Fang, Xueyang

Sound from Antiquity: A Music Archaeological Study of Chime Stones in Ancient China (Ca. 2400 BCE - 8 CE)

SOUND FROM ANTIQUITY: A MUSIC ARCHAEOLOGICAL STUDY OF CHIME STONES IN ANCIENT CHINA (ca. 2400 BCE - 8 CE)

XUEYANG FANG

A thesis submitted to the University of Huddersfield

in partial fulfilment of the requirements for the

degree of Doctor of Philosophy

October 2019

Copyright Statement

Declaration

This dissertation is the result of my own work. The collaboration work that has been previously published as a reference is: Fang, X., & Till, R. (2019). A Study on nine chime stones found in an Eastern Zhou tomb in Hebi, China. In R. Eich-mann, E. Hickmann, L.-C. Koch (Eds.), *Studien zur Musikarchäologie XI, Orient- Archäologie* (Vol.40, pp. 69-87). Berlin: DIA. Dr. Dara Mojtahedi also cooperated on quantitative analysis using SPSS. These relate particularly to Chapter 9.

Abstract

This thesis focuses on researching the chime stone, a form of ancient stone-made percussion instrument that originated in ancient China. According to the taxonomy of the *Ba Yin* (eight tones) system, chime stones belong to the category of "stone", and are a kind of percussive lithophone that can be categorised as an idiophone using the Hornbostel-Sachs system. Archaeologists and musicologists have begun in recent years to study the chime stone in past societies, but research has generally been limited to individual case studies or restricted to a particular historical period and geographical area, while systematic research remains scarce.

This thesis examines chime stone finds and distribution, their classification and typology, evolution of shape, manufacture, combinations, pitch measurement, tuning systems, acoustic properties, as well as their use and function, including performance, ensemble, and their social and political meaning in the ancient Chinese *Li Yue* (ritual and music) cultural context. The research covers chime stones ranging from the late Neolithic Age (ca. 2400 BCE), through the Qin dynasty (221-207 BCE), up to the Western Han dynasty (202 BCE-8 CE).

The methodologies in this thesis combine different approaches. Music archaeology is an interdisciplinary subject which involves various aspects of knowledge and technology. This thesis employs archaeo-organology, pitch measurement, acoustic experimentation, statistical and computational analysis. It comprises 11 Chapters and includes discussion of chime stones found in archaeological sites, as well as analysis of data from new field work carried out by the author in 2016. It establishes statistical relationships between the tuning systems of the stones, their dimensions and cultural context, and concludes that chime stones were a marker of cultural authority for the ruling classes.

Acknowledgements

I would like to express my great appreciation to my parents, for their continuous support and encouragement. My deepest gratitude to Liu Bingqiang and Pan Haibo, curators of the Hebi City Museum, and all other curators and staff members at different Museums, including Zhou Wei, the City Museum of Anyang (Henan); Wang Geyang, Henan Provincial Museum (Henan-Zhengzhou); Fan Wenquan, Henan Provincial Institute of Cultural Relics and Archaeology in Xinzheng Working Branch (Henan-Xinzheng); Gao Xisheng, the City Museum of Luoyang (Henan); the staff at Shandong Provincial Museum (Shandong-Jinan); Fang Qin and Zhang Xiang, the Hubei Provincial Museum; Li Guoxue, Chaoyang City Museum; Sun Bingjun, Shaanxi Provincial Institute of Archaeology. I am grateful for their support and patience; they provided me with a comfortable environment to make sound recordings, photography and video recordings as well as dimensional measurements during my field work. Those sources obtained from my field work are first hand materials that are extremely precious. Thanks also to the University of Huddersfield for giving our graduate students the opportunity to apply for conference funding.

My heartfelt gratitude to my main supervisor Professor Rupert Till, of the Department of Music and Drama, he has been very generous and supportive to me on many academic occasions, which has been sincerely appreciated. From 2016 till this present, he has encouraged me to take part in several international conferences. For example, the 10th International Study Group for Music Archaeology (ISGMA) conference in Wuhan China, the 14th Music Iconography conference held in New York, and the 15th Symposium of the ICTM Study Group for Music Archaeology in Slovenia. Through participation in these conferences, not only has my experience and self-confidence increased, but also I gained greater interdisciplinary knowledge during my periods of study.

Timely interest and advice came from Frederic Dufeu, a research fellow in the Department of Music and Music Technology. He is gratefully acknowledged for offering suggestions on my acoustic analysis, he also programmed software for me to carry out sonic analysis on chime stones. Thanks also to Dara Mojtahedi, who cooperated on quantitative analysis using SPSS.

I would like to thank my examiners in first two years, Dr. Lisa Colton and Professor Monty Adkins for their encouragement and support on my previous work as well as their specific comments. Thanks to my co-supervisors Professor Rachel Cowgill and Dr. Emily Worthington for their guidance of my studies. Special thanks to Rachel, she encouraged me to take part in numbers of activities both at and outside the University of Huddersfield. Many thanks to my PhD viva examiners Professor Jonathan Stock and Lisa, they gave greatest recognition to my research.

Thanks also to Arnd Adje Both, Bo Lawergren, Cajsa S. Lund, and Stefan Hagel, they kindly gave me advice and suggestions on my current studies. Also many thanks to Pat Hill and Tatyana Karpenko, for their endless support and help with my English academic writing. And thanks to Fulong, who took care of me and gave me valuable assistance during my PhD career in the UK.

Nomenclature, Map and Chronology

Figure 1 provides detail of specific chime stone nomenclature. Below this is a map detailing the geographical distribution of chime stones found in China (map. 1). Also listed is the chronology of ancient China in historical perspective (table. 1).

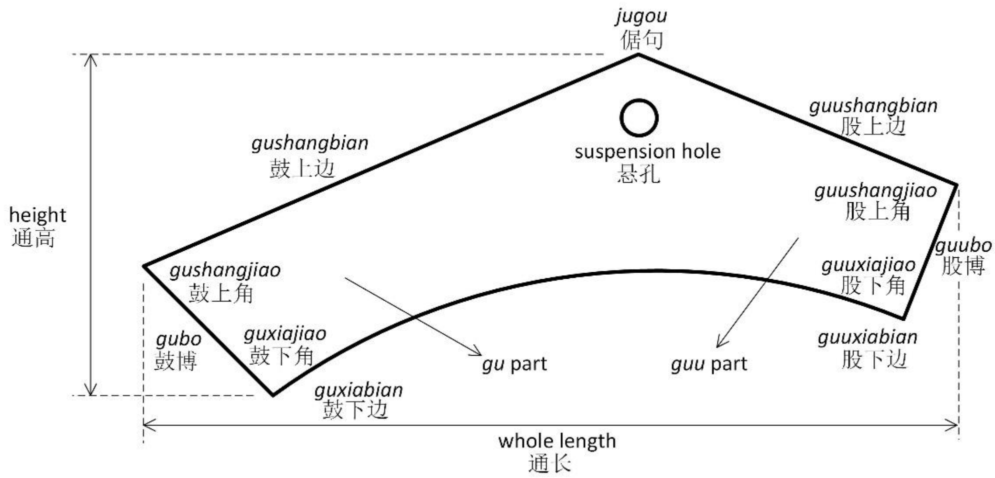


Figure 1. The basic structure and nomenclature of chime stone from the Eastern Zhou (770-256 BCE) to Western Han periods (202 BCE- 8CE).

Except for length, height, and suspension hole, the other part-names using the Chinese *Pinyin* system are taken from classical text *Kaogongji* (The records of examination of craftsmen), author(s) unknown, probably dating to the 3rd century BCE.

Map 1. Geographical distributions of archaeologically excavated Chinese chime stones dating from the late Neolithic Age to the Western Han dynasty (ca. 2400 BCE-8 CE).

The upper blue line is the Yellow River, and the lower blue line is Yangtze River. The provinces on the map represent locations where chime stones have been found.

Table 1. The historical chronology of ancient China
(From the Xia dynasty to the Han dynasty)

<table>
<tr><th colspan="3">Dynasty</th><th>Date</th><th>Capital</th><th>Modern site</th></tr>
<tr><td colspan="3">Xia</td><td>ca.2070-1600 BCE</td><td>Zhen Xun</td><td>Henan-Yanshi</td></tr>
<tr><td colspan="3">Shang</td><td>ca.1600-1046 BCE</td><td>Yin Xu
(late period)</td><td>Henan-Anyang</td></tr>
<tr><td rowspan="3">Zhou</td><td colspan="2">Western Zhou</td><td>1046-771 BCE</td><td>Hao Jing</td><td>Shaanxi-Xi’an</td></tr>
<tr><td rowspan="2">Eastern Zhou (770-256 BCE)</td><td>Spring and Autumn period</td><td>770-476 BCE</td><td rowspan="2">Luo Yi</td><td rowspan="2">Henan-Luoyang</td></tr>
<tr><td>Warring States period</td><td>475-221 BCE</td></tr>
<tr><td colspan="3">Qin</td><td>221-207 BCE</td><td>Xian Yang</td><td>Shaanxi-Xianyang</td></tr>
<tr><td rowspan="2">Han (202 BCE-220 CE)</td><td colspan="2">Western Han</td><td>202 BCE-8 CE</td><td>Chang An</td><td>Shaanxi-Xi’an</td></tr>
<tr><td colspan="2">Eastern Han</td><td>25-220 CE</td><td>Luo Yang</td><td>Henan-Luoyang</td></tr>
</table>

Note: Archaeologists regard Zhen Xun as the legendary capital of the Xia dynasty according to finds from the site of Yanshi Erlitou, other legendary Xia capitals include Yangcheng, Yangdi and Shangqiu.

Chinese archaeologists classify the Western Zhou dynasty into three periods (Chen, 2004), namely the early, middle and late periods, which correspond with the Zhou Kings’ lineage as follows:

Early Western Zhou Wu, Cheng, Kang, Zhao (four Kings)

Middle Western Zhou Mu, Gong, Yi (懿), Xiao, Yi (夷) (five Kings)

Late Western Zhou Li, republican time, Xuan, You (three Kings)

According to the Xia Shang Zhou Duandai Gongcheng (The project of the Xia, Shang and Zhou dynasties chronology), the reigning dates of every King in the Western Zhou dynasty are listed below (Experts in the project of Xia, Shang and Zhou dynasties chronology, 2000, p. 36-37, 88).

King Wu	1046-1043 BCE
King Cheng	1042-1021 BCE
King Kang	1020-996 BCE
King Zhao	995-977 BCE
King Mu	976-922 BCE
King Gong	922-900 BCE
King Yi	899-892 BCE
King Xiao	891-886 BCE
King Yi	885-878 BCE
King Li	877-841 BCE
Republic	841-828 BCE
King Xuan	827-782 BCE
King You	781-771 BCE

To define the periods of the Spring and Autumn, and the Warring States, historians and archaeologists commonly divide them into three periods—early, middle and late (Lu, 2017).

Early Spring and Autumn	770-686 BCE
Middle Spring and Autumn	685-547 BCE
Late Spring and Autumn	546-476 BCE
Early Warring States	476-387 BCE
Middle Warring States	386-285 BCE
Late Warring States	284-221 BCE

Table of Contents

List of Figures

List of Tables

List of Maps

List of Examples

Chapter 1: Introduction

This thesis focuses on researching the chime stone, a form of ancient stone-made percussion instrument that originated in ancient China. In antiquity, people regarded the chime stone as an important musical instrument because its presence was a representation of the wealth and status of tomb owners. In the late Neolithic Age, people initially found the differences between each stone with their quality of sound. Chime stone manufacture focused on the sounding of inartificial stone, as opposed to both materials and sounding based selection in later periods, which formed a part of making a perfect and delicate chime stone. In the earlier period the chime stone was only a musical instrument for producing rhythmic sound but as time went by, they gradually became melodic musical instruments and were played with string, wind, and other percussion instruments in ensemble.

This chapter first explores the reasons for studying chime stones. After setting out the aims of this research, it explores the use of terminology and the choice of Chinese characters used to represent the chime stone. The literature dealing with chime stones and related issues are then reviewed in order to contextualise this research. Details of research materials and methods then follow, before detailing the thesis structure.

1.1 The Significance of Studying Chime Stones

Chime stones and bronze chime bells were some of the most important musical instruments in the royal court of ancient China. Ownership indicated high political and social rank or status; usually they were the paraphernalia of kings and aristocrats. They therefore had symbolic meanings of wealth and power. Both bronze bells and chime stones were important components of the "*Jin Shi zhi Yue*" ("metal and stone music")[1]

1 In particular, "metal and stone music" was a kind of ritual music including bronze bells and chime stones accompaniment, symbolizing high-ranking status in the ancient elite society.

in pre-imperial China. Alongside the chime bells, the chime stones not only served as musical instruments, but also represented ritual objects. Both chime stones and chime bells are equally components of an ancient social hierarchy. The reasons why scholars have concentrated heavily on researching chime bells rather than chime stones are difficult to assess. One reason is that chime bells are more plentiful and better preserved in the archaeological record and many of them are carved with inscriptions. Normally, chime bells had better-preserved condition than chime stones when excavated archaeologically. Due to the brittleness of the stone material, chime stones have relatively poor preservation, and the integrity of chime stone sets is less than that of the bronze bells. Additionally, only a few inscriptions on chime stones have been found so far. It is likely that this is the main reason that researchers have focused their studies primarily on chime bells rather than chime stones.

Nevertheless, chime stones were usually played alongside chime bells in ritual and ceremonial events as one of the main components of “metal and stone music”. In the last twenty years or so Chinese archaeological excavations have discovered a large number of new musical instruments, including chime stones and bronze bells. In particular, the new finds contain a number of complete sets of chime stones. For instance, sets of late Western Zhou (1046-771 BCE) and Western Han chime stones have been unearthed from tombs in recent years, so such archaeological sources can be used to carry out comprehensive analysis and discussion.

The goal of the present research is to follow a historical perspective of development, exploring the evolution of shape and manufacture of chime stones, including materials, design, tools, techniques, as well as pitch and tuning, and furthermore to research the acoustic properties and musical capabilities of both singly used chime stones and sets of chime stones. It is also crucial to study their combinations, tone series and scales from the viewpoint of different archaeological sites and historical periods. This study will research their timbre evolution and recreate a piece of music based upon a traditional Chinese composition by means of samples from original timbres of unearthed chime stones, bronze bells, clay ocarinas, as well as traditional Chinese instruments *guzheng* zither and *di* bamboo flute. Through pitch measurement[2], I will research the acoustic properties of chime stones. Whereas this has often previously focused only on identifying a single pitch, this project also explores sound spectrum, timbre and ensemble. It provides new important information on musical practice in ancient China. Finally, I will explore the chime stones in different archaeological contexts, and the application of chime stones, their use and function in the ancient royal court, their role and characteristics in ensemble, as well as their significance in the context of the system of ritual and music (*Li Yue* Zhidu) in ancient China.

1.2 Terminology of the Chime Stone

Among the many percussion instruments of oriental origin used in musical performance, the chime stone is very interesting acoustically. According to Chinese historical documentation *Zhou Li* (the ritual system of the Zhou)[3], *Ba Yin* (eight tones) was a classification system of musical instruments, which divided all musical instruments into eight groups based upon their manufacturing materials. Joseph Needham and Wang Ling explain *Ba Yin*: "The earliest known system by which the Chinese classified sounds was according to the materials from which their instruments were made. These originally numbered four: stone, metal, bamboo, and skin or leather. Their number was later increased to eight" (Needham & Wang, 1962, p. 151). The other four included such materials as clay, wood, silk and gourd. The chime stone, in its Chinese term *qing* 磬 belongs to the category of stone, and it is a kind of percussive lithophone which can be classified as an idiophone within the H-S system[4].

2 It is usually described by Chinese researchers as "tone measurements" when exploring chime stones.
3 Author (s) unknown, probably dating to the 3rd century BCE. See Anonymous 1980 in bibliography.
4 The Hornbostel-Sachs or Sachs-Hornbostel system of musical instruments classification was devised by Erich Moritz von Hornbostel and Curt Sachs, and first published in the Zeitschrift für Ethnologie in 1914. It is a systematic classification of western and non-western instruments. See Sadie, S., & Tyrrell, J. (2001). *The new Grove dictionary of music and musicians* (2nd ed., XXII). 75. London: Macmillan. See also Myers 1992, p. 444–461. English translated by A. Baines and K.P. Wachsman.

“Terminology is an important but problematic subject” (Till, 2014, p. 292). There is no unique or standard terminology for describing and discussing stone-made percussion musical instruments. Currently, scholars have used the terms rock gongs, sonorous stones, ringing stones, stone bells, lithophones, chime stones and the Chinese character *qing*. Lithophone is a term frequently used in the literature, but to date there is no consensus about describing such a stone-made percussion musical instrument. Many scholars have concentrated on addressing lithophones (Steggerda, 1944; Kuttner, 1953; Montagu, 1965; Dams, 1985; Fagg, 1997; Lund, 2009). Steggerda (1944), in a related study, alleges that stone gongs or ringing stones have the same meaning and could be used interchangeably. He argues that stones could produce different tonal pitches according to a fieldwork case study in one of the Maya villages in Yucatan. As he explains, the tones could not form our musical scale but chimed very nicely when struck simultaneously. In his study on lithophones, Fritz Kuttner (1953) uses “lithophone” to refer to a single stone, and “lithophones” to represent the sets of stones, whereas as we will see others use lithophone to represent a group of stones. M. Catherine Fagg (1997), on the other hand, uses the term “rock gong” to indicate stones that are natural and large or unmoveable, in contrast to other lithophones which are portable and have been either artificially tuned or selected for their tonal suitability. However, according to Cajsa Lund (2009), these sorts of instruments should be named “ringing stones” as an overall term. The entry “Lithophone” in the *New Grove dictionary of music and musicians* is described as “a sounding stone or series of resonant stone slabs or plaques, suspended horizontally or vertically, or circular stone discs arranged chromatically…such lithophones may more appropriately be termed rock gongs” (Sadie, 2001, Vol.14, p. 886). Interestingly, in the dictionary, “stone chime” is used for describing Chinese stone-made instruments in remote antiquity. This term is also mentioned in Fagg’s *Rock music*, as he states, however, “The best known and most carefully constructed are the chime stones, common in the culture area of ancient China” (Fagg, 1997, p. 1-2). In his *Suspended music*, Lothar von Falkenhausen uses a compound word “chimestone” to replace “chime stones” (Falkenhausen, 1993).

To sum up, a lithophone generally refers to man-made stone musical instruments, like bar idiophones in Vietnam, chime stones in China and so on. A rock gong is a natural stone, often extremely heavy and not portable in contrast to lithophones. *Qing* is a unique word which specifically refers to five-sided chime stones and their previous types in ancient China. However, there is no uniform approach to describe the entire range of stone-made musical instruments. It is useful to separate the Chinese chime stone from other stone-made instruments since it has a particular shape and tuning system. In Chinese phonology/pronunciation (*Pinyin* system), *qing* has different possible meanings, such as celebrating events, as light as a feather, and inviting somebody to somewhere. As a result, it is problematic to use *qing* as the primary term for the Chinese chime stone, as it introduces some inconsistencies and confusions in the terminology relating to stone-made instruments. In this research, I adopt chime stone as an overall term to represent these stone-made instruments instead of using the Chinese character *qing* or other terms that are difficult to distinguish. The singular form of chime stone is actually described as *Te Qing* 特磬 (singly used chime stone, usually shaped, and large in size) which individually appeared in early times, from the late Neolithic (ca. 2400 BCE) to the Western Zhou period (1046-771 BCE). The plural form chime stones are usually the symbol of sets of chime stones (*Bian Qing* 編磬), which appeared approximately in the late Shang dynasty (ca. 1260-1050 BCE) throughout the Western Zhou (1046-771 BCE) and Eastern Zhou dynasties (770-256 BCE), and extended to the Western Han period.

The term *qing* also leads us to the further issue of Chinese characters. Various characters have been used to depict the chime stone; Chinese classical texts indicate this evolution. Different characters for *qing* occurred several times in antiquity. Initially, "shi" 石 (stone) referred to the chime stone. In *Shang Shu* (Venerable documents from antiquity), it describes: "[People] playing chime stone, and dressing up as a variety of animals to dance."[5] This depicts a scene featuring a performance with accompanying chime stones. The inscription "shi" also appears on a chime stone unearthed from the tomb of Fu Hao, a consort of Shang king dating approximately to the thirteen century BCE, shown as "Renzhu ru Shi" 妊竹入石 (Renzhu sends stone as a gift). Another example is the inscription engraved on the chime stones' box found in the tomb of Marquis Yi of the Zeng state (the early Warring States period, 433 BCE), "Guxi shi Shi you san zaici" 姑洗十石又三才（在）此 (thirteen stones of Guxi are installed here), Guxi also referring to one of *twelve-lü* names[6]. The term "*mingqiu*" 鳴球 (sounding ball or ringing ball) is another name for chime stone. According to *Shang Shu Yi Ji*, it depicts a scene as "Striking sounding ball, playing the *qin* and *se* zithers" (Ruan, 1980. *Shang Shu Yi Ji*).

Another notable example of the chime stone in classical texts is the pictographic character  *qing*. This character appeared on oracle bone inscriptions in the late Shang period (ca. 1260-1050 BCE), although there is no evidence that this character has been previously used in connection with the stone instrument previously described. In *Zuo Zhuan* (The commentary of Zuo, probably fourth century BCE) it also depicts "*qing*", and tells a story of people in the Zheng state bribing someone in the Marquis of the Jin state with gifts including "two sets of chime bells, *bo*-bells and chime stones, as well as sixteen female musicians".[7]

In short, it seems that the terms *shi*, *mingqiu*, and *qing* are all used to depict the chime stone. They simultaneously existed in the past and could be used alternately. A single chime stone is also addressed as *Te Qing* and this inscription appeared on a chime stone dating to the Qing dynasty (1636-1911 CE), although we do not have evidence to conclude that *Te Qing* was used before the Han dynasty. *Bian Qing* refers to sets of

5 Translated by Xueyang Fang, similarly hereinafter unless an exception with footnotes.
6 See Chapter 8 for detailed discussion about traditional Chinese *twelve-lü*.
7 *Zuo Zhuan:* "Xianggong shiyinian". For the Chinese version, see Ruan, 1980, p. 1951.

chime stones that were frequently combined with chime bells in instrumental performance in the royal court. It seems that defining the character of chime stones was a challenging task in ancient times. However, in later times, *qing* became the unique word referring to a percussive stone-made musical instrument and this has survived to be used in modern society.

1.3 Previous and Recent Studies

The chime stone is mentioned many times in *Shi Jing* (The book of songs: the ancient Chinese classic of poetry, 900-700 BCE), *Shang Shu* (Venerable documents from antiquity, also known as *Shu Jing*, allegedly compiled by Confucius), as well as in other classical poems and in the literature of ancient China; but there is no detailed explanation of them. During the Song dynasty (960-1279 CE), the discipline of "epigraphy" (Jin Shi Xue, Jin means metal, which refers to objects made of bronze, Shi is equal to stone-made objects) became popular and it is regarded as the predecessor of Chinese archaeology, although not the archaeological study in modern meaning that we commonly know.

Chinese epigraphy mainly researched ancient bronzes and their inscriptions, only a few cases involved inscriptions on or associated with stone artefacts. With emphasis on bibliography and textual data, the purpose of epigraphy is to prove details of Chinese history. In these writings there is much valuable information preserved. Some of the books created in this period contain images of bronze objects and stone tools, and the names and contents of their inscriptions, which reflect the core of the discipline of epigraphy. For example, the chime stone uncovered from a hoard in Shaanxi Fufeng and housed by Wangshi was recorded in the book *Kaogu tu* (Illustrations for inquiring into antiquity, Lü, 1092), then followed the monograph *Bogu tu* (Bronze objects with pictures, Wang, 1123) and *Lidai zhongding yiqi kuanzhi fatie* (Assessment of bells, tripods, and other ritual vessels from historical times, Xue, 1144), which also discussed the same chime stone. Later in Yu Xingwu's (1940) monograph *Shuangjianyi guqiwu tulu* (The philological studies on ancient texts and findings), a chime stone excavated from Henan Luoyang Jincun was also cited as an example. However, the discipline of epigraphy did not conduct an in-depth study on musical instruments or music itself and failed to carry out any chronological study of bronzes and other artefacts.

With the development of Chinese archaeology, more research has focused on different aspects of chime stones. It is interesting to compare the various attitudes both in the past and present toward chime stones. Topics include typological study, the evolution of types and decoration, origin and manufacture, set combinations, scales and modes, sound experimentation and acoustic properties, inscriptions, use and function as well as social and political meaning in ritual and cultural context in ancient China.

Most Chinese scholars have concentrated their studies on tone series, scales and modes of chime stones, discussing their regularity (Huang, 1978; Li, 1996; Fang & Zheng, 2007a, 2007b; Fang, 2010a). In order to examine the development of the tone series and investigate different possibilities of scale formation, Huang Xiangpeng (1978) conducted the tone measurement and illustrates the tone series of chime stones. He explores variety within chime stones' tone series, which evolved from three (such as *shang-jue-zhi*, which contains a minor third) to four tones (*gong-jue-zhi-yu*), and eventually reached five (pentatonic scale) from the late Shang (ca. 1260-1050 BCE) to the Warring States period (475-221 BCE). He reviews the development of musical scales from Neolithic to pre-Qin China, in particular demonstrating the differences of pentatonic scales between the ancient Chinese and Greek. In his comparison, five-degree harmonic relation occupies the predominant position in the Greek scale, whereas the harmonic relationship of the minor third figured prominently in the Chinese scale. Li Chunyi, a significant researcher of ancient Chinese music historiography and Chinese music archaeology, has conducted much research on ancient Chinese musical instruments found archaeologically. In his *Zhongguo shanggu chutu yueqi zonglun* (The comprehensive discussion of unearthed musical instruments of ancient China, Li, 1996), Li constructs a theoretical perspective on chime stones, including a comparative study of scales and modes in order to find possible scale paradigms. Scales of chime stones will be discussed in Chapter 8 of this thesis. Fang Jianjun (2010a) measures the tone data on both chime bells and chime stones excavated from the Luozhuang Western Han tomb, suggesting that the fundamental frequency becomes much clearer with the increasing pitch of chime stones. This effect is explored in Chapter 9.

Another research area that scholars have explored is the typology of chime stones. Several types and subtypes of chime stones have been classified (Chen, 1988; Li, 1996; Fang, 1996; Zichu Wang, 2004; Anchano Wang, 2005a; Zheng, 2005). According to Li Chunyi, the chime stones could be mainly divided into four types based upon the evolution of shape. Following the historical development of chime stones, Fang Jianjun also contributes a similar classification of four-type chime stones. Fang allocates them depending on the subtle differences of the top part of the chime stones. Wang Anchao proposes a classification system of four types of chime stone focused on shape and decoration (Wang, 2005). Chime stones have also been divided into three types according to their shape, manufacture and acoustic properties (Zheng, 2005). Wang Zichu (2004), divides the stones based on the dates of chime stones in different periods, as well as their shapes and types. Other similar methods for classifying types of chime stones focus on the evolution of shape and profile (Gao, 2004; Ren, 2008).

The shape of chime stones (five sides with a curved base) led to discussion among scholars as to whether the instruments had an ancestor. Some have suggested that it came from a stone-made tool used in agricultural production (Wang & Jia, 1991; Xiu & Wang, 2001; Wang, 2006a), while others (Kuttner, 1953; Suo, 2009) suggest the chime stone and other objects have an evolutionary relationship. Kuttner (1953) claims that the chime stones were connected to the Chinese *pi* disk (*bi* in *Pinyin* system), and he suggests that the *bi* disk was the embryonic form of the chime stone. Suo Quanxing (2009) also argues that this rectangular stone implement with a square-hole that was chiselled on the surface of it was the ancestor of the chime stone. Chime stone shape typology is discussed in Chapter 3.

Dating methods in this music archaeological field can be problematic. The application of the ^{14}C (Carbon-14) dating system (Kovar, 1966; Bowman, 1990; Mook & van der Plicht, 1999; Qiu & Zhang, 1999; Qiu & Cai, 2001) cannot be used to date the stones themselves, but is used to date items found in association with them, and thus the date of their burial. Cajsa Lund (2009) discusses dating ringing stones found in Sweden through observing cup marks on them. As she suggests, this method of dating gives a broad range of dates by using this cup mark criterion. No matter how one dates stone-made musical instruments, the time suggested is not a fixed point but rather an approximate range.

