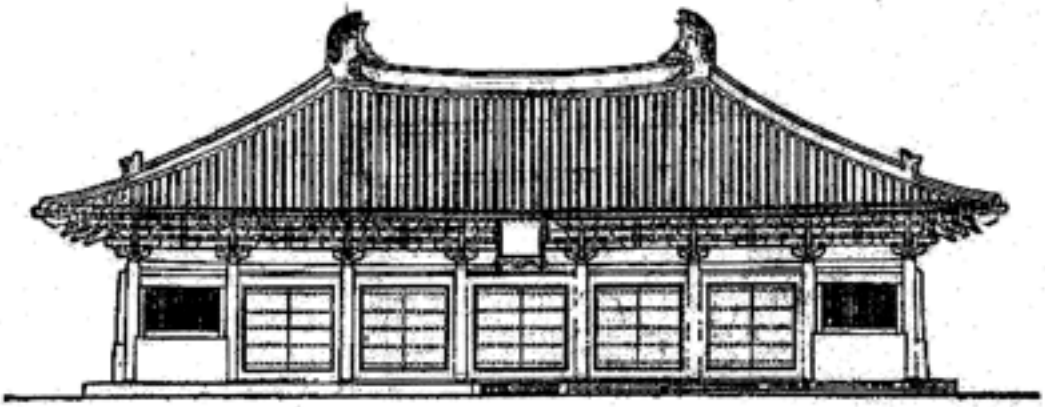
•江苏邗江县老虎墩汉墓陶塔
(《文物》1991年10期)

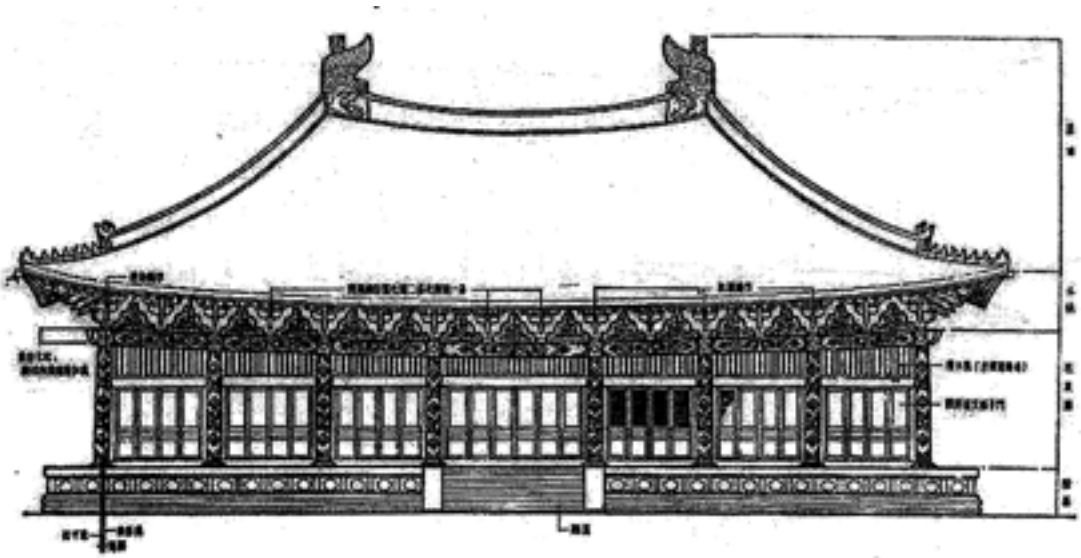
•湖南长沙市小林子冲东汉1墓出土陶屋
(《考古》1959年11期)

#9- Han Dynasty Residential Architecture

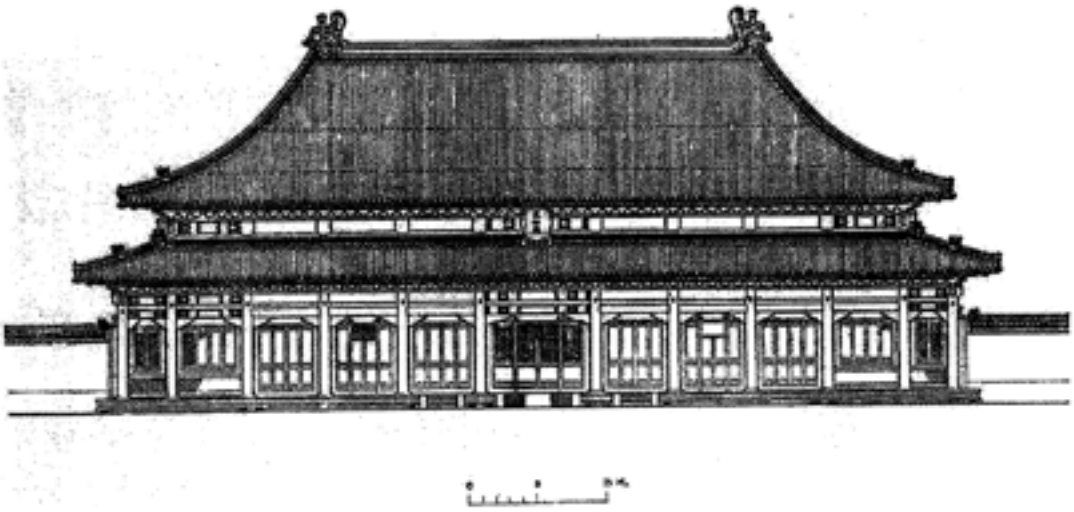
We notice during the Han dynasty, 200 B.C.-220 A.D, that wooden buildings have become prevalent throughout most of China. In this era builders begin to use a modular system to design buildings. They start using math and measurement. They standardize sizes and measurements in order to mass-produce parts.

佛光寺大殿外观





宋《營造法式》立面殿堂者圖



北京故宮大和殿正立面

#10- Tang, Song, Ming, and Qing Wooden Architecture

There are eight special features that define classical Chinese wooden architecture. All major buildings- imperial palaces and residences, religious temples, pagodas, drum and bell towers, merchant homes, town halls and city gates- exhibit most if not all of the following features:

1.LOAD-BEARING WOODEN FRAMEWORK- “In-fill walls may crumble, but the frame will stand”.

Long ago our ancestors made a critical decision when they

opted to build structures with a load-bearing post-and-beam frame. Posts can also be called columns, and beams can be named architraves. Especially because these early builders started using wood joinery to connect the frame, they gained the freedom to create a great variety of structures.

One of the inherent benefits of building with wood is that wood frames connected by joinery are somewhat elastic. This means that if a force pushes laterally on the side of a frame, it will tend to bend but not break. The elasticity of wood will allow it to return to its original position. Also, in large-scale construction, wood joints, like human joints, are flexible and allow the frame to bend without breaking. This is why timber frames are able to absorb lateral shock from earthquakes. Masonry and stone buildings, by contrast, are brittle and tend to fracture when subjected to a lateral force.

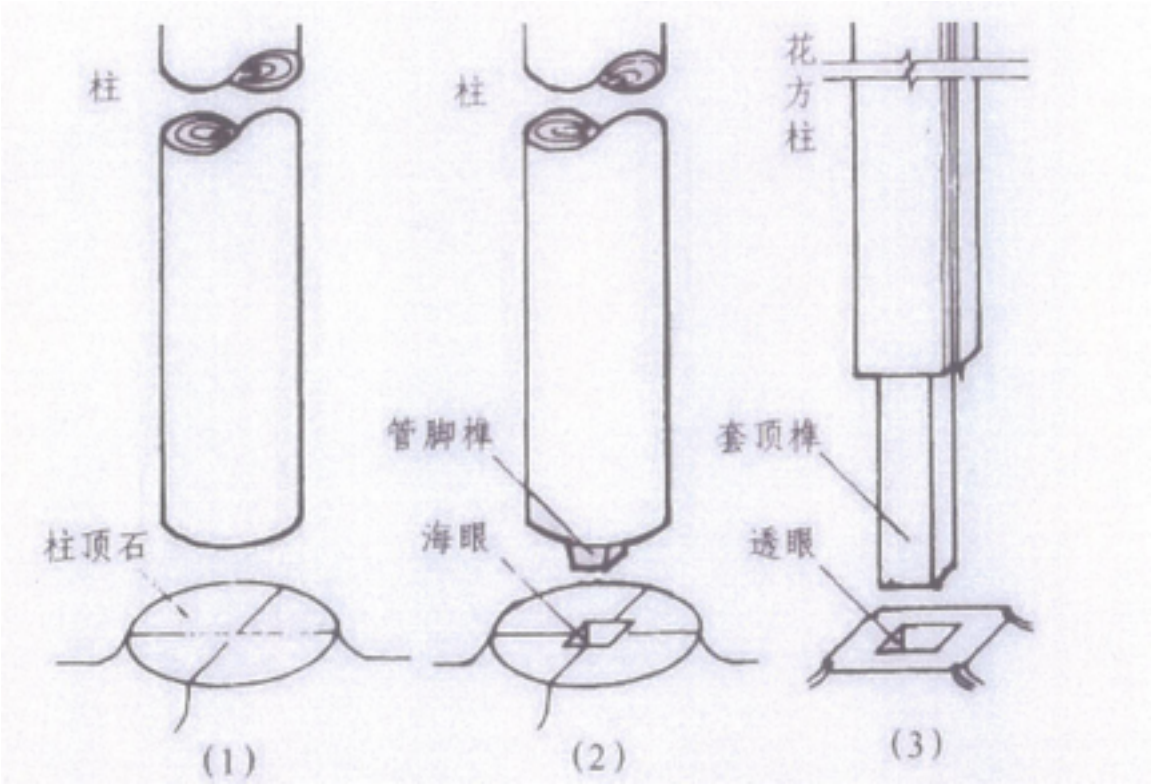
Traditional timber-framed buildings are completely different from today's steel-reinforced concrete buildings. These modern structures are stiff, and if they are not strong they can be completely destroyed by an earthquake. By contrast, timber-frames can absorb and dissipate earthquake shocks because of the flexibility of joinery and the inherent flexibility of wood. In fact, a wood frame can be considered as a safety factor in earthquake country.

To give a real example, in my early years I worked on a timber-framed project as a carpenter's assistant. After tearing down the in-fill masonry walls and removing the roof, only the frame was standing. We wanted to demolish the wood frame, so we used a steel cable and pulled on the frame until it was leaning about 10 degrees from vertical. When we loosened the cable so we could re-fasten it and pull again, much to our surprise the frame sprang back to its original position. This little story shows the strength and elasticity of a timber frame and its ability to resist external forces, especially earthquakes. After the Great Tangshan earthquake in 1976, I went to inspect buildings and investigate structural failures. All ordinary brick houses were destroyed. Only some wood-framed residential houses were still standing. After the big 2008 Sichuan earthquake, many historic wood buildings were damaged and their roof tiles came tumbling down, but the timber frames survived. They were damaged but did not suffer catastrophic

collapse.

#11- Wood-Framed Buildings Hit by Earthquake

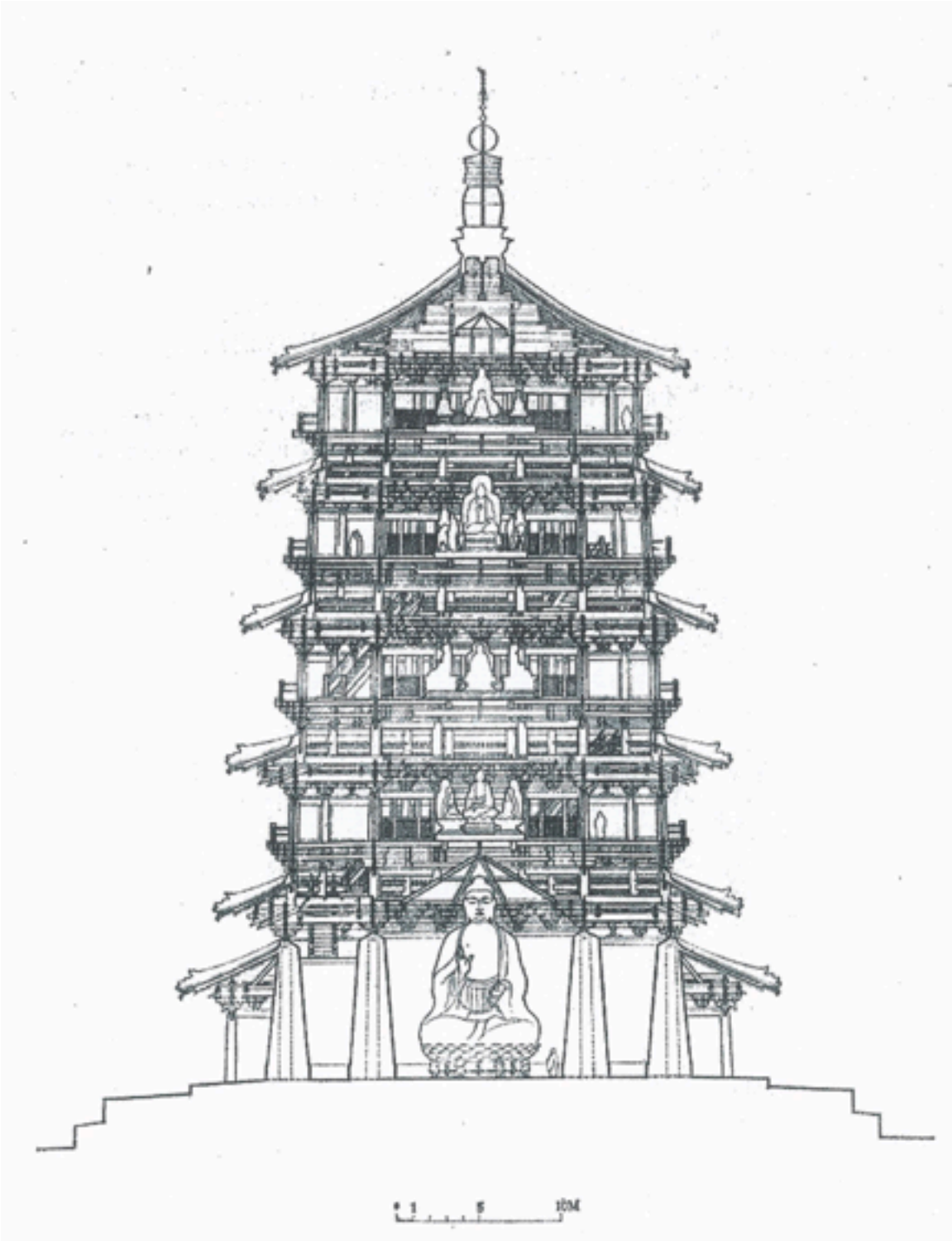
Besides the inherent elasticity of wood, and the imbued flexibility of wood joinery, another reason that Chinese timber-frame structures are good at surviving earthquakes lies in the connection between building and foundation. In fact, it is the lack of connection between the building and its base that helps buildings to survive. To put it another way, there is no strong connection between post and foundation.



#12- Column and Stone Base Connections

Traditional palaces and temples are very heavy, especially because of the weight of roof timbers, clay bedding and tiles. On these buildings, the bottom of each post is flat, and the stone base under the post is also flat on its top surface. If one can imagine a table on an ice-skating rink, when an earthquake strikes, the horizontal shock waves will jolt the ice sideways. The table may slide to and fro, but it won't collapse because its legs are free to slide on the smooth ice. Vertical quake forces may jiggle or lift the table, bounce it around, but the table will not be shaken to pieces because it is not connected to the ice. Chinese timber-framed buildings react similarly. Quakes may destroy earthen or brick walls and tiled roofs, but the frame will most likely survive. There is a Chinese phrase: "walls may fall, but frame will stay".

One ancient wood-framed building is the famous Fengjia Ta, also known as Muta or Wooden Pagoda of Fogongsi. It is located in Yingxian, Shanxi province. Nearly 200 feet tall, it has survived intact since the Liao dynasty.It is about 1000 years old and has been shaken by many major quakes. Yet it still proudly stands today. It is a good example of how timber framed structures can survive earthquakes.



#13- Section Drawing and Exterior Photo of Yingxian Muta (Wood Pagoda)

2.RAISED PLATFORM FOUNDATION- Buildings sit on a raised

earthen platform. The platform serves as the foundation. Prestigious buildings sit on a three-tier platform.

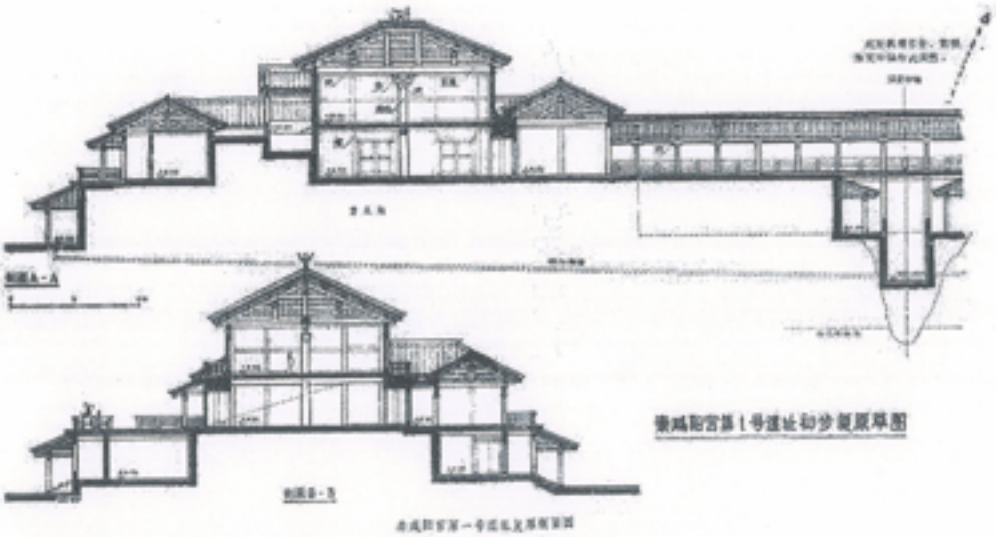
From my introduction, you may recall that primitive architecture started with “Pit” dwellings, progressed to “Shallow Pit” dwellings, and later advanced to “Platform“ dwellings. Earthen platform construction is recognized as one of the special characteristics of Chinese architecture.

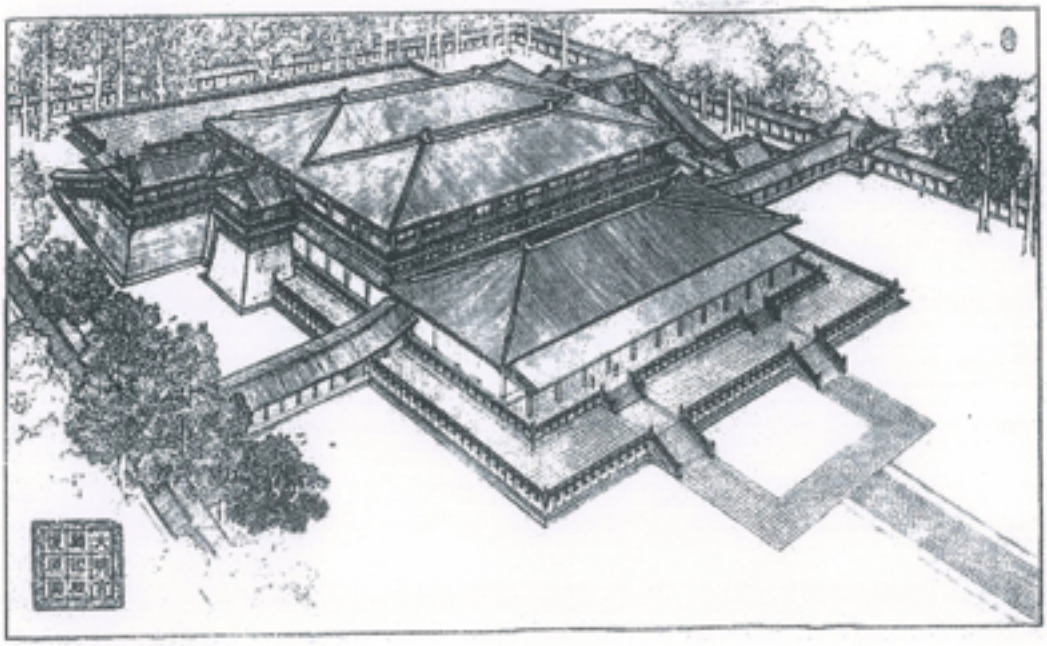
Our early ancestors were perhaps inspired by the old saying “use a hillock for home” and began constructing buildings on a raised platform. One can see that a raised platform is a man-made mound. There is much evidence to show that since the birth of Chinese architecture, whether it is artifacts unearthed at sites in Henan dating from the Xia and Shang dynasties, or from Shaanxi province, or historic buildings from the Tang, Sung, Ming and Qing dynasties, all major structures have been built on a raised platform.

The main reason to build on a platform is to separate the building from the ground. It keeps the bottom end of posts from getting wet and rotting in damp earth rife with mold, mildew and termites. An elevated platform also protects walls built of rammed earth or unfired brick from ground water, and minimizes the deleterious effects of moisture and insects.

Historically, grand palaces were built on tall platforms that were sometimes several meters tall. The most important and magnificent of these buildings, such as the Taihedian or Hall of Supreme Harmony in the Forbidden City in Beijing, sat atop three tiers of platforms. These imposing imperial platforms not only protected the building fabric, but also awed commoners and gave them a lofty impression of the emperor’s power and wealth. When the first Han emperor, Liu Bang, assumed power, he advocated simplicity in all things. He did not desire an opulent palace. But his Prime Minister Xiao He said: “The emperor’s realm covers the four seas and his palace must reflect his power”. So afterwards, emperors built palaces that were grand and glorious.

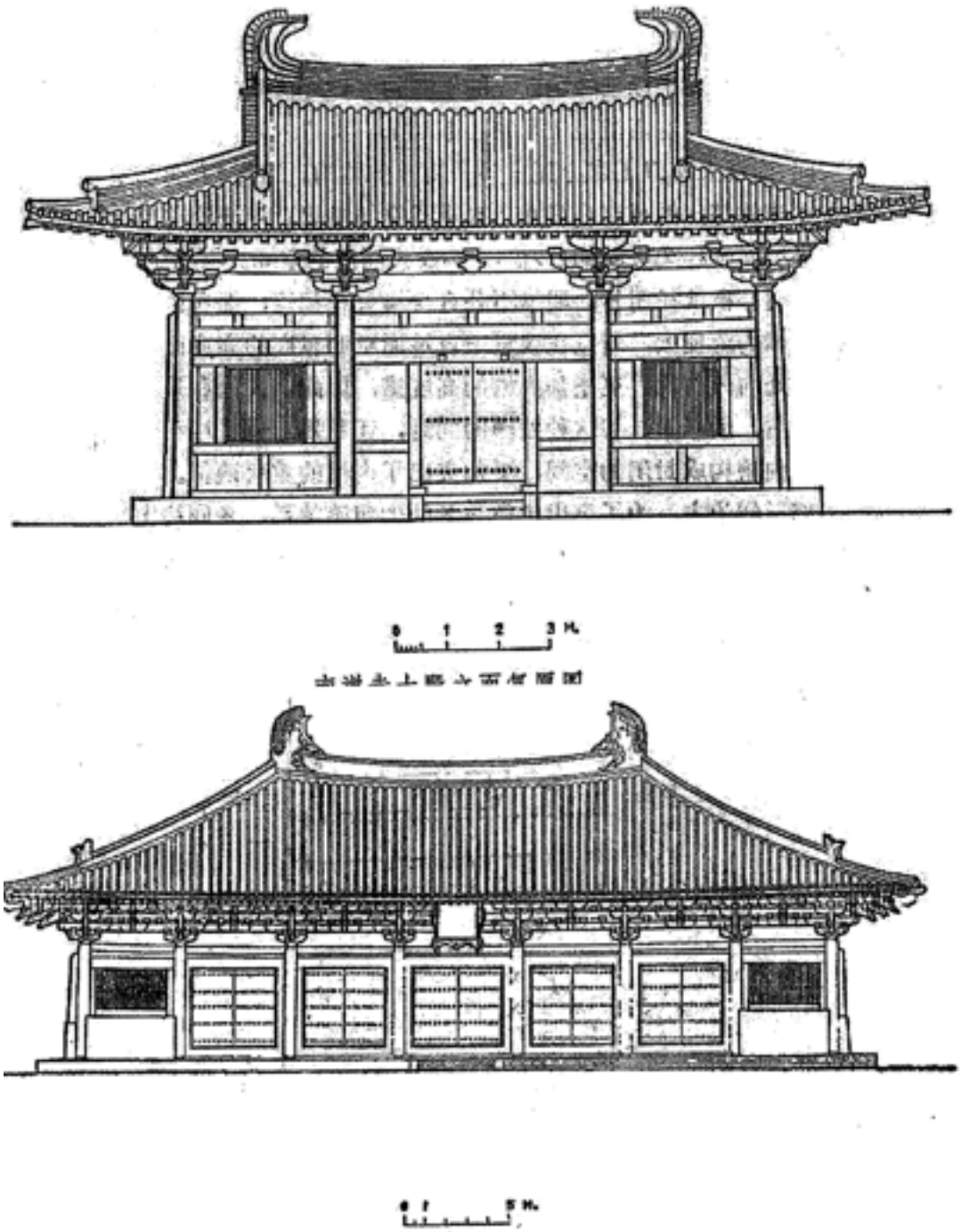
中山王陵享堂原建视图（文见第127页）


秦咸阳宫第1号遗址和沙盘原草图



#14- Theoretical Drawings of Ancient Imperial Buildings on Platform Foundations

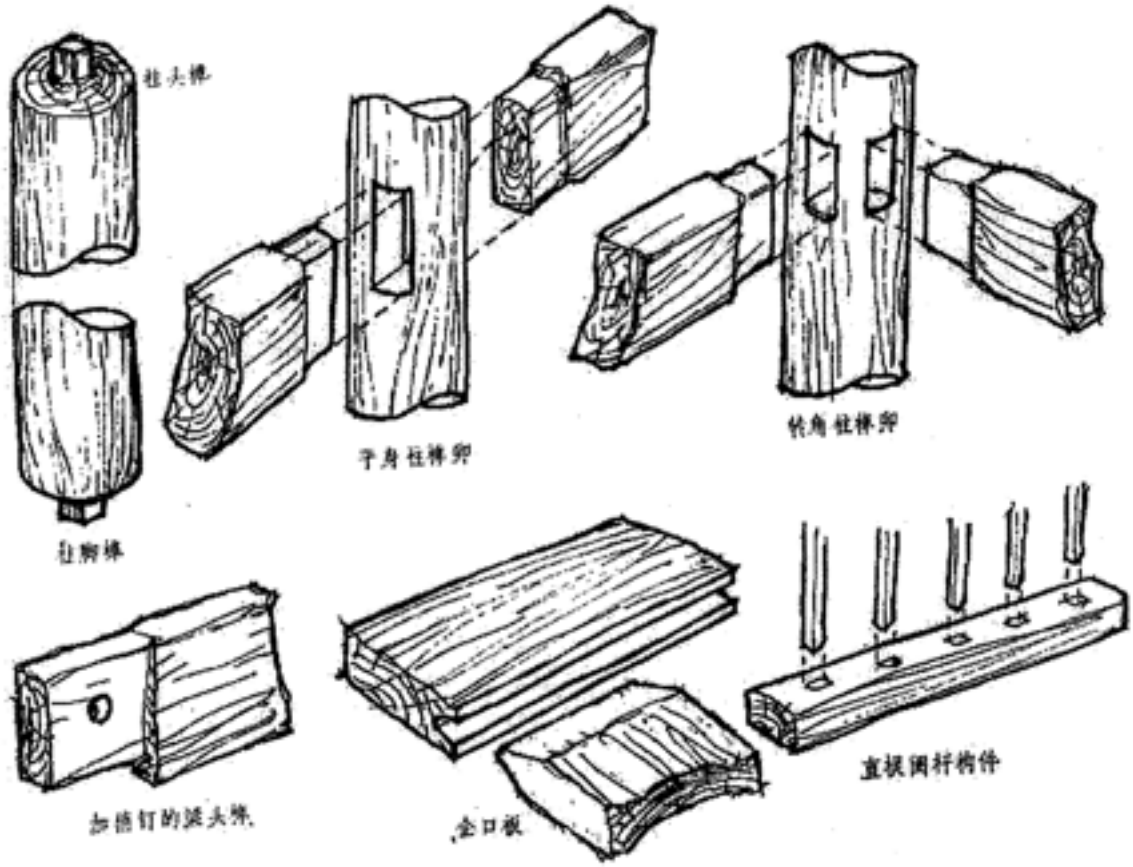
When viewed in elevation, Chinese structures can be visually divided into three elements. The famous architectural historian Liang Sicheng defined these elements as: 1. Raised Platform, 2. Timberframe, and 3. Roof Structure. In multi-story buildings one can see these same three elements, with frame and roof sections stacked up repeatedly, as in the Muta Wood Pagoda. Thus, raised earthen platform and the three elements of platform, frame and roof are important characteristics of Chinese architecture.



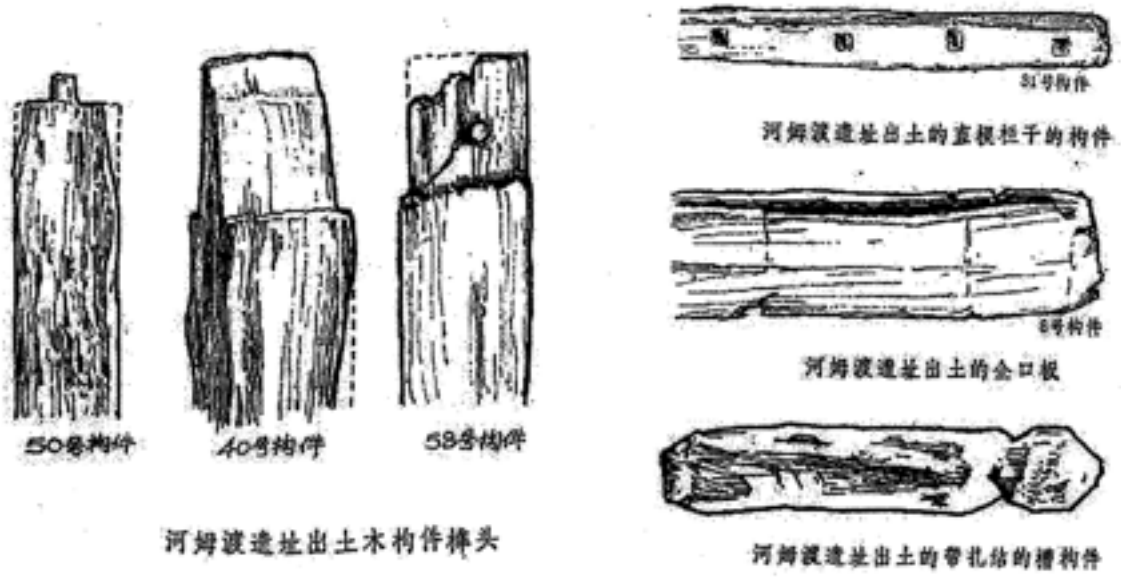
#15- Buildings Showing Three Elements- Platform, Frame and Roof

3. MORTISE-AND-TENON JOINERY, PRE-FABRICATION OF STRUCTURAL ELEMENTS, MATED ASSEMBLY

Chinese architecture matured over the course of untold centuries. The method of connecting various parts of a frame began with lashing branches together with vines or rattan. Over time builders improved their wood connection method by using mortise-and-tenon joinery. Scientists have excavated many wood beams with mortise-and-tenon joinery from the Hemudu archaeological site in Jejiang province. They have used Carbon 14 dating to find the age of these wood pieces, which they estimate to be about 6900 years old. Builders have used mortise-and-tenon joinery since ancient times and joinery has flourished continuously up to today.



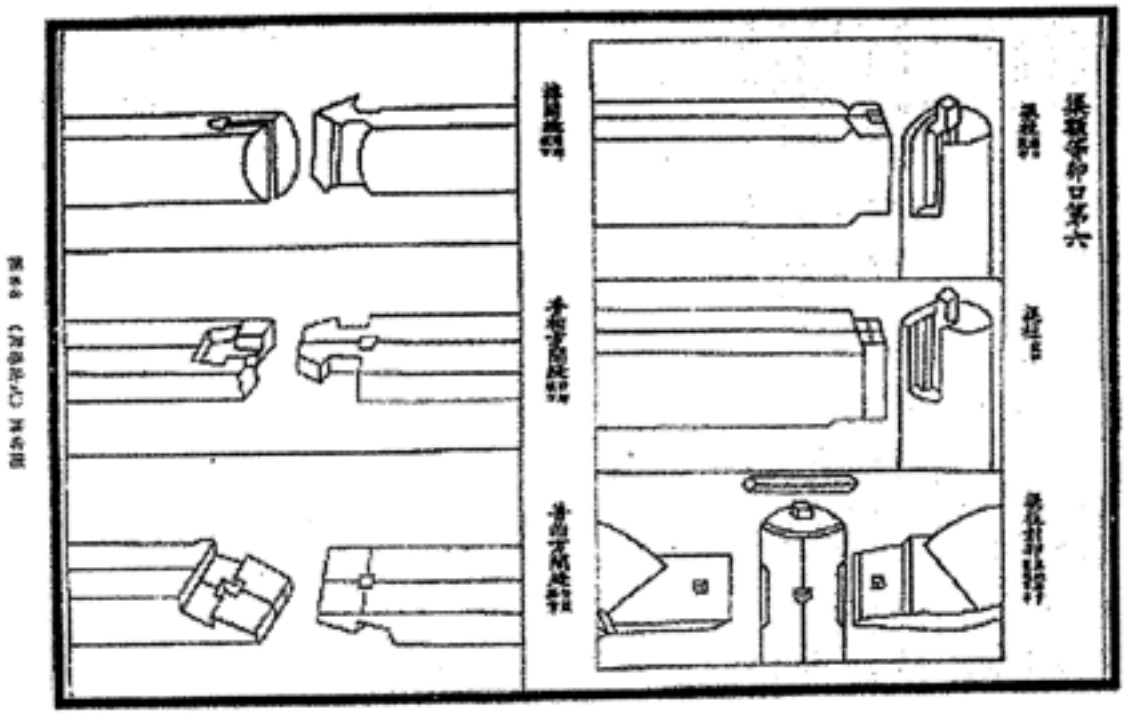
河姆渡遗址第四层所见的木构榫卯类型



#16- Excavated Examples of Mortise-and-Tenon Joinery in Wood, Hemudu

Mortise-and-tenon joinery is not limited to China. It was also discovered and developed by early inhabitants of many other countries. It has played an especially significant role in China. There are also many other types of joinery in the Chinese repertoire.

One can see examples of Sung dynasty joinery in the book "Yingzaofashi", a manual of official building regulations and methods that was published in 1102. Illustrated pages from this book show that after the Iron Age, wood joinery reached a high level of complexity and sophistication.



#17- Joinery Examples from Song “Yingzaofashi” Manual

Examples of joinery in Qing dynasty architecture are in Illustration 18. Qing style joinery was simplified from Ming and earlier joinery.