Other related research includes inscriptions, decorations, and metaphor relating to the chime stones. A comparative study on inscriptions between chime stones and drum-shaped stones of the Qin state in the Spring and Autumn period discusses the possible date of manufacture and the similarity of styles of these inscriptions (Hao & Hao, 2007). Different decorations or inscriptions on each chime stone may be more metaphorical, depending on their type of patterns, contents and archaeological contexts. The essence of either inscriptions or decorations is that they can reflect the ritual power and status of the owners (Qiu & Li, 1981; Huang, 1981; Li, 1983; Chen, 2002; Ye & Wang, 2005; Wang, 2006b). Inscriptions also sometimes explore the musical theories relating to the tuning system (Hubei Provincial Museum, 1981; Fang & Zheng, 2007a, 2007b).

In relation to the manufacture technique of the chime stones, the *Kaogongji* (The records of examination of craftsmen) describes the method of pitch tuning and also the ratios between different dimensions of chime stones in the chapter of *Qingshi* (*Qing* family). This book is a Chinese historical document that records the specification and manufacturing process for various types of work in the official handicraft industry. *Qingshi* was a craftsman and an expert at making chime stones professionally. In general, historians treat this book as an official record in relation to the Qi state in northeast China of the early Warring States period (476-387 BCE), but the author is anonymous. It exemplifies a formula that shows how to calculate the ratio of the sizes of the main parts of the chime stone, during the Eastern Zhou periods (770-256 BCE. See Chapter 4).

In the 1960s, Zhuang Benli (1966) conducted a research project focused on musical instruments in museum collections in Taipei, which include chime stones and clay ocarinas that were discovered in the 1930s in Anyang, Henan province, and were then transferred to Taiwan before 1949. In order to explore the evolution of shape and design of chime stones collections in Taipei during the Shang (ca. 1600-1046 BCE) and Zhou dynasties, he measured four chime stones to compare with the *Kaogongji Qingshi* text. The results show that the actual sizes of chime stones are different from the text. Also based on the formula in *Kaogongji*, Fang Jianjun (1989c) examines nine Western Zhou (1046-771 BCE) samples of chime stones found in different geographical locations. By comparing with this formula, he found that dimensions and ratios of unearthed chime stones are a little smaller than that of the *Kaogongji Qingshi*. Chapter 4 explores various geographic locations and periods of the sample of chime stones, using both the present project's fieldwork and existing research data from the past.

Sun Chen (2009) focuses on attempting to find different meanings of the formula in *Kaogongji*, and verifies the text by calculating the dimensions of unearthed chime stones. Other scholars have discussed the possible date in which *Kaogongji* was written (Xuan, 1993; He, 2009; Sun, 2009) and examined the acoustic theories the book describes (Du, 1965; Wenren, 1982). Among them, Wenren Jun (1982) proposes a specific explanation of acoustical descriptions relating to the chime stones in light of modern acoustical theory, and his research shows that the vibration of a chime stone is equivalent to the sound mechanism of transverse vibration of elastic plate.

Acoustic research on stone-made musical instruments has in recent years aroused much interest. For instance, Thomas Rossing and Junehee Yoo (2006) carried out comparative acoustic research focused on Chinese chime stones and Korean *pyeongyeong*. They provide conclusions about relationships of chime stone vertex angle and fundamental frequencies, and their work is discussed in Chapter 9, which explores the wider spectra of the larger sample group of stones under study in this thesis.

Rupert Till (2010) conducts acoustic analysis of a digital model of Stonehenge by using software designed for architects' use, exploring acoustics and stone in the context of a large stone monument. Aaron Watson (2013) focuses his study on acoustics of Neolithic monuments and discusses whether the acoustics of Neolithic monuments are intentional or fortuitous. Apart from these studies, a significant amount of research exists on the tuning systems of chime stones in ancient China (Dai, 1993; Wu, 1994; Miao, 1996; Feng et al., 1996), through which the history of acoustics in China is described. Other studies (Kuttner, 1953; Zhu, 2010) are associated with musical and physical qualities of chime stones. Kuttner proposes that the curved base of chime stones acts to improve the acoustical qualities of the stone. Zhu Guowei (2010) argues that it is possible to obtain reduced overtones in the lower frequency range when a curved base chime stone vibrates. They both suggest that the curved base of some chime stones has a specific acoustic effect (see Chapter 9).

Research on vibration patterns in chime stones is also significant. Vibrating models can be examined by using a number of different methods (JSDTKGD, 1988; Chen & Wang, 1989; Yoo & Rossing, 2006; Zhang, Cheng & Zhu, 1997). Chinese archaeologists have conducted experimental work to calculate key vibrating frequencies and modes and to research vibrating properties in the various shapes of the chime stones. To analyse these different vibrating modes, it is necessary to find relationships between vibrational mode frequencies and shapes of ancient chime stones. Using FEM (Finite Element Method), the Jiangsu Dantu archaeological team have calculated the vibration characteristics and frequencies of the chime stones in various shapes and sizes. Chen Tong and Wang Zhongyan have carried out similar research by using FEM to obtain an empirical formula for the calculation of the fundamental frequency of a stone. Thereafter, Yoo and Rossing have conducted an experiment to make a comparison between the Korean *pyeongyeongs* and Chinese chime stones. They highlight that the most important parameter is the vertex angle of the chime stones, but the curvature of the base of chime stones may have a smaller influence. These experiments were theoretical computer studies, and they dealt only with straight sides, whereas most real chime stones have curved bottoms, which are far more difficult to analyse.

Another approach is to use Nearfield Acoustic Holography to simulate the vibration modes of chime stones (Zhang, Cheng & Zhu, 1997). Zhang Dejun, Cheng Jianzheng and Zhu Nianqiu (1997) focus on studying different aspects of chime stones in order to obtain a specific formula for pitch design, through building different models of chime stones. The first two experiments used the same methodology and concentrated on the fundamental frequencies and primary modes of Chinese chime stones. The third experiment used a parallel comparison to find similarities and differences between the Chinese chime stones and Korean *pyeongyeongs*. Nearfield Acoustic Holography was used to detect the vibrational modes present, but these methods do not include the curvature of the base, and the formula it informed has some deviations from computer based experiments.

Other related research on chime stones are based on computational and technological analysis. Zhang Baocheng, Xu Xuexian, Chu Meijuan and Han Liusheng (1983) primarily use computer analysis of the sonic properties of chime stones, in particular to investigate their vibration model through the use of spectrograms, combined with mathematical equations for calculating their frequencies. In contrast to this, Jae-hyun Ahn and Richard Dudas (2015) focus on physical model studies that rely on computational Modal software. They have created a physical model that can be used in musical studies. They have also constructed a framework on use of synthesis of ancient chime stones. Both projects are based on computer models rather than actual chime stones.

Much research has been carried out on the 32 piece set of chime stones from the Marquis Yi's tomb of the Zeng state. The tomb contains large numbers of musical instruments, including a sixty-five-part assemblage of bronze bells and many other wind and string instruments. Relevant studies on chime stones from Marquis Yi's tomb have involved the textual explanation of the inscriptions (Huang, 1981; Hubei Provincial Museum, 1981; Qiu & Li, 1981; Li, 1983; Chen, 2002; Wang, 2006b), the scale structure of chime stones (Gao, 1988; Wang, 2005b, 2007; Liu, 2014; Liu, 2015), and the reconstruction of chime stones (Tong, 1981; Hubei provincial Museum & ZKYWWYS, 1984; Xu, Zhang & Feng, 1988; Zhang, 2006). These comprehensive studies, to some extent provide a reference for researching chime stones from other mausoleums during the Eastern Zhou period (770-256 BCE). Studies of this set of stones provide a model approach, as discussed in Chapter 8, which explores scales and modes in chime stones.

Although both archaeologists and musicologists have paid considerable attention to the acoustics of chime stones, their cultural significance and relationship with the ancient Chinese system of ritual and music (*Li Yue* Zhidu) have been largely ignored. Previous studies pay insufficient attention to acoustical properties, especially timbre analysis of partials. Scholars have highlighted the data acquired from tone measurement of chime stones, but there has been little widely cast fieldwork or broad analysis. Some issues need further discussion, for instance, how did ancient people create the convex pentagon-shaped chime stone, and what is the meaning of this unique shape? What is the significance of the chime stone with arching base? What are the sound qualities and timbre characteristics of chime stones archaeologically found in different regions and historical periods? These questions outline, the persisting mystery of the chime stones, and that it is worthy of further discussion.

1.4 Research Sources and Methodology

In order to obtain specific and reliable results, I chose only to study chime stones that were uncovered archaeologically by means of scientific excavation with published formal or brief reports, and included only a very few unearthed samples without archaeological context. References examined for the project include an extensive number of research articles related to chime stones published in scientific journals. Owing to the emergence of newly excavated finds and their studies, I generally defined the deadline of research materials in this thesis as published before October 2018.

In this dissertation, I rely on archaeological sources including excavation texts such as inscriptions on chime stones. The most valuable materials for this study are the musical instruments themselves, which have been found in aristocratic tombs as well as some small tombs with unknown occupants. Those archaeological sources, as Li Chunyi says, are full of authentic, accurate materials and facts (Li, 1986). The data from my fieldwork provides extra evidence. It covers chime stones in museum collections and creates original sound recordings. In addition, I consulted a number of historical documents. The range of textual sources reveal more about real musical practice during ancient times, which include classical texts such as *Zhou Li, Shi Jing* and the volume of *Yue Ji* (Record of music) in the *Li Ji* (The book of rites).

The principal methodology in this thesis is music archaeology, a new discipline with approaches including classification, analysis and typological study (Hickmann, 2001, p. 848-854), followed by methods of archaeoacoustics and sound archaeology. From a diachronic and synchronic perspective, I classify the chime stones into specific types and subtypes, and explore their evolutionary development of shape and manufacture. I will investigate how the chime stone evolved from beginning to maturity and their variety, and consider how it evolved from the late Neolithic Age (ca. 2400 BCE) to the Western Han dynasty (202 BCE-8 CE) during two thousand years.

I then conduct an acoustical study of the chime stones. Firstly, I take pitch measurements and obtain pitch data, then examine the combinations of the chime stones, their tone series, scales and modes, and their connection with bronze bells and other sorts of musical instruments. I adopt the archaeoacoustics method for exploring the acoustic experimentation related to pitch, timbre and frequency spectrum of the chime stones by using computer software, in order to find the relationship between frequencies and dimensional elements.

The project methodology is in part derived from the theoretical framework of organology within ethnomusicology, as discussed by Mantle Hood (1971). He suggests that research on musical instruments should combine ontology of technology with their cultural background. His "organogram" demonstrates that organological research should be sited within a comprehensive context of economy, culture, rite, symbol, and gender. Hood regards music in its relation to society and culture, stating that ethnomusicology is "an approach…not only in terms of itself but also in terms of its cultural context" (Hood, 1969, p. 40). He later concludes, "Music is inseparable from the cultural context as distinct from its social context and it both affects and is affected by the context" (Hood, 1971, p. 250). Moreover, Alan Merriam mentions "the study of music in culture" (Merriam, 1960, p. 109), he later emphasizes this point in his *The anthropology of music* (Merriam, 1964, p. 17-36).

Lothar von Falkenhausen adds that research into ancient musical instruments such as chime bells, should not only stress their type, but also their culture (Falkenhausen, 1993). Indeed, unearthed musical instruments cannot be defined and studied without reference to their archaeological context or archaeological culture. All these theories emphasise that we should put music into its cultural context in the course of study. Thus, it is crucial to research the chime stone based upon a system of ritual and music (*Li Yue* Zhidu) and combine musical research with cultural perspectives to explore the role, function and significance of the chime stone in the specific time and space of ancient China. It is important to study both material culture and spiritual culture of the instruments in an archaeological context, rather than to study them in isolation, as has been the approach of many previous studies. Furthermore, it is necessary to pay attention to the excavated ruins, tombs, ancient states and ethnicities that chime stones belonged to.

Field work in music archaeology uses observation, sound recording, physical measurement and pitch measurement, and collection of a range of data. In 2013, I carried out field work in Hebi City Museum (Henan) with colleagues and students from Tianjin Conservatory of Music, to measure the chime stones and chime bells dating to the Spring and Autumn period (770-476 BCE), which were excavated from the tomb M4 in Qixian Songzhuang (Henan). In 2016, I went to various sites in China, including Anyang, Hebi, Xinzheng and Zhengzhou (all in Henan province), as well as Xi'an (Shaanxi), Chaoyang (Liaoning), Chifeng (Inner Mongolia), Zhangqiu, and Jinan (Shandong) to visit museum collections of chime stones and other instruments. During my field work, I observed one hundred and eleven chime stones. Some of them are well preserved, but some had already broken, and thus I could not always take sound recordings and measurements. Even so, I have measured the dimensions and pitch data of 65 chime stones in total, and other published data of pitch measurements are also discussed in this thesis.

In addition, the research makes a comprehensive application of tables, figures and spectrograms to demonstrate relevant data and analysis. The sound of 65 chime stones was recorded through fieldwork and subsequent testing by computer. In previous studies, scholars mainly focused solely on the pitch and scales that the ancient chime stones produced. By means of experimental composition, the project searches for possibilities of combining sound samples from ancient chime stones and other instruments such as bronze bells, clay ocarinas, *guzheng* zithers, and *di* bamboo flute, through which we may encounter the sound of remote antiquity. Through sound experimentation and analysis, I identify the relationship and inner connections among tones, dimension data, shape and materials of chime stones found in different regions and different historical periods in ancient China. It is this comprehensive and detailed methodology that differentiates the present study from previous studies, which tended to be narrowly focused.

1.5 The Organization of the Thesis

This thesis is divided into 11 chapters. The present chapter is an overview of recent studies and methodological discussion. In Chapter 2, I will survey the geographical distribution of the chime stones found in the Yellow River and the Yangtze River valley areas, and describe the unearthed circumstances and archaeological contexts. Chapters 3 to 8 will contain an in-depth discussion of chime stones unearthed from those regions, involving classification and typology, evolution of shape, manufacture, performance and assemblage of the chime stones as well as the detailed pitch measurement and analysis. Chapter 9 examines acoustic properties of chime stones through sound experimentation and acoustics. Chapter 10 looks at the use and function of chime stones, which includes chime stones in ancient ensemble, cultural context, used in ritual music, and the symbolic meaning of chime stones in ancient China. The final chapter draws conclusions, looks at research barriers and proposes future studies on chime stones.

1.6 Summary

This chapter has provided a comprehensive view of existing research, presents the aims of the present research, alongside material sources and methodology, and elaborates the theoretical framework of this thesis. The chapter contains a detailed comparison of different terms used to refer to chime stones. The variety of terminology can be confusing in this research area, which is why I attempt to offer my own definition. A summary of the main chime stones findings at the two river basins, together with geographical features of distributions, is provided in the next chapter.

Chapter 2: Archaeological Finds and Distributions

This chapter aims to survey and discuss the geographical distributions and features of unearthed chime stones in the "two river basins", the Yellow River and the Yangtze River areas. A large number of archaeological sites and artefacts including chime stones and many other musical instruments have been excavated from these two regions.

2.1 The Yellow River Valley Region and the Area to its North

The Yellow River, with its length of more than five thousand kilometers, is the second longest river in China and the sixth longest in the world. Originating from the Bayankala Mountains in Qinghai province, it flows through nine provinces of China and empties into the Bohai Sea. The upper reaches of the Yellow River flow from Qinghai, Sichuan, Gansu and Ningxia. The middle and lower streams of the Yellow River pass through Inner Mongolia, Shaanxi, Shanxi, Henan and Shandong. Since its valley is the main birthplace of Chinese civilization and the most prosperous region in early Chinese history, it is called the "Mother River of China" and also hailed as "the Cradle of Chinese civilization" (Liu, 2016). The most ancient archaeological findings are distributed along the Yellow River valley and some beyond its northern part, especially musical instruments, offer rich research possibilities. The following will survey archaeological finds of chime stones, according to ancient Chinese chronological sequences.

2.1.1 The Neolithic Chime Stones

Ten samples of Neolithic chime stones have been archaeologically discovered in China (see table. 2). The table contains details of all Neolithic chime stones including some broken and restored specimens. The first four specimens are representative of the earliest chime stones, which were all uncovered from large tombs in the cemetery at the

Neolithic site of Xiangfen Taosi (Shanxi)[8]. They belonged to the Taosi culture (previously named late Longshan culture Taosi type). The Taosi site lies within the boundaries of Xiangfen county, Linfen city in Shanxi province. The Taosi archaeological culture was contemporary with the late Longshan period and it dated to around 2450-1900 BCE, based on 24 reliably calibrated radiocarbon dates. The tombs in Taosi which contained early period chime stones are dated from around 2400-2300 BCE according to carbon-14 dating (ZSKKGS & LFWWJ, 2015). A chime stone (M3002:6) from tomb M3002 is made of chert with a caesious colour, by using the chipped stone tool manufacturing process (figs. 2&3; see also Chapter 5). The tomb has a passageway leading to the main chamber. Similarly, the other three chime stones were also buried in tombs with this layout. On the basis of the rich funerary artefacts present, archaeologists suggest that a tomb with such a passageway not only symbolizes wealth, but also the high standing and social status of the deceased tomb occupant, and it is a characteristic of the royal cemetery in later periods (e.g. the Shang dynasty).

In tomb M3015, two crocodile skin drums and one pottery drum were discovered close to a chime stone made of hornfels stone of grey colour (figs. 4&5). Figure 4 shows the layout of the tomb; the proximity of the drums and chime stone offers the possibility that they were played together. The other two chime stones unearthed from different tombs were also coexistent with such instruments (fig. 6). These chime stones are close to grey-green colour and music archaeologists have measured their tone pitches (see Chapter 8). In view of the geographical location where these chime stones were unearthed, the site and tombs probably belonged to some ancient tribes (ZSKKGS & LFWWJ, 2015). Zhang Qingli and Zhang Jie have asserted that this middle Neolithic Age is when super settlements and tribes began to appear (Zhang & Zhang, 2017). However, proof of this theory would be assisted by further archaeological excavation.

As shown in table 2, around half of the Neolithic chime stones were found in Shanxi, only two examples were discovered in Henan and Qinghai, suggesting that the Neolithic

8 Since the source will be listed in all tables, I here do not cite them repeatedly.

chime stones were mainly found in both the upper and middle areas of the Yellow River valley, with no evidence to show their appearance in the lower region. From current evidence it is likely that the former region is where Chinese chime stones were first manufactured.

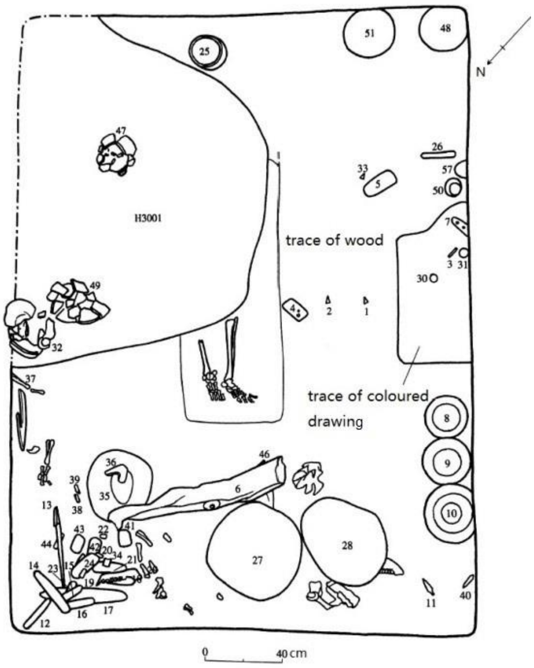


Figure 2. Diagram of Shanxi Xiangfen Taosi M3002.
Crocodile skin drums (nos.27-28), chime stone (no. 6). After ZSKKGS & LFWWJ, 2015, p. 454, fig. 4-37 (A). Redrawn by Xueyang Fang.

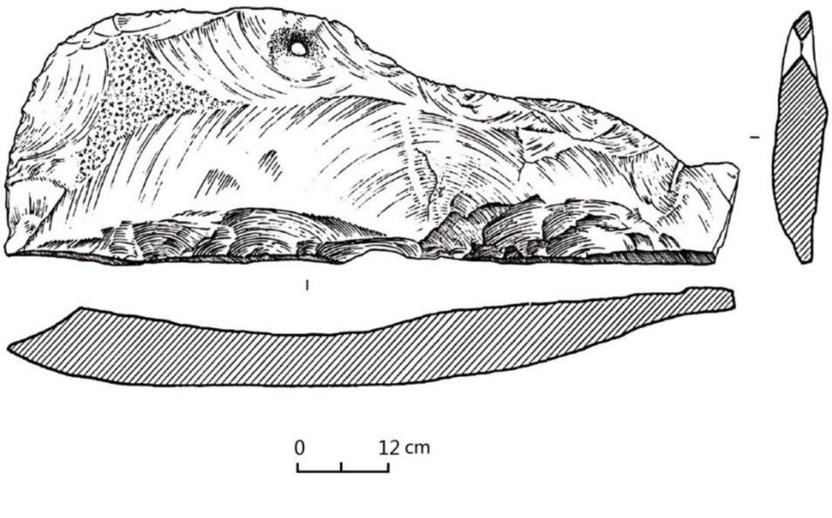


Figure 3. Chime stone from Shanxi Xiangfen Taosi M3002.
Early Taosi culture (ca. 2400-2300 BCE). Length: 95 cm. After ZSKKGS & LFWWJ, 2015, p. 672, fig. 4-147. Redrawn by Xueyang Fang.

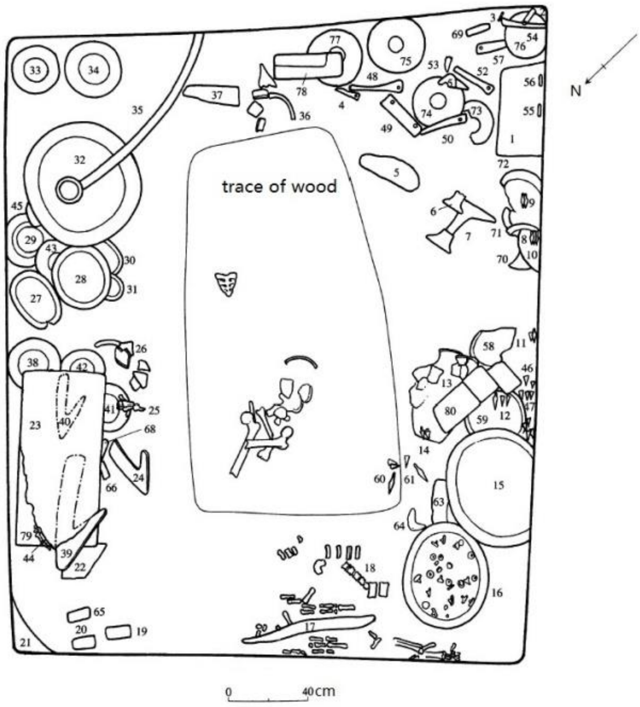


Figure 4. Diagram of Shanxi Xiangfen Taosi M3015.
Crocodile skin drums (nos.15-16), chime stone (no. 17). After ZSKKGS & LFWWJ, 2015, p. 452 fig. 4-36 (A). Redrawn by Xueyang Fang.

Figure 5. Crocodile skin drum from Xiangfen Taosi M3015.
Early Taosi culture (ca. 2400-2300 BCE). Height: 110 cm. After ZSKKGS & LFWWJ, 2015, color plate 21.

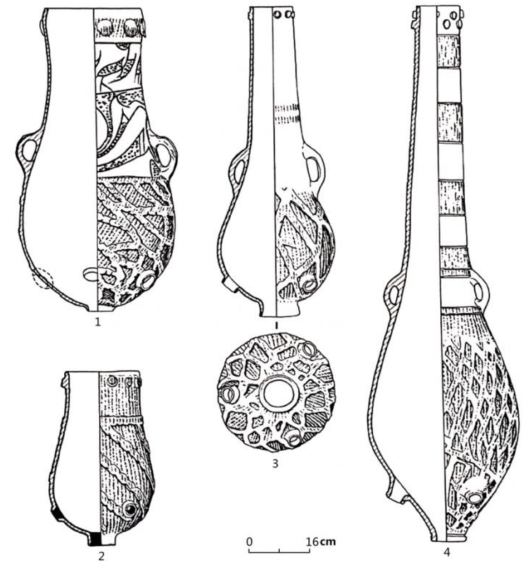


Figure 6. Pottery drums from Xiangfen Taosi large tombs.
1. M3072:11, Height: 80.4 cm; 2. M3016:33, Height: 45.6 cm; 3. M3002:53, Height: 81.4 cm; 4. M3032:1, Height: 140.5 cm. Early Taosi culture (ca. 2400-2300 BCE). After ZSKKGS & LFWWJ, 2015, p. 1333, fig. 2.

Table 2. The Neolithic chime stones unearthed in northern China

No.	Excavation year	Site and/or tomb[9]	Specimen no.	Date	Chime stone	Other musical instruments	Source
1	1979	Shanxi Xiangfen Taosi M3002	M3002:6	Early Taosi culture (ca.2400-2300 BCE)	1	2 crocodile skin drums, 1 pottery drum	ZSKKGS & LFWWJ, 2015 [10]
2	1978-1980	Shanxi Xiangfen Taosi M3015	M3015:17	Early Taosi culture (ca.2400-2300 BCE)	1	2 crocodile skin drums, 1 pottery drum	ZSKKGS & LFWWJ, 2015
3	1978-1980	Shanxi Xiangfen Taosi M3072	M3072:10	Early Taosi culture (ca. 2400-2300 BCE)	1	1 crocodile skin drum, 1 pottery drum	ZSKKGS & LFWWJ, 2015
4	1978-1980	Shanxi Xiangfen Taosi M3016	M3016:39	Early Taosi culture (ca.2400-2300 BCE)	1	2 crocodile skin drums, 1 pottery drum	ZSKKGS & LFWWJ, 2015
5	1988-1989	Shanxi Xiangfen Daguduishan	-	Taosi culture (ca. 2450-1900 BCE)	1 semi-finished product	-	Tao, 1988
6	1987	Shanxi Wutai Yangbai	87SWYH111:1	Early Longshan culture (ca. 2100-2000 BCE)	1	-	Wang & Jia, 1991
7	1978	Shanxi Wenxi Nansongcun	-	Early Taosi culture (ca. 2400-2300 BCE)	1	-	Li & Han, 1986
8	1983	Henan Yuxian Yanzhai M14	YHY83T11M14	Late Longshan culture (ca. 2400-1900 BCE)	1	-	Kuang & Jiang, 1984
9	1974-1978	Qinghai Ledu Liuwan M1103	M1103:35	Early Qijia culture (ca. 2200-1600 BCE)	1	-	QHWGKGD et al., 1984
10	1976	Gansu Lanzhou Yuzhong Majiawa	-	Qijia culture (ca. 2000-1900 BCE)	1	-	WWDXBJB, 1998

9 Normally, Chinese archaeological excavation report uses M to indicate tomb, for instance, M1 means tomb 1, and M1: 36 is a specimen number of an artefact or a funerary object. The data from tables are all based on scientific excavations.
10 The abbreviation of these sources. See "The abbreviation of institutions in China" in Appendix 2.

2.1.2 The Xia and Shang Chime Stones

Recorded in the second volume *Xia Ben Ji* (Record of the Xia dynasty) in *Shi Ji* (The records of the grand historian, Sima, [145 or 135-90 BCE] 1993), the Xia was an early dynasty in ancient China, which was dated from around 2070-1600 BCE. Archaeological evidence has shown that the capital of the Xia dynasty was located in the area of southern Shanxi and Western Henan (WWDXBJB, 1996a, 2000). Following the Xia, the Shang was the second dynasty, and was divided into early and late periods. Absolute dates are hard to establish, as they vary almost with each scholar. According to the Xia Shang Zhou Duandai Gongcheng (Experts in the project of the Xia, Shang, and Zhou dynasties chronology, 2000), a new dating system has emerged, which I adopt (see table. 1).

Archaeological excavation shows that in the Xia dynasty, the typical representative culture is the Erlitou culture. Erlitou culture (1-4 periods) belonged to the Xia dynasty according to the chronological research project mentioned above. In three separate sites, Shanxi Xiaxian Dongxiafeng, Xiangfen Zhanghuai and Henan Yanshi Erlitou, single chime stones have been found. These chime stones were manufactured using the chipped stone tool method. The Erlitou chime stone has a concave *gu* (the slanting part of the chime stone when it is suspended from a rack) and *guu* part (opposite to the *gu* part); in other stones these two parts are straight. This distinction will be further detailed in Chapter 4, but it is clear that, even in these early periods, there is a developing tradition of particular shaping.

The archaeologically found musical instruments of the Shang dynasty (ca. 1600-1046 BCE) are separately located in the middle and lower river areas in Shaanxi, Shanxi, Inner Mongolia, Henan and Shandong. Moreover, there are several chime stones unearthed in the northern area of the Yellow River—the northern Hebei and western Liaoning province. The early Shang musical instruments mainly appeared in the site of Erligang culture (ca. 1600-1300 BCE). For example, a single chime stone was found in Zhengzhou Xiaoshuangqiao at the site of a large palace building dating to the upper layer of Erligang culture.