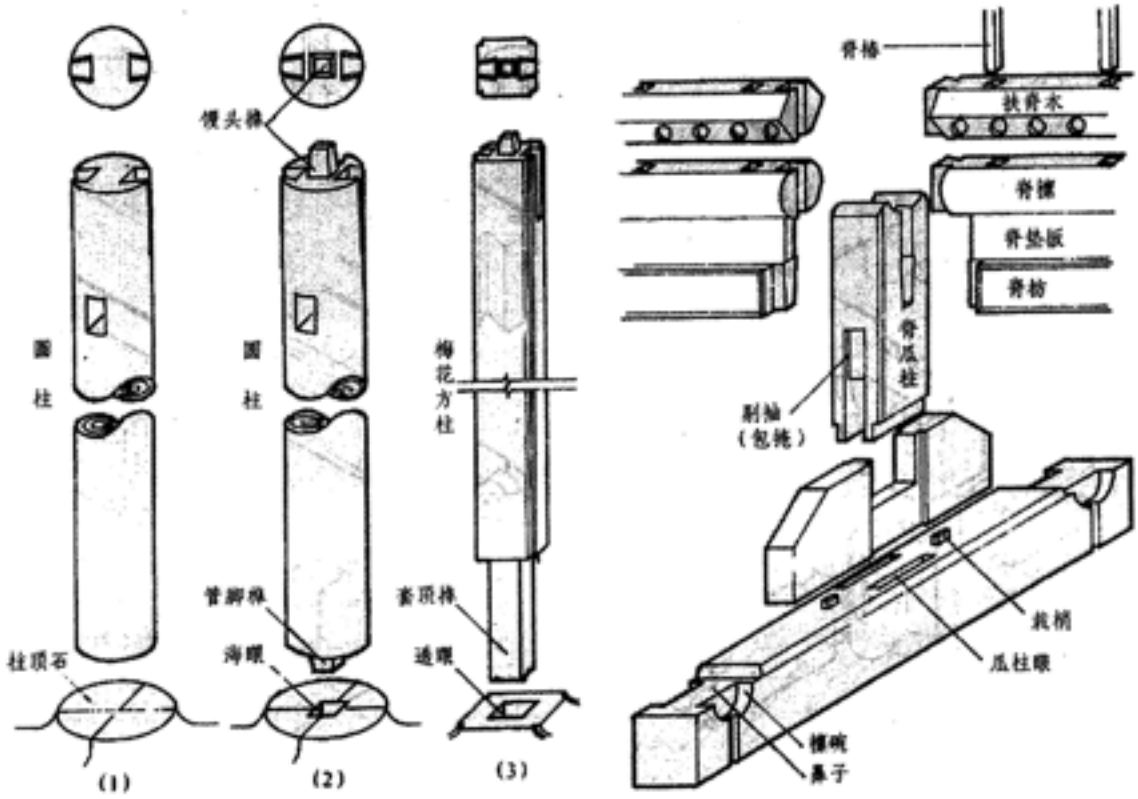
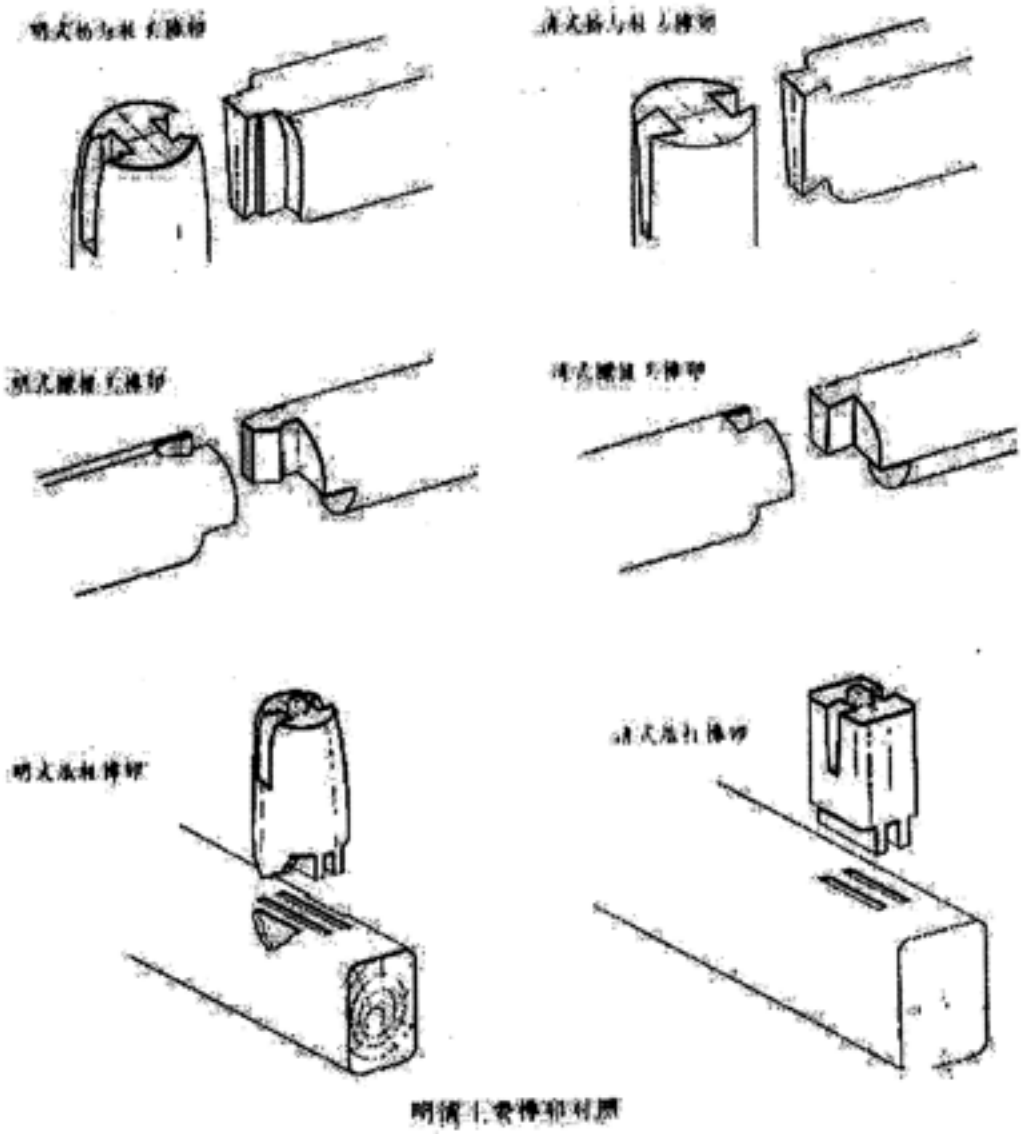


图 3-2 管脚榫、馒头榫、套顶榫

图 3-3 脊瓜柱、角背、扶脊木节点榫卯

#18- Examples of Qing Dynasty Timber Frame Joinery



#19- Comparison of Important Joinery Connections in Ming and Qing Dynasties

Why was the discovery of joinery important? Joinery enabled builders to speed up the construction process and to erect buildings faster and more easily. Carpenters first made standardized wood members and cut joints in posts, beams, purlins, architraves, brackets, etc. By connecting mated pieces such as a mortised beam and a matching tenoned post, they could systematically assemble the whole frame.

This is only possible when there exists an architectural plan that shows the location and spacing of the major parts of the timber-frame. Also, builders and carpenters need

knowledge of arithmetic and measuring in order to make the right size of parts that properly fit together. With good layout and accurate cutting of joinery, builders can quickly raise the frame.

As an example, an enormous wood palace building like the Taihedian (Hall of Supreme Harmony) in the Forbidden City in Beijing can be built in about 2 years. I myself worked on the renovation in Beijing of the famed Tiananmen Gate in 1970. This project, including making new wood frame parts, took a little more than one year. Raising the frame, building brick infill walls, building the roof, setting roof tiles, and completing the decorative painting all together took less than eight months. By historical comparison, it often took decades or even centuries for western builders to complete stone palaces and cathedrals.

Joints used in architecture are quite similar to joints connecting the human skeleton: both are flexible and yet keep the whole thing together. The proportions and ratios of Chinese architecture are surprisingly similar to ratios in the human body. The height of a person is about 7.5 times their head height. Open arm-span is about equal to height. People's eyes are about in the center of their head height. Head width is about five times eye width. Using these ratios we can sketch a human figure. Every piece of wood in Chinese architecture also conforms to certain ratios.

4. MODULAR CONSTRUCTION, FIXED RATIO BETWEEN ALL PARTS

The quick and easy assembly of a timber frame cannot be achieved without a strict modular system. From analyzing historical documents, we can see that Chinese builders were already using modular systems more than a thousand years ago. They use modules to design buildings and to specify dimensions of wooden parts.

What is a modular system? It first defines one certain measurement as the module. The module becomes the basic

unit for measuring. (In the West, the inch is a module of a foot, a centimeter is a module of a meter; the relation between inch and foot is a ratio or proportion of 1:12, centimeter to meter is 1:100).

Builders use proportional formulas based on multiples and fractions of the module to determine dimensions of wood posts, beams, purlins, rafters, and brackets, and to decide the spacing and elevation of elements. For example, the space between two posts is X times the module; the height of a post is Y times the module; the depth of a beam is Z times the module. Every measurement is a function of the module.

After all the parts are cut, carpenters can assemble the frame by fitting together mated parts. They know from their architectural plan, which is an early version of today's blueprint, where each part is supposed to go. And they have chosen suitable joints so that during the assembly process the joints will fit together and unify the frame.

When builders reach a certain level of sophistication in making architectural plans and applying math and measurement, they can fabricate multiple parts that are interchangeable. In essence, they can mass-produce standardized parts. This knowledge makes it easy to build larger and more complex structures.

In the Sung modular system, master-builders followed the motto: " Use Cai as Module". All dimensions of all parts depended on the size of Cai. Length, width, height, diameter were all measured as ratios- multiples and fractions- of Cai. There were large Cai and small Cai depending on the status of the building.

There were eight Sung status Grades of building that were regulated by governmental sumptuary laws. For each grade there was a corresponding Cai. Cai was defined as being equal to the width of a bracket arm beam. And the bracket arm beam varied according to the Grade of building. (A bracket arm is a relatively small beam that is part of a cluster of small beams that supports the eaves). A Grade One structure required the largest bracket arm and therefore the largest Cai. Grade One reserved for the emperor, whose status merited the largest building with the biggest posts, beams, everything. Grade Two was smaller,

and so on down to Grade Eight, which was designated for minor officials.

A Sung dynasty Grade One bracket arm beam was about 6 Sung inches wide x 9 Sung inches tall. By definition, taking the bracket arm width as equal to Cai Unit Measure, a Grade One Cai was equal to 6.0 Sung inches. Grade 2 Cai=5.5 Sung inches, Grade 3=5.0, Grade 4=4.8, Grade5=4.4, Grade 6=4.0, Grade 7=3.5, and Grade 8=3.0 Sung inches.

Perhaps confusing to Westerners, Cai was a relative measurement that varied with the social status of the structure. All eight Grades of building used similar ratios and proportions, but Cai was a different measurement for each Grade. Large Cai made large buildings.

Later on in the 17-19 century Qing dynasty, the module was called Doukou. There were eleven status Grades of buildings and eleven sizes of Doukou. Doukou was defined as the width of the mortise in the Ludou, the base part of the bracket set, wherein was placed a bracket arm. The width of the Qing bracket arm mortise- Doukou- and the width of the Sung bracket arm- Cai- were identical- just different names for the same measurement.

All the parts of a Qing building are measured as ratios to the module. For example, if the diameter of an exterior post is specified as 6 Doukou, and you are using a Grade 8 Doukou that measures 8 cm, then the diameter of the post is 6 Doukou x 8cm/Doukou =48 cm. If the height is 60 Doukou, then it would be 60x8=480 cm tall. If the diameter of the round rafter is 1.5 Doukou, then it is 1.5x8=12 cm.

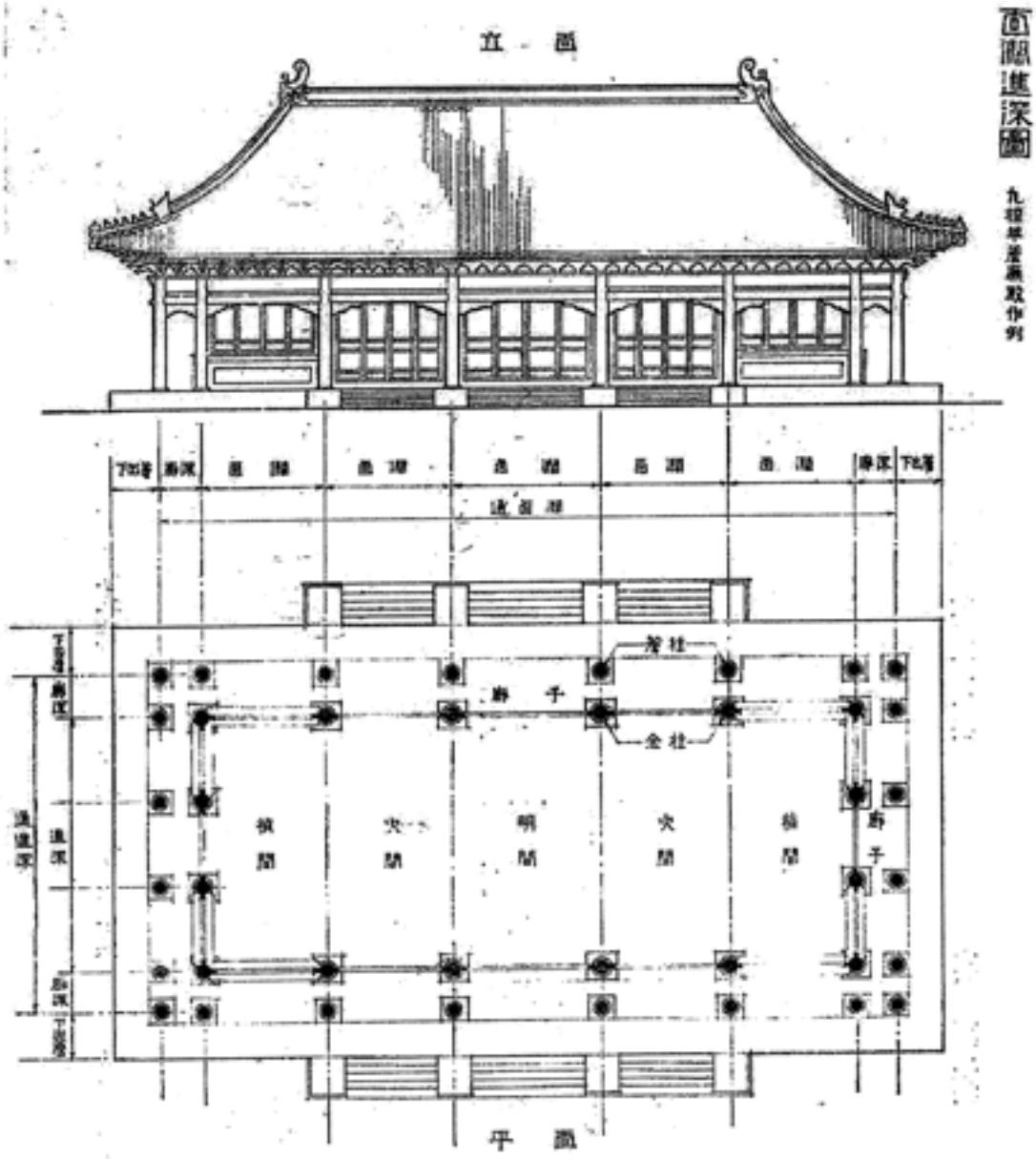
If you use a different grade of Doukou which is larger, say 12.8 cm, then the round rafter diameter will be 1.5x12.8= 19.2 cm.

The largest Qing Grade One Doukou is 19.2 cm, and the smallest Grade Eleven is 3.2 cm. There are 1.6 cm increments between each grade of Doukou. Qing builders usually used Grade 5 Doukou (12.8 cm) down to Grade 9 (6.4 cm).

Not only did masters mark each piece of wood according to proportional regulations, they designed the whole

structure, plan and elevation, based on proportions. For the central bay, for example, the ratio of width to height was 1: 0.8. Side bays had a 1:1 ratio of width to height (or 0.8:0.8). For exterior posts, the height to diameter ratio was 10:1. The eave projection was related to post height 3:10, or sometimes 21 Doukou. The raised platform foundation was built to extend from the wall 2/3 to 4/5 of the eave projection.

So we may say that the size of parts and the relation of parts were based on a modular system of proportions, and this system is a special characteristic of Chinese traditional architecture.


面間進深圖
九間單簷殿作例
立面
平面
廊子
明間
次間
稍間
金柱
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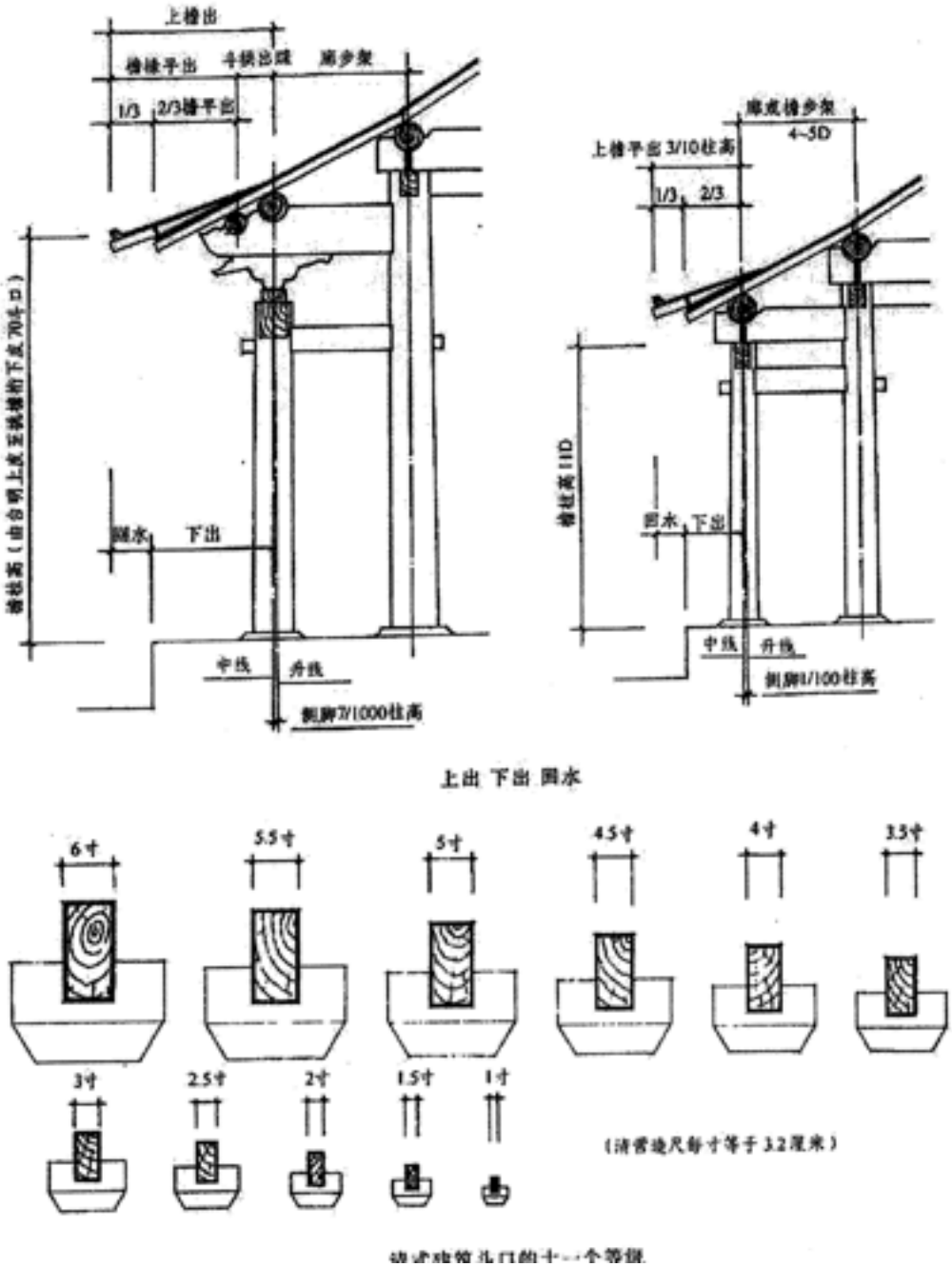
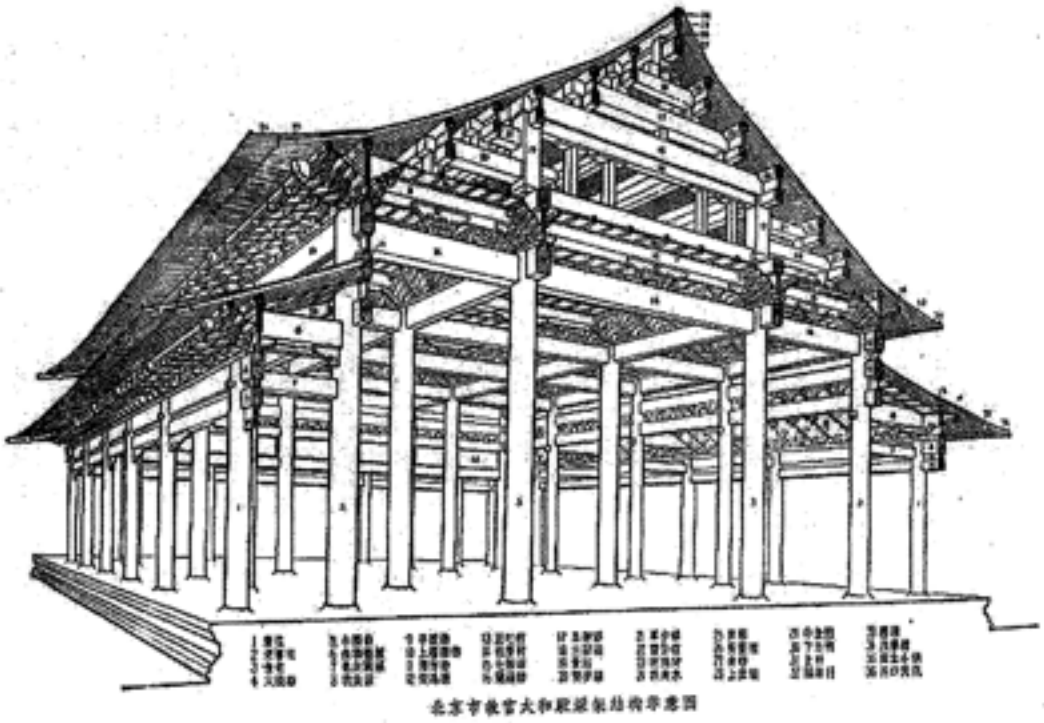


#20- Building Plans, Elevations and Design Details

5. DEEP EAVES, CURVED ROOF

A curved roof is the most splendid symbol of traditional Chinese timber-frame architecture. There are two obvious features of this large roof: deep eaves and curved shape. The eaves project far beyond the walls, and the roof is not a flat plane but a curved plane. The roof curves in two directions: it curves from the eave to the ridge, and it curves from the center of the building to the corners of the roof. When looking at the roof, one sees it gracefully rise animated with the lightness and beauty of the curve.



#21- Structural Framework of Taihedian, Forbidden City

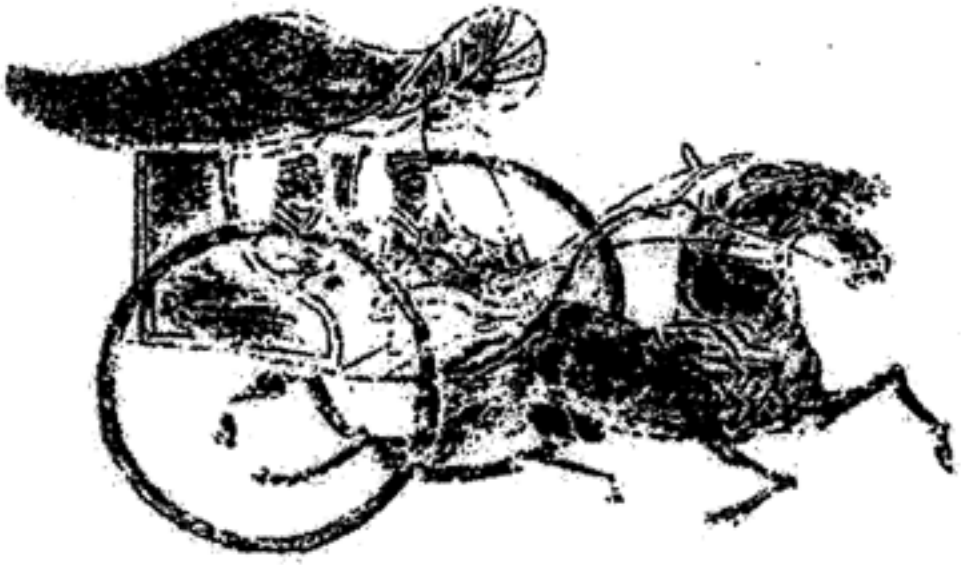
A roof with deep eaves protects the wood frame and the walls from sun and rain, thereby prolonging the life of the structure. In pre-Sung times, builders rarely used brick for walls. They commonly used rammed earth or clay plaster or straw and mud to make walls, all of which were easily eroded by rain.

After the Ming dynasty, when brick was widely used for walls and the danger of moisture damage was greatly reduced, the eave width was reduced, but not by enough to ruin the beauty of the roof.

The reason that Chinese builders could create such deep

eaves is because they invented a unique method of wood cantilever construction- bracket sets. Bracket sets support exterior purlins that in turn are able to carry wood rafters farther beyond the exterior wall of the building. In brick buildings, because of the brittle nature of the material, it is not possible to have such a deep eave. Western architecture does not have great curved roofs with such deep eaves. It is more a characteristic of China, Japan, Korea, Vietnam, etc.

The Chinese curved roof appeared slowly over time. Before and including the Qin and Han dynasties, up to about 200 A.D., one finds little evidence of a curved roof. The early Chinese roof was built with straight ridges and hips and the roof surfaces were flat planes. The first inklings of curves are found in a few pre-Han literary references to curved canopies on carriages.



汉代轺车

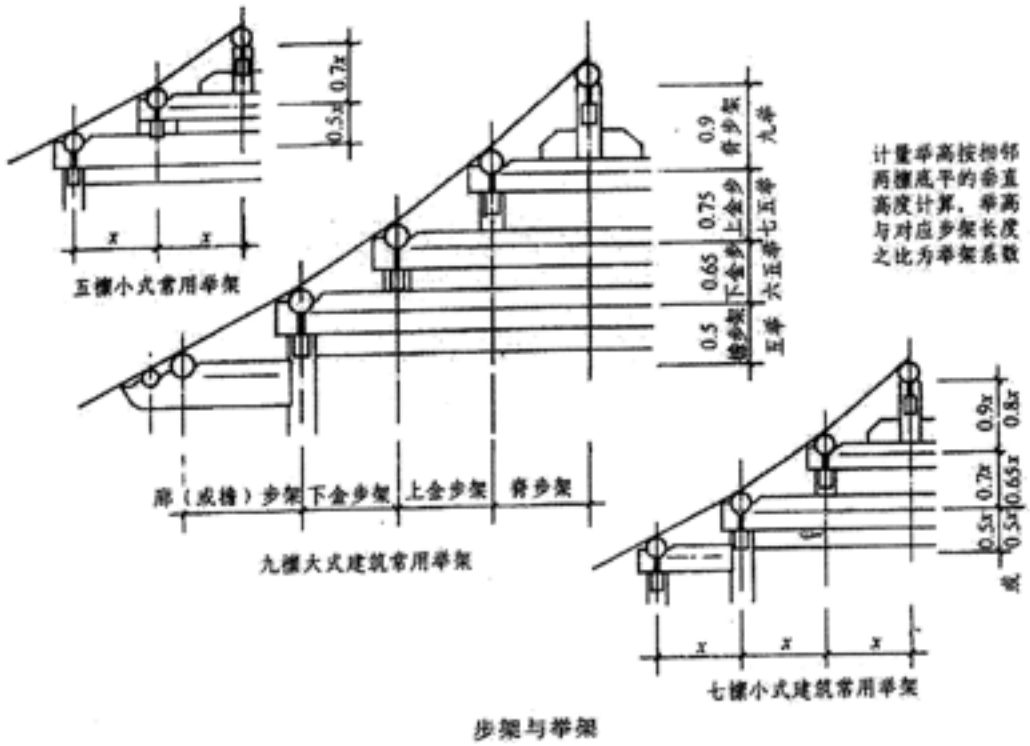
#22- Curved Canopy on Han Chariot

A Han text tells us about the benefits of a curved roof. The curved shape is said to cast rain water further away from the building, while at the same time admitting more daylight into the building. So, two thousand years ago, Chinese builders started thinking how to protect their buildings against rain and how to improve interior light.

These ideas about the functions of a curved roof became widely accepted after the Han dynasty. Looking from the

present into the past, we can see from architectural evidence that sophisticated curved roofs were prevalent as early as the Sui and Tang dynasties, after 580 A.D.

Builders were able to make the curved roof shape by changing the slope of rafters between purlins.



#23- Roof Layout of Purlins to Create Curved Slope

In Chinese architecture, rafters are relatively short. They only span the distance from one purlin to the next. Purlins are horizontal beams in the roof frame that support rafters. The slope of a rafter is determined by the relative height of two purlins supporting it. For example, if a roof has three purlins on one side of the ridge, the purlins are designed so that eave rafters spanning from the first to second purlin have a certain slope, and the rafters from the second purlin to the third purlin have a steeper slope. And rafters from the third purlin to ridge have an even steeper slope.
As far as the roof framing and rafters are concerned, the shape of the roof is a series of straight segments between purlins that approximates a curve.

So the next question is how is the curved roof shape made?

After sheathing boards are fixed across rafters to make a wooden deck, workers spread damp mud-clay on top of the boards and then trowel this mud into a true smooth curve. Roof tiles are set onto this mud bed and follow the smooth curve.

Looking from the courtyard, the roof curves. The roof curvature is most obviously visible at the hips- or sloping ridge as it is referred to in Chinese- on a hip, hip-gable or pyramidal roof, and at the ends on a gable roof. Peering up at the roof from inside the building, where typically the roof framing is visible, one can observe the segmented shape of the roof as the short rafters increase pitch from purlin to purlin to ridge.

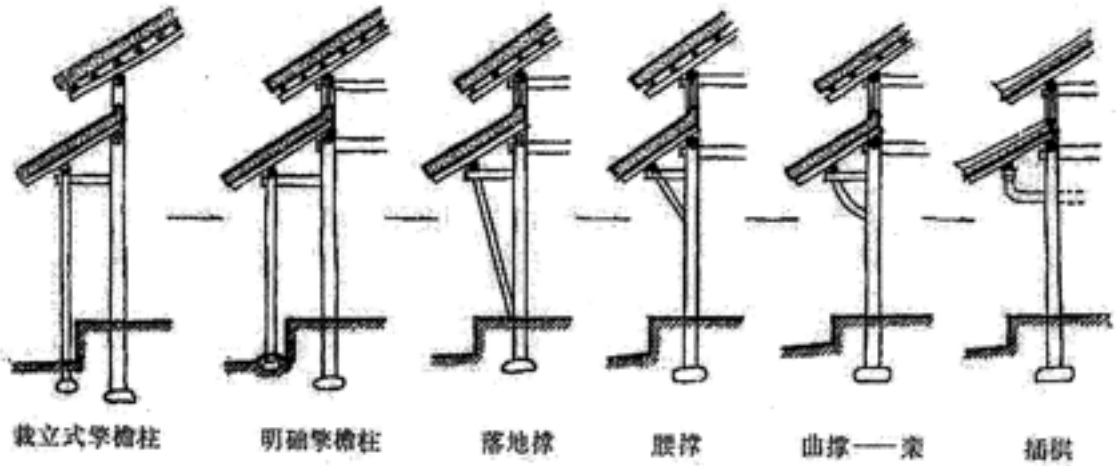
On a curved roof, the roof slope is steep at the ridge and shallower at the eaves. It suggests a natural curve like a catenary curve, which is the shape of a length of chain hanging between an upper and a lower point. It has been suggested that the steep roof pitch at the ridge helps to accelerate the downward flow of rainwater, while the lower pitch at the eaves helps to fling rainwater further from the building. Significantly, the lower roof pitch at the eaves allows more sunlight into the building. In winter, when the sun is at its lowest angle to the earth, light can enter under the shallow-pitched eaves and brighten about 2/3 of the interior space. In summer, when the sun is at its highest in the sky, the deep eaves protect against the baking ray of the sun and afford cool shelter from the sweltering heat.

6. BRACKET SETS AND THEIR SPECIAL FUNCTION

Bracket sets are a truly unique structural feature of traditional Chinese architecture. Bracket sets (Dougong in Chinese) are made up of short wooden beams that are stacked up on top of each other in the shape of an inverted pyramid. Each higher level cantilevers out beyond the bracket beam beneath it. It is possible to have five or

more levels of brackets beams in one bracket cluster. There are three locations for bracket sets: on top of a post, between posts, and at the corner. They are called column sets, intermediate sets and corner sets. The components of a bracket set vary with location and building size.

Bracket sets have several functions. The most important functions are to support the eaves and transmit the roof load down to a post. Scholars have extensively studied the origins of bracket sets. They suggest that a Chinese style of architecture that uses earth and wood for its basic materials demands a roof with wide eaves to protect structural members and earthen walls. Yet if the eave is too wide, the roof will sag or collapse. The heavy weight of clay and tiles will bend or break the rafters. This then suggests the need for posts outside the building to prop up the deep eave overhang. This is exactly what early builders did. From a site is Anyang, Henan, archaeologists have discovered this method of using exterior posts to support eaves.



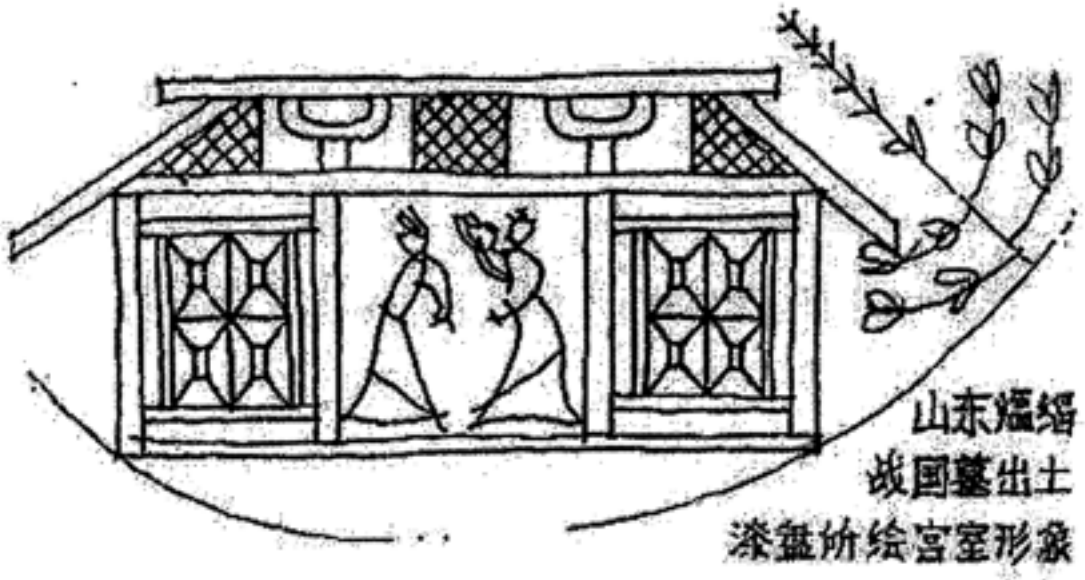
由擎檐柱到插拱的发展示意图

#24- Evolution of Eave Support from Exterior Post to Inserted Bracket Arm

Initially the bottoms of these eave-support posts were buried in the ground and they were exposed to rain. As they were likely to stay damp in the ground, they were also very likely to rot. To rectify this problem, builders changed the position of the post. First, the base of the post was set on a stone base at ground level. At a later period the post base was moved to the wall line, so that the post was

not plumb but rather angled up to the eaves. Later on builders omitted the post and opted for a knee brace, which is a diagonal strut mounted on the side of the house and angled out to support the eave. Eventually this brace was modified into an “inserted-arm” which was mortised into a wall post.