Some musical instruments have been excavated from the Lower Xiajiadian culture (the upper limit dated to around 2300 BCE and lower limit to approximately 1600 BCE). The chime stones from this culture had an angular top shape and their date was similar to that of the late Shang dynasty (Fang, 2006). In the late Shang in Anyang, the representative archaeological culture is known as the Yinxu culture, which was mainly found in the Shang capital Yinxu (present day Anyang in Henan) and divided into four historic periods, their chronological sequence is shown below (Jiang, 2001, p. 130):

Yinxu culture	Period I	1260-1235 BCE
Yinxu culture	Period II	1230-1120 BCE
Yinxu culture	Period III	1150-1080 BCE
Yinxu culture	Period IV	1097-1050 BCE

Some Shang dynasty (ca. 1600-1046 BCE) chime stones were found in archaeological sites far from the Central Plain region and this suggests that they belonged to local states or tribes. The single chime stone unearthed from the Lower Xiajiadian culture in western Liaoning, for instance, belonged to the Guzhu 孤竹 state of north-eastern China (Fang, 2006, p. 138). The same archaeological culture also spread across southeast Inner Mongolia, where a single chime stone was also excavated (Zheng & Zhang, 1983). Tomb M4 in Shandong Tengzhou Qianzhangda also contained a single chime stone. M4 is a tomb with two passageways, which possibly had a relationship with the Xue 薛 state (ZSKKGSSDGZD, 1992). According to inscriptional evidence from M4, Shi 史 appears on bronze vessels; Wang Entian argues that the tomb probably belonged to a tribe of Shi (Wang, 2000). These stones appear to be high status items that probably had a meaning to the whole tribe.

Of the Shang (ca. 1600-1046 BCE) chime stones, four were discovered in Liaoning, two in Inner Mongolia, one in Tianjin, five in Shanxi, 27 in Henan, five in Shandong, and one each in Hebei and Shaanxi. It seems that chime stones are largely found in the middle reaches of the Yellow River area during the Shang period, especially in the late Shang capital city Anyang. 27 single chime stones were unearthed in Henan; nearly 90% of all the finds of the Xia and Shang dynasties (table. 3).

At Houjiazhuang Xibeigang in the late Shang capital Anyang, located in the district of late Shang Kings' mausoleum, some large cross-shaped tombs with four passageways contained musical instruments. However, only a few survived due to a large number of tomb robberies (Yang, 2002. fig. 7). In Wuguancun, the contents of tomb WKGM1 included a single chime stone engraved with a tiger motif (fig. 8). In Houjiazhuang, M1217 contained a single chime stone and a drum together with the remains of a chime-rack and drum stand. M1004 contained three chime stones, whereas M1001 only had broken pieces of chime stones accompanied by two ocarinas. Other large tombs such as M1550 only unearthed one ocarina. These tombs belonged to different kings during the late Shang periods (between Yinxu culture II-III).

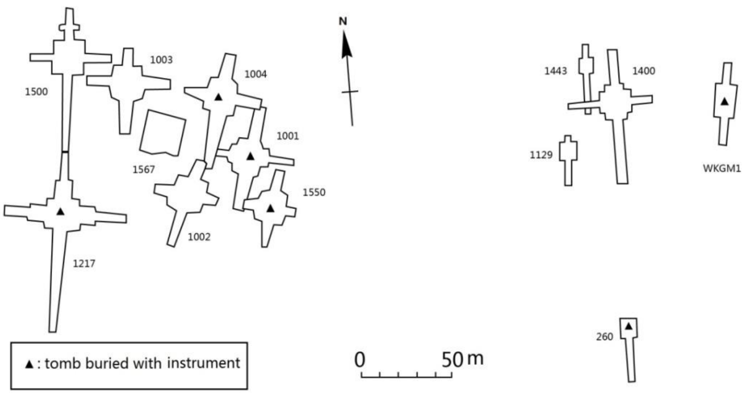


Figure 7. Plan of late Shang kings' mausoleum in Anyang Yinxu.
After Yang Baocheng, 2002, fig. 18. Redrawn by Xueyang Fang.

Figure 8. Chime stone from Henan Anyang Wuguancun WKGM1.
Late Shang dynasty (ca. 1260-1050 BCE). Length: 82.6 cm. After WWDXBJB, 1996a, fig. 1.3.2.

Sites and tombs other than the Kings' mausoleum also contained chime stones. Near the site of the palace building in Anyang Yinxu Huanshui Nan'an, a single chime stone decorated with a dragon image was discovered. Fu Hao, a consort of Shang king Wu Ding, was a military general. Her tomb was a rectangular pit without a tomb passageway, but it contained extremely rich funerary objects including bronze vessels, weapons and musical instruments. Five chime stones, five chime bells and three ocarinas were excavated from Fu Hao's tomb (ca. 1200 BCE. ZSKKGS, 1980); sadly, the poor condition of the chime stones prevents acoustical study. In two singly used chime stones, one is ornamented with an owl-like pattern, another as I mentioned in Chapter 1, was carved with the inscriptions "Renzhu ru Shi" (Renzhu sends stone as a gift; fig. 9). Renzhu is assumed to be the ethnic minority Guzhu, which was associated with the Lower Xiajiadian culture (Cao, 1993).

Figure 9. Chime stone from Fu Hao's tomb.
Late Shang (ca. 1200 BCE). Length: 45 cm. Right: rubbing of inscription. After WWDXBJB, 1996a, fig. 1.3.3.

In the western district of Yinxu, some aristocratic tombs contained musical instruments. Tomb M701 contained one single chime stone, while M93 was a medium-sized tomb with a passageway, from which five chime stones with painted patterns on their surface and a few other artefacts survived (fig. 10). Whereas most chime stones have holes placed so that the stone hangs at an angle, more horizontal than vertical, the Fu Hao chime stone would have hung vertically, as the hole was near one end of the stone.

The finds from tombs of the Shang dynasty (ca. 1600-1046 BCE) provide strong evidence that these bronze bells and chime stones are a part of the ancient court ritual "metal and stone music", showing that this preliminary ritual music system had been established as early as the late Shang period (ca. 1260-1050 BCE).

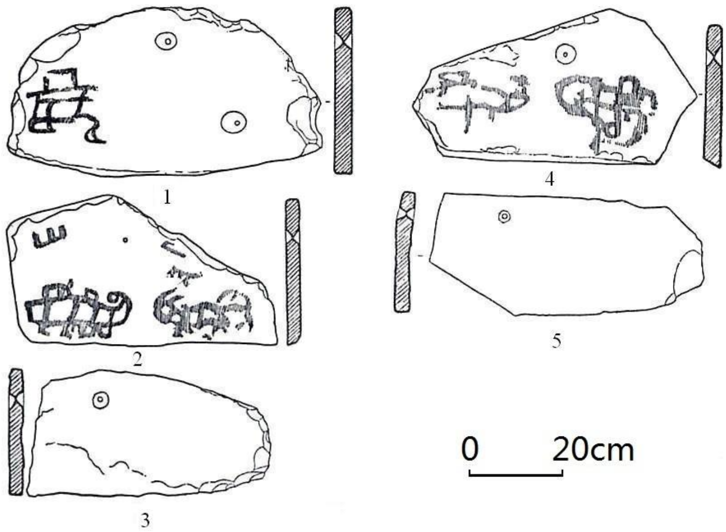


Figure 10. Chime stones from Yinxu Xiqu M93.
Late Shang. 1.M93:2; 2. M93: 5; 3. M93:3; 4. M93:6; 5. M93: 20. After ZSKKGSAYGZD, 1979, p. 103, fig. 78. Redrawn by Xueyang Fang.

Table 3. The Xia and Shang chime stones found in northern China

No.	Excavation Year	Site and/or tomb	Specimen no.	Date	Chime stone	Other musical instruments	Source
1	1974	Shanxi Xiaxian Dongxiafeng	74SW26H15: 60	Dongxiafeng type of Erlitou culture, Xia dynasty	1	-	DXFKGD, 1980
2	1975	Henan Yanshi Erlitou	75YLVIK3: 21	Erlitou culture III, Xia dynasty	1	-	ZSKKGSELTGZD, 1976
3	2003	Shanxi Xiangfen Zhanghuai	H1:1	Xia dynasty	1	-	Xiangfen Museum, 2007
4	1972	Hebei Gaocheng Taixi M112	M112:24	The upper layer of Erligang culture (ca.1300 BCE)	1	-	HBWYS, 1985
5	1990	Henan Zhengzhou Shifoxiang Xiaoshuangqiao	ZSXT189 (3):1	The upper layer of Erligang culture (ca. 1300 BCE)	1	-	HNWYS, 1993
6	1973	Shaanxi Lantian Huaizhenfang	-	The upper layer of Erligang culture (ca. 1300 BCE)	1	-	Fan & Wu,1980
7	2010	Shandong Jinan Daxinzhuang M139	-	Erligang culture	1	-	SDKGX &SDWYS, 2010
8	1971	Henan Anyang Hougang M47	-	Yinxu culture I	1	-	ZSKKGSAYFJD, 1972
9	1950	Henan Anyang Wuguancun M1	WKGM1	Yinxu culture II	1	traces of chime rack	Guo,1951
10	1976	Henan Anyang Xiaotun Fu Hao's tomb AXTM5	AXTM5:2, 316, 332, 1595, 1596	Yinxu culture II	5	3 clay ocarinas, 5 chime bells	ZSKKGS, 1980
11	1984	Henan Anyang Wuguancun M260	-	Yinxu culture II	1	-	ZSKKGSAYFJD, 1987
12	1935	Henan Anyang Houjiazhuang Xibeigang	HPKM1001	Yinxu culture II	broken pieces	1 clay ocarina, 1 bone ocarina, traces of chime rack	Liang & Gao, 1962

No.	Excavation Year	Site and/or tomb	Specimen no.	Date	Chime stone	Other musical instruments	Source
13	1990	Henan Anyang Yinxu Xiqu Dasikongcun M991	ASM991:20	Yinxu culture II	1	-	WWDXBJB,1996a
14	1980	Henan Anyang Dasikongcun M539	ASM539:11	Yinxu culture II	1	-	WWDXBJB,1996a
15	2001	Henan Anyang Huayuanzhuang M54	M54:207	Yinxu culture II	1	3 chime bells	ZSKKGSAYGZD, 2004
16	1935	Henan Anyang Houjiazhuang Xibeigang	HPKM1217:R1754	Yinxu culture III	1	1 drum with drum stand, 1 chime stone rack	Liang & Gao, 1968
17	1935	Henan Anyang Houjiazhuang Xibeigang	HPKM1004	Yinxu culture III	3	-	Liang & Gao, 1970
18	1976	Shandong Qingzhou Subutun M8	-	Yinxu culture III	1	3 chime bells	SDWYS et al., 1989
19	1990	Henan Anyang Guojiazhuang M160	M160:6	Yinxu culture III	1	3 chime bells	ZSKKGS, 1998
20	1973	Henan Anyang Xiaotuncun Huanshui	-	Yinxu culture III	1	-	ZSKKGSAYFJD, 1976
21	1991	Shandong Tengzhou Qianzhangda M4	M4:97	Yinxu culture IV	1	1 *ling* clapper-bell, 2 crocodile skin drums	ZSKKGSSDGZD, 1992
22	1991	Shandong Tengzhou Qianzhangda M203	-	Yinxu culture IV	1	1 *ling* clapper-bell	ZSKKGSSDGZD, 1992
23	1991	Shandong Tengzhou Qianzhangda M210	-	Yinxu culture IV	1	1 *ling* clapper-bell, 2 crocodile drums	ZSKKGSSDGZD, 1992
24	1977	Henan AnyangYinxu Xiqu M701	M701:72	Yinxu culture IV	1	-	ZSKKGSAYGZD,1979
25	1977	Henan Anyang Yinxu Xiqu M93	M93:2, 3, 5, 6, 20	Yinxu culture IV	5	-	ZSKKGSAYGZD,1979
26	1976	Shanxi Lingshi Jingjie M1	76LJM1:13	Yinxu culture IV	1	1 broken crocodile skin drum	SXKGS, 1986

No.	Excavation Year	Site and/or tomb	Specimen no.	Date	Chime stone	Other musical instruments	Source
27	1976	Shanxi Lingshi Jingjie M3	-	Yinxu culture IV	1	-	Dai & Liu, 1980
28	1987	Henan Anyang Angang Zhongban M1769	87AGM1769: 1	late Shang	1	-	WWDXBJB, 1996a
29	1978	Henan Anyang Houjiazhuang Beidi	AHBM1	Yinxu culture	Unknown	-	ZSKKGSAYGZD, 1982
30	1959	Henan Anyang Xiaotun Xidi M258	-	Late Shang	1	-	ZSKKGS, 1987
31	1990	Shanxi Pinglu Qianzhuang	-	Late Shang	1	-	WWDXBJB, 2000
32	1965	Tianjin Zhangjiayuan	-	From late Shang to Western Zhou	1	-	Liang & Mei， 2012
33	1978	Liaoning Jianping Shuiquan	-	Lower Xiajiadian culture	1	-	Fang, 2006
34	1997	Liaoning Beipiao	-	Lower Xiajiadian culture	1	-	Fang, 2006
35	1996	Kalaqin Dashanqian (Inner Mongolia)	-	Lower Xiajiadian culture	1	-	ZSKKGS, CFD, NMWYS & JDKGX,
36	1977	Kalaqin Xifu (Inner Mogolia)	-	Lower Xiajiadian culture	1	-	Zheng & Zhang, 1983
37	1980	Liaoning Jianping Kalaqin Hedong	-	Lower Xiajiadian culture	1	-	LNSBGZD & CYBWGWWZ et al.,
38	1978	Liaoning Jianchang Erdaowanzi Dongnangou	-	Lower Xiajiadian culture	1	-	Feng & Deng, 1983

2.1.3 The Western Zhou Chime Stones

Located in the Central Plain region of China, the area now known as Fufeng Zhouyuan (Shaanxi) was the political centre of the Western Zhou dynasty (1046-771 BCE). There are relatively few discoveries of chime stones belonging to the early period of the Western Zhou, while more chime stones have been archaeologically excavated dating from the middle to late Western Zhou period. Western Zhou musical instruments are located primarily in the middle and lower areas of the Yellow River. Some chime stones unearthed in Shaanxi, Shanxi, Henan, and Shandong provinces are preserved well enough for study of their musical properties through sound experimentation.

The Western Zhou chime stones were mainly distributed in the Shaanxi region, however, only a few aristocratic tombs have been excavated from the Zhou central realm, with at least ten chime stones found in Fufeng, Chang'an and Qishan (table. 4). Because of looting, only tombs in Chang'an Zhangjiapo contained chime stones and bronze bells. In other states such as the Ce and Rui some chime stones and other musical instruments have survived. In Chang'an Zhangjiapo, the cemetery of the Jingshu (or Xingshu) family contained some musical instruments, including three bronze bells and some broken chime stones excavated from M163; with the bell inscriptions showing the tomb occupant was a wife of Jingshu. Other Jingshu family tombs (M157, M152 and M170) also featured chime stones, but without additional musical instruments (fig. 11), unfortunately their poor condition prevents making sound recordings of them.

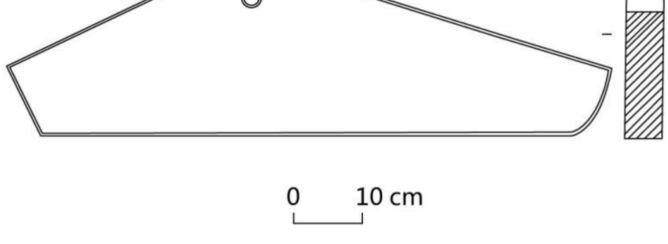


Figure 11. Chime stone from Jingshu family tomb (M157: 81).
Late Western Zhou (877-771 BCE). After ZSKKGS et al., 1999, fig. 228-8. Redrawn by Xueyang Fang.

From Changzikou's tomb (fig. 12) in Henan Luyi Taiqinggong, one triangular-shaped chime stone was excavated with six small musical bells (usually called *nao* 鐃 or occasionally *yong* 庸)[11] and five bone panpipes dating to the early Western Zhou period (1046-977 BCE. fig. 13). The tomb has two passageways and contained very rich funeral objects including ritual vessels such as the bronze *ding* 鼎 (a cooking vessel with three tripods), *jue* 角 (three legged wine cup) and *hu* 壺 (wine vessel), suggesting that the tomb occupant was a noble man and a chief leader of the Chang state.

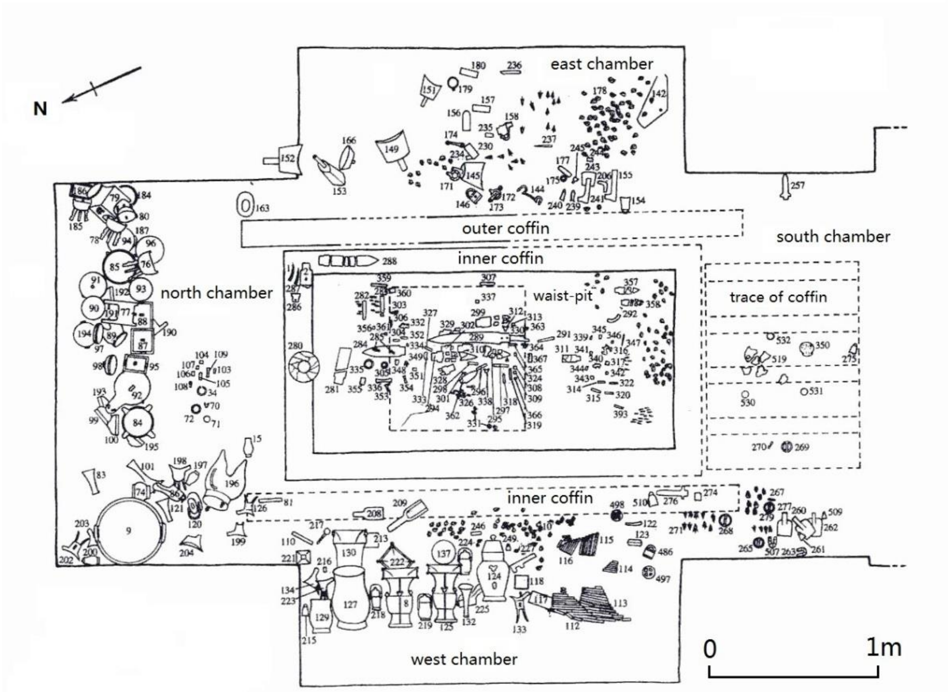


Figure 12. **Diagram of Changzikou's tomb.**
Early Western Zhou (1046-977 BCE). Chime stone (no. 142). After HNWYS et al., 2000, p. 16, fig. 10. Redrawn by Xueyang Fang.

11 Li Chunyi explains that the late Shang small chime bells found in Anyang were likely named yong 庸 according to information from oracle bone inscriptions and the classic poem *Shi Jing*, while their large counterpart found in southern China such as Hunan, Jiangxi, Anhui, and so forth was called yong 鏞, both are the same pronunciation in *Pinyin* system but different Chinese characters.

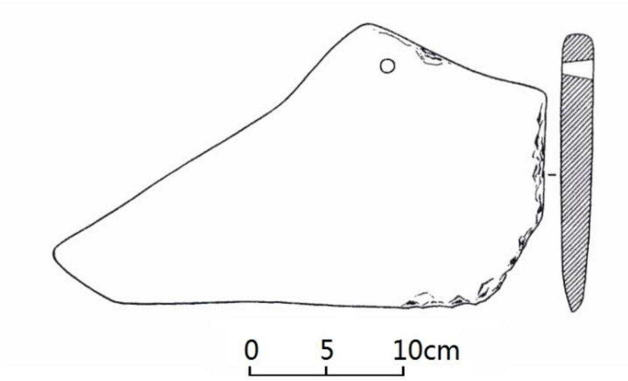


Figure 13. Chime stone from Changzikou's tomb.
Early Western Zhou (1046-977 BCE). Height: 18.2 cm. After HNWYS et al., 2000, p. 182, fig. 151. Redrawn by Xueyang Fang.

Other Western Zhou (1046-771 BCE) tombs in the neighboring provinces of Shaanxi, such as the cemetery of Marquis Jin in Shanxi Tianma Qucun, the Guo state cemetery in Henan Sanmenxia, the Wei sate tomb in Henan Xunxian Xincun, and the Ying state tomb in Henan Pingdingshan have included many chime stones.

Dating from early Western Zhou (1046-977 BCE) to the end of late Western Zhou (877-771 BCE), several tombs in the cemetery of Marquis Jin in Shanxi Tianma Qucun contained musical instruments including musical bells and chime stones (fig. 14). Five tombs (M33, M91, M64, M8 and M93) included chime stones as part of funerary artefacts (fig. 15), and additional instruments such as bronze bells as well as singly appearing bronze *zheng* 鉦 (a long-shanked mallet-struck bell). All tombs with musical instruments had one or two passageways except M33; tomb M93 with two passageways was dated later than other tombs.

The extremely rich paraphernalia from a Marquis tomb M93 demonstrates the wealth of the deceased; it consists of two sets of chime bells (each set has eight bells) and ten chime stones. In tomb M64, a set of eight chime bells belonging to the Chu state, accompanied by 16 chime stones and one bronze *zheng*, have been found. The tomb M91 was a large tomb with a single tomb passage of 20 metres in length; buried within the tomb were approximately 20 chime stones, seven chime bells as well as bronze ritual vessels such as *ding*, *dou* and plates. In Marquis Su's tomb (M8), ten chime stones and 16 chime bells were found, bell inscriptional evidence showing that the tomb occupant was Su, a Marquis of the Jin state. In brief, the occupants of those five tombs belonged respectively to different generations of the local ruler—the Marquis Jin.

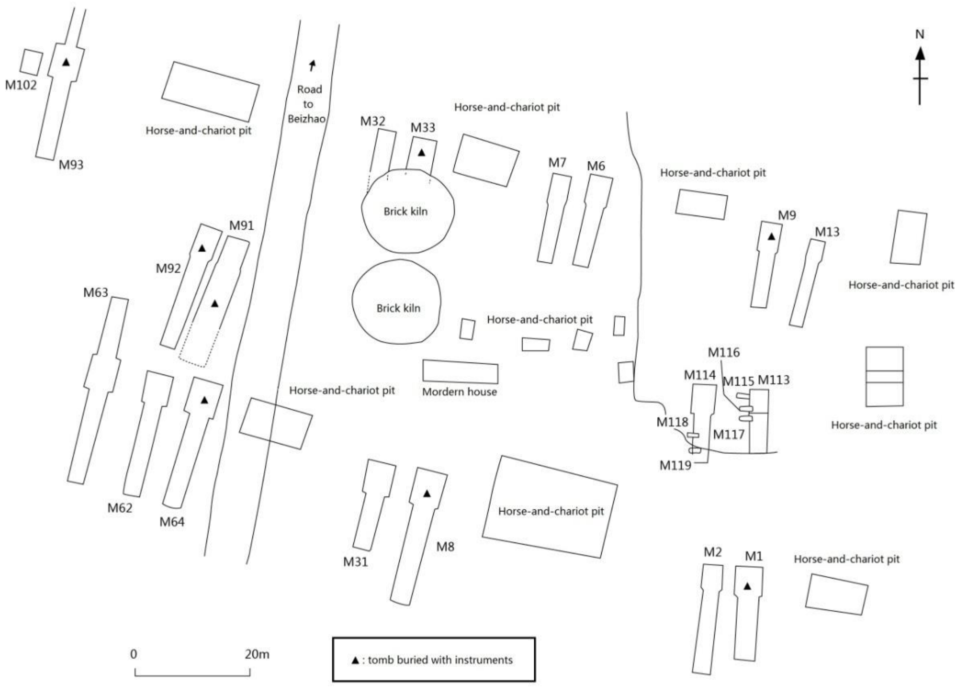


Figure 14. Plan of the cemetery of Marquis Jin in Tianma Qucun.
After BDKGXX & SXKGS, 2001, p. 4, fig. 1. Redrawn by Xueyang Fang.

Figure 15. Chime stone from tomb M8 of Marquis Su of the Jin state.
Late Western Zhou (877-771 BCE). Length: 49 cm. After WWDXBJB, 2000, fig. 1.2.1b.

Two Monarch’s tombs M2001 and M2009 of the Guo state found in Henan Sanmenxia Shangcunling all included bronze chime bells, bronze *zheng* and chime stones (fig. 16). By this point the stones are more carefully and regularly shaped than the earlier examples of irregular shape, and often with carefully crafted lines. With ten chime stones in M2001 and 20 in M2009, the occupants of the tombs were Guo Zhong (M2009) and Guo Ji (M2001) respectively, and the tombs dated to the late Western Zhou dynasty (877-771 BCE). In another Guo state tomb M2011 (fig. 17), 18 chime stones and one bronze *zheng* were recovered (fig. 18), the tomb belonged to a prince of Guo state and was dated to the end of the Western Zhou period.

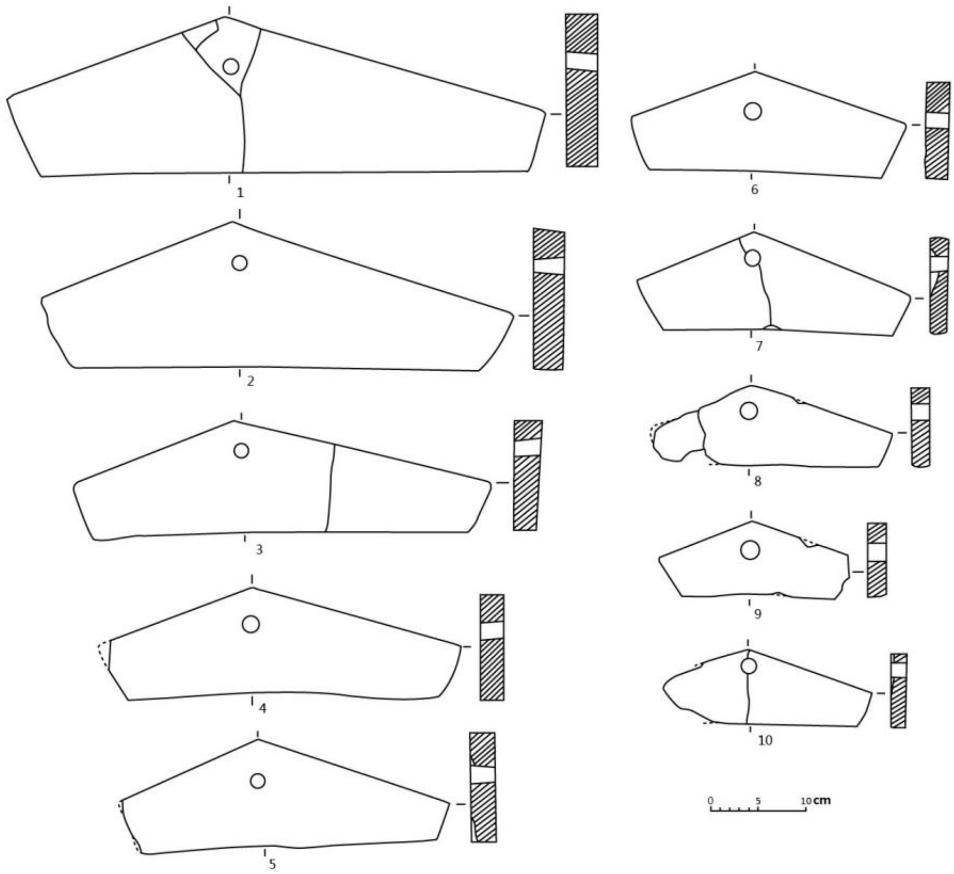


Figure 16. Chime stones from Sanmenxia Guo state tomb M2001.
Late Western Zhou (877-771 BCE). Length: 20.6-58 cm. After HNWYS et al.,1999, p. 200, fig. 153. Redrawn by Xueyang Fang.

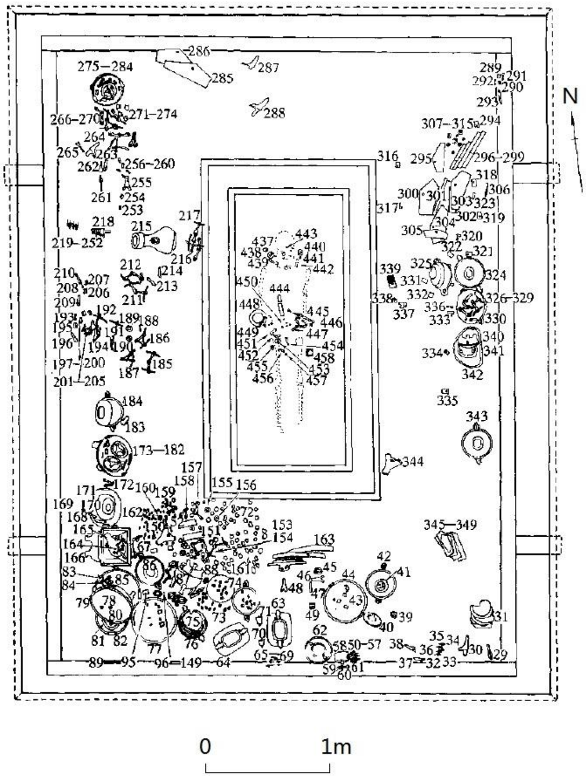


Figure 17. Diagram of Sanmenxia Guo state tomb M2011.
Late Western Zhou (877-771 BCE). Chime stones (no. 285, 286, 300, 295, etc). After HNWYS et al., 1999, p. 322. fig. 219.