Builders reached this “inserted-arm” stage by late Western Zhou, (2800 years ago). This marked the birth of “Dougong” bracket arms. On pottery shards of the Warring States period 475-221 B.C. we find the earliest images of different bracket arms that extend to the left and right of the post in the wall plane.



山东临淄郎家庄一号墓出土战国漆盘所绘宫室形象中栋(脊檩)的交接处用曲枅(栾)

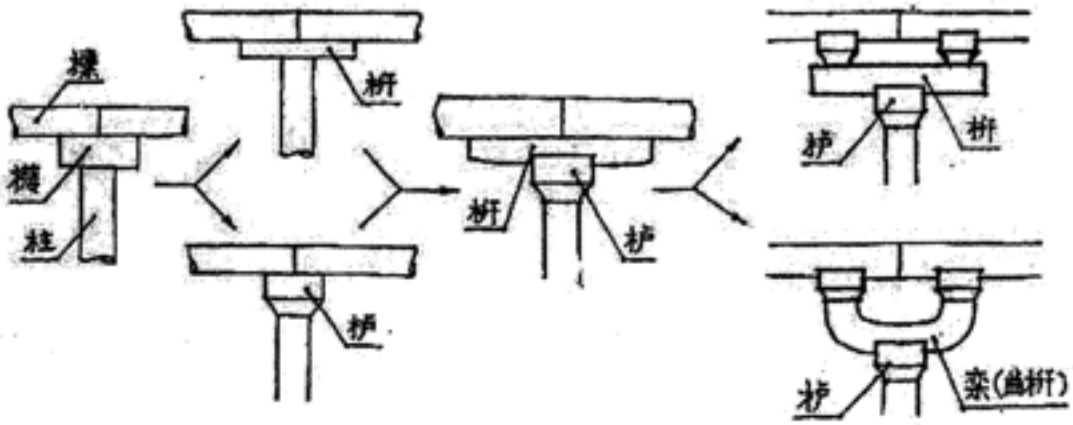
#25- Curved Bracket Arms Support Beam in Warring States Period.

This type of horizontal beam in the wall-plane does two things. It increases the bearing surface of the post and shortens the clear span of the beam. This style of horizontal beam support matured in Han times.

a 江苏省睢宁县双沟汉画像石所示栱的形象

#26- Han Structures from Jiangsu

We can see in the Western Chou period (1122-255 B. C.) the birth of the Ludou- Base Block- at the bottom level of a bracket set. It is also named Dadou, or Zuodou. It was placed on a post top in order to increase the bearing capacity of the post. It also positioned the horizontal bracket arm above it.



由栿到栾的发展示意图

#27- Change from Flat to Curved (Yoke) Bracket Arm

We discover the first examples of “inserted arm” eave braces and the earliest bracket system that combines a Base Block supporting horizontal arms parallel to the wall plane during The Warring States era 2500 years ago. The basic

bracket format of One Base Block and Three Bearing Blocks (Yi Dou San Sheng) was widely used by the Han dynasty.

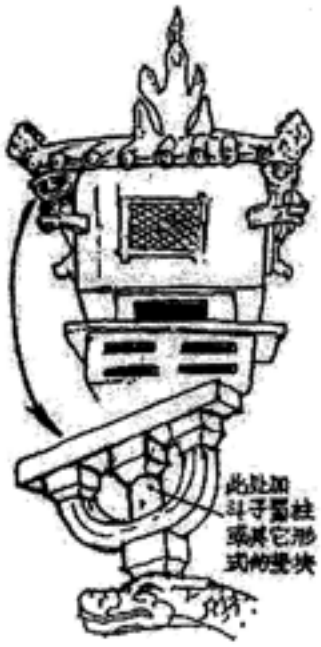
灵宝东汉墓出土三层陶望楼——上层用曲木斜撑；底层用斜撑支持插栱上托"一斗二升"，中间加斗子蜀柱或其它形式的垫块

曲枅（栱）中间加斗子蜀柱发展而成"一斗三升"

山东高唐县东园河采集东汉绿釉陶楼——檐下及顶层平座均有"一斗三升"斗栱

河南三门峡刘家渠73号墓出土东汉陶楼——檐下"一斗三升"，底层转角作龙头插棋

灵宝出土东汉绿釉陶楼所示"一斗三升"的原始形态



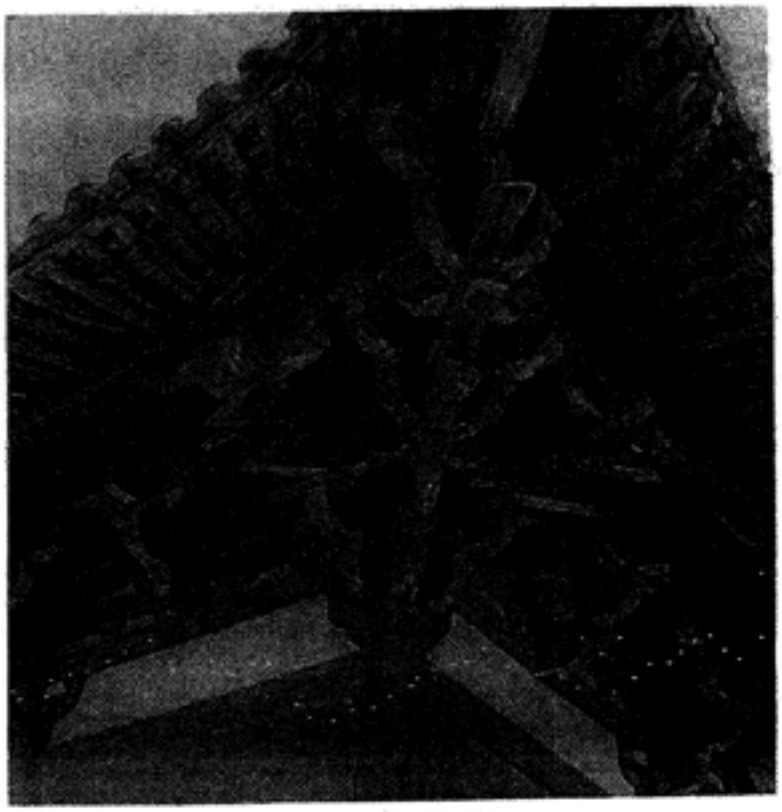
#28 Han Ceremonial Pottery Buildings with One-Base-Three-Block Brackets Excavated in Henan and Shandong

The most obvious purpose of Dougong brackets is to support deep eaves and allow the builder to move the edge of the roof further away from the building.

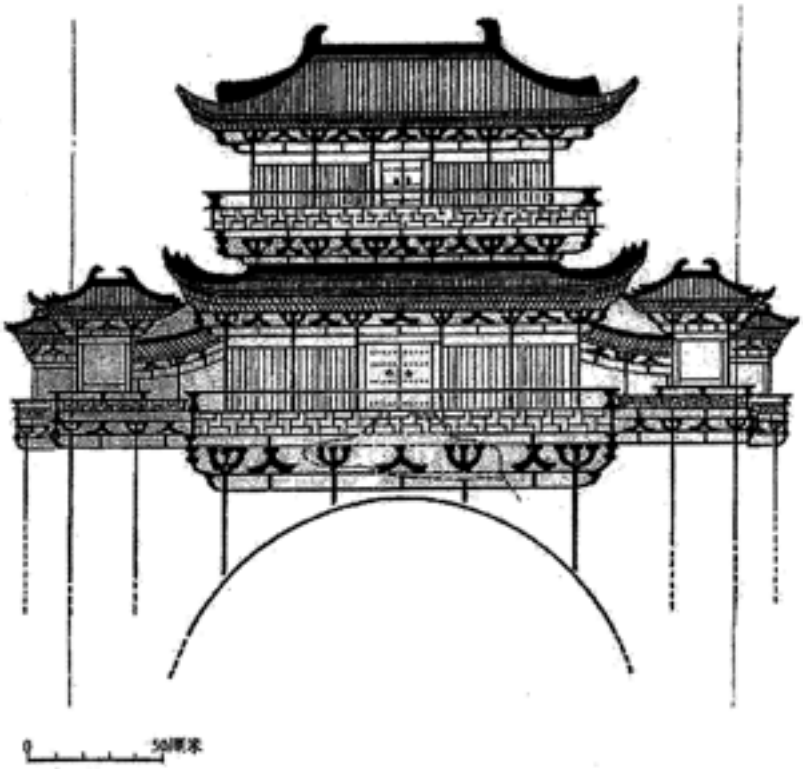
Dougong bracket set design and construction flourished and reached its zenith in the Sui and Tang dynasties about 600-900 A. D., about 1000 years ago. In Sung dynasty, 960-1278, bracket sets started to look standardized and regulated, and by the Ming (1368-1644) and Qing (1644-1911), bracketing was totally formulaic. The historic trend was from large to small, plain to ornate.

Early Sui and Tang period bracket sets were massive. They strengthened the timber frame and supported very wide eaves. Some eaves were as much as 5 meters deep. In later

eras when bricks were used for walls instead of adobe or rammed earth, the eave overhang was not so crucial in protecting the walls from rain. Therefore eaves became shallower and bracket sets were less necessary structurally. Bracket sets shrank in size and became more of a decorative item, although they retained some of their other structural functions, such as stabilizing the exterior wall, and connecting the exterior wall to the interior framework. Though smaller, brackets continued to be a unique visual and structural element of Chinese architecture.



山西五台佛光寺大殿翼角



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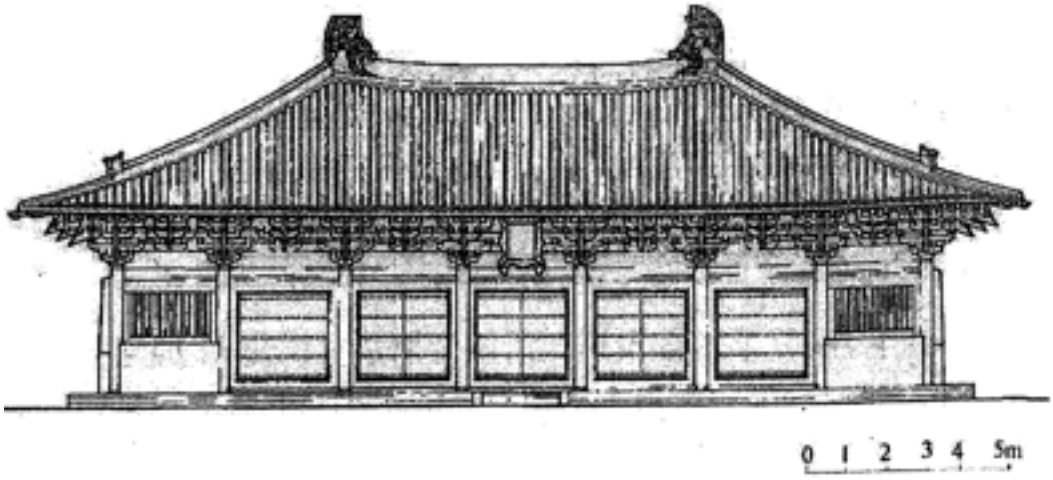
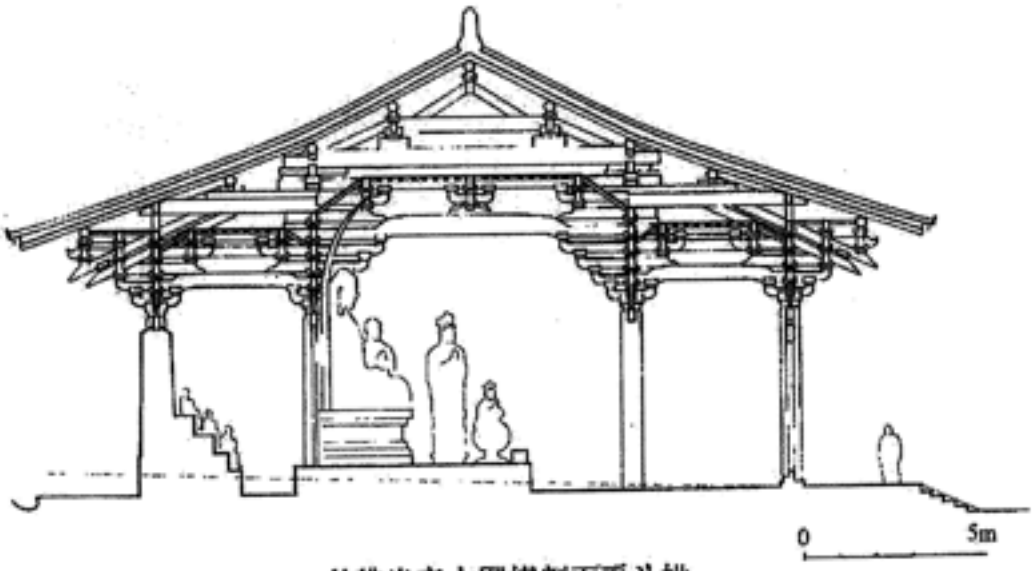
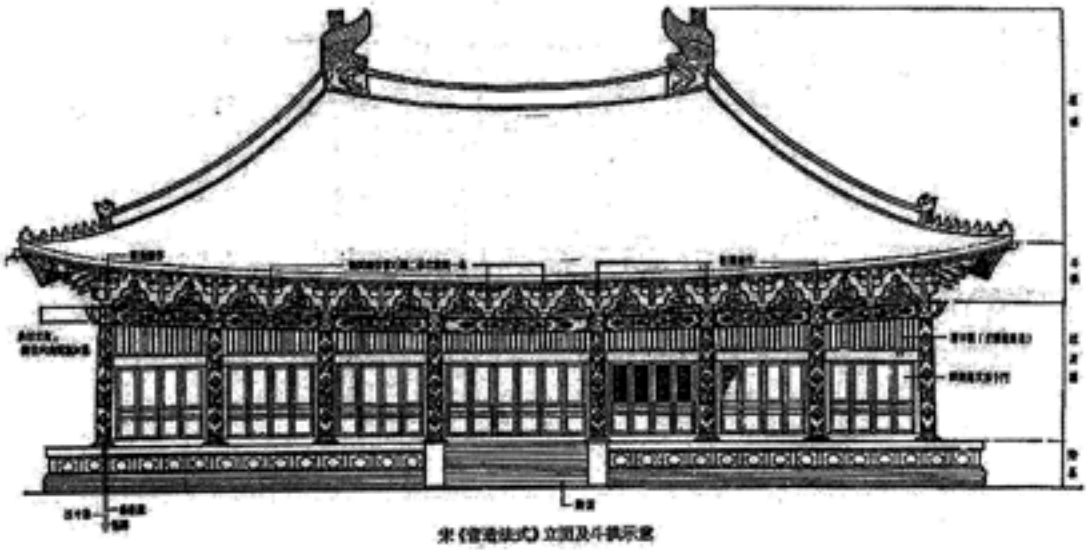
陕西三原唐李寿墓壁画二重子母阙及城楼



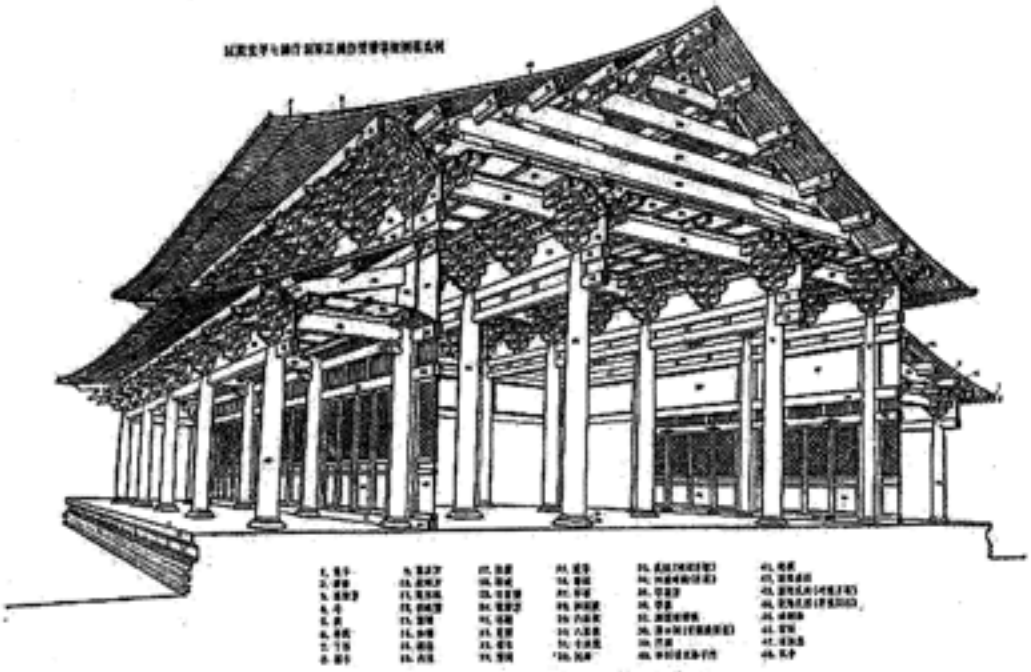
从佛光寺大殿正立面看斗拱



从佛光寺大殿横剖面看斗拱



宋《营造法式》立面及斗栱示意



宋《营造法式》大木制度示意图中的斗栱

#29- Comparison of Tang, Sung, Ming and Qing Brackets

7.LIVELY AND VARIED ARCHITECTURAL FORMS

Builders found it very convenient to express themselves in lively and varied styles when using wood as the principal material for a load-bearing frame, and using joinery to connect parts together.

Just speaking of architectural shapes, ancient Chinese architecture had five basic roof shapes: flush gable roof, overhanging gable roof, hip roof, hip-and-gable roof, and pyramidal and conical pointed roof. Within each roof style, many variations were possible, including single eave, double eave, or even triple eave. The hip and gable roof might have single or double eave, as could the simple hip roof and the pointed roof. Looking from a bird’s-eye view, buildings and their roofs might be square, hexagonal, octagonal, round, etc. For example, Tiantan Temple of Heaven in Beijing is famous for it’s round roof with three eaves.