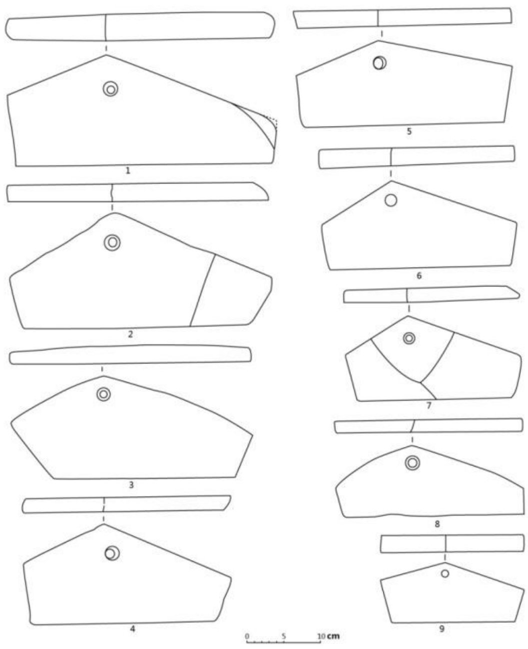


Figure 18. Chime stones from Sanmenxia Guo state tomb M2011.
Late Western Zhou (877-771 BCE). Length: 20.8-38.4 cm. After HNWYS et al.,1999, p. 371, fig. 259. Redrawn by Xueyang Fang.

The chime stones from tombs M27 and M28 of the Rui state cemetery in Shaanxi Hancheng Liangdaicun should also be considered as late Western Zhou (877-771 BCE) remains (fig. 19), since they are shaped with the straight base that was a specific feature of chime stones belonging to this period, although the excavators assumed they were later, from the beginning of early Spring and Autumn period (770-686 BCE. fig. 20). With two passageways to the south and north of the central area, M27 was the largest tomb in the cemetery, others including M28 were smaller than M27 with one passageway. Tomb M27 contained many bronze ritual vessels, weapons, chariot fittings, ironware, gold vessels and jade artefacts. The musical instruments found included eight musical bells, seven bell hooks, ten chime stones, one *zheng*, one *chunyu* 錞於[12], one *jiangu* 建鼓 (pole drum) and one small drum. An inscribed bronze *gui* 簋 (a round-mouthed food vessel) has the word "Rui duke made this *gui* for travel", suggesting that the tomb occupant was a ruler entitled "duke" of the Rui state. Tomb M28 contained bronze vessels, weapons, chariots and many practical items; the musical instruments included eight chime bells with eight hooks, ten chime stones and a *sheng* 笙 (mouth organ), as well as additional fittings comprising the remains of racks for the bells and chime stones. According to the archaeological excavation report, the date of tomb M28 was later than M27; the owner of M28 was probably a duke of Rui state, which was a generation after M27.

The data from table 4 show a majority of finds of chime stones in the middle and lower reaches of the Yellow River area, including Shaanxi, Henan, Shanxi and Shandong. Especially in the Central Plain regions such as Shaanxi, Shanxi and Henan, a large number of chime stones have been excavated, around 60 are distributed in Shaanxi, more than 55 in Shanxi, over 50 in Henan, and only one in Shandong. The chime stones listed in the table include broken pieces and restored examples. These stones are found

12 *Chunyu* is a class of mallet-struck bronze bell with oval cross-section and bulging manufactured in ancient China.

in increasingly elaborate graves, belonging to very high status individuals.

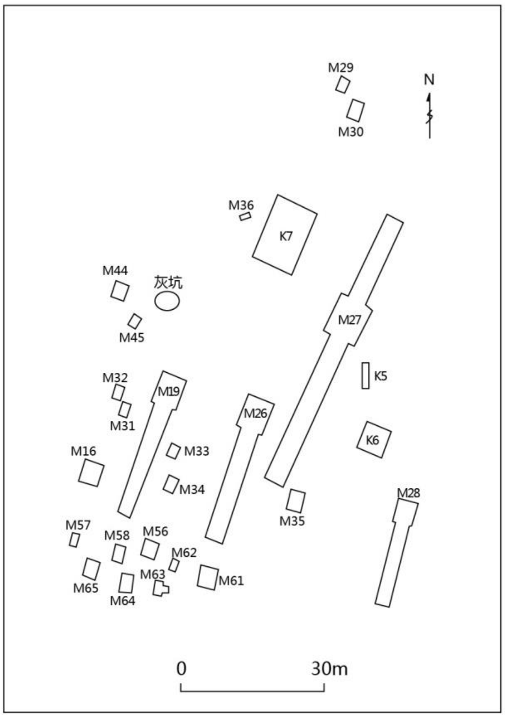


Figure 19. Plan of the Rui state cemetery in Hancheng Liangdaicun.
Late to early Spring and Autumn (770-686 BCE). After SXKGYJY & WNKGBHS, 2007, p.3. fig. 1. Redrawn by Xueyang Fang.

Figure 20. Chime stone from Hancheng Liangdaicun M27.
Late Western Zhou (877-771 BCE). length: 49.5 cm. Photo by Fang Jianjun.

Table 4. The Western Zhou chime stones found in northern China

No.	Excavation year	Site and/or tomb	Date	State	Chime stone	Other musical instruments	Source
1	1973-1974	Henan Luoyang Beiyao M14	Early Western Zhou	Unknown	1	-	Luoyang City Museum, 1981
2	1997	Henan Luyi Taiqinggong M1 (Changzikou's tomb)	Early Western Zhou, king Cheng period	Chang	1	6 chime bells, 5 bone panpipes	HNWYS et al., 2000
3	1965	Shandong Jiaoxian Zhangjiazhuang	Middle Western Zhou	Unknown	1	-	WWDXBJB, 2001
4	1987	Shaanxi Fufeng Qizhen	Middle Western Zhou	Zhou	1	-	WWDXBJB, 1996b
5	1994	Shanxi Tianma Qucun M33	Middle Western Zhou, Xiao-Yi period (891-878 BCE)	Jin	Approx. 10	-	BDKGXX et al.,1995
6	1984	Shaanxi Chang'an Zhangjiapo M152	Middle Western Zhou, Gong-Yi-Xiao period	Probably Zhou	4	-	ZSKKGS et al., 1999
7	1980	Shaanxi Fufeng Zhouyuan Shaochen Yiqu	Mid- to late Western Zhou	Zhou	15 (3 have been restored)	-	Luo, 1987
8	1986	Henan Pingdingshan M95	Late Western Zhou	Ying	4 broken	7 chime bells, 9 *ling* clapper-bells	HNWYS, 1992
9	1932	Henan Xunxian Xincun M24	Late Western Zhou	Wei	2	-	Guo, 1964
10	1984	Shaanxi Chang'an Zhangjiapo M157	Late Western Zhou	Probably Zhou	5 (only 2 remain)	-	ZSKKGS et al., 1999
11	1984	Shaanxi Chang'an Zhangjiapo M163	Late Western Zhou	Probably Zhou	several broken pieces	3 chime bells	ZSKKGS et al., 1999
12	1969	Shaanxi Baoji Jiacunyuan Shangguancun	Late Western Zhou	Ce	more than 10 pieces, but only 1 extant	-	Lu & Yi, 1982

No.	Excavation year	Site and/or tomb	Date	State	Chime stone	Other musical instruments	Source
13	1982	Shaanxi Fufeng Huangdui Yuntang	Late Western Zhou	Zhou	1	-	Luo, 1987
14	1984	Shaanxi Chang'an Fengxi M17	Late Western Zhou, Zhao-Mu period	Zhou	1broken	-	ZSKKGSFXFJD, 1987
15	1973	Shaanxi Qishan Hejiacun M1	Late Western Zhou, Wu-Cheng period	Zhou	1broken	-	Shaanxi Provincial Museum et al.,1976
16	1990	Henan Sanmenxia Shangcunling M2001(Guo Ji)	Late Western Zhou, Xuan-You period	Guo	10	8 chime bells,1 *zheng*	HNWYS et al.,1999
17	1990	Henan Sanmenxia Shangcunling M2009 (Guo Zhong)	Late Western Zhou, king Xuan period	Guo	20	16 chime bells	HNWYS et al.,1999
18	1990	Henan Sanmenxia Shangcunling M2011(Guo Taizi)	Late Western Zhou, Xuan-You period	Guo	18 broken	1 *zheng*	HNWYS et al.,1999
19	1992	Shanxi Tianma Qucun M1	Late Western Zhou	Jin	2	-	BDKGXX et al., 1993
20	1994	Shanxi Tianma Qucun M91	Late Western Zhou, king Li period	Jin	Approx. 20	7 chime bells	BDKGXX et al., 1995
21	1993	Shanxi Tianma Qucun M64	Late Western Zhou, king Xuan period	Jin	Approx. 16	8 chime bells, 1 *zheng*	SXKGS et al.,1994b
22	1992	Shanxi Tianma Qucun M8	Late Western Zhou, king Xuan period	Jin	10 (6 complete)	16 chime bells	BDKGXX et al.,1994a
23	1994	Shanxi Tianma Qucun M93	Late Western Zhou, You-Ping period	Jin	10	16 chime bells	BDKGXX et al., 1995
24	1999	Shaanxi Fufeng Yuntang	Late Western Zhou	Zhou	1	-	ZYKGD, 2002

No.	Excavation year	Site and/or tomb	Date	State	Chime stone	Other musical instruments	Source
**25[13]	2005-2007	Shaanxi Hancheng Liangdaicun M27	Late Western Zhou	Rui	10	8 chime bells, 1 *zheng*, 1 *chunyu*, 1 pole drum, 1 small drum	SXKGYJY et al., 2007
26	2005-2007	Shaanxi Hancheng Liangdaicun M28	Late Western Zhou	Rui	10	8 chime bells, 4 wooden chime racks	SXKGYJY et al., 2007
27	1971	Henan Xichuan Longcheng Xiawanggang	Western Zhou	Unknown	2	-	WWDXBJB,1996a
28	2004	Shaanxi Qishan Zhougongmiao M18	Western Zhou	Zhou	1	-	Xu, 2006

13 * my fieldwork data (Some data from my fieldwork do not have archaeological context information thus will be stated in the rest of contents). ** chime stones which I have observed.

2.1.4 The Eastern Zhou Chime Stones

After the Western Zhou (1046-771 BCE), the Eastern Zhou (770-256 BCE) moved its capital from Shaanxi to Henan Luoyang. The Eastern Zhou was subdivided into two periods, the Spring and Autumn (770-476 BCE), and the Warring States (475-221 BCE), during which some vassal states were located along the Yellow River basin. In the first half of the Eastern Zhou times, the vassal states were competing for political power for more than two hundred years; that period was historically described as the “Spring and Autumn”. In the second half of the Eastern Zhou era, the emperor of the Zhou dynasty (Zhou Tianzi) had gradually lost his political power, hence the “Warring States” period came about (Sima, [145 or 135-90 BCE] 1993).

There are 54 tombs distributed in the Yellow River basin during the Eastern Zhou period. The chime stones found in this area belonged to different vassal states located in present Shaanxi, Shanxi, Henan, Hebei, and Shandong. Among them, more than half of the tombs dated to the Warring States (475-221 BCE), others belonged to the Spring and Autumn period (770-476 BCE, see details in table. 5).

In Gansu Lixian Dapuzishan Qin Gong cemetery, a sacrificial pit (K5) dating to early Spring and Autumn (770-686 BCE) contained only musical instruments without any other artefacts accompanying them, excavators therefore named it as a “musical instrument pit”. From this pit, eight chime bells, three *bo* (large bell), ten chime stones and accessories such as bell hooks and chime racks have been excavated. Bronze bells and chime stones were buried in an ordered manner along two lines running from west to east. Bells were in the south line and the chime stones in the north in two groups, each of five (fig. 21); a likely indication of how they would have been laid out for performance. The inscriptional evidence on the *bo*-bells shows that the owner of those instruments was a duke of the Qin state. All instruments are preserved in good condition to afford the possibility of undertaking further studies of their musical capabilities and acoustic properties.

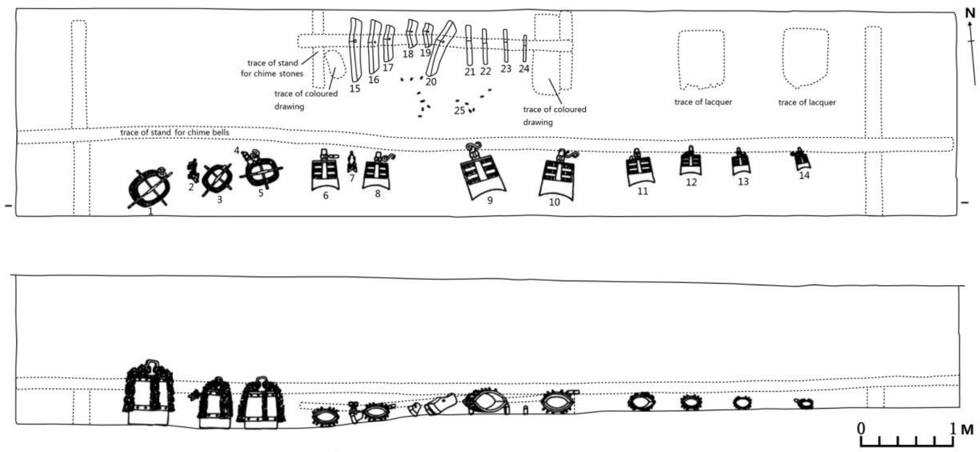


Figure 21. Plan and cross-section of a musical instrument pit from Lixian Dapuzishan. Early Spring and Autumn (770-686 BCE). After EQJT, 2008, p. 25, fig. 27. Redrawn by Xueyang Fang.

Shaanxi Fengxiang Nanzhihui Qin Gong No.1 tomb contained many large-sized chime stones, including 26 with inscriptions (fig. 22); unfortunately, most of them were broken into pieces. The 190 inscriptional words mentioned Qin Jing Gong 秦景公, a ruler of the Qin state, who made a sacrifice to the king of the Zhou court and reigned from around 576-537 BCE (Hao & Hao, 2007). Dating to the beginning of the late Spring and Autumn period (546-476 BCE), archaeologists believe that the tomb occupant was Qin Jin Gong, and the date of the tomb was around 537 BCE.

Figure 22. Rubbing of chime stone inscriptions (M1:579) found in Qin Gong no. 1 tomb. Mid- to late Spring and Autumn (685-476 BCE). After WWDXBJB, 1996b, fig. 1.3.6j.

Zhou tombs found in Luoyang contained a number of chime stones, for example, ten chime stones dating to late Spring and Autumn (546-476 BCE) were unearthed from a tomb in Luoyang Zhongzhou Daqu (fig. 23), and over 80 chime stones dating to the Warring States period (475-221 BCE) from tombs (M7984, M7983) in Luoyang Tanggong Xilu. All other chime stones from Luoyang belonged to the Warring States period, for instance, chime stones respectively excavated from tombs in Jincun, Erqingju M131[14], Xigong M4, Jiefanglu C1M395, Baihuogongsi M1 and M2621, and Wangcheng Guangchang M190 (see details in table. 5).

Figure 23. Chime stones from Luoyang Zhongzhou Daqu.
Late Spring and Autumn (546-476 BCE). Length: 25.1-55 cm. Photo by Xueyang Fang.

Besides the Zhou state tombs found in Luoyang, other Eastern Zhou (770-256 BCE) tombs in Henan represent various vassal states. From the tombs of the Ying state in Henan Pingdingshan, chime bells with chime stones are only seen in several Monarch's tombs, and some of these vassal states tombs have chime stones buried without chime bells. For instance, 13 chime stones have been excavated from M25 and M11 respectively without other accompanying musical instruments.

Chime stones from four Wei state tombs have been uncovered: Henan Hebi Qixian Songzhuang M4 (fig. 24), Jixian Shanbiaozhen M1 and Shaanxian Houchuan M2040 and M2041. Among those tombs, the latter two have ten chime stones each. Qixian Songzhuang M4 was a large-sized tomb with one tomb passage; the base measured 4.40 metres by 4.20 metres (HNWYS, 2015). In it were buried nine chime stones and eight chime bells, while Shanbiaozhen M1 contained ten chime stones and 14 bronze bells.

14 The tomb M131 is a rectangular shape of 4.2 metres in length and 3.4 metres width. Six chime stones are buried in the northeast corner of the chamber.

Figure 24. Chime stones from Qixian Songzhuang M4.
Late Spring and Autumn (546-476 BCE). Length: 24-55.7 cm. Photo by Xueyang Fang.

Chu state tombs have been archaeologically excavated in the southern part of Henan, including the Xichuan Xiasi tomb (M1, M2 and M10), the Heshangling tomb (M1 and M2), the Yexian tomb (M4) and the Shangcai Guozhuang tomb. In these tombs, chime stones are commonly in a set of 13, Xichuan Xiasi M2 is a typical example (fig. 25).

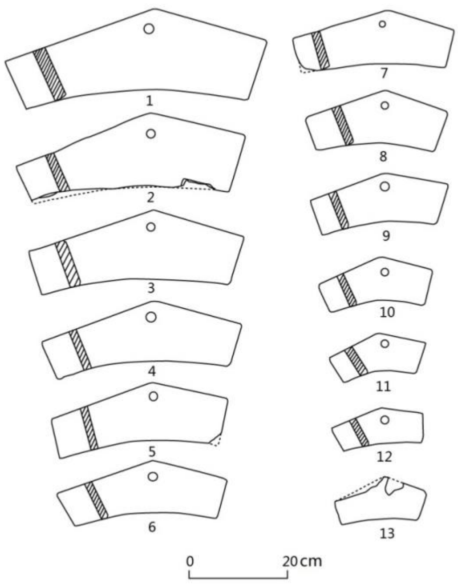


Figure 25. Chime stones from Xichuan Xiasi M2.

Mid- to late Spring and Autumn (685-476 BCE). Length: 13.6-56 cm. After HNWYS & DJWFD et al., 1991, p. 196, fig. 147. Redrawn by Xueyang Fang.

Other vassal states such as the Jin state in Shanxi, the Qi, Teng, Jiang, Shi 邿[15], and Ju state in Shandong, Yan and Zhongshan state in Hebei show that the distribution of chime stones is geographically widespread across the region (see table. 5), illustrating

15 In order to distinguish from the previous Shi 史 tribe, I marked in different Chinese character.

the extensive tradition of "metal and stone music" in ancient times.

Following the Western Zhou period (1046-771 BCE), the Jin state continued to build its capital in the Shanxi area, from where chime stones were excavated. Jin state chime stones have been found in Houma, Changzhi, Taiyuan, Wenxi, Linyi, Jiaokou, Xiangfen and Yicheng. In particular, the two cemeteries of the Jin state in Houma Shangma and Changzhi Fenshuiling had important music archaeological finds. Tombs M13 (fig. 26), M1004 and M5218 contained sets of ten-part chime stones (fig. 27), two tombs have nine bronze bells, whereas M5218 features 13 bells (nine *niuzhong*-bells and four *bo*-bells). The tombs are filled with extensive funerary objects, which included ritual bronzes, jade artefacts, chariot fittings and household utensils, M13 even featured bronze weapons, leading to the suggestion that the tomb's occupants were members of nobility.

The most dramatic feature of finds distribution is that the chime stones were principally concentrated in the Central Plain area around the Zhou cultural circle. However, chime stones have also been found in some other vassal states, notably those from Shandong, northeast China, suggest that the considerable popularity of chime stones was concentrated in the middle and lower region of Yellow River valley during the Eastern Zhou times (770-256 BCE).

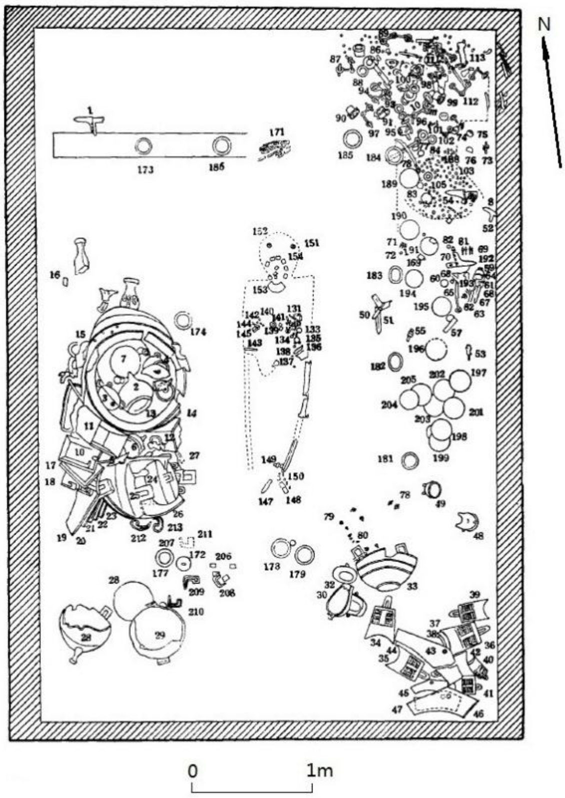


Figure 26. **Diagram of Houma Shangma M13.**
Mid- to late Spring and Autumn (685-476 BCE). Chime stones and bells are at the lower right corner. After SSWGHHMZ, 1963, p. 234, fig. 7.

Figure 27. Chime stones from Houma Shangma M1004.
Mid- to late Spring and Autumn (685-476 BCE). After WWDXBJB, 2000, fig. 1.2.8.

Table 5. The Eastern Zhou chime stones found in northern China

No.	Excavation year	Site and/or tomb	Date	State	Chime stone	Other musical instrument	Source
1	1995	Shandong Changqing Xianrentai M6	Early Spring and Autumn	Shi	10	11+9 chime bells, 2 chime racks	SDKGX, 1998
2	1994-2006	Gansu Lixian Dapuzishan K5	Early Spring and Autumn	Qin	10	wooden chime racks, 3+8 chime bells	EQARG, 2007
3	1975	Shandong Junan Dadian M2	Middle Spring and Autumn	Ju	12 (5 restored)	9 chime bells	Shandong Provincial Museum et al., 1978
4	1978	Henan Xichuan Xiasi M1	Mid- to late Spring and Autumn	Chu	13	9 bells, 1 stone-made panpipe	HNWYS, DJWFD et al., 1991
5	1978	Henan Xichuan Xiasi M2	Mid- to late Spring and Autumn	Chu	13	26+18+8 chime bells	HNWYS, DJWFD et al., 1991
6	1978	Henan Xichuan Xiasi M10	Mid- to late Spring and Autumn	Chu	13	8 + 9 chime bells	HNWYS, DJWFD et al., 1991
7	1961	Shanxi Houma Shangmacun M13	Mid- to late Spring and Autumn	Jin	10	9 chime bells	WWDXBJB, 2000
8	1961	Shanxi Houma Shangmacun M5218	Mid- to late Spring and Autumn	Jin	10	13 chime bells	SXKGS, 1994
9	1961	Shanxi Houma Shangmacun M1004	Mid- to late Spring and Autumn	Jin	10	9 chime bells	SXKGS, 1994
10	1987-1989	Shanxi Linyi Chengcun M1001	Mid- to late Spring and Autumn	Jin	10	9 chime bells	ZSKKGS, SXKGS et al., 2003
11	1987-1989	Shanxi Linyi Chengcun M1002	Mid- to late Spring and Autumn	Jin	10	9+4 chime bells	ZSKKGS, SXKGS et al., 2003
12	1986	Shaanxi Fengxiang Nanzhihui Qin Gong No.1 tomb	Mid- to late Spring and Autumn (537 BCE)	Qin	28 (most broken)	-	Hao & Hao, 2007.
13	1995	Shandong Changqing Xianrentai M5	Late Spring and Autumn	Shi	14	9 chime bells	SDKGX, 1998

No.	Excavation year	Site and/or tomb	Date	State	Chime stone	Other musical instrument	Source
*14	2009-2010	Henan Hebi Qixian Songzhuang M4	Late Spring and Autumn	Wei	9	8 chime bells	HNWYS, 2015
15	2012	Shandong Yishui Jiwanggu M1	Late Spring and Autumn	Probably Jiang	10	9+9+4 chime bells, 2 *chunyu*	SDWYS, 2013
16	1958	Shanxi Wanrong Miaoqiancun M1	Late Spring and Autumn	Probably Wei	10 (5 extant)	9 chime bells	WWDXBJB, 2000
17	1978	Shandong Tengzhou Jiangtunzhen Zhuanglixicun	Late Spring and Autumn	Teng	13 (11 extant)	4+9 chime bells	WWDXBJB, 2001
18	1990	Henan Xichuan Heshangling tomb M1	Late Spring and Autumn	Chu	9 (only one complete)	-	WWDXBJB, 1996a
19	1990	Henan Xichuan Heshangling tomb M2	Late Spring and Autumn	Chu	12	9+8 chime bells	WWDXBJB, 1996a
20	Unknown	Henan Pingdingshan M25	Late Spring and Autumn	Ying	13	-	WWDXBJB, 1996a
21	Unknown	Henan Pingdingshan M11	Late Spring and Autumn	Ying	13	-	WWDXBJB, 1996a
*22	1958	Henan Luoyang Zhongzhou Daqu	Late Spring and Autumn	Zhou	10	-	ZSKKGS,1959
**23	1988	Shanxi Taiyuan Jinshengcun M251	Late Spring and Autumn	Jin	13(most broken)	5+14 chime bells	SXKGS et al., 1989
**24	1972	Shanxi Changzhi Fenshuiling M269	Late Spring and Autumn or the early Warring States	Jin	10	9+9 chime bells	Shanxi Changzhi City Museum et al., 1974
**25	1972	Shanxi Changzhi Fenshuiling M270	Late Spring and Autumn or the early Warring States	Jin	11	8+9 chime bells	Shanxi Changzhi City Museum et al., 1974
**26	1965	Shanxi Changzhi Fenshuiling M126	Late Spring and Autumn or the early Warring States	Jin	16	1 complete chime bell	Bian, 1972

No.	Excavation year	Site and/or tomb	Date	State	Chime stone	Other musical instrument	Source
27	1965	Shandong Linzi Yujiazhuang	Spring and Autumn	Probably Qi	12	-	WWDXBJB, 2001
28	2002	Henan Yexian Jiuxian M4	Spring and Autumn	Chu	15	37 chime bells	PDSWGJ&YXWHJ, 2007
29	2017	Shaanxi Chengcheng Liujiawa M1	Spring and Autumn	Rui	10	chime bells, drum	Chong, 2019
30	2017	Shaanxi Chengcheng Liujiawa M2	Spring and Autumn	Rui	Approx. 10	clay ocarina, chime bells, drums	Chong, 2019
31	1977	Shandong Yishui Liujiadianzi	Spring and Autumn	Ju	Most broken, only 1 complete	-	WWDXBJB, 2001
32	1940	Henan Luoyang Jincun	Early Warring States	Zhou	3	-	Yu, 1940
33	2005-2006	Henan Shangcai Guozhuang tomb	Early Warring States	Chu	10+13 chime stones	chime bells	Xu, 2012
34	1988	Henan Xinyang Xibeicun	Early Warring States	Chu	13	5+9 chime bells	WWDXBJB, 1996a
35	1983	Shanxi Lucheng Luhe M7	Early Warring States	Han	10	16+ 4+8 chime bells	SXKGS et al., 1986
36	1979	Shanxi Houma Xintian M302	Early Warring States	Jin	10 (9 extant)	12 chime bells	SXKGS, 1996
37	1992	Shanxi FushanYangcunhe	Early Warring States	Jin	9	-	WWDXBJB, 2000
**38	1994	Shanxi Taiyuan Jinshengcun M88	Early Warring States	Jin	10	chime bells and drum stand	WWDXBJB, 2000
**39	1995	Shanxi Taiyuan Jinshengcun M673	Early Warring States	Jin	10 (only 1 complete)	chime bells	WWDXBJB, 2000
40	1935	Henan Jixian Shanbiaozhen M1	Early Warring States	Wei	10	14 chime bells	Guo, 1959
41	1992	Shandong Linzi Zihedian M2	Early Warring States	Qi	24	8+16+10 chime bells	SDWYS,2000