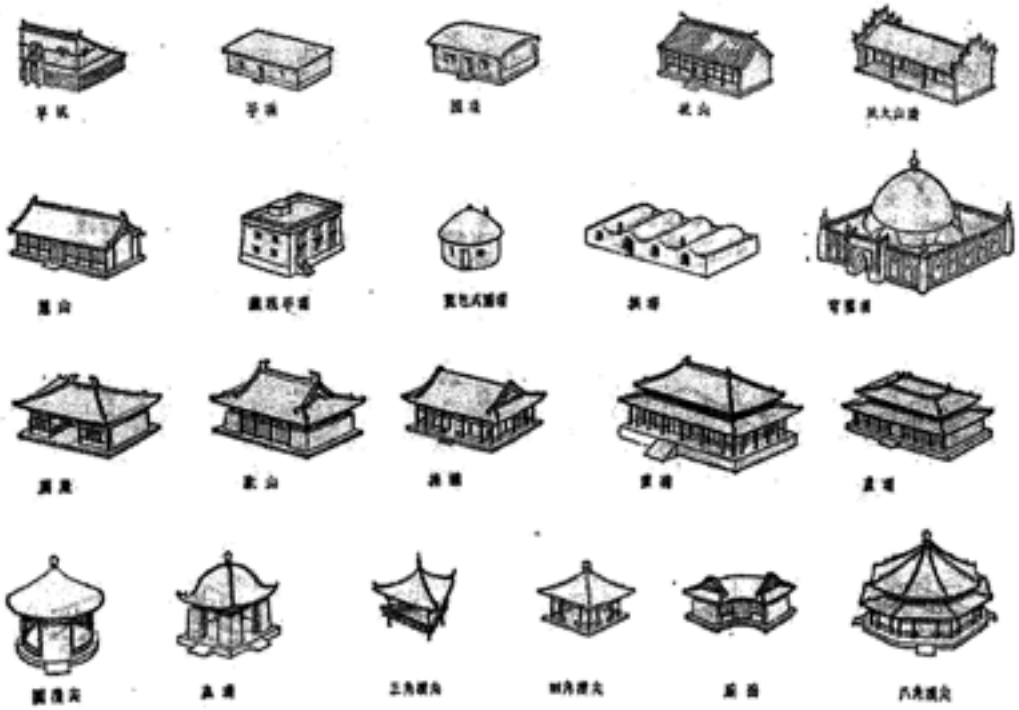


图 8-1 中国古代建筑屋顶——单体型式(一)

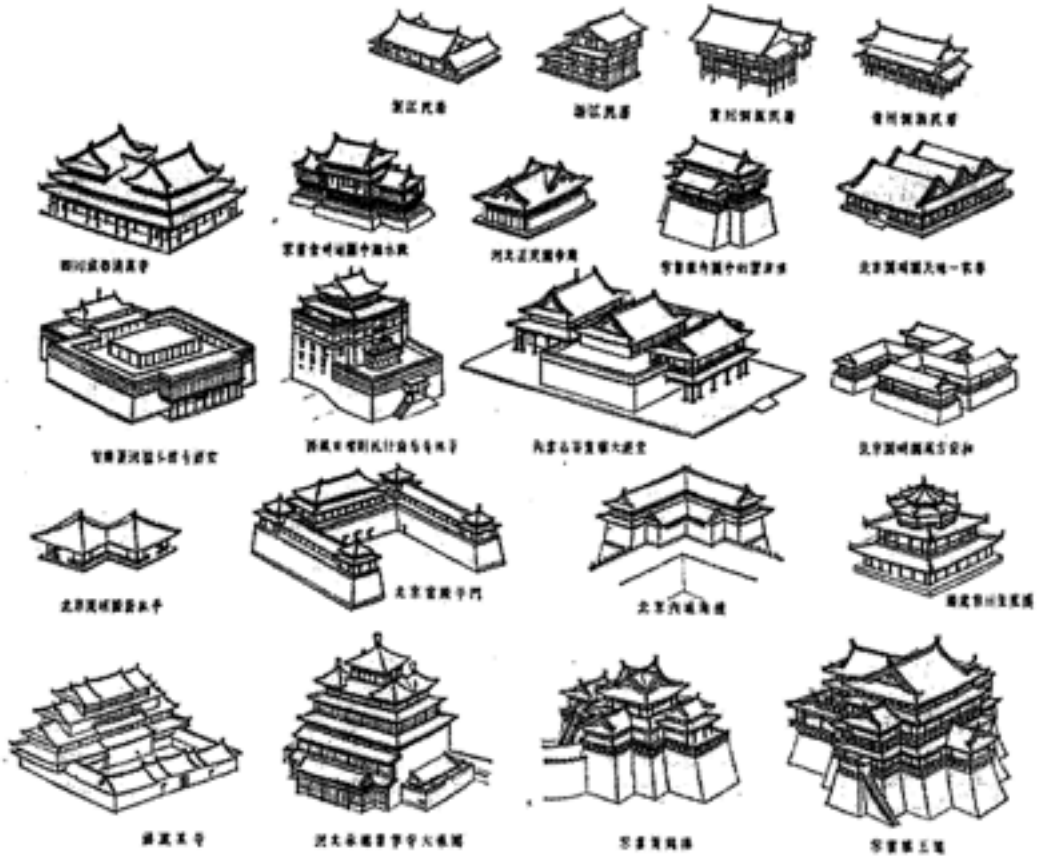
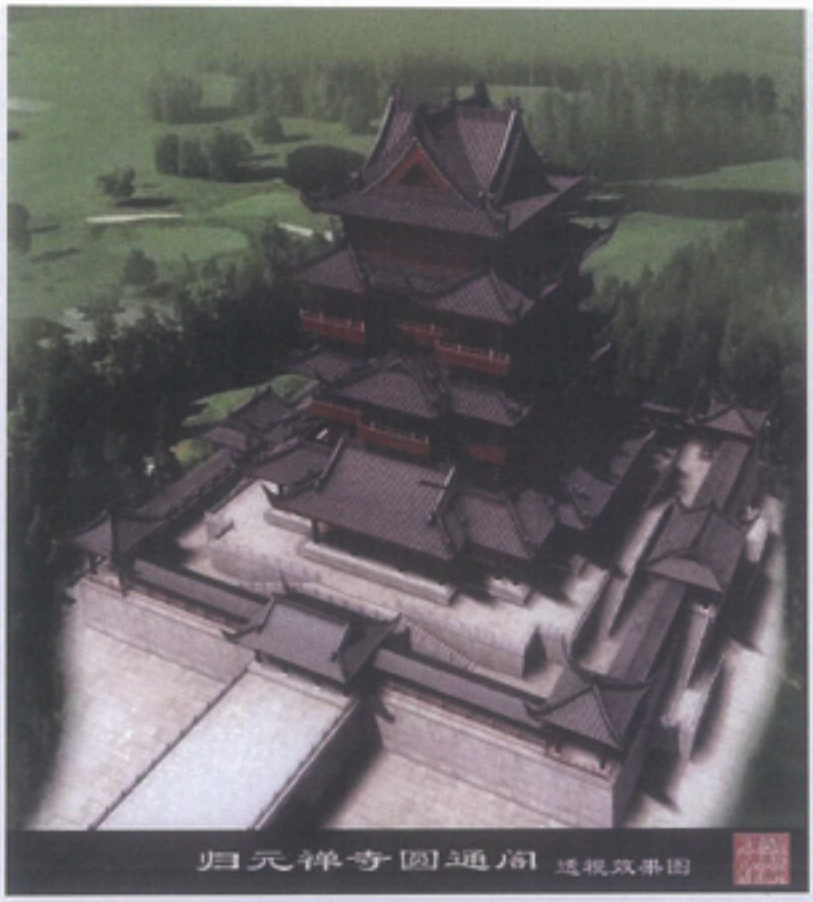


图 8-2 中国古代建筑屋顶——组合形体举例(二)


归元禅寺圆通阁 透视效果图

#30- A Variety of Chinese Roof Shapes

Chinese architecture evolved into many colorful and complex styles. China is a vast land with many different peoples, regions, customs, and varied architectural forms, materials, techniques, and it is no wonder that there is such a rich legacy of styles.

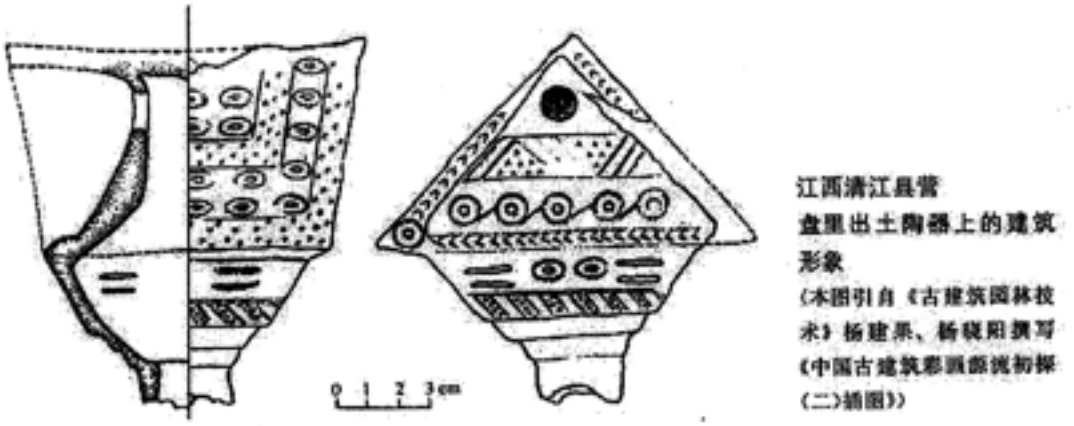
Architectural experts, in describing traditional architecture, use the phrase " It all looks the same, but it is full of variety and complexity." The reason the experts say "It all looks the same" is because for millennia buildings have been designed with the same post-and-beam system using proportional ratios and a modular system. Following these ratios and proportions over twenty centuries means using the same basic formulas, which have produced a unified history of architecture.
If Chinese buildings look similar, they are most interesting and individual in their details. No two great buildings are the same. It has always been feasible for architect/builders to freely engage their imagination. One might imagine that a talented architect would want to demonstrate his talent by introducing some unique elements into his building. And in fact, most important buildings do have unique features not found in other structures. No two temples or palaces are exactly the same.

8. CARVING, PAINTING, DECORATION

People of every nation and race have engaged in carving, painting, decorating and beautifying their buildings. Each group has their own artistic expression. Because Architecture is Art, it not only provides shelter and home, and a place to meet and carry on production and commercial activity, but it can also provide a sanctuary for people's ideals and beliefs, and a place to appreciate art. No matter on which continent- Europe, America, Africa, Asia- the architecture of every nation and its people expresses unique artistic character and content.

One can see the special characteristics of traditional Chinese wooden architecture in buildings that are brightly painted with colorful oil paints and decorated with carving

in a particularly Chinese style. Our ancestors started painting and decorating the earliest buildings, and decorative arts evolved along with architecture. In one of the most recent archeological finds related to drawing, painting and decoration, a model of a clay house from the Stone Age was found in Jiangxi province. It was decorated with neatly lined heart shapes, triangles, and diagonal lines. This suggests that artistic decoration was quite common in the culture of that early time.



#31- Architectural Patterns on Pottery Shards from Jiangnan

There are three important reasons for painting timber frame structures: First, oil paint helps to preserve wood. By applying oil paint, wood is protected from sun and rain. It is less likely to dry out and crack in the heat of the sun, and less likely to rot in the rain. When builders started applying coats of tung oil and flax fibers to wood, then covering it with several coats of cement paste which was smoothed after hardening, and finally covering all with paint, they had encased the wood in a painted hard shell. This was the best protection they could give to wood. Second, painting with colorful oil paints raises the artistic value of a building and beautifies architecture. Third, certain colors and patterns of decoration tell the social status or Grade of the building. For example, painted dragons which decorated beams and ceiling panels could only be painted on Imperial buildings. Early in the Spring and Autumn Age, one finds in the Confucian Analects discourses which explain that architectural painting and decoration were not only widespread, they were strictly regulated according to social class and status.

河南洛阳出土
彩陶豆纹饰

河南辉县出土
金银错车马饰

河南辉县出土镂花银片

河南辉县出土铜质车马饰

河南辉县出土水纹饰

河南信阳木椁墓出土透花玉佩

河南信阳木椁墓出土大鼓彩绘鼓开纹饰

河南信阳木椁墓出土铜嵌镶孔雀形器
(展开1/3)