No.	Excavation year	Site and/or tomb	Date	State	Chime stone	Other musical instrument	Source
42	1988	Shandong Yangxin Chengguanzhen Xibeicun	Early Warring States	Unknown	13	9+5 chime bells	SDYXWHG, 1990
43	1989	Shandong Tanchen Erzhong M1	Early-to-mid Warring States	Tan	13 pottery versions	8 chime bells	Liu et al., 1996
44	1964	Hebei Yixian Yanxiadu M16	Early Warring States	Yan	15 (only 1 complete)	35 pottery bells	HBWHJWGD, 1965
45	1957	Henan Shaanxian Houchuan M2040	Early-to-mid Warring States	Wei	10	9+20 chime bells	ZSKKGS, 1994
46	1957	Henan Shaanxian Houchuan M2041	Early-to-mid Warring States	Wei	10	-	ZSKKGS, 1994
47	1990	Shandong Zhangqiu Nülangshan M1	Middle Warring States	Qi	7(M1)+2(Pit I)	7+5 chime bells, 1 clay ocarina, 2 chime bell racks from M1; 2 pole drums and 2 chime bells from pit I	SDWYS, 1993
48	1970	Shandong Zhucheng Zangjiazhuang and Gebukoucun	Middle Warring States	Ju	13(only 2 complete)	7+9 chime bells	Shandong Zhucheng Museum, 1987
49	1959	Shanxi Changzhi Fenshuiling M25	Middle Warring States	Han	10	4+5+9 chime bells	SXKGS et al., 1964
50	2001	Henan Luoyang Tanggong Xilu C1M7984	Middle Warring States	Zhou	10	-	LYWGD, 2003
*51	2001	Henan Luoyang Tanggong Xilu C1M7983	Middle Warring States	Zhou	72	-	LYWGD, 2003
*52	1981	Henan Luoyang Erqingju C1M131	Middle Warring States	Zhou	6	16 chime bells	LYWGD, 2009
53	1997	Hebei Pingshan Sanji, tomb of King Cuo in Zhongshan state	313 BCE	Zhongshan	13	14+3+8 chime bells, 9 *ling* clapper-bells	HBWYS, 1996

No.	Excavation year	Site and/or tomb	Date	State	Chime stone	Other musical instrument	Source
54	2012	Shandong Linzi Fanjiacun	Late Warring States	Qi	2	-	LZWWJ, 2015
55	1992	Shandong Linzi Yongliuxiang Shangwangcun M2	Late Warring States	Qi	16	14	WWDXBJB, 2001
56	1974	Henan Luoyang Xigong M4	Late Warring States	Zhou	4	-	LYWGD, 2009
57	1979-1980	Henan Huaiyang Pingliangtai M16	Late Warring States	Chu	5 ceramic versions	5 chime bells (ceramic versions)	HNWYS et al, 1984
58	2015	Shaanxi Xianyang	Late Warring States	Qin	Unknown		Xu, Zhang & Geng, 2016
59	1995	Henan Shangcai M2	Warring States	Chu	1	-	WWDXBJB, 1996a
60	1957	Henan Xinyang Changtaiguan M2	Warring States	Chu	18 wooden chime stones	13 wooden chime bells, 1wooden chime stone rack, 1 chime bell rack, 3 wooden *se* zithers, 2 drums	HNWYS, 1986
61	1982	Henan Luoyang Jiefanglu C1M395	Warring States	Zhou	23	22+4+18 chime bells	LYWGD, 2002
62	Unknown	Henan Luoyang Baihuogongsi M1	Warring States	Zhou	8 (4 complete)	-	Provided by Luoyang Museum
63	1954-1955	Shanxi Changzhi Fenshuiling M14	Warring States	Zhao	22	2+8 chime bells	SXWGH, 1957
64	1982	Hebei Handan Shexian Beiguan M1	Warring States	Zhao	10	-	WWDXBJB, 2008
65	Unknown	Shandong Linzi Shifotang	Warring States	Qi	8	-	WWDXBJB, 2001
66	1979	Shandong Linzi Dafuguan	Warring States	Qi	16	8 chime bells	WWDXBJB, 2001
67	1988	Henan Luoyang Baihuogongsi M2621	Warring States	Zhou	3	-	LYWGD, 2009
68	1995	Shanxi Wenxi Qiujiazhuang	Warring States	Jin	10	-	WWDXBJB, 2000
69	1985	Shanxi Jiaokou	Warring States	Jin	10	-	WWDXBJB, 2000

No.	Excavation year	Site and/or tomb	Date	State	Chime stone	Other musical instrument	Source
		Taohongpozhen Yaowacun					
70	1989	Shanxi Xiangfen Zhaokang M2	Warring States	Jin	12	-	WWDXBJB, 2000
71	1985	Shandong Tengzhou Xueguo Gucheng M117	Warring States	Xue	7	-	WWDXBJB, 2001
72	1982	Shandong Linzi Shaoyuancun	Eastern Zhou	Qi	1	-	Linzi City Museum, 1988
73	Unknown	Shaanxi Fufeng	Eastern Zhou	Qin	1	-	Lü,2016 [1092]
74	Unknown	Henan Sanmenxia	Eastern Zhou	Guo	9	-	WWDXBJB, 1996a
75	Unknown	Henan Luoyang Wangcheng Guangchang ZM190	Eastern Zhou	Zhou	5	-	LYWGD, 2009
76	1983	Shanxi Jiaocheng Hongxiang	Eastern Zhou	Unknown	5 (3 complete. Copper-made pseudo version)	-	WWDXBJB, 2000
77	1992	Shanxi Yicheng Heyuncun	Eastern Zhou	Jin	9	-	WWDXBJB, 2000
78	1990	Shanxi Tunliu Chewanggou	Eastern Zhou	Jin	10	-	WWDXBJB, 2000

2.1.5 The Western Han Chime Stones

Qin Shihuang (259-210 BCE) was the first emperor in ancient China. He led the unification of the whole of China and built the Qin dynasty (221-207 BCE); however, the dynasty ruled for only 14 years, to be followed by the Han dynasty which can be divided into two historic phases: the Western Han (202 BCE-8 CE) and the Eastern Han (25-220 CE). Thus far, there are no archaeological discoveries of chime stones of the Qin dynasty and Eastern Han chime stones have been very rarely found. I will therefore concentrate my study on Western Han chime stones.

In the northern area of China, there are a limited number of locations in which chime stones dating to the Western Han dynasty have been found (table. 6). In addition to stone-made chime stones, some *mingqi* 明器 (pseudo instruments) such as pottery and porcelain chime stones were discovered, which were ornamental imitations of the stone instruments. The ceramic chime stones unearthed in Xi'an Hongmiaopo and Xi'an Fannancun M92 suggested that the pottery versions were an imitation of the real ones, which were unplayable (fig. 28).

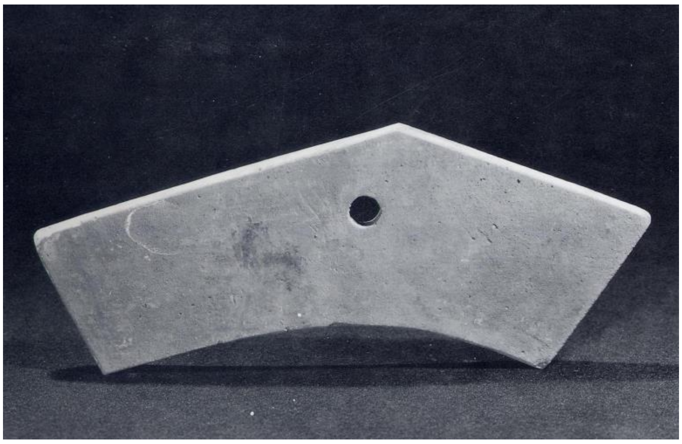


Figure 28. Pottery version of chime stone from Xi'an Hongmiaopo.
Western Han (202 BCE-8 CE). Length: 17 cm. After WWDXBJB, 1996b, fig. 1.3.7.

In Shandong Zhangqiu Luozhuang Western Han Tomb (187-180 BCE), there was a funeral pit numbered 14 (fig. 29). 22.6 metres long, 2.3 metres wide, and 2.5 metres deep, the pit contained a number of instruments including 107 chime stones (fig. 30), 19 bronze bells, one bronze *chunyu* and one *zheng*, one *ling* clapper-bell 鈴 (*ling*), eight ball-shaped rattles, seven broken drums, and the remnants of eight zithers (seven *se* and one *qin*). The pit was close to the main tomb which belonged to Lü Tai who was a lord of the local state government. The musical instruments in the pit were Lü's paraphernalia. The 19 bronze bells were originally suspended from a two-tier wooden rack. The lower tier had five large bells with a long shank and a suspension hook, their height is from 50.7-58.7 cm. The upper tier supported 14 small bells with inverted U-shaped suspension loops, and their height is from 13.4-28.9 cm. All bells are well preserved except two on the lower and one on the upper. The chime stones have an otherwise smooth surface but with some inscriptions, which describe the suspension order of the chime stones and some other information (see details in Chapter 8).

Figure 29. A partial distribution of funeral pit no. 14 in Luozhuang Western Han tomb (187-180 BCE).

After JNKGS et al., 2004, plate 5-2.

Figure 30. Chime stones from pit no.14 in Luozhuang Western Han tomb (187-180 BCE).
The racks are the imitation. Photo by Fang Jianjun.

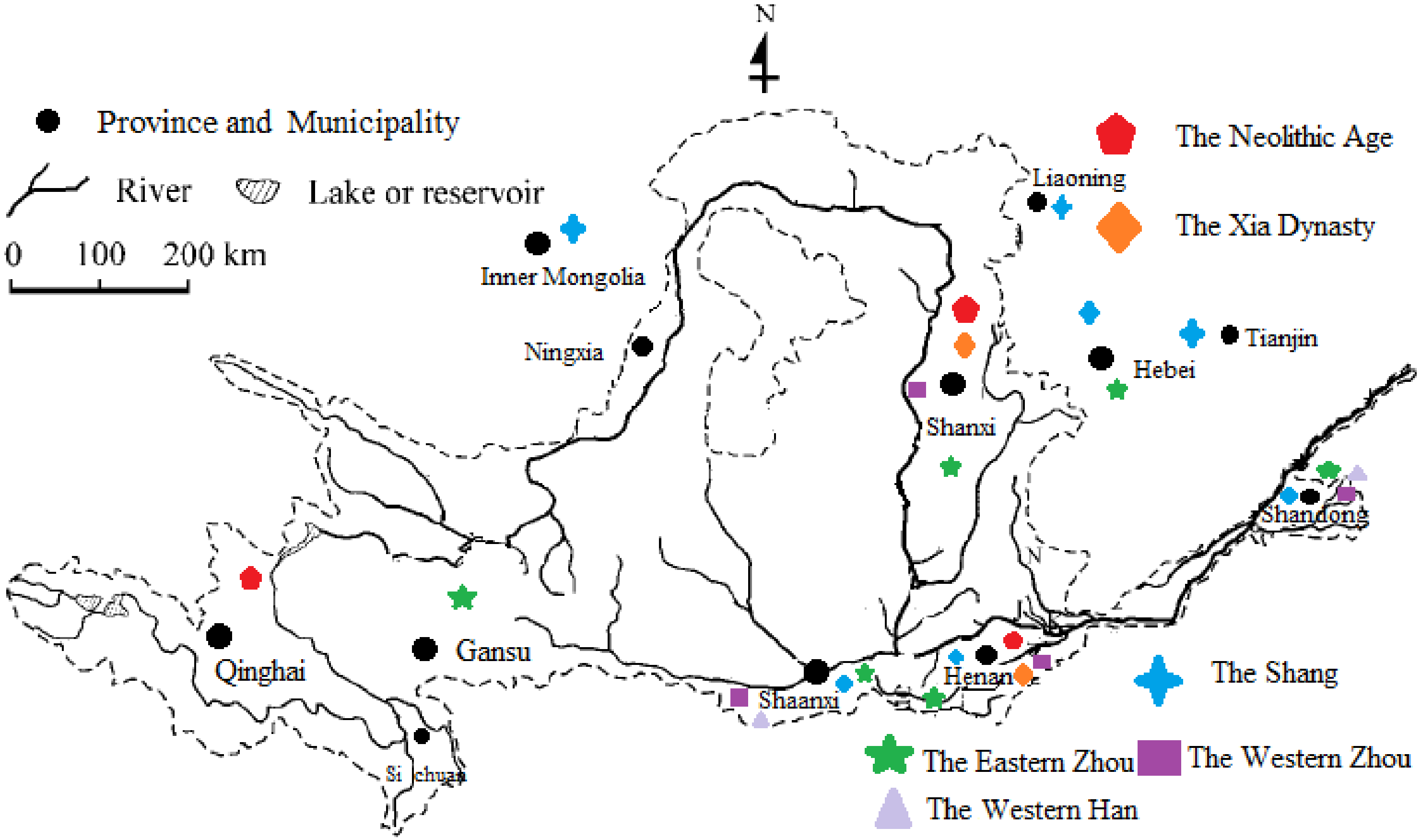
107 chime stones have been archaeologically excavated from Shandong in northeast China, and another 38 non-stone versions have been found in Shaanxi in northwest China.

Based on the above survey of archaeological finds dating from the Neolithic to Western Han period, I summarize the geographical distribution of chime stones in the Yellow River Valley on map 2.

Table 6. The Western Han chime stones found in northern China

No.	Excavation Year	Site and/or tomb	Date	Chime stone	Other musical Instruments	Source
1	1979	Shaanxi Xi'an Hongmiaopo tomb	Early Western Han	19 pottery versions	4 +9 pottery bells, 2 clay *se* zithers	WWDXBJB, 1996b
2	1991	Shaanxi Xi'an Fannancun M92	Early Western Han	19 pottery versions	5 + 10 pottery bells, 6 bronze *se rui*[16]	WWDXBJB, 1996b
**3	2000-2002	Shandong Zhangqiu Luozhuang Western Han tomb, pit no.14	187-180 BCE	107	1 *qin*,7 *se*, 19 chime bells,1 *zheng*, 1 *chunyu,* 2 drums, 1 *ling* clapper- bell, 5 pole drums, 8 ball-shaped rattles, chime stone racks	JNKGS et al., 2004

[16] *Se rui* is a bronze anchor for fixing the strings of the *se* zither, it usually appeared with four post on one end of the wooden front-panel.



Map 2. The distribution of chime stones found in the Yellow River valley. Drawn by Xueyang Fang.

2.2 The Yangtze River Valley Region

The Yangtze River is the longest river both in China and Asia, and the third-longest in the world, after the Nile in Africa and the Amazon in South America. The river is about 6,300 km long and flows from its source in Qinghai province, eastwards into the East China Sea at Shanghai. Traditionally, the Yangtze River is regarded as a dividing line between the north and south of China, although geographers consider the Qinling-Huaihe line to be the official line of geographical division. As the largest river in the region, the Yangtze is historically, culturally, and economically important to China.

2.2.1 Chime Stones from Shang to Western Zhou

There is no evidence from archaeological excavation to show that Neolithic chime stones occurred in the region of the Yangtze River valley, suggesting a difference of early musical culture between the south and north. According to current archaeological evidence, it seems most likely that the chime stone was an instrument invented in the Yellow River valley of northern China. The earliest chime stone so far known in the Yangtze River valley belonged to the late Shang dynasty (ca. 1260-1050 BCE).

From late Shang (ca. 1260-1050 BCE) to Western Zhou (1046-771 BCE), chime stones in Yangtze River valley are found in Sichuan, Chongqing, Hunan and Hubei (table. 7). A few cases dating to this period appeared in Sichuan Guanghan, Sichuan Chengdu Jinsha and Hunan Shimen Zaoshi[17]. As far as we know, only one complete single chime stone dating to middle Western Zhou (976-878 BCE) has been found in Hubei Suizhou Maojiachong[18], where one *bo*-bell was coexistent with a chime stone (fig. 31). Other

17 In Hunan Miluo, a different kind of chime stone dating to the late Shang dynasty made of bronze with a curled snout of pig-shaped profile appeared. Its construction, consisting of several bosses, is relatively complicated compared to other chime stones. It can produce different sounds by striking each boss on its surface. However, it is not certain that it was used as a musical instrument, and it requires more evidence to be sure.

18 Two chime stones allegedly unearthed in Hubei Wufeng without any archaeological context and excavation data (WWDXBJB, 1996c); I therefore do not consider them in this thesis.

broken chime stones survived in Hubei Zaoyang Guojiamiao M1, accompanied by a *se* zither, pole drum and chime rack, archaeologists regard them as remains of the earlier Zeng state, dating from the late Western Zhou (877-771 BCE) to the early Spring and Autumn period (770-686 BCE). Some chime stones of the ancient Shu 蜀 state have been found, for example, one late Shang (ca. 1260-1050 BCE) chime stone excavated from Sichuan Wushan Dachangzhen Shuangyantang, and two Western Zhou (1046-771 BCE) specimens unearthed at the site of Sichuan Chengdu Jinsha (fig. 32).

Figure 31. Chime stone from Hubei Suizhou Maojiachong, Middle Western Zhou (976-878 BCE).
After WWDXBJB, 1996c, fig. 1.7.2.

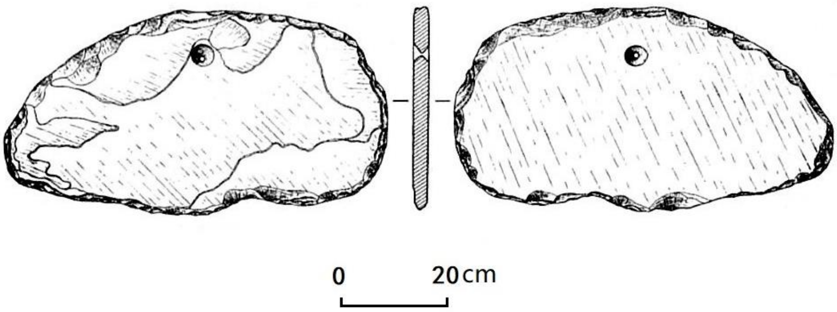


Figure 32. Chime stone from Sichuan Chengdu Jinsha (L62: 1), Western Zhou (1046-771 BCE).
After Xing & Wang, 2012, p. 64, fig. 3.

In contrast with the few Western Zhou (1046-771 BCE) chime stones have been discovered in the Yangtze River valley, a large number of musical bells have been found in this area. Late Shang (ca. 1260-1050 BCE) bells in the south were similar to their northern counterpart *nao* or *yong* but with an enlarged shape; they appear not to have been used as sets of chime bells, but rather used singly. By the time of Western Zhou, the bronze bells in the south gradually began to be used as sets of chimes and became a melodic musical instrument throughout Eastern Zhou (770-256 BCE) and Western Han times. On the other hand, chime stones in the south had increased in quantity from the beginning of Eastern Zhou to the Western Han, showing that the chime stones were popularized in the same way as chime bells during that period. These archaeological findings suggest that geographically differentiated musical instruments and musical culture existed between the south and north during the late Shang and Western Zhou times. Furthermore, before the Eastern Zhou period, the chime bell in southern China seems to have been more important than chime stones (Fang, 2006).

Table 7. The Shang and Western Zhou chime stones found in southern China

No.	Excavation Year	Site and/or tomb	Date	State	Chime stone	Other musical Instruments	Source
1	1981	Hunan Shimen Zaoshi	Yinxu culture II or III	Unknown	1	-	HUNWYS, 1992
2	1929	Sichuan Chengdu Guanghan	From late Shang to early Western Zhou	Probably Shu	1	-	Xing, 1992
3	1994	Chongqing Wushan Dachangzhen Shuangyantang	From Shang to Zhou	Shu	1	-	Xing, 2002
4	2006	Sichuan Chengdu Jinsha	Western Zhou	Shu	2	12 *ling* clapper-bells	Xing & Wang, 2012
5	1995	Hubei Suizhou Maojiachong	Middle Western Zhou	Unknown	1	1*bo*-bell	Suizhou City Museum, 1998
6	2002-2014	Hubei Zaoyang Guojiamiao M1	From late Western Zhou to early Spring and Autumn	Zeng	Several broken chime stones	2 *se* zithers, 1 pole drum stand, bells and chime stones racks	Fang, 2015

2.2.2 Eastern Zhou Chime Stones

Eastern Zhou (770-256 BCE) chime stones were mostly distributed in the middle and lower reaches of the Yangtze River valley in Hubei, Anhui, Jiangsu and Zhejiang (table. 8), with more than 200 chime stones found, including *mingqi* imitations.

Many chime stones have been excavated from several tombs in Anhui. There are in total 30 chime stones found in Bengbu Shuangdun M1 (fig.33), Fengyang Bianzhuang M1, Fengyang Dadongguan M1 and Shucheng Jiulidun, all of which belonged to an ancient local state Zhongli 鐘離 and were dated to the early to late Spring and Autumn period (770-476 BCE). The occupants of those tombs were different generations of local Zhongli rulers. Shuangdun M1 contained 12 chime stones, nine chime bells and one bronze *duo* 鐸 (a class of handbell with clapper), the Bianzhuang M1 contained nine chime stones, nine chime bells and five *bo*-bells. Evidence from the inscriptions on the bells makes it clear that the owners of the two tombs were different monarchs of the Zongli state (AHWYS & FYWGS, 2010). The Dadongguan M1 contained four chime stones, eight chime bells and seven *bo*-bells; according to the geographical location, shape and ornamentation of artefacts unearthed from this tomb, excavators regard them as remains of Zhongli state, although no inscriptional sources were found in the tomb.

As for chime stones of the Wu state, there are 37 chime stones dating to late Spring and Autumn (546-476 BCE) distributed in the ancient Wu region, corresponding to the present Jiangsu province. In particular, from tombs M3 and DIIM in Jiangsu Pizhou Jiunüdun, many chime stones have been excavated. The artefacts from these tombs included chime bells, one exceptional tomb in Jiangsu Dantu Beishanding contained bronze *chunyu* and *zheng* percussions as well (see table. 8). As the contents of these tombs consisted of ritual vessels, chariot fittings and bronze weapons, excavators view the occupants of the tombs as aristocrats with high social status.

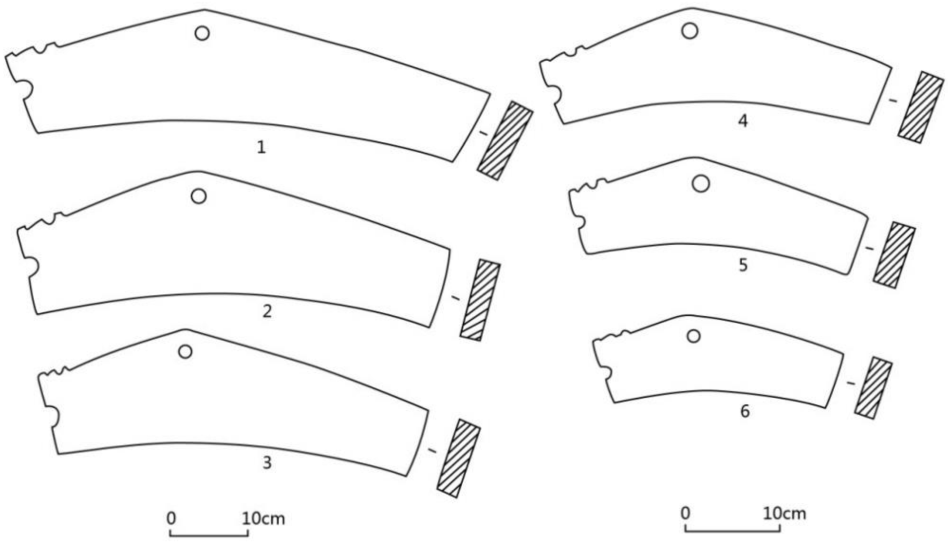


Figure 33. Chime stones from Anhui Bengbu Shuangdun M1.
Mid- to late Spring and Autumn (685-476 BCE). After AHWYS & Bengbu City Museum, 2013, p.267, fig. 43. Redrawn by Xueyang Fang.

There are three excavated locations belonging to the ancient Yue state, separately in Wuxi Hongshan, Changxing Bizishan and Haiyan Huangjiashan, all containing porcelain or pottery versions of chime stones. Besides chime stones, tombs in these locations also included porcelain imitations of bronze bells, *bo, goudiao*[19] and *zheng*. Based on the large and varied amount of funerary objects present, especially musical instruments, archaeologists believe that the tombs' owners were aristocrats of the Yue state.

Zeng was a vassal state with the same lineage as the Zhou court, and had close relations with its neighboring Chu state. Located in today's Hubei Suizhou (formerly Suixian), the Zeng state chime stones appeared as early as the late Western Zhou era (877-771 BCE). Dating to the late Spring and Autumn period (546-476 BCE), the Zeng tombs in Suizhou Wenfengta M1 and M2 included 5 and 12 chime stones respectively, most of them were broken into pieces, and additional instruments included chime bells and *ling* clapper-bells in tomb M1. Inscriptions on the bells show that the tomb occupant in M1

19 *Goudiao* is a kind of mallet-struck bronze bell, which is mounted mouth-up; its distribution is limited to the south-eastern region of China, belonging to the remains of Wu and Yue culture.

was Marquis Yu 輿 of the Zeng state. M2 is 60 metres from M1, and dates to slightly later than M1, archaeologists assume the tomb occupant was possibly another Marquis of the Zeng.

Twelve chime stones were found in Hubei Suizhou Leigudun M2 and 32 in the tomb of Marquis Yi of the Zeng state; unfortunately, the chime stones were all broken and I was unable to test their sound properties. The Leigudun M2 had 36 chime bells and one bronze drum stand, and dated to middle Warring States (386-285 BCE), which was later than the Marquis Yi's tomb of early Warring States (433 BCE). Since these two tombs are only 100 metres apart, excavators believe the tomb occupant of Leigudun M2 was a monarch of the Zeng state (Hubei Provincial Museum & Suizhou Museum, 1985; Hubei Provincial Museum, 1989).

In Marquis Yi's tomb, a total of 125 musical instruments were found. Besides 32 chime stones from a two-tier rack, other instruments were 65 chime bells including one from king Xiongzhang of the Chu state, suspended from a three-tier rack, transverse flutes, a pole drum, panpipes, *qin* and *se* zithers, as well as mouth organs. In particular, the Zeng inscriptions on the bronze bells and chime stones show the names of the tones that would be emitted, proving the phenomenon of "one bell with *two-tone*"[20] in pre-imperial China (Hubei Provincial Museum, 1989).

My research indicates that the Chu state chime stones were mainly found in Hubei, where the Chu capital was established. Apart from Hubei, such Chu tombs have been found in Hunan and southern Henan such as Xinyang and Xichuan aforementioned (see 2.1.4), which formed the Chu culture circle during the Eastern Zhou times (770-256 BCE). 25 chime stones with painted patterns were excavated from a site in Hubei Jiangling Jinancheng, buried in a Warring States (475-221 BCE) layer with no other associated funerary objects, their tones were in disorder (Hubei Provincial Museum,

20 The ancient Chinese musical bell can produce *two-tone* 雙音. The first tone is heard when the bell is struck in the centre above the mouth and the second tone produces when it is struck to the right (sometimes the left) of this area, which is so called one bell with *two-tone* phenomenon.

1972). Hubei Zaoyang Jiuliandun M1 and M2 contained several Warring States chime stones[21], unfortunately, most of them were broken into pieces. In Jiuliandun M2, however, many other musical instruments were found, including bronze bells, *se* zithers, a bird-and-tiger drum, transverse bamboo flutes, panpipes, mouth organs, wooden percussions and chime stone racks. Jiangling Tianxingguan M1 contained chime stones, chime bells, *se* zithers, mouth organs, bird-and-tiger drums, small drums, chime stone racks and wooden mallets. Unfortunately, this tomb had been robbed, the result of which was that the surviving musical instruments were incomplete, and the chime stones were decayed. The tomb occupant, according to the record of bamboo inscriptions from this tomb, was Fan Cheng, a senior military officer. Another 12 pottery versions of chime stones were unearthed from Anhui Liu'an Chengxi Yaochang, this also belonged to the Chu state and dated to the early Warring States period.

This distribution of chime stones shows that the prevalence of chime stones in the Yangtze River valley was the same as that in the Yellow River valley during Eastern Zhou times (770-256 BCE). As a component of ritual music ("metal and stone music"), chime stones were as important as chime bells in the same period in ancient China.

21 Detailed archaeological data about Zaoyang Jiuliandun M1 have not yet been published.

Table 8. The Eastern Zhou chime stones found in southern China

No.	Excavation Year	Site and/or tomb	Date	State	Chime stone	Other musical instruments	Source
1	1991	Anhui Fengyang Dadongguan M1	Early to middle Spring and Autumn	Zhongli	4	15 chime bells	AHWYS & FYWGS, 2010
2	2007	Anhui Fengyang Bianzhuang M1	Mid- to late Spring and Autumn	Zhongli	9	9+5 chime bells	AHWYS，FYWGS et al., 2009
3	2006-2008	Anhui Bengbu Shuangdun M1	Mid- to late Spring and Autumn	Zhongli	12	9 chime bells	AHWYS & Bengbu Museum, 2010
4	1980	Anhui Shucheng Jiulidun tomb	Late Spring and Autumn	Zhongli	5	4 chime bells, 1 drum stand	AHSGZD，1982
5	1984	Jiangsu Dantu Beishanding tomb	Late Spring and Autumn	Wu	12	12 chime bells, 3 *chunyu* percussion, 1 *zheng* and drum accessories	JSDTKGD 1988
6	1993	Jiangsu Pizhou Jiunüdun M3	Late Spring and Autumn	Wu	13	4+6+9 chime bells, 1 stone-made drum hammer	Kong & Chen, 2002
7	1995	Jiangsu Pizhou Jiunüdun DIIM	Late Spring and Autumn	Wu	12	6+8 chime bells	Nanjing Museum et al., 1999
8	2009	Hubei Suizhou Wenfengta M1	Late Spring and Autumn	Zeng	5	8 chime bells, 4 *ling* clapper-bells	HUBWYS & Suizhou City Museum, 2014
9	2009	Hubei Suizhou Wenfengta M2	Late Spring and Autumn	Zeng	12	-	HUBWYS & Suizhou City Museum, 2014
**10	1978	Hubei Suizhou Zenghouyi mu (the tomb of Marquis Yi of the Zeng state)	Early Warring States (433 BCE)	Zeng	32	65 chime bells, 2 transverse flutes (*chi*), 2 bamboo panpipes, 6 mouth organs (*sheng*), 2 *qin* and 12 *se* zithers, 4 drums (including 1 pole drum), 2 chime stones mallets, 3 chime boxes, 1 chime stone rack, 1 bell rack, 8 bell mallets	Hubei Provincial Museum, 1989
11	1981	Hubei Suizhou Leigudun M2	Middle Warring States	Zeng	12	36 chime bells, bell hooks, 1 drum base	Hubei Provincial Museum & Suizhou Museum, 1985

No.	Excavation Year	Site and/or tomb	Date	State	Chime stone	Other musical instruments	Source
12	1991	Anhui Liu'an Chengxi Yaochang M2	Early Warring States	Chu	12 pottery versions	12+5 ceramic bells	AHWGS, 1995
13	1970	Hubei Jiangling Jinancheng	Warring States	Chu	25	-	Hubei Provincial Museum, 1972 (3)
14	1978	Hubei Jiangling Tianxingguan M1	Chuxuanwang or Weiwang period (340 BCE)	Chu	several	4 chime bells, 1 chime bells rack and 1 chime stones rack, 2 bell mallets, 6 chime stones mallets, 5 *se* zithers, 1 bird-and-tiger drum[22], 2 drum mallets, 1 wooden drum, 6 *sheng* mouth organs	Hubei Jingzhou Museum, 1982
15	2002	Hubei Xiangfan Zaoyang Jiuliandun M2	Warring States	Chu	19 broken pieces	11 chime bells, 4 *chi* transverse flutes, 2 panpipes, 5 *se* zithers, 2 drums (one bird-and -tiger drum), 4 *sheng* mouth organs,1 *ya*[23], 1 z*hu*[24], 1 *chongdu*[25], 1 chime stone rack and 2 mallets, 1 bell rack and 4 mallets	HUBWYS & XYWYS., 2018
16	2005	Jiangsu Wuxi Hongshan Qiuchengdun tomb	Warring States	Yue	16 porcelain versions	-	Nanjing Museum et al., 2007
17	2003-2005	Jiangsu Wuxi HongshanWanjiafen tomb	Warring States	Yue	18 porcelain versions	24+16 chime bells, 23 *goudiao*, 2 *chunyu*. All are porcelain versions	Nanjing Museum et al., 2007
18	2003-2005	Jiangsu Wuxi Hongshan Laohutun tomb	Warring States	Yue	20 porcelain versions	11 porcelain chime bells	Nanjing Museum et al., 2007
19	2004	Zhejiang Changxing Bizishan aristocratic tomb	Warring States	Yue	13 pottery versions	Pottery chime bells, *bo, goudiao, chunyu* and *zheng*	ZJKGS&CX Museum, 2007

22 Usually with tiger-shaped wooden drum stand and bird-shaped wooden rack, the bird-and-tiger drum were all found in the Chu Culture area concentrated primarily in Hubei, Hunan, and southern part of Henan province.
23 *Ya* is a kind of wooden percussion resembling an ox horn in shape.
24 *Zhu* is a kind of wooden percussion in the shape of a box by pounding with a pestle.
25 *Chongdu* is a kind of bamboo-made percussion.

No.	Excavation Year	Site and/or tomb	Date	State	Chime stone	Other musical instruments	Source
20	1983	Zhejiang Haiyan Huangjiashan	Warring States	Yue	4 porcelain versions	Porcelain chime bells, *goudiao* and *chunyu*	ZJKGS & HY Museum, 1985

2.2.3 The Western Han Chime Stones

Archaeologists have excavated several Western Han tombs in the Yangtze River valley, the southern part of China, where chime stones were buried with other sorts of musical instruments (table. 9). In addition to stone-made chime stones, there were pottery, wood, glass and porcelain chime stones uncovered. Three relatively well-protected large tombs dating to the Western Han period exist.

The Nanyue King's tomb at Xianggangshan in Guangzhou (Guangdong) is a large sized tomb with seven coffin compartments dating to about 122 BCE. An abundance of funerary artefacts, including ritual objects and musical instruments, was discovered in this tomb. Bronzes, iron weapons, chime bells, *se* zithers and household artefacts were all found. There are two sets of chime stones from this tomb, one set has ten stones and the other has eight. They were located beside bronze chime bells, arrayed from the west to the east. Unfortunately, the poorly preserved condition of these chime stones makes them unavailable for acoustic research. The tomb occupant, according to the excavation report, was Zhao Mo, a king of second generation in Nanyue state, who reigned from 137 to 122 BCE (GZWGW, 1991).

Dating to the Western Han dynasty, the tomb M1 at Dayunshan in Xuyi (Jiangsu) was large, with a vertical stone pit tomb between two passageways (fig. 34). It measures 35.2 metres in length, 26 metres in width and is 19 metres deep. In a side compartment were buried a number of weapons, lacquerware and bronze vessels. A set of 20 glass-made chime stones, accompanied by 22 pottery *mingqi* imitations, were excavated from this tomb. Excavators concluded that the tomb occupant was Liu Fei (168-128 BCE), a king of Jiangdu area, the tomb could therefore be dated to 128 BCE (NJBWY&XYWGJ, 2013b). Although the 20 glass-made chime stones were broken into pieces, chemical experiments have demonstrated that the making of ancient $PbO\text{-}BaO\text{-}SiO_2$ glasses in ancient China had reached to its developmental peak during the Western Han period (Li et al., 2016). However, scholars are still unsure if these glass-made chime stones could really be played in a musical performance.

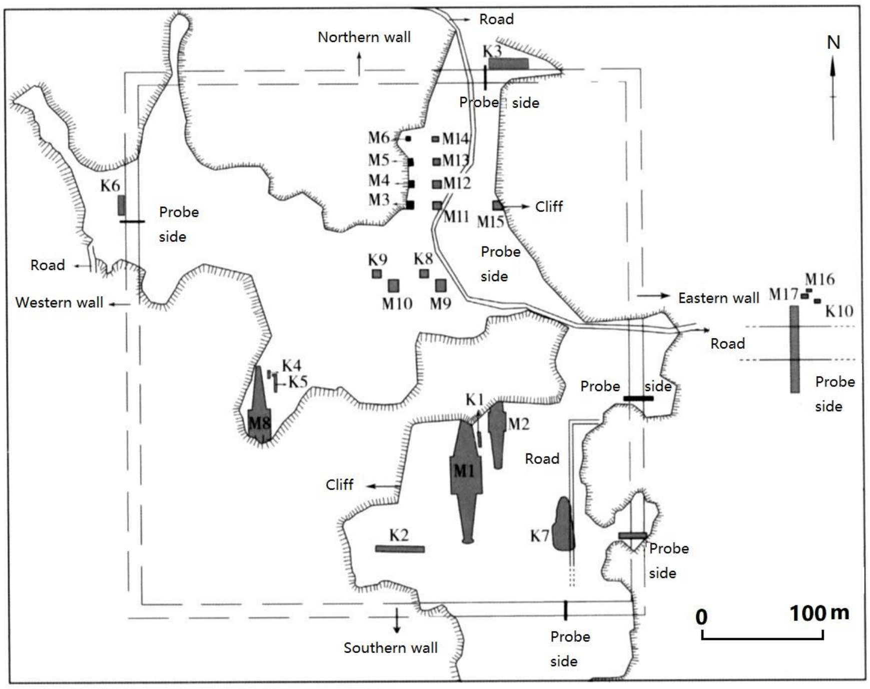


Figure 34. The plan of the Han tombs in Jiangsu Xuyi Dayunshan.
After NJBWY&XYWGJ, 2013b, p. 4, fig. 2. Redrawn by Xueyang Fang.

The tomb of Haihunhou in Nanchang (Jiangxi) is another typical example of tomb from this period. With a tomb passageway and a rectangular wooden coffin chamber, it dated to around 200 BCE. There are about ten glass-made chime stones unearthed from this tomb, but their poor condition prevents further study on their shape and sound (Zhang & Ke, 2019, p. 49)[26.] The owner of the tomb was probably Liu He (92-59 BCE), who was known as Marquis Haihun. The artefacts unearthed from the tomb include gold objects, bronzes, jade artefacts, lacquered and woodenwares, textiles, pottery wares, bamboo slips and a wooden tablet. Musical instruments present included a set of 10 + 14 chime bells, *qin* and *se* zithers, panpipes and approximately 36 figurines of musicians. Additionally, four chime bell racks with animal shaped stands and two chime stone racks were present (JXWYS, 2016).

Western Han chime stones are less common than in the Zhou dynasty, including both Western (1046-771 BCE) and Eastern Zhou periods (770-256 BCE). By contrast, no Eastern Han (25-220 CE) chime stones and other musical instruments have yet been

26 According to Zhang Wei and Ke Li, these chime stones are made of glasses. See page 49.

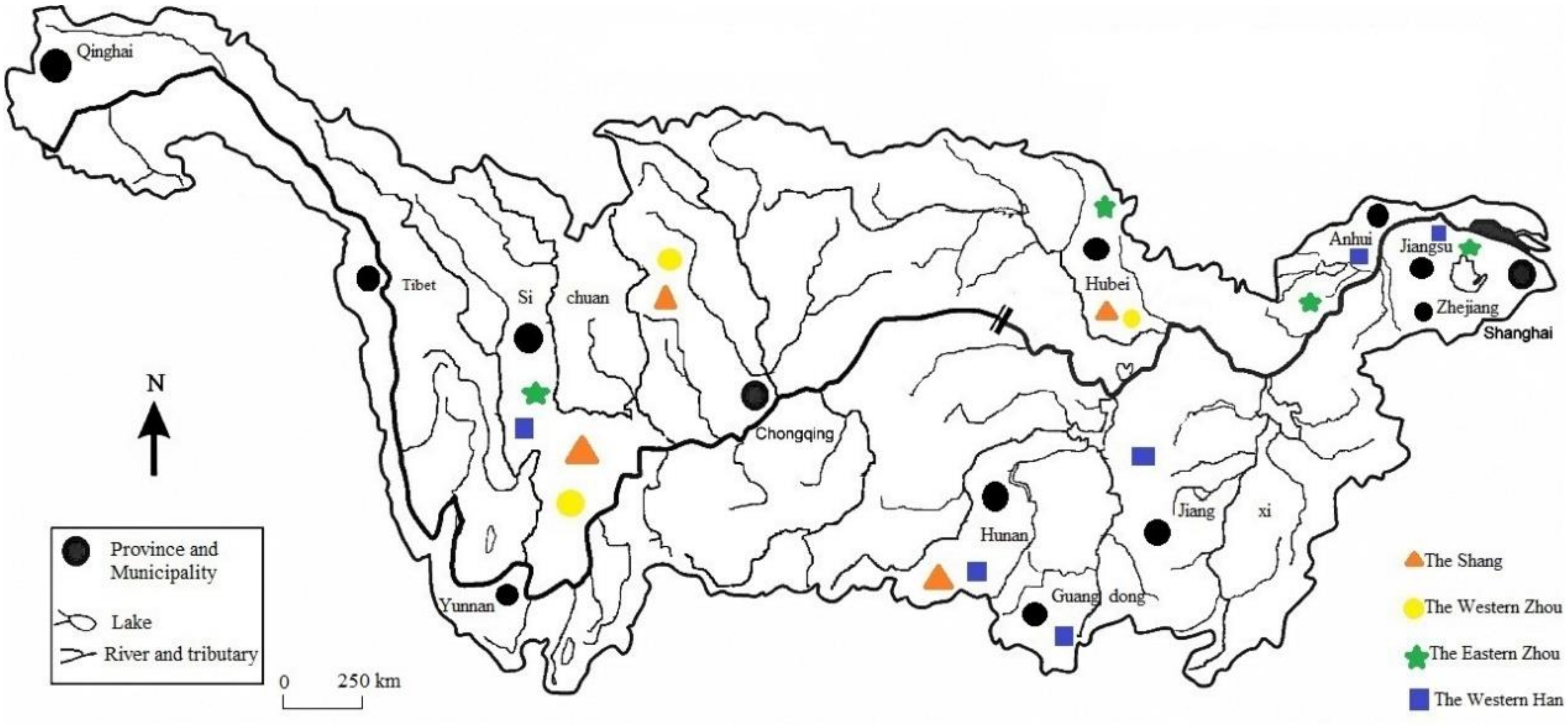
recorded archaeologically. With the decline of the ritual and music system alongside transformative changes in burial customs in the Han dynasty, one of the consequences was the decrease in the use of musical instruments as funerary objects. Instead, people often used *mingqi* as symbolic artefacts to satisfy the life of the tomb owner in another world.

To sum up the above discussion, the location and distribution of chime stones found in the Yangtze River basin from the Shang (ca.1600-1046 BCE) to Western Han period (202 BCE-8 CE) are shown on map 3.

Table 9. The Western Han chime stones found in southern China

No.	Excavation Year	Site and/or tomb	Date	Chime stone	Other musical instruments	Source
1	1977	Anhui Fuyang Shuanggudui M1	Early Western Han	10+10 ceramic versions	chime bells (pottery version, pseudo instruments)	AHSGZD & FY Museum, 1978
2	1973	Hunan Changsha Mawangdui M3	168 BCE	10 wooden versions	10 wooden chime bells, 3 *se* zithers,1 *zhu* zither, 2 *yu* mouth organs (pseudo instruments), 1 *qin* zither*,*1*se* zither*,* 1 *yu* mouth organ*,* 2 flutes, 1 chime rack	Hunan Provincial Museum et al., 2004
3	1983	Guangdong Guangzhou Xianggangshan Nanyue king's tomb	122 BCE	10+8	14+5 chime bells, 8 *goudiao* percussions, several *qin* zithers, 2 *se* zithers and 8 *se rui*	GZWGW, 1991
4	1974	Hunan Changsha Xianjiahu Caozhuan tomb	Middle Western Han	14+14 pottery versions	chime bells (pottery version)	CSWHJWWZ, 1979
5	1986	Jiangsu Xuzhou Beidongshan Chuwang tomb	Middle Western Han	14 stone-made and 1 pottery version	3 chime bells	Xuzhou City Museum & NDLSX,1988
6	1980s	unprovenanced museum collections	late Western Han	14	-	Wang, 1997
7	2009-2011	Jiangsu Xuyi Dayunshan Han tomb M1	128 BCE	20 glass-made chime stones, 22 pottery imitations	2 *chunyu* percussions, 2 *zheng* percussions, 5 *ling* clapper-bells, 14+5 bronze bells, several copper-made pseudo bells	Nanjing Museum et al., 2013b
8	2011	Jiangxi Nanchang M1, the tomb of Marquis	200 BCE	10 glass-made	10+14 chime bells, 3 *se* zithers, several	JXWYS et al.,

No.	Excavation Year	Site and/or tomb	Date	Chime stone	Other musical instruments	Source
		Haihun		chime stones	*qin* zithers, panpipes, 4 bell racks and 2 chime stones racks	2016
9	1992	Sichuan Mianyang Yongxing	Western Han	3 pottery versions	7 pottery chime bells	WWDXBJB, 1996d
10	1990	Jiangsu Nanjing Yizheng Zhangji Tuanshan M1	Western Han	12 pottery versions	9 pottery chime bells, 43 *ling* clapper-bells, 1 *zheng* percussion	NJBWY et al., 1992



Map 3. The distribution of chime stones found in the Yangtze River Valley. Drawn by Xueyang Fang.

2.3 Summary

Chapter 2 explores the distribution of chime stones, which were all located in two river basins. The entire distribution varied over time. In the early stage, during the late Neolithic Age, they were discovered mainly in the middle and upper area of the basin. The Shang dynasty (ca. 1600-1046 BCE) chime stones were found in Anyang, the political centre of the Shang dynasty. The Western Zhou (1046-771 BCE) chime stones were distributed mainly over the political centre and metropolitan area of Shaanxi, as well as some states of its peripheries, whereas in the Eastern Zhou dynasty (770-256 BCE) a great number were spread widely across the two river basins. However, following changes of funeral customs, the late Western Han period chime stones gradually declined from the archaeological record. The chime stones along the Yangtze valley in south China came from the north in the late Shang period (ca. 1260-1050 BCE). Judging from the shape of chime stones, they may have an inheritance relationship. In the section that follows, the classification and typology of chime stones, and disparity and similarity in shape development is discussed.

Chapter 3: Classification and Typology

3.1 Classification

As discussed in Chapter 1, *Ba Yin* (eight tones) was a classification system that appeared in the Zhou dynasty. The *Ba Yin* classification system divides the musical instruments into eight different groups, based on the different materials from which they are made (See Chapter 1 for reference). It was an ambitious attempt at creating a classification system for musical instruments used in ancient China; however, it attributed musical instruments with different playing methods and acoustic properties to the same category. For example, in the case of chime stones and stone panpipes unearthed from the tomb M1 of Xichuan Xiasi (Henan) dating to the Spring and Autumn period (770-476 BCE), both instruments are made of stone and are therefore placed in the same group, but have different playing methods, one is percussion and the other is a wind instrument. Another flaw with this classification system is that the issue of how to define bone-made instruments such as bone flutes has not been solved. Therefore, it is not a perfect system to classify all instruments into eight categories relying on their manufacturing materials.

The Hornbostel-Sachs (H-S) system (See Chapter 1 for reference) is another classification of musical instruments, and is referenced by most scholars today. Musical instruments are divided into four categories (idiophones, membranophones, chordophones and aerophones) according to the nature of the sound-producing method; solid objects, membranes (such as drum skins), strings or the air. The chime stone is set in vibration by being struck, thus it belongs to the struck idiophones category according to H-S system (Sadie & Tyrrell, 2001).

The category of idiophones generates two main branches: struck idiophones and plucked idiophones (Hornbostel & Sachs, 1992). In related studies of African sound-instruments, the following classifications are shown as: Ia, Ib, Im, In; IIa, IIb., the lower case letters having distinct meanings. The letters a, b, m and n are defined as culturecircles (Hornbostel, 1933). “A system of classification has theoretical advantages as well as practical uses. Objects which otherwise appear to be quite unrelated to each other may now become associated, revealing new genetic and cultural links” (Hornbostel & Sachs, 1992, p. 5).

Although the *Ba Yin* and H-S systems do have their own positive features, the inherent property of the chime stone is unchanged whether the chime stone belongs to the *Ba Yin* or the H-S system.

Chime stones could be divided into six classes according to their manufacturing substances:

A. Stone-made chime—the real instrument, chime stone.
B. Pottery substitution—the *mingqi*, unplayable imitation.
C. Wooden substitution—the *mingqi,* unplayable imitation.
D. Porcelain substitution—most likely *mingqi*, unplayable imitation.
E. Vitreous substitution—possibly the real instrument.

The vast majority of archaeological discoveries are stone-made chime stones, and they were one of the leading instruments of ritual music (“metal and stone music”) in ancient China. Pottery-made chime stones or wooden versions are classified as funerary objects, or *mingqi* (unplayable pseudo instrument). Pottery chimes are easy to break when being struck, and wooden ones are less melodic in sound, they are clearly an imitation of chime stones (Hunan provincial Museum & HUNWYS, 2004; WWDXBJB, 1996b). The porcelain versions of chime stones were limited to the Yue minority culture area in the region of south-eastern China, and they were most likely the *mingqi* imitations as well. The vitreous substitutions have rarely been found in an archaeological context at present, and almost all of them have been seriously damaged when found. Nevertheless, like stone-made chimes, the materials of vitreous chimes are solid for mallet-struck playing, so they were probably useable instruments. However, whether they could be used as practical instruments or not still requires experimental study. These are not my main research subject and are simply mentioned for reference. This thesis only studies the stone-made chime stone as a component of “metal and stone music” in ancient China.

3.2 Typological Research

3.2.1 Discussion about Current Studies

Chinese archaeologists and musicologists have conducted typological studies on chime stones in recent years. Chen Zhenyu divides the pre-Qin chime stones into eight types; he has observed changes at the top of stones and used them as the main basis for subdivision, which is an insightful approach to typological research of chime stones (Chen, 1988). Apart from the top part of the stone, however, he also takes the bottom shape into consideration, and as he sometimes relies on the top shape and sometimes the bottom to classify the types of chime stones, the typological classification criteria are not consistent.

Li Chunyi, a pioneer in the field of Chinese music archaeology, creates a typological system according to the top shape of chime stones based on extensive fieldwork and investigation. He divides chime stones into four types, and each of them has several subtypes (Li, 1996). The four types and their subtypes are as follows:

I: The straight top.

  I-1: The horizontal bar-shape.

  I-2: The vertical bar-shape.

II: The irregular top[27].

27 It is inaccurate to describe the second type as fold-lined top according to Li’s description. The top shape of the second type is actually irregular, with only trend line of fold.

II-1: The pentagonal shape.

II-2: The trapezoid.

III: The arched top.

III-1: The whale-head shape.

III-2: The bream-head shape.

IV: The angular top.

IV-1: The obtuse triangle.

IV-2: The convex quadrilateral.

IV-3: The pentagonal shape, which has three subdivisions depending on the base shape—the flat (IV-3a), curved (IV-3b) and angled (IV-3c) base.

IV-4: The hexagonal.

Li describes type II as the “fold-lined top”. This top shape does not fit well in his categorisation as some stones have an irregular top shape. Moreover, the hexagonal type (IV-4) seems vague when compared with IV-3c. Only one sample stone of M93:6 in Yinxu has been found to be type IV-4 as yet. There are no criteria to distinguish these two types. Except for a stone from Shandong Jiaoxian Zhangjiazhuang (fig. 42), IV-3c can only be seen in pottery or wooden *mingqi* substitutions. Nevertheless, this type of IV-3c became common in later dynasties, for example, the Ming (1368-1644 CE) and Qing (1636-1911 CE) chime stones were all of such type (Fang, 2011, p. 147-155). By the time of Eastern Zhou (770-256 BCE), all types had disappeared except type IV-3b, which means the shape of chime stones eventually became unified and standardized into only one type.

Fang Jianjun proposes another typological system that is slightly different from Li’s description. Fang aims to define types of chime stones depending on the subtle differences of their top (Fang, 1996). While Fang and Li differ in the specifics of their interpretations, the main idea is similar.

Wang Anchao, creates a further chime stone typological system with four types. Wang's definitions include A) indistinct type, B) evolving type, C) stable type, and D) beautifully decorated type. As he states, the earliest chime stones were imperfect and had vague geometrical shapes in morphology; therefore it is possible to attribute these chime stones to the indistinct type. He explains the beautified type, suggesting that during the Shang dynasty (ca. 1600-1046 BCE) ornamentation appeared only occasionally; some chime stones were adorned with patterns but most were not. It is thus appropriate to classify them by virtue of decoration (Wang, 2005).

This typological system, however, lacks both in historical and logical aspects; the classification criteria are not uniform. Wang's descriptions are vague and inaccurate, and can include almost any type. The stable type is actually a convex pentagonal type, whilst the so-called beautifully decorated type is based solely on the chime stone's decoration, rather than the shape. Therefore, the typological classification leads to different standards. Decoration is a surface description of chime stones, and does not address important factors in association with their shape and sound. Change of shape seems most important in the evolution of musical instrument manufacturing, and the typological classification should reflect an evolutionary process, and address any historical sequence.

In contrast to Wang, Zheng Zuxiang (2005) divides chime stones into three types according to their shape and sound properties. They are the uneven type, obtuse triangular type and angular top type. In fact, on the basis of the examples cited by Zheng, the so-called obtuse triangle is actually an irregular type; sometimes it has four or five angles, sometimes even no angle but a circular arc.

Wang Zichu (2004) does not create a typological system for chime stones, but dates their historical periods according to certain elements of chime stones, such as the shape of bottom, vertex angle and tone pitch.

Typological research on chime stones is also considered by a small number of other scholars, however, their type attributions are not widely accepted or discussed (Gao, 2004; Ren, 2008; Deng, 2009).

The above typological classification methods are established based on different perspectives and it is not easy to judge which one is more convincing. The taxonomy in Li's system places emphasis on specific shape development, however, the four types that he created do not accurately address the irregularity of the shape of the top of the stones. It is sometimes difficult to distinguish between types II and III. Such a large variety of typological research is reflective of the fact that the shape of chime stones was not uniform before the Spring and Autumn period (770-476 BCE).

Li's typological system is the most consistent in terms of its application of classification criteria, and is most adopted within the present research. However, owing to the diversity of chime stones not fully covered by his system, I explore a newly developed typological system in the following section.

3.2.2 Types and Subtypes

William Adams and Ernest Adams explore the evolution of types in an example of a Nubian pottery family (Adams & Adams, 1991, p. 211). This typological system precisely reflects the chronology of these ancient findings. However, "no one method of type formulation is inherently right or wrong, and in fact many practical typologies include types that were formulated in more than one way" (Adams & Adams, 1991, p. 183).

The advantages of such a division of types are that the relative chronological sequence can be defined and it can expose the developmental process of archaeological artefacts. The disadvantages are that it can only determine the logical order in which these distinctions appeared, but not their absolute date in chronology.

“A typology is a particular kind of classification” (Adams & Adams, 1991, p. 47). To attribute ancient findings of chime stones into specific types categories according to features of shape and create a new typology, a number of procedures have been carried out: selecting scientifically excavated specimens with a clear date; observing and defining their common characteristics in shape and allocating these artefacts distinguishing types and subtypes; and analysing these findings within the framework of a typological system which allows chronological sequence in the development of chime stones.

The chime stones, according to their top and bottom shape, can be divided mainly into two types, each having two subtypes:

A. The irregular shape.

A-1. The straight top (fig.35).

A-2. The non-straight top (fig. 36-37).

B. The angular top.

B-1. The straight base (fig. 38).

B-2. The curved base (fig. 39).

B-3. The angled base (fig. 43)

Such a typological system can be shown in a structural diagram (fig.40). The developmental date of each type of chime stones may be seen in a schematic diagram (fig. 41). Type A-1 (the straight top) appeared from late Neolithic to the middle Western Zhou (ca. 2400-878 BCE). Type A-2 (the non-straight top) was from Neolithic to the late Western Zhou (ca. 2400-771 BCE). Type B-1 (the straight base) occurred from the late Shang (ca. 1260-1050 BCE) and developed to the end of Western Zhou or the beginning of the early Spring and Autumn period (770-686 BCE). Type B-2 (the curved base) appeared early in the Xia dynasty (ca. 2070-1600 BCE) and then it seems to have disappeared until the early Spring and Autumn period, when this type of chime stone occurred again and developed throughout the Warring States (475-221 BCE) and Western Han dynasty (202 BCE- 8CE). The reason why the B-2 chime stone had this break in its occurrence is unclear, but eventually, the B-2 became the dominant type of Chinese chime stone.