湖南长沙木椁墓出土彩绘漆扇押

河南信阳木椁墓出土彩绘方盒纹饰

河南信阳木椁墓出土彩绘木豆纹饰

河南信阳木椁墓出土彩绘裙板

战国装饰纹样

50

雷纹　河南洛阳出土汉砖

绳纹　山东嘉祥武氏祠石刻

直线纹　河南洛阳烧沟汉砖

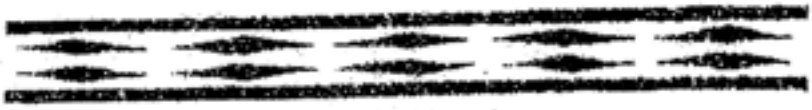
垂幕纹　山东沂南石墓石刻

齿形纹　山东沂南石墓石刻

S纹　陕西绥德汉墓门框石刻

三角纹　陕西绥德汉墓门框石刻

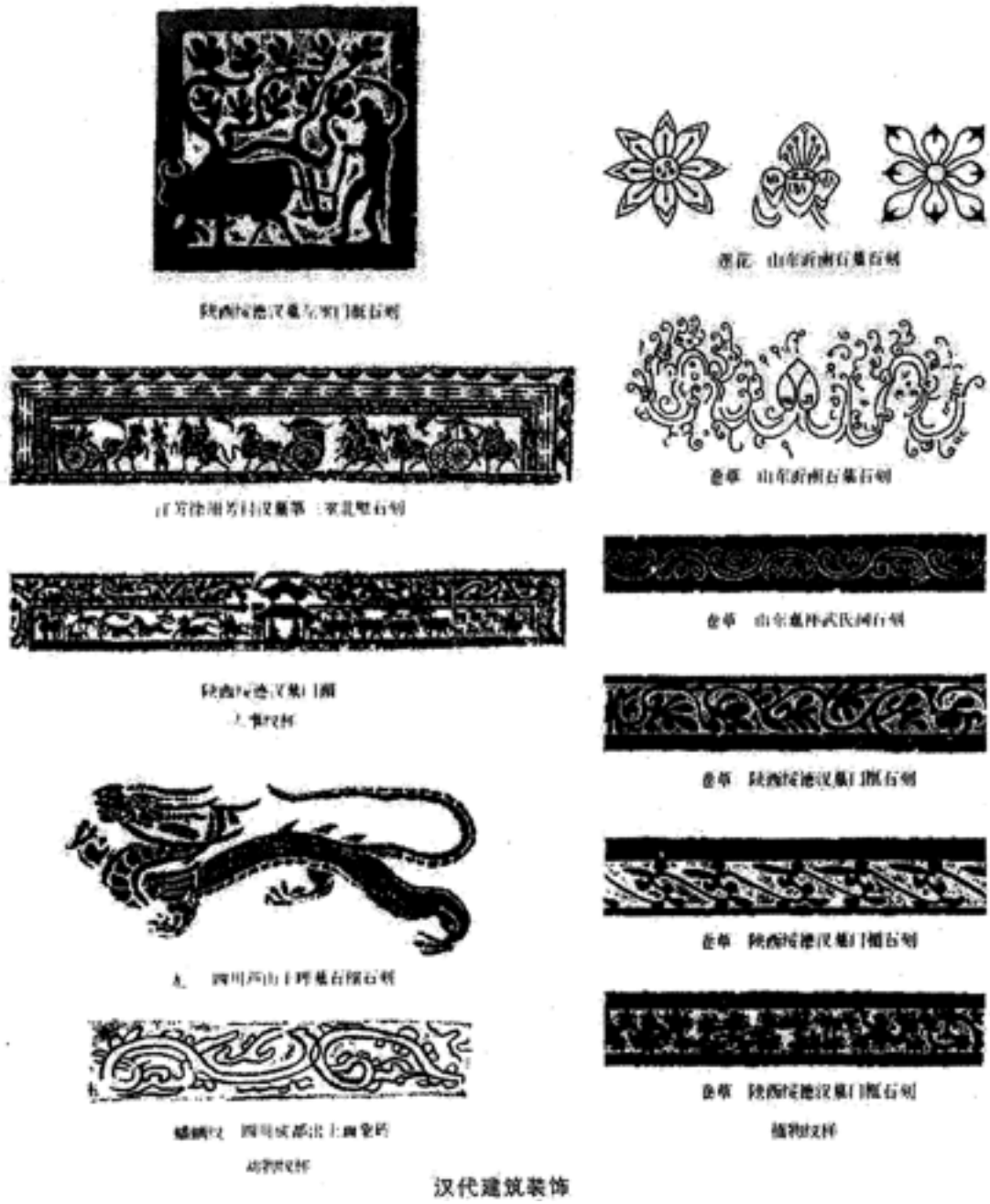
菱形响铃纹　陕西绥德汉墓门框石刻



菱形纹　江苏徐州茅村汉墓墓室北壁石刻

连弧纹　江苏徐州茅村汉墓墓室北壁石刻

波形纹　江苏徐州苗山汉墓墓室前壁石刻



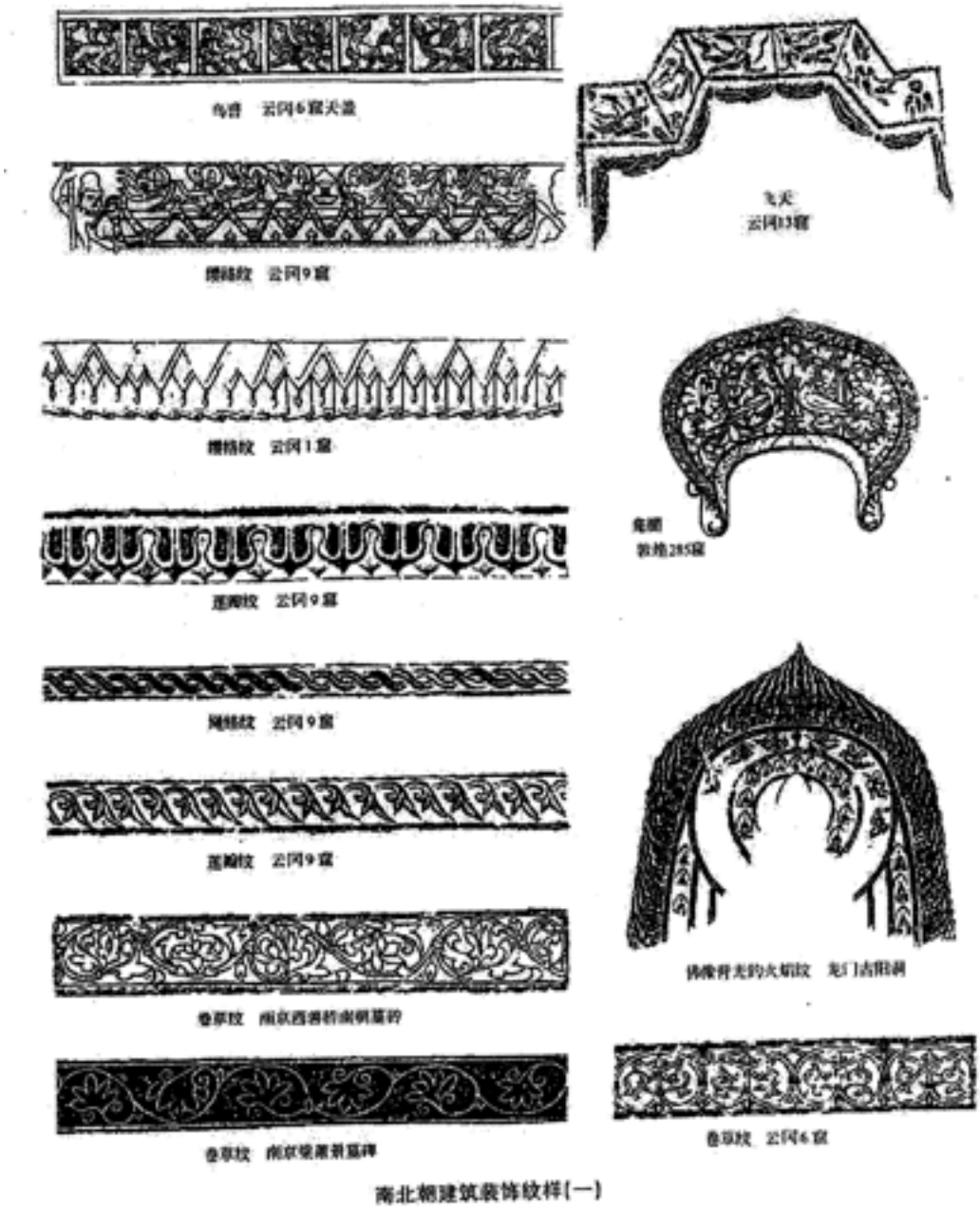
汉代建筑装饰

#32- Architectural Themes and Decorative Patterns from Warring States Period

In ancient times, architectural decoration consisted of geometric designs. Line patterns represented water, rope, teeth, lightening, triangles and “S” shapes. In the North and South era of the fifth and sixth century AD, patterns

became more complex. Artists were inspired to create patterns and images based on birds, animals, tassels, and bundles of grass. Moreover, artists drew more realistically the shapes of birds, lightning, fairies, and lions.

南北朝建筑装

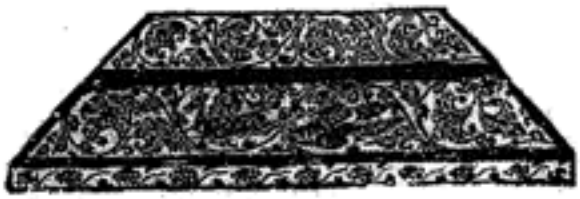


#33 Decorative Designs from the North-South Period (420-580 AD)

Decorative patterns in the Sui, Tang and Five Dynasties became more complex and refined.

卷草凤纹　西安南杨村一墓门额图

佛像迦陵频加卷草纹
西安唐大智禅师碑图



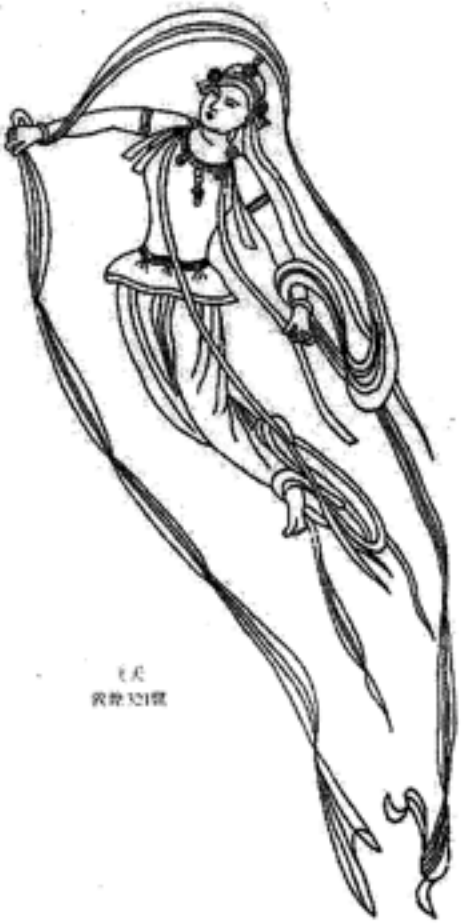
狮兽卷草纹　西安南杨村一夫人墓志盖

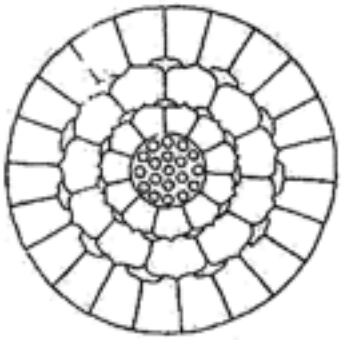
卷草纹　西安隋王昌墓志盖

卷草纹　西安隋独孤罗墓志盖

回纹　敦煌360窟藻井

连珠纹　敦煌360窟藻井





流苏纹　敦煌331窟藻井

铃铛流苏纹　敦煌360窟藻井

葡萄纹　敦煌322窟

带状花纹　敦煌197窟

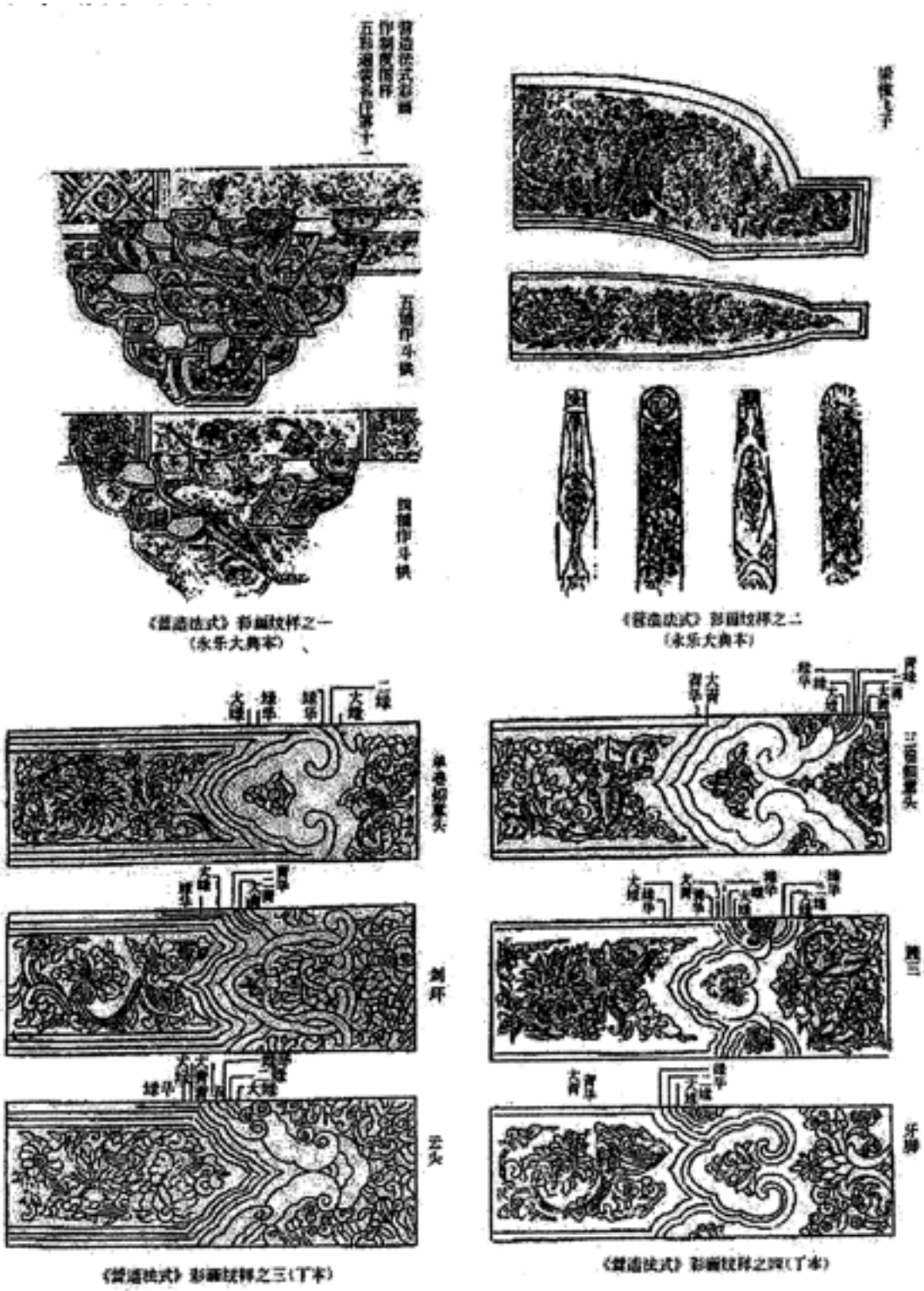
带状花纹　敦煌66窟

团草纹　敦煌319窟藻井

卷草纹　江苏南京李升陵前室西壁立柱彩画

#34- Decorative Patterns of Sui, Tang and Five Dynasties

In the Sung dynasty, patterns were even more delicate and complex.



《营造法式》彩画纹样

#35-Sung Decorative Patterns from “Yingzaofashi”

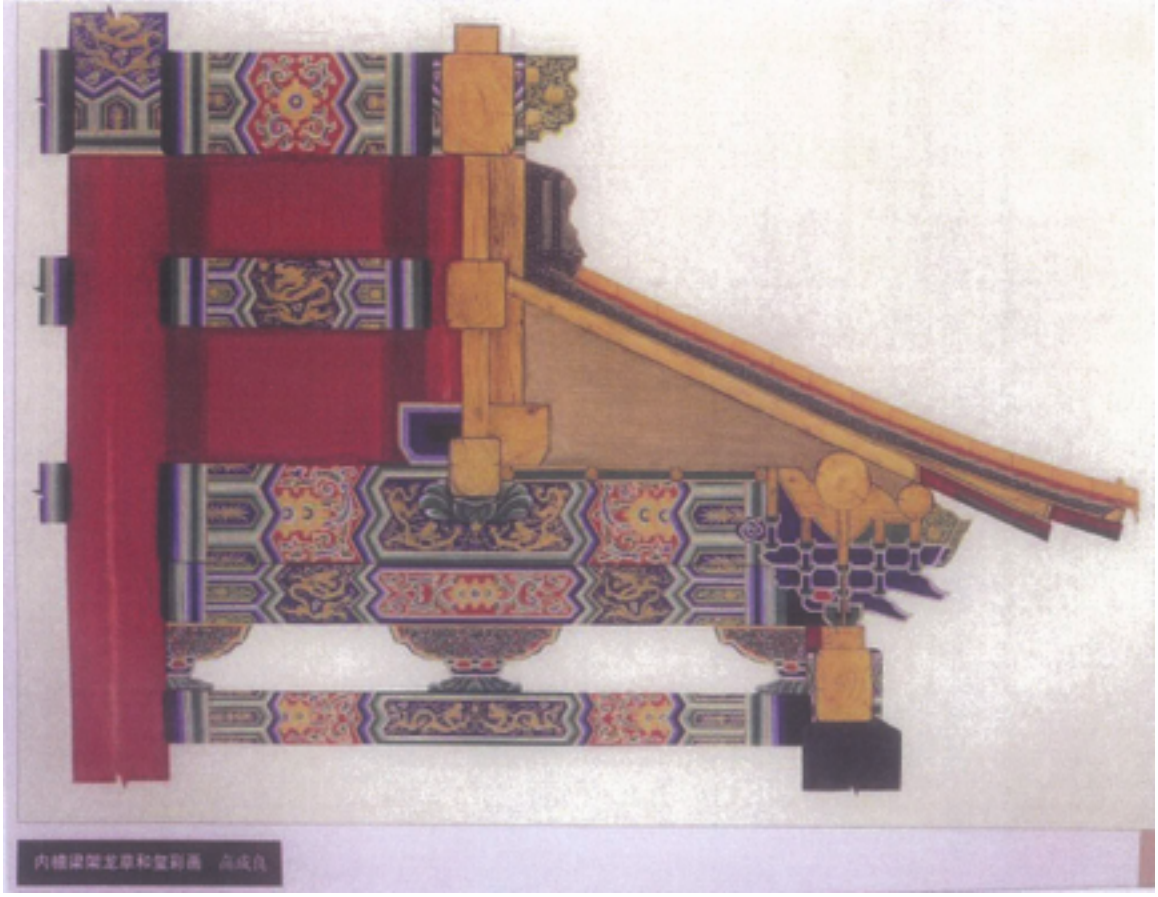
Lin Hui-ying, a noted twentieth century architectural expert, wrote an essay on the origins, development and use of decorative painting. She commented that when you put bright colors on grand buildings, the effect is one of elegance and prosperity. Colorful painting and carving on buildings is one of the earliest and most distinctive characteristics of traditional Chinese architecture. In the beginning, painting was rather simple and it was for practical reasons- to prevent rot and insect damage to the wood structure. Paints were made from red mineral pigments and black tung oil. Over time this utilitarian protective painting blossomed into a rich decorative art.

Most of the existing art on Qing dynasty buildings evolved from Tang, Sung, Yuan and Ming styles. Qing official style painting can be divided into three categories: Imperial style, Tangent Circle Whirlpool Style, and Suzhou style. Each style had its own purpose for different types of buildings.

The Imperial style is exclusively for decorating imperial buildings. It is often identified with a shape that looks like the Greek sigma. Paintings mainly depict dragons and phoenixes, symbols of imperial power.