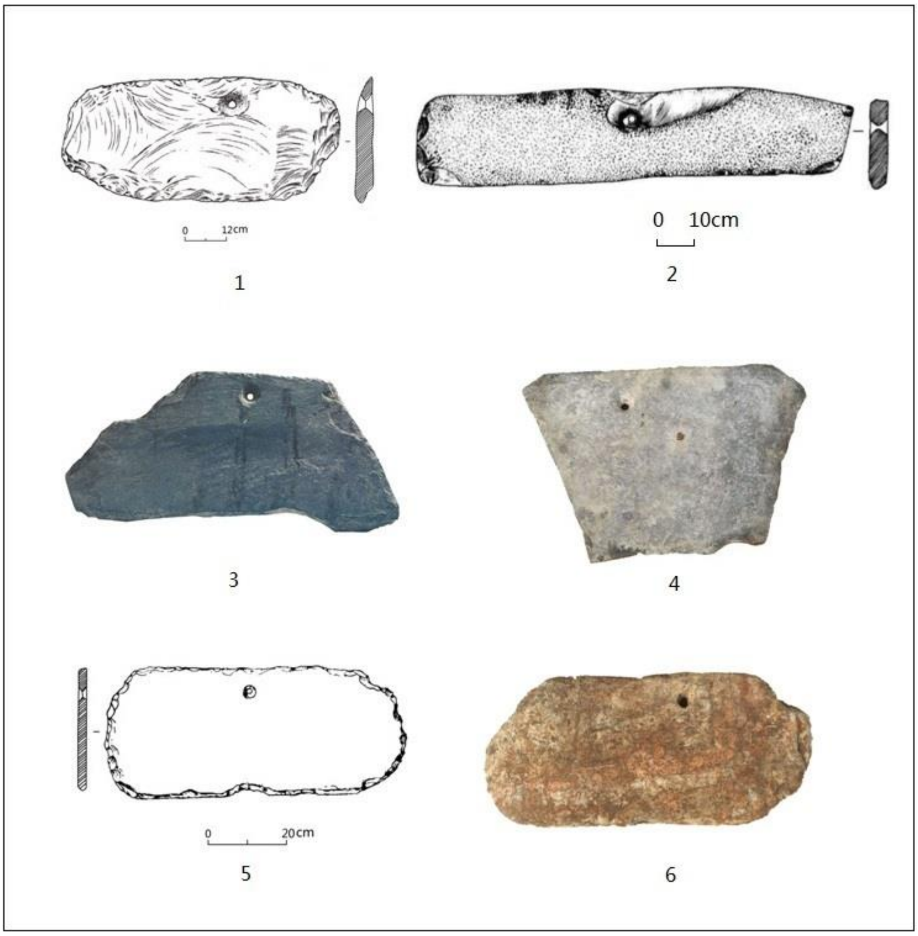


Figure 35. Type A-1 irregular shape with straight top of chime stones from late Neolithic to late Shang period (ca. 2400-1050 BCE).

1. From Shanxi Xiangfen Taosi (M3015: 17), ca. 2400-2300 BCE. After ZSKKGS & SXLFWWJ, 2015, p. 672, fig. 4-147; 2. From Shanxi Xiangfen Zhanghuai (H1: 1), ca. 2400-2300 BCE. After Xiangfen County Museum, 2007, p. 85, fig. 2; 3. From Gansu Lanzhou Yuzhong Majiawa, ca. 2000-1900 BCE. After WWDXBJB, 1998, fig. 1.3.1; 4. From Henan Anyang Yinxu Guojiazhuang (M160: 6), late Shang. Photo by Xueyang Fang; 5. From Henan Anyang Yinxu Xiqu (M701: 72), late Shang. After ZSKKGSAYFJD, 1979, p. 103, fig. 78-6; 6. From Henan Anyang Yinxu Dasikongcun (M991: 20), late Shang. Photo by Xueyang Fang.

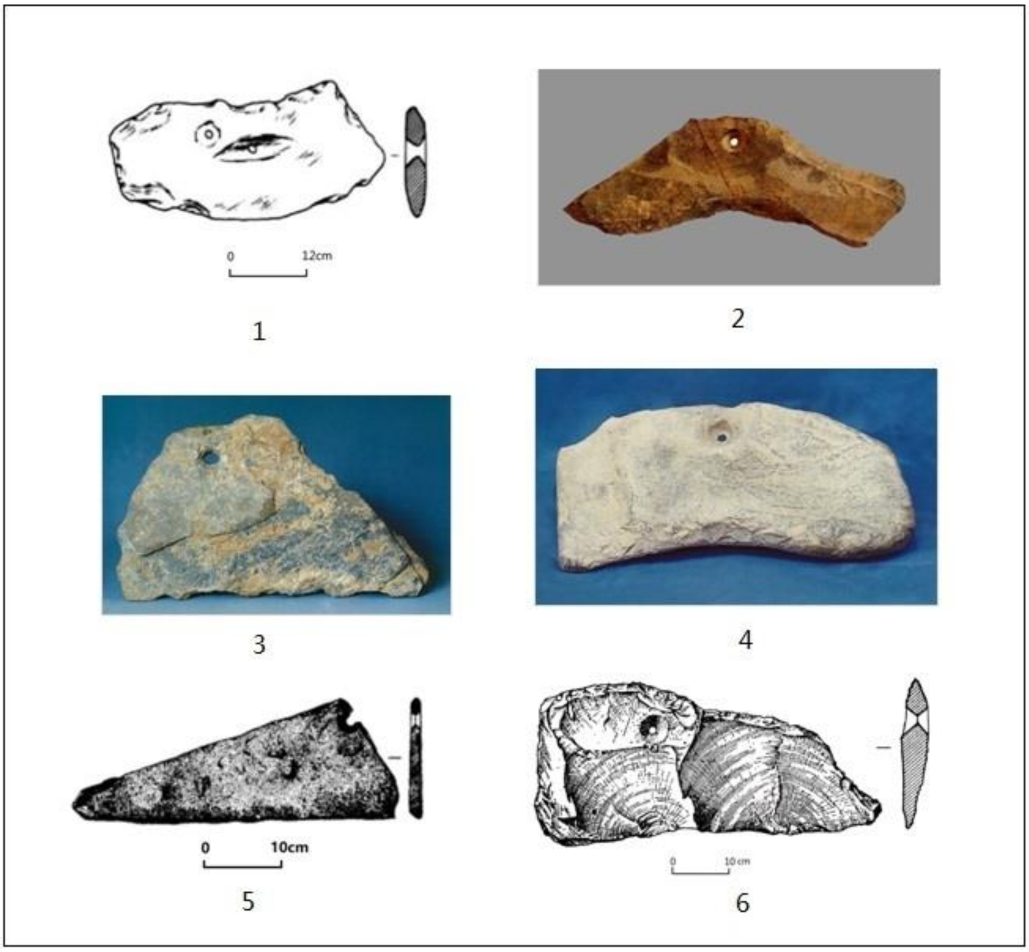


Figure 36. Type A-2 irregular shape with non-straight top of chime stones from late Neolithic to Xia dynasty (ca. 2400-1600 BCE).

1. From Shanxi Xiangfen Taosi (M3016: 39), ca. 2400-2300 BCE. After ZSKKGS & SXLFWWJ, 2015, p. 673, fig. 4-147; 2. From Henan Yuxian Yanzhai M14, ca. 2400-1900 BCE. After WWDXBJB, 1996a, fig.151; 3. From Shanxi Wutai Yangbai (H111: 1), ca. 2100-2000 BCE. After WWDXBJB, 2000, fig. 1.1.1; 4. From Shanxi Wenxi Nansongcun, ca. 2400-2300 BCE. After WWDXBJB, 2000, fig. 1.1.3a; 5. From Qinghai Ledu Liuwan (M1103: 35), ca. 2200-1600 BCE. After QHWGKGD, p. 232, fig. 141-5; 6. Shanxi Xiaxian Dongxiafeng (H15: 60), Xia dynasty. After DXFKGD, p. 98, fig. 92-4.

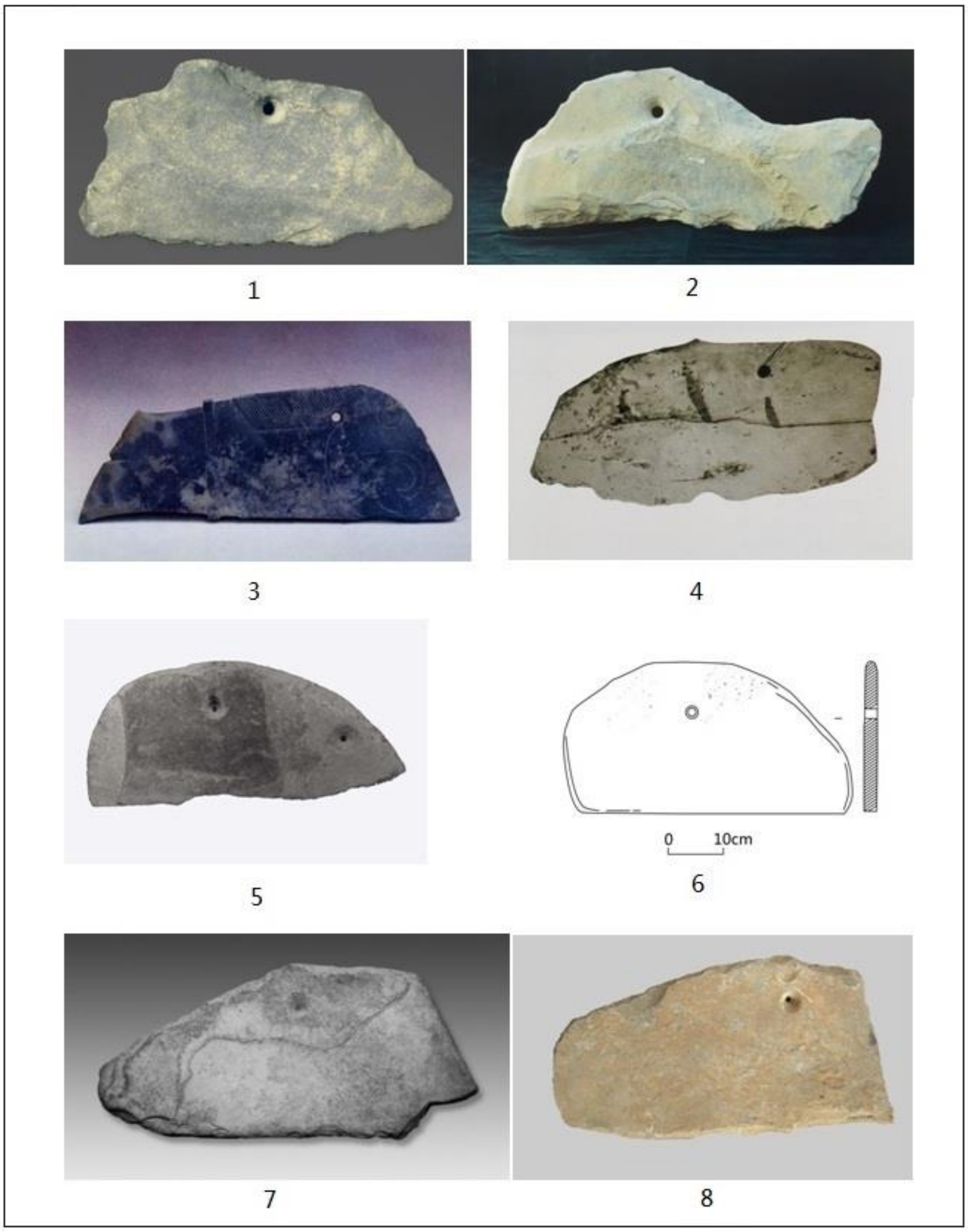


Figure 37. Type A-2 irregular shape with non-straight top of chime stones from Shang (ca.1600-1046 BCE) to Western Zhou period (1046-771 BCE).

1. From Henan Zhengzhou Xiaoshuangqiao (T189-3:1), early Shang (ca. 1600-1300 BCE). After Wu, 1999, fig. upper 4.6; 2. From Shaanxi Lantian Huaizhenfang, early Shang. Photo by Fang Jianjun; 3. From Henan Anyang Yinxu (M1769: 1), late Shang. After WWDXBJB, 1996a, fig. 1.5.5; 4. From Shanxi Lingshi Jingjie (M1: 13), late Shang. After WWDXBJB, 2000, fig. 1.1.10; 5. From Shaanxi Fufeng Qizhen, middle Western Zhou (976-878 BCE). Photo by Fang Jianjun; 6. From Shaanxi Chang'an Zhangjiapo (M152: 24), middle Western Zhou. After ZSKKGS et al., 1999, p. 305, fig. 228-1; 7. From Sichuan Chengdu Jinsha (L62: 2), Western Zhou (1046-771 BCE). After Xing & Wang, 2012, p. 65, fig. 4; 8. From Henan Anyang Yinxu Xiqu (M93: 3), late Shang. Photo by Xueyang Fang.

Figure 38. Type B-1 angular top with straight base of chime stones from Shang to late Western Zhou period (877-771 BCE).

1. From Hebei Gaocheng Taixi (M112: 24), early Shang (ca. 1600-1300 BCE). After WWDXBJB, 2008, fig. 1.6.2; 2. Liaoning Beipiao, Lower Xiajiadian culture. After Wu, 1999, p. 33, fig. upper 4.5; 3. From Kalaqin Xifu, Inner Mongolia, Lower Xiajiadian culture. Courtesy of Kalaqin Museum; 4. Collection of Anyang Museum (A01609). Photo by Xueyang Fang; 5. Collection of Anyang Museum (2416/0198). Photo by Xueyang Fang; 6. From Shaanxi Baoji Shangguancun, late Western Zhou. Photo by Fang Jianjun; 7. Shaanxi Chang'an Zhangjiapo (M157: 81), late Western Zhou. After ZSKKGS et al., 1999, p. 305, fig. 228-8; 8. From Shaanxi Fufeng Zhouyuan Shaochen Yiqu, mid- to late Western Zhou. Photo by Fang Jianjun.

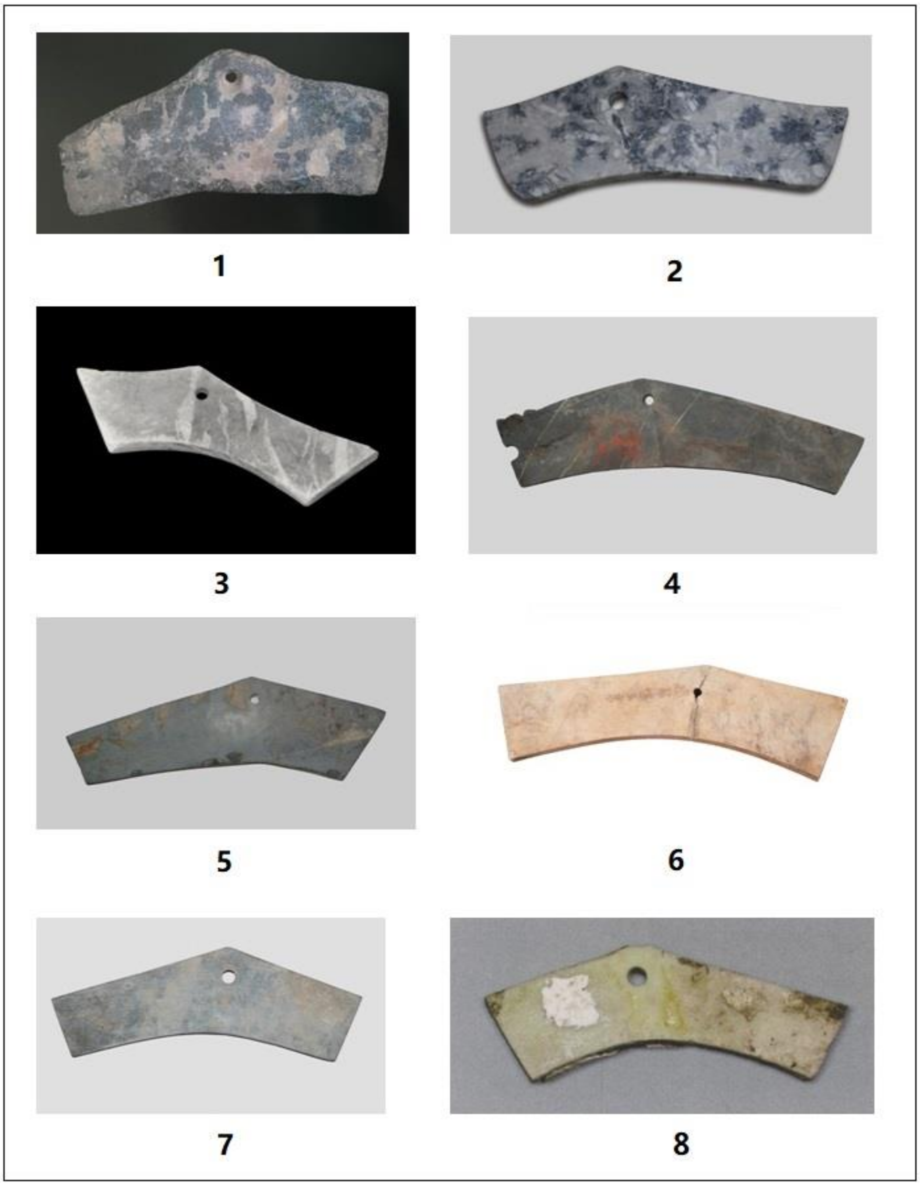


Figure 39. Type B-2 angular top with curved base of chime stones from Xia (ca. 2070-1600 BCE) to Western Han period.

1. From Henan Yanshi Erlitou, Xia dynasty. After WWDXBJB, 1996a, fig. 1.5.2; 2. From Gansu Lixian Dapuzishan, early Spring and Autumn (770-686 BCE), Photo by Fang Jianjun; 3. From Shaanxi Fengxiang Qin Gong no. 1 tomb, 537 BCE. Photo by Fang Jiajun; 4. From Anhui Bengbu Shuangdun M1, mid- to late Spring and Autumn (685-476 BCE). Photo by Fang Jianjun; 5. From Henan Qixian Songzhuang M4, late Spring and Autumn (546-476 BCE). Photo by Xueyang Fang; 6. From Marquis Yi's tomb of the Zeng (lower tier 2-11), 433 BCE. After WWDXBJB, 1996c, fig. 3.8.11d; 7. From Shandong Zhangqiu Luozhuang Western Han tomb (187-180 BCE), pit 14, Western Han. Photo by Fang Jianjun; 8. From Jiangsu Xuyi Dayunshan M1, Western Han (128 BCE). After NJBWY&XYWGJ, 2013, fig. 36.

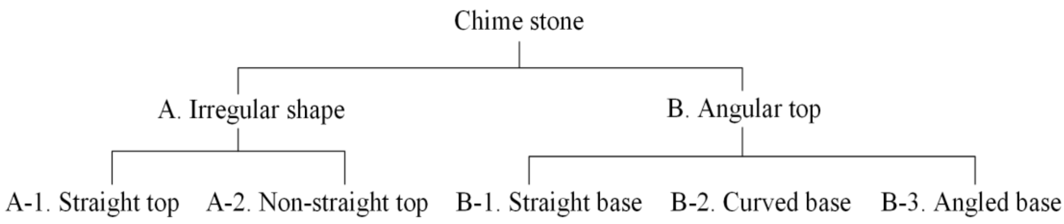


Figure 40. The structural diagram of typological system of chime stones

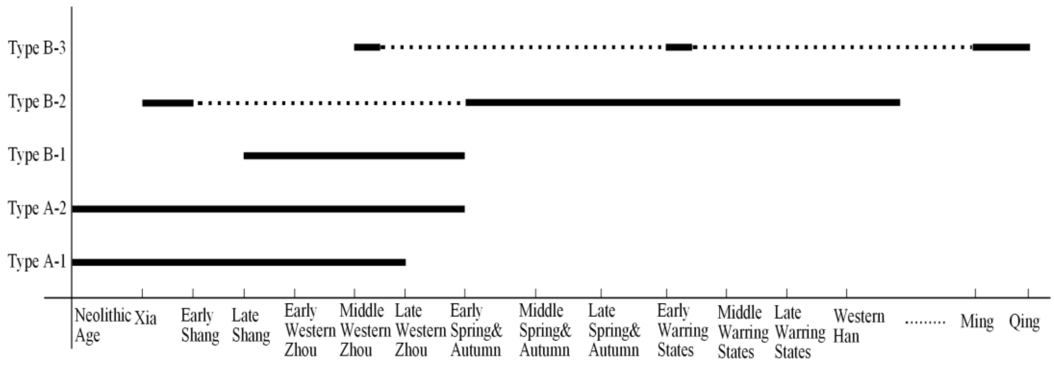


Figure 41. Schematic diagram of typological and chronological development of chime stones

Type A has varied irregular shapes. The entire geometry can have irregular features, with various quadrilateral shapes and polygons. The so-called top is defined by the end closest to the hanging hole. In this type, there are two subtypes: The subtype A-1 has a relatively straight top. Although some of these stones appear to not have very straight tops, it is likely that the purpose of the design was to make it straighter but this was hampered by the limitations of manufacturing tools and techniques. Examples of such a subtype are the Zhanghuai chime stone; Dasikong M991 chime stone; M701 and M93:5 chime stones in Yinxu Xiqu (fig.35). Evidence from archaeological excavations suggests that straight top chime stones ceased to be used in the period before the late Western Zhou dynasty (877-771 BCE) and were most likely no longer used during the late Western Zhou times (WWDXBJB, 1996a,b,c,d,e,1998, 2000, 2001, 2006, 2008, 2010).

The second subtype A-2 has a non-straight top. In this type, some chime stones are of profiles similar to animals such as fish, tiger and dragon (fig.37). The top shape on some chime stones has a tendency to form an angle, although the top may still have an irregular shape, for example, the Yuxian Yanzhai chime stone and the Jinsha chime stone. The subtype A-2 chime stones remained unto the late Western Zhou dynasty and then disappeared.

By contrast, Type B, with angular top has a more uniform with a vertex angle over 90 degrees. Similarly, there are two subtypes divided from type B. The first is B-1 with a straight base and the second is B-2 with a curved base. The profiles of these two subtypes show little variation. Some examples, such as the Yanshi Erlitou chime stone, Liaoning Beipiao chime stone and Inner Mongolia Kalaqin chime stone, are a variant of this type (figs. 38 & 39), but as a whole, they still belong to the angular top type, although the shape of their top edge is partly or slightly different.

Chime stones with an angled base (Type B-3) were rarely found between the Neolithic and Western Han periods. Dating back to the Western Zhou dynasty (1046-771 BCE), one chime stone from Shandong Jiaoxian Zhangjiazhuang has a profile of this type (fig. 42); its base is angled irregularly, but it is an unusual case. Most of this type of chime stone appeared after the Han dynasty, for example those belonging to the twenty-sixth year of the Qing Emperor Qianlong (1761. fig. 43) [28]. However, chime stones from the Qing dynasty are not studied in this thesis as they are outside the time frame of research. Pseudo chime stones with an angled base have also been discovered. The terracotta figures excavated from the Warring States (475-221 BCE) tomb in Shandong Zhangqiu Nülangshan included a statuette of a musician playing a pottery model of angled base chime stones suspended from a rack (fig. 44). The other Warring States example was the pottery *mingqi* chime stones (fig. 45) excavated from an aristocratic tomb of the Yue state in Zhejiang Changxing Bizishan (ZJKGS & CX Museum, 2007). Because they were not real instruments and cannot be used as a reliable source to include in my typological classification system, chime stones with an angled base are not considered in this thesis.

28 "Twenty-sixth year" refers to the time of making chime stones, and it was also the twenty-sixth year of Qianlong's reign (1761). It is a part title of this chime stone.

Figure 42. Chime stone from Shandong Jiaoxian Zhangjiazhuang.
Middle Western Zhou (976-878 BCE). Length: 82 cm. After WWDXBJB, 2001, fig. 1.9.8.

Figure 43. Chime stone from the twenty-sixth year of the Qing Emperor Qianlong's reign (1761).
Collection of the Art Institute of Chicago. Length: 71 cm. Photo by Fang Jianjun.

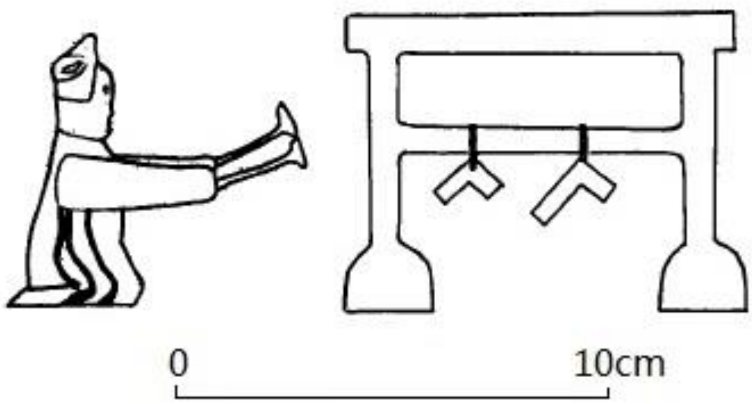


Figure 44. Terracotta figure from Shandong Zhangqiu Nülangshan.
Warring States (475-221 BCE). After Li Yuexun, 1993, fig. 3.

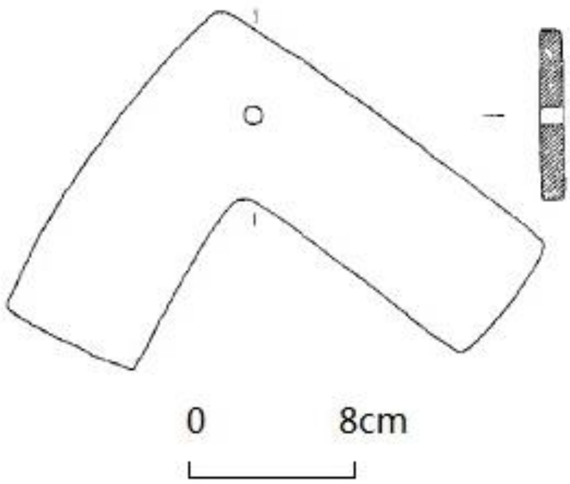


Figure 45. Pottery chime stone from Zhejiang Changxing Bizishan.
Warring States (475-221 BCE). After ZJKGS & CX Museum, 2007, p. 20, fig. 40-1.

3.2.2.1 Fieldwork data and application

Based on my fieldwork, 65 chime stones are presented and allocated into two subtypes. Below are the figures.

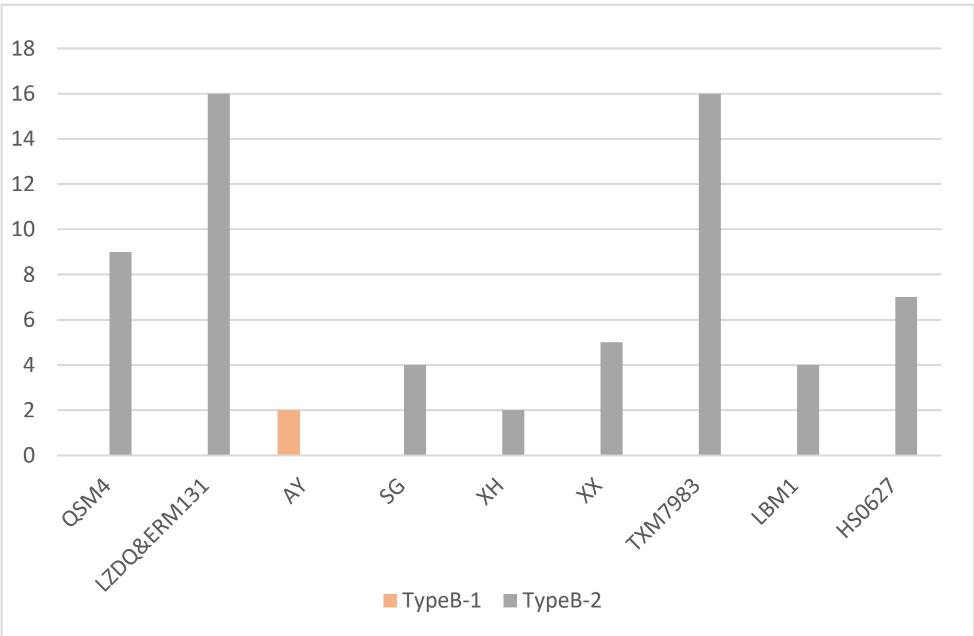


Figure 46. Type allocation based on locations

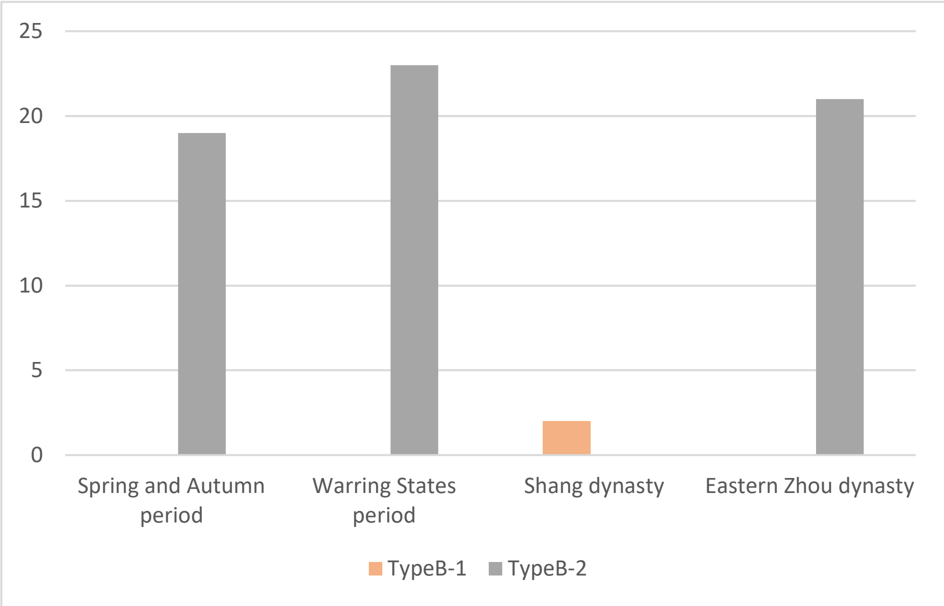


Figure 47. Type allocation based on period

The two figures above show how many chime stones from my fieldwork belong to types B-1 and B-2 when related to different locations and time periods. In figure 46, numbers 1-9 in the horizontal axis represents location. The vertical axis is the number of stones. The excavated locations are respectively listed as Henan Hebi Qixian Songzhuang M4 (QSM4), Henan Luoyang Zhongzhou Daqu & Luoyang Erqingju M131 (LZDQ&ERM131), Henan Anyang (AY), Henan Shangcai Guozhuang M2 (SG), Henan Xinzheng Hanwangling M2 (XH), Henan Xinzheng Xugang M3 & M4 (XX), Henan Tanggong Xilu M7983 (TXM7983), Henan Luoyang Baihuogongsi M1 (LBM1) and Henan Sanmenxia 0627 (HS0627) according to serial numbers. Figure 47 shows four periods of allocated chime stones, which are respectively from the Spring and Autumn period (770-476 BCE), the Warring States period (475-221 BCE), the Shang dynasty (ca. 1600-1046 BCE) and the Eastern Zhou dynasty (770-256 BCE). As a whole, the two figures indicate that type B-1 chime stones occupy only 20%: type B-2 form the majority of types found in fieldwork.