龙和玺彩画　杜创昌 高成良

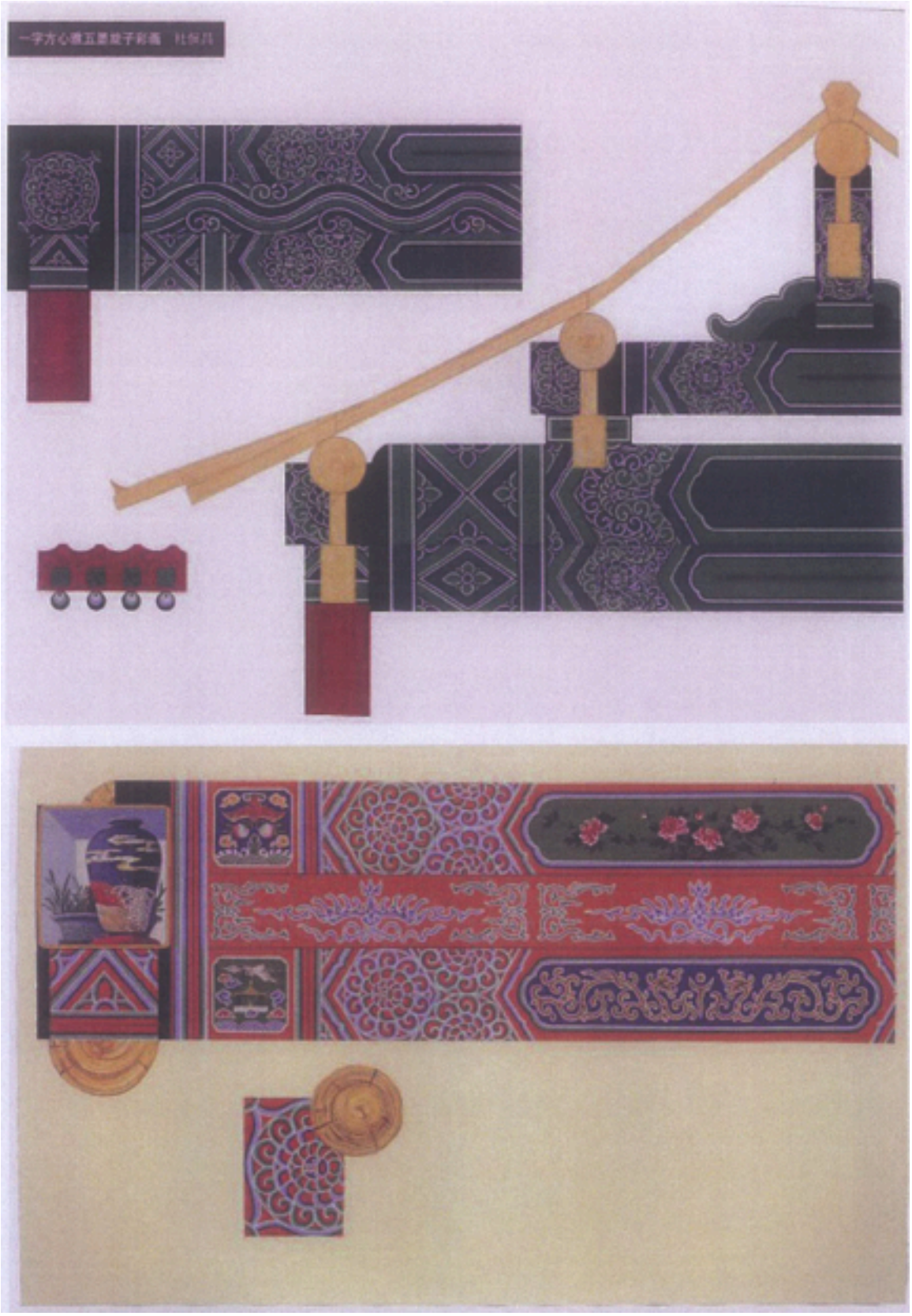
凤和玺彩画　冯广全



36-Qing Imperial Style Decoration

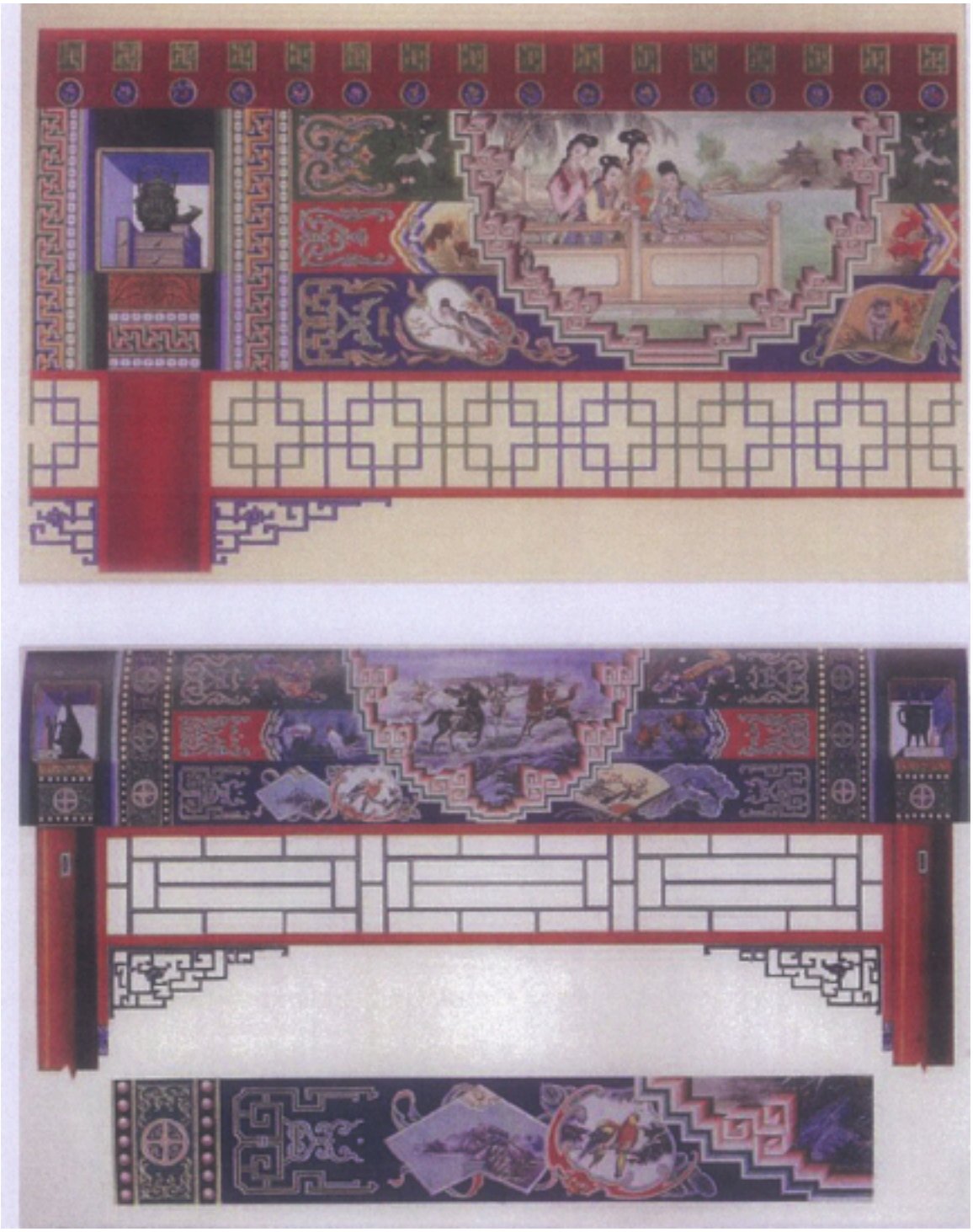
Paintings of the emperor’s seal are done in gold leaf, and glow with elegance.

Tangent Circle Whirlpool style painting is used for decorating temples and residences of high officials. The main linear design is a swirl, and the decorative linear pattern is a zig-zag line. Artwork varies with more or less gold according to client status. They use a yellow jade color for carriage house, armory and food storage buildings. This yellow jade color is poisonous for insects.



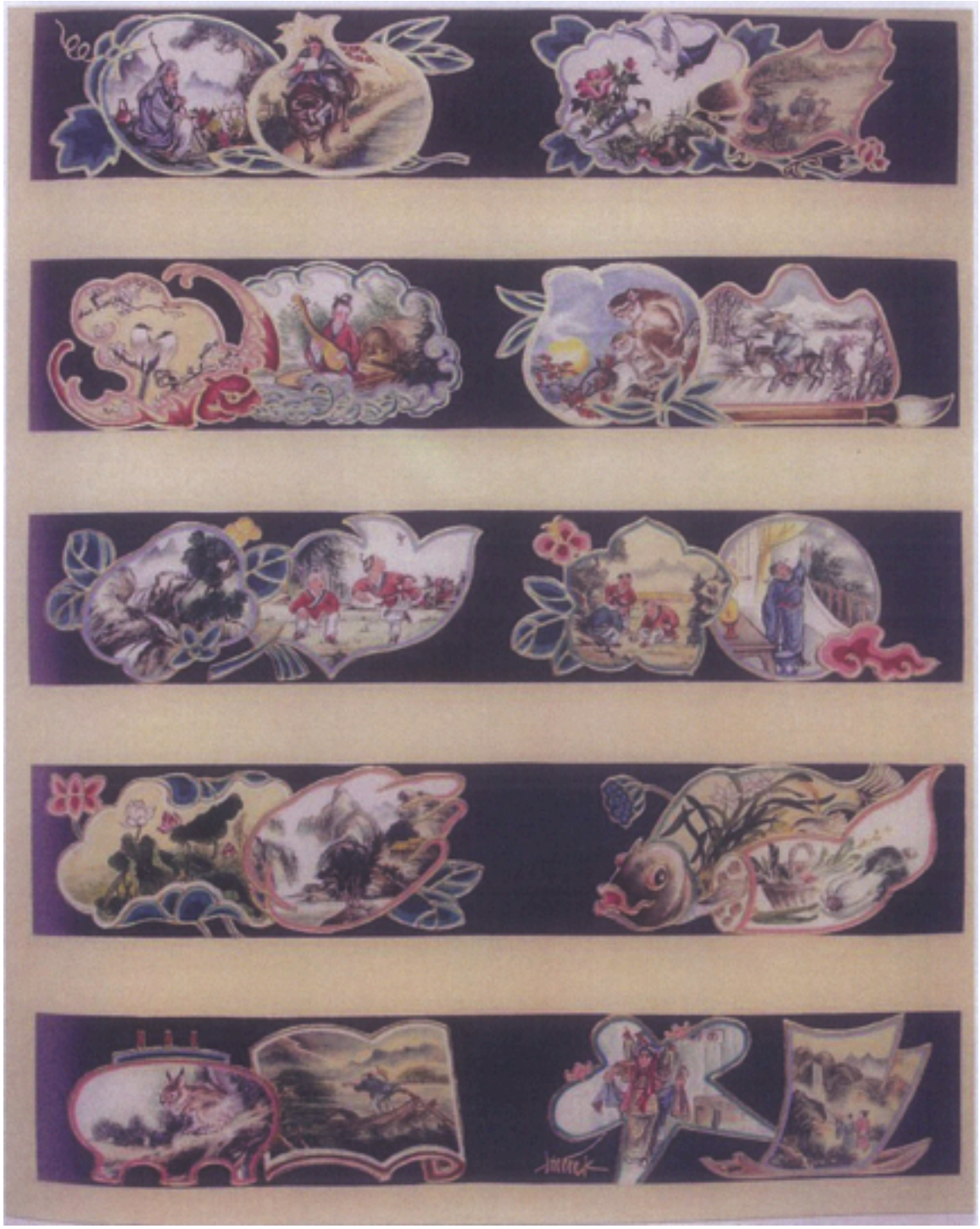
#37- Qing Hsuan Style Decoration

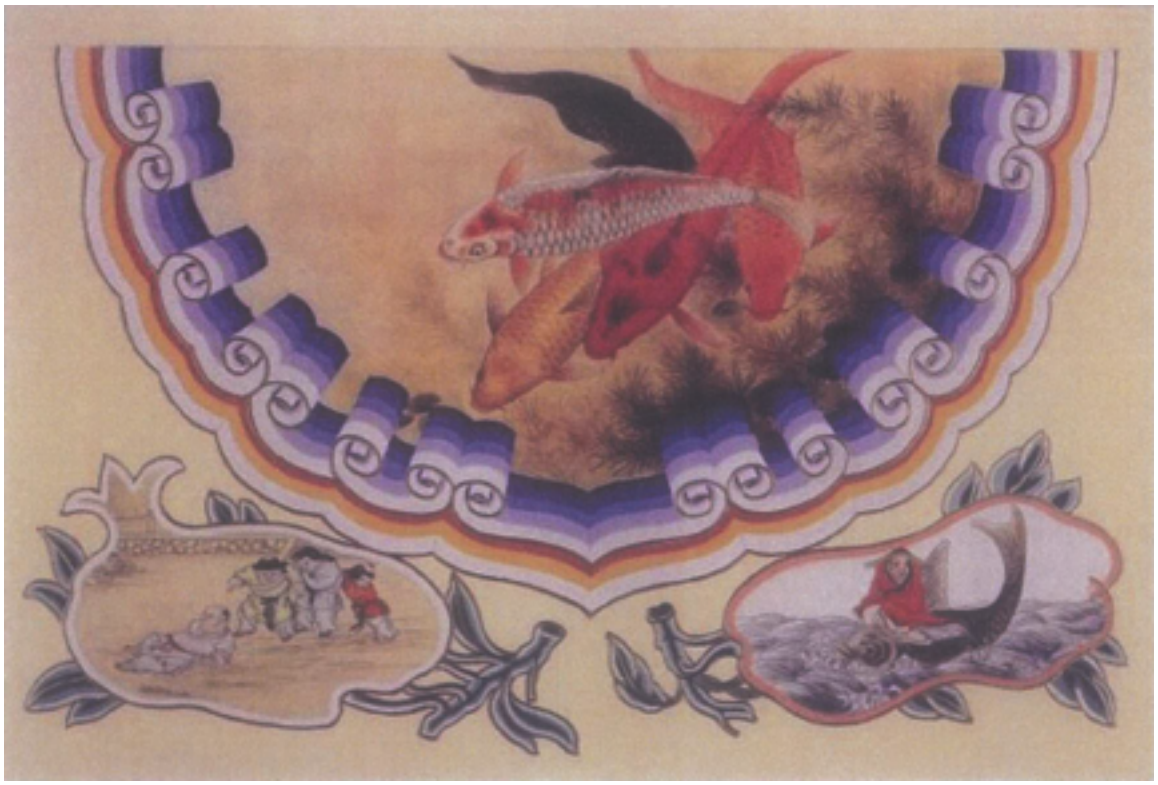
The third style of decorative painting is called “Suzhou style.” This is a lively style, rich in color and decoration, mainly used to decorate garden structures and residential and commercial buildings. Often the image is a landscape scene with some Western influence.



包袱彩画 南广全

包袱复制彩画 高成良





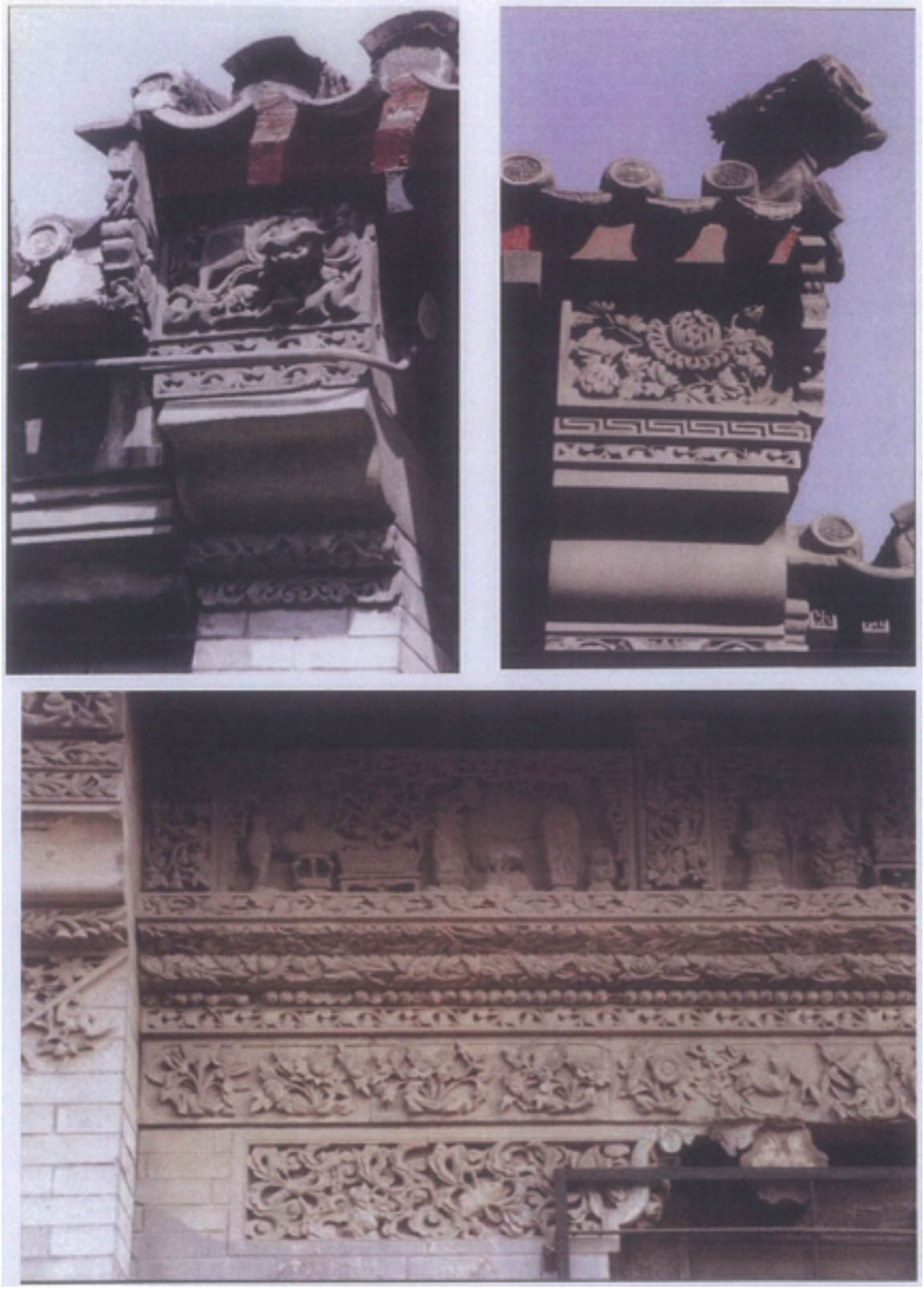
#38- Suzhou Style Decoration

In addition to decorative painting on the wood frame, artisans also paint colorful ceiling panels.


六字真言天花

#39- Ceiling Panel Designs

Painting styles on residences are somewhat different from official buildings. Beside oil painting, decorative patterns are also made on stone, brick and tile. Artisans make both incised carving and raised line patterns.



#40-Examples of Wood, Stone and Brick Carving

In the above eight sections we have discussed the special characteristics of traditional Chinese wood architecture. Palaces, temples, ritual halls and residences are all outstanding expressions of Chinese architectural style. Besides these eight characteristics, there are other obvious differences between Chinese and Western architecture. In “Quadrangle style” houses (Siheyuan), buildings are situated around an enclosed courtyard. There is a central garden area with connected residential structures on all four sides. This style of housing is different from most Western residential building styles.

#41- Plan View of the Forbidden City Palace Compound

Chinese palaces and temples very often are complexes with tens and dozens of buildings on one site. (The Forbidden City in Beijing has more than 1,000 structures inside the palace walls). Most Western palaces, temples and churches are single structures, or perhaps a few buildings clustered together.

The unique curved Chinese roof mimics a bird spreading its wings to fly. It gives one an uplifting feeling of movement. In Dougong bracket sets, special terms that denote the number of tiers of horizontal bearing beams and the progressive cantilevered extension of bracket beams in a set are named after human or animal activities, such as “jump” “step” “arrange”. This suggests that various aspects of Chinese architecture mimic living nature. There is a connection between architecture and the movements of people and birds and animals. It is a special feature of Chinese architectural terminology.

My introduction to Chinese architecture now comes to a temporary end. The time span of Chinese timber framing is as wide as an ocean. I encourage those of you who are interested to please continue your research and deepen your understanding. Before ending this lecture, I would like to

extend my thanks to the Timber Framers Guild, especially to the Executive Director, Mr. Will Beemer, who provided this wonderful opportunity, and I also want to thank friends and guests who traveled a long way to sit here and listen to my talk. Moreover, I want to thank my friends and translators, Richard and Jean Wiborg, who have spent time and effort to make this possible. Thank you again. Ma Bingjian.

Written by Ma Bingjian

Lecture- April 2010 at the Timber Framers Guild Western Conference in Idaho.