3.3 Summary

With reference to several research-based typological studies of chime stones, this chapter discusses the advantages and disadvantages of previous classification methods, and proposes a new taxonomy. The new taxonomy system will be explored in relation to the evolution of shape, in the next chapter.

Chapter 4: The Evolution of Shape

4.1 The Origin of Chime Stones

Evidence relating to the origin of chime stones has been presented by both Li Chunyi and Ingrid Furniss. Li points out that the chime stone excavated from Henan Yanshi Erlitou is not the earliest example, he suggests that the earliest chime stone is dated to the late Neolithic Age, referring to the single chime stones that have been unearthed in Shanxi and Henan (Li, 1996). According to a recent excavation report by the Institute of Archaeology at the Chinese Academy of Social Sciences (2015), the earliest Chinese chime stones were found in the Neolithic tombs at Taosi in Shanxi Xiangfen. Four stones were found at this site which provided extensive archaeological context and dated to around 2400-2300 BCE.

Similarly, Furniss agrees with the conclusion that the earliest known stones were those excavated from this late Neolithic Yellow River valley site (Furniss, 2008). Neolithic chime stones always appeared singly, not in sets. During the Shang (ca. 1600-1046 BCE) and the Western Zhou dynasties (1046-771 BCE), chime stones continued to be concentrated in the northern region. Wang Renxiang discusses another early chime stone uncovered at Minhe Lajia in Qinghai in the upper reaches of the Yellow River (Wang, 2001). Belonging to the Qijia culture, the site where the chime stone was unearthed is located in Lajia village. The chime stone is 100 cm in length, 60 cm in width and is 4 cm in thickness, according to the brief report. Wang argues that this is the earliest chime stone in ancient China. However, this chime stone was found accidentally without any other artefacts and the Qijia culture, according to Carbon-14 dating, belongs to around 2180-1760 BCE (QHWGKGD et al., 1984), so this stone is more recent than the Taosi culture stone discussed above (ca. 2400-2300 BCE).

Although the earliest chime stones so far identified were from the Xiangfen Taosi site, this does not provide conclusive evidence for the origin of chime stone. This is not only because of the limited extent of present-day excavation, but also a lack of clarity as to the extent that Stone Age stone tools were used for sound production. Early stone tools may have been used as everyday practical tools but they may also have been used as sound tools or even sound instruments; these two functions are not easy to distinguish from each other and it is fair to say that the Chinese chime stone may have originated earlier than the Taosi stones we have so far found. According to current archaeological findings, all early chime stones were unearthed in the Yellow River Basin of Northern China, suggesting that this area might have been the birthplace of the chime stone, and it may be in the Central Plain area where ancient Chinese people lived and gathered. Hence, the Chinese chime stone probably originated in its native land and there is no present evidence to show a foreign origin of the Chinese chime stone.

The embryonic form of the chime stone was presumably some simpler stone tool. This idea is suggested by *Er Ya* (an anonymous ancient text, approximately dating to the 3rd century BCE. In volume *Shiyue*, a chapter from *Er Ya*, "the chime stone is made of jade and stone, and is similar to a ploughshare in shape"[29]. According to Wang Bin and Jia Zhiqiang, chime stones possibly originated from a stone knife with a rectangle-like shape, which appeared in the late period of the Yangshao culture (ca. 3500-2900 BCE). The chime stone at that time was used in ritual celebrations in local tribes. Sequentially, there might be three stages of development inferred by both these ideas. The first stage would be the worship of a production tool like a stone plough, or a kind of tool that had the function to connect with supernatural beings, like a ritual stone knife. The second stage was as a symbol of religious power, more separated from a functional use. The last was as a musical instrument, consolidated within a system of ritual and music (*Li Yue* Zhidu), which was meant to strengthen the internal rules of the imperial family (Wang & Jia, 1991). A similar hypothesis stated by Xiu Hailin and Wang Zichu suggests that the origin of the chime stone was in association with the usage of the stone knife or stone plough (Xiu & Wang, 2001). Yang Yinliu and Li Chunyi also propose that the

29 For the Chinese version, see Ruan, 1980, p. 2601.

chime stone was most likely derived from a functional tool (Yang, 1980; Li, 1996). An alternative view is that the chime stone was not only derived from the production tools, but also diversified stone tools. Some chime stones have a fish-like shape, Wang Anchao suggests they could be derived from the shape of fish (Wang, 2006a).

Suo Quanxing argues that some stone-made square implements with a hole may be regarded as an ancient musical chime stone (Suo, 2009). Square-shaped stone implements with a hole in the top have been found in the Yangshao culture of the Neolithic Age (ca. 5000-3000 BCE) and the Yueshi culture of the Xia (ca. 2070-1600 BCE) and Shang dynasties (ca. 1600-1046 BCE. fig. 48); we do not know the precise purpose of this object. Similar objects were also found in the early Shang (ca. 1600-1300 BCE) site of Xiaoshuangqiao in Henan Zhengzhou, and here they are thought to be a farm implement, called *shijue* 石鑺 (a kind of polished stone tool), *fangkong chanxingqi* 方孔鏟形器 (a spade-shaped tool with a square hole) and were rectangular perforated stone implements, farming tools used for digging the ground. There is a lack of archaeological evidence to attest that this sort of artefact might have had sound usage, and these items differ from Neolithic chime stones in a number of important ways. However, it is possible this is some kind of precursor.

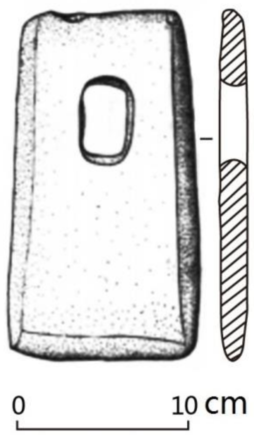


Figure 48. Square-holed stone tool from Henan Zhengzhou (H247).
Late Yangshao culture (ca.3500-2900 BCE). After Suo, 2009, fig. 1. Redrawn by Xueyang Fang.

With regard to the origin of chime stones, Fritz Kuttner examines the relationship between the chime stone and the ancient Chinese *pi* (*bi* in *Pinyin* system) 璧 disk (Kuttner, 1953). The *bi* disk is an ancient Chinese ritual object made of stone or jade of a round disk shape with a hole in the centre (fig. 49). As a ritual artefact, the *bi* disk, was used in most situations as an ornamentation of the human body as well as for ritual activities (the volume *Shiqi*, a chapter from *Er Ya,* dating approximately to the 3rd century BCE). Kuttner suggests that chime stones are connected to the *bi* disk, and that the *bi* disk is the embryonic form of the chime stone. He compares the inner circle of a *bi* disk to the bottom of the chime stone, as if the disk was broken in half. However, Kuttner's view is simply a hypothesis without the support of archaeological evidence.

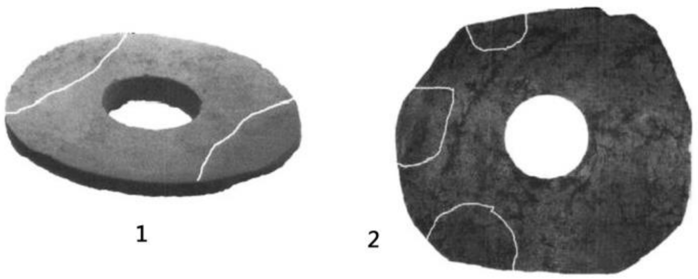


Figure 49. Stone *bi* disk from Gansu Wuwei Huangniangniangtai.
1. From tomb M38; 2. From tomb M41. Qijia culture (ca. 2180-1760 BCE). After Xing et al., 2008, fig. 2, 4.

In sum, given that the chime stone was originally found in the Yellow River valley, this area could be the birthplace of chime stones. According to recent archaeological discoveries, the origin of the chime stone could be much earlier than the late Neolithic Age from which the earliest Taosi chime stones have so far been excavated (ca. 2400-2300 BCE). Chime stones could perhaps originate in the earlier part of the Neolithic period, but we have no evidence to support this hypothesis.

The chime stone presumably originates from some kind of stone artefacts used in daily life which might have also sounded when struck. This phenomenon may have been discovered by ancient people, and a special chime stone used for sounding derived from this source, which gradually became a musical instrument. However, it is still unclear which kind of stone tools were, or influenced the making of, the earliest chime stones.

4.2 Development of Shape

4.2.1 Multi-Type Period

This developmental period, in which multi-types of chime stones coexisted, began in the Neolithic and continued throughout the Xia (ca. 2070-1600 BCE), Shang (ca. 1600-1046 BCE), and Western Zhou dynasties (1046-771 BCE). As time went by, some shapes gradually disappeared. In the Western Zhou dynasty, there were only non-straight top (type A-2) and angular top with straight base (type B-1) chime stones left, other types (type A-1, type B-2 and type B-3) of chime stones were rarely found.

During this period, the occurrence of chime stones had changed from single incidences of stones in the Neolithic to the coexistence of single stones and sets of multiple stones throughout the Shang and Western Zhou periods. Sets of chime stones occupied the mainstream in the late Western Zhou (877-771 BCE), while the single version largely exited the historical stage with the beginning of the Eastern Zhou (770-256 BCE) (Although it is worth noting that in the Qing dynasty (1636-1911 CE) looking back to ancient ideology was popular, and the single chime stone reemerged but with differences). To clarify the evolution of these multi-shaped chime stones, several separate aspects are relevant. The most important factors are variations of the base and also those affecting the bilateral top edges of the chime stone: *gushangbian* (the long top edge of the chime stone) and *guushangbian* (the short top edge of the chime stone, see figure 1).

From the Neolithic age to the Western Han dynasty, the base or bottom of the chime stones changed incrementally. In the earlier periods, the chime stone has a rough base with an irregular or sometimes nearly straight outline. As I discussed previously in Chapter 3, the late Neolithic chime stones were roughly shaped with an irregular base. As time went on, the base of the chime stone gradually became straight, from the late Shang (ca. 1260-1050 BCE) through Western Zhou (1046-771 BCE), with a few early examples from the early or middle Spring and Autumn (770-686 BCE or 685-547 BCE).

For instance, chime stones from Shaanxi Chengcheng Liujiawa M1 and M2 dating from early to middle Spring and Autumn period occasionally show a straight base (fig. 50), whilst both top edges look like an animal head, but actually that is a variation on the straight top edge. Similar cases from Anhui Bengbu Shuangdun M1, dating from early to mid Spring and Autumn, also resemble an animal head on their *guu* part, and one may distinguish a mouth and nose (fig. 51). From the Eastern Zhou (770-256 BCE) through the Western Han dynasty (202 BCE-8 CE), a curved bottom with a straight *gushangbian* and *guushangbian* became popular. The basal curvature can be varied; chime stones excavated from southern China often display a large radian.

Figure 50. Chime stone from Shaanxi Chengcheng Liujiawa M2.
Early to mid Spring and Autumn. After Chong, 2019.

Figure 51. Chime stones from Anhui Bengbu Shuangdun M1.
Mid- to late Spring and Autumn (685-476 BCE). Photo by Fang Jianjun.

Some previous studies concentrate on the properties of the base. As Kuttner (1953) states, chime stones with a straight base are older than those with an arc-shaped base. He also concludes that the curved base can improve the acoustical qualities of the stones. According to Li Chunyi (1996), a curved base can maintain the stability of the chime stone when hanging from a rack.

The chime stone flourished and increased in number during the Eastern Zhou dynasty

(770-256 BCE) with the development of type B-2, which has an angular top, pentagonal shape and curved base. A straight *gushangbian* and *guushangbian* became the most common shape from the late Western Zhou (877-771 BCE) to the Western Han period (202 BCE-8 CE). Although the B-3 type did appear during this period, it is usually only as the *mingqi* imitations.

The chime stones excavated from Qin Gong no.1 tomb in Shaanxi Fengxiang Nanzhihui, which dates to the mid- to late Spring and Autumn period, are unusual examples. These 28 chime stones have attracted particular attention since they have a concave curve to both *gushangbian* and *guushangbian* parts of the top (see fig. 39-3 in Chapter 3), which is highly unusual. According to Li Xueqin (2000), another unprovenanced chime stone recorded by a scholar (Xue, 1144) of the Song dynasty (960-1279 CE) also shows a concave curved *gushangbian* and *guushangbian* (fig. 52)[30]. In his view, the owner of this chime stone, according to inscriptions on the stone, was "Huai Hou", a wife of the Qin Gong, and this inscriptional chime stone was most likely from her tomb.

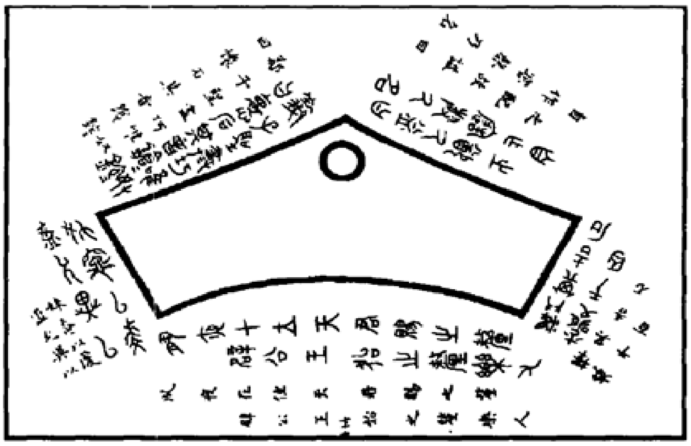


Figure 52. An unprovenanced inscriptional chime stone.
Dated to the Late Spring and Autumn (546-476 BCE), it probably belonged to the wife of Qin Jing Gong of the Qin state. After Xue, 1144 [1986], p. 38.

The content of inscriptions on these similar looking chime stones is different. The Huai Hou chime stone records sacrificial offerings etc. that were dedicated to the wife of the

30 According to Xue Shanggong, the chime stone was allegedly part of Wang's private collection. Wang came from Shaanxi Fufeng, not far from Shaanxi Fengxiang Nanzhihui Qin Gong no. 1 tomb.

ruler Qin Gong. Li Xueqin focuses on the content of inscriptions (Li, 2000), while other scholars not only consider the content of the chime stone inscriptions from Qin Gong no.1 tomb, but also the inscriptions' font and style (Hao & Hao, 2007). So far, there is no authoritative evidence to explain why the "Huai Hou" chime stone and the chime stones from Qin Gong no. 1 tomb have a concave curved top edge in both *gushangbian* and *guushangbian*. Interestingly, a Xia dynasty (ca. 2070-1600 BCE) chime stone excavated from the site of Yanshi Erlitou (Henan) in 1975 is similar in shape to the chime stones mentioned above (see fig. 39-1 in Chapter 3). As Li Chunyi describes, it belongs to the same type with a curved top edge *gushangbian* and *guushangbian* (Li, 1996). However, their dates are considerably far apart so there is no reason to argue that those chime stones are connected in some way.

Ten chime stones with surviving chime racks have been excavated from a sacrificial pit near the tomb of Qin Gong in Lixian Dapuzishan (Gansu) and dated to the early Spring and Autumn period (770-686 BCE). These chime stones belonged to a duke of the Qin state, the date of them is earlier than chime stones found in Qin Gong no.1 tomb. According to the archaeological excavation report, "the discovery of the musical instrument burial pit brought us extremely valuable data for the confirmation of the Qin Duke tomb, and for study into the early Qin peoples' ritual and sacrificial institutions as well as bronze casting technology" (EQARG, 2007, p. 38). The ten chime stones can be divided into two groups, each has five in total, and they were arranged in the pit from the west to the east side. The lacquered wooden rack for hanging the musical stones is similar to a bell rack found in the same pit. The length of the rack is 2.5 metres and the width is 0.8 metres. These chime stones from Dapuzishan have a similar feature to the Qin state chime stones in that they also have a curved top-edge in both *gushangbian* and *guushangbian* (see fig. 39-2 in Chapter 3), but it is less curved than the stones found in Qin Gong no.1 tomb which all belonged to the Qin state (888-221 BCE). The chime stones from Dapuzishan could be some sort of prototype or earlier form of the Qin Gong no.1 tomb examples, since the former dated earlier than the latter. However, more archaeological finds are needed for further studies into the shape development of the

Qin state chime stones.

In summary, the shape of chime stones from the late Neolithic Age to the Western Han dynasty (202 BCE-8 CE) gradually evolved from an irregular to a regular shape. From the late Neolithic to the Shang dynasty (ca. 1600-1046 BCE), there are various diverse shapes, such as triangular, rectangular and trapezoid. From the Western Zhou (1046-771 BCE) to the Eastern Zhou (770-256 BCE), chime stones have several changing features. Firstly, the whole shape of the chime stone changed from longer and thicker to shorter and thinner. Secondly, the base of the chime stone gradually transformed from a low vaulted base line to a higher vaulted one; the chime stone maker aimed to improve the whole balance of the chime stone's body and to increase stability when hanging it from the rack, making it a smaller shape and giving it a higher musical range.

There are no archaeological finds of chime stones from the Qin dynasty (221-207 BCE) although the pattern of shape change is contiguous before and after this period. Hopefully some new Qin dynasty chime stones will appear in the future. During the Western Han dynasty (202 BCE-8 CE), the shape of chime stones did not change very much, instead, they followed the shape of the Eastern Zhou chime stones, especially the Warring States (475-221 BCE) ones. The diagram below shows the diachronic development of the shape of chime stones (fig. 53).

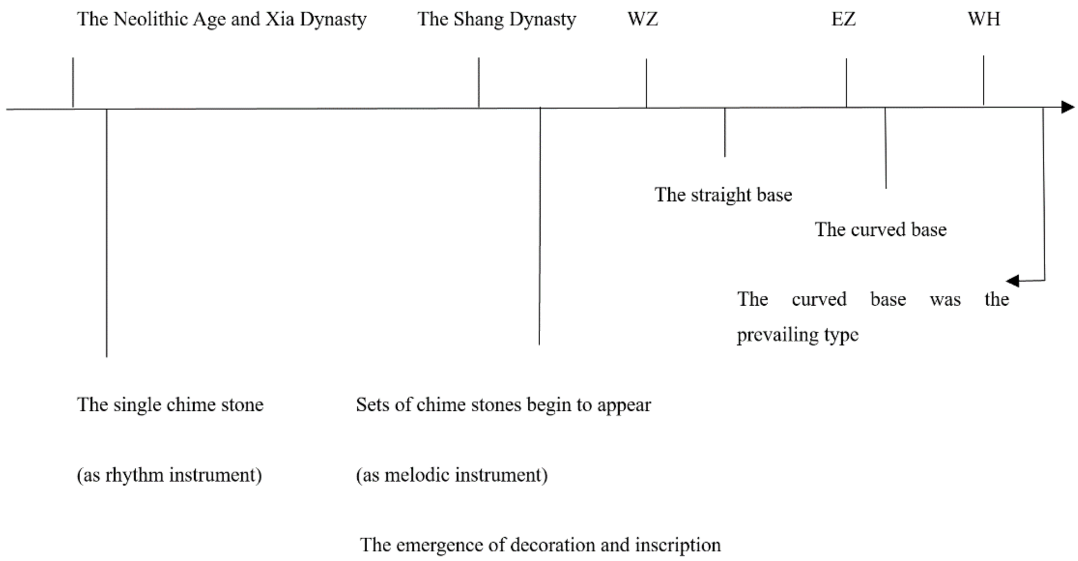


Figure 53. The shape development of chime stones in Ancient China.
WZ=Western Zhou, EZ=Eastern Zhou, WH= Western Han

4.2.2 Uni-Type Period

The uni-type period of the chime stone began approximately at the end of the Western Zhou dynasty (1046-771 BCE) and lasted until the Western Han dynasty (202 BCE-8 CE). The shape of the chime stone becomes fixed as type B with an angular top, and its popularity grows to its peak during the Eastern Zhou (770-256 BCE) and the Western Han dynasties (202 BCE-8 CE).

Although all chime stones become unified with only one type, there are also individual cases with special characteristics; for example, as discussed above, the chime stones unearthed from Qin Gong no.1 tomb have a concave top edge *gushangbian* and *guushangbian*. The proportions of these special or common cases are shown in figure 54.

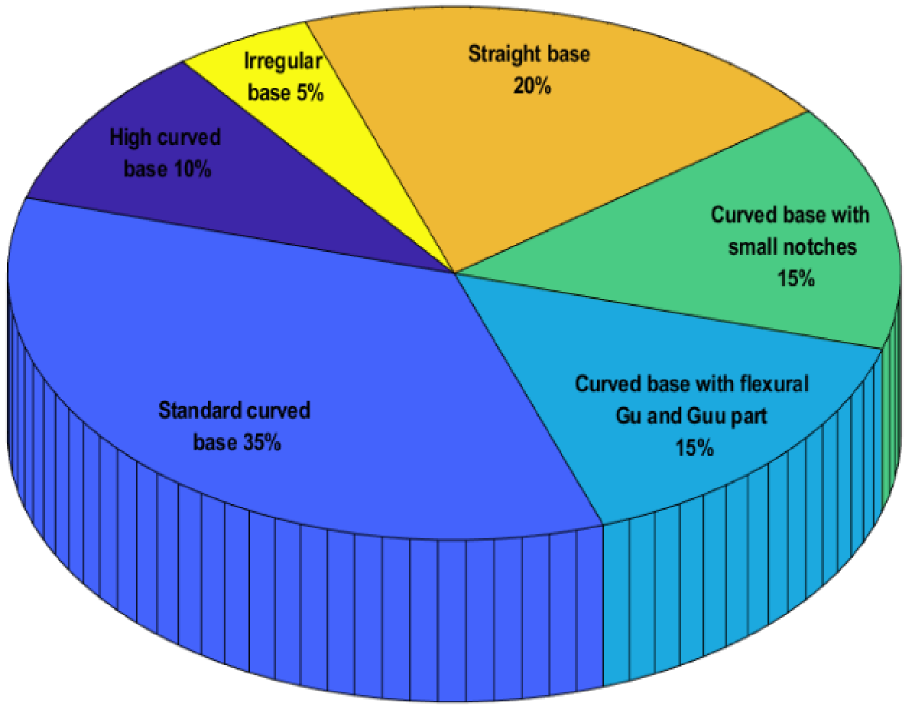


Figure 54. Statistics of base categories of chime stones from late Western Zhou (877-771 BCE) to the Western Han period

The overwhelming majority (75%) of the stones have a curved base. A standard curved base accounts for 35%, 15% have a curved base with small notches, 15% have concave *gu* and *guu* parts, and 10% have a high curved base. 20% have a straight base and irregular based chime stones are relatively rare, only 5%.

In the classical text *Kaogongji* (The records of examination of craftsmen), there is a design scheme with the scale and proportions for the manufacture of chime stones:

> When the artisan Qingshi makes a chime stone, the top angle is a right angle plus a half of it, the *guubo* is one, *guushangbian* is two, and *gushangbian* is three. Divide *guubo* into three equal parts and then use two thirds for *gubo*. Divide *gubo* into three equal parts, and then use one third as thickness (For the Chinese version, see Ruan, 1980, p. 923).

From the above citation, we may calculate the ratio of the various parts of a chime stone and obtain a formula as below:

jugou (vertex Angle) = $90^{\circ}\times1.5=135^{\circ}$

guubo (short end) = 1

guushangbian (short top edge) = $1\times2=2$

gushangbian (long top edge) = 1×3=3

gubo (long end) = $\frac{2}{3}$ × *guubo* = 0.67 *guubo*

thickness = $\frac{2}{9}$ × *guubo* = 0.22 *guubo*

This demonstrates the formula used for a chime stone maker (Qingshi) to design a chime stone. The vertex angle *jugou*, is set at 135 degrees, the length of *guubo* is regarded as one unit, *guushangbian* is two units, twice as long, and *gushangbian* is three units. When one divides the length of the *guubo* into three parts and takes away one, this is the length of *gubo*, which is two thirds of a unit. If one divides the length of the *gubo* into three parts, each will equal the measurement of the thickness.

Through this formula, we can easily calculate the length, thickness and top angle of each chime stone. What is noteworthy, however, is the *Kaogongji* merely has the ratio in relation to the *guubo*, *gubo*, *gushangbian*, *guushangbian*, *jugou* and thickness, whereas other parameters such as the angles of *gushangjiao* and *guushangjiao* are not involved. This formula is only a reference for manufacturing chime stones, and does not correspond exactly to fieldwork results. Fang (2006) has carried out analysis of archaeological finds of chime stones of the Western Zhou period (1046-771 BCE), to compare their dimensions with the *Kaogongji* formula. He concluded that the result achieved by using this formula is a little greater than the real dimensions of unearthed chime stones.

However, the *Kaogongji* was an official record in relation to the Qi state in northeast China of the early Warring States period (476-387 BCE) of the Eastern Zhou dynasty (770-256 BCE), which is later than the Western Zhou stones analysed by Fang. In recent years, many chime stones of the Qi state dating to the Eastern Zhou period have been excavated, mainly in Shandong province. I have compared the ratios of chime stones from *Kaogongji* with chime stones found in the Qi state during this period, in order to best assess the accuracy of this model.

I chose 15 samples of chime stones from the Qi State in the Eastern Zhou period, taking measurements from excavation reports as none of my own field work examples are from Qi state, from exactly the same context as the *Kaogongji* document. I calculated the equivalent ratios (see table. 10) to the *Kaogongji* formula. These selected samples are all well preserved. Detailed information relating to excavation location can be seen in Chapter 2. Subsequently, I selected 10 examples from my fieldwork, and 5 further examples from other excavation reports (see table. 11), each of which is from the same dynasty, the Eastern Zhou, but from a different region, outside Qi state, and thus outside Shandong province. This was to explore whether the *Kaogongji* guidelines are more relevant in the area in which this document was written.

Table 10. Ratios of Eastern Zhou chime stones found in Shandong and the record of *Kaogongji Qingshi*

Serial no.	Excavation Location	Specimen no.	*Gushangbian* to *guushangbian*	Difference	*Guushangbian* to *guubo*	Difference	*Gubo* to *guubo*	Difference	*Gushangbian* to *guubo*	Difference	Thickness to *guubo*	Difference	*Jugou* (Vertex angle)	Difference
Kaogongji Qingshi			1.5		2		0.67		3		0.22		135°	
1	Changqing Xianrentai M6	M6:35	1.36	-0.14	1.99	-0.01	0.88	+0.21	2.71	-0.29	0.20 ~ 0.22	-0.02 ~ 0	143°	+8°
2	Changqing Xianrentai M6	M6:36	1.42	-0.08	1.94	-0.06	0.89	+0.22	2.74	-0.26	0.22 ~ 0.27	0 ~ +0.05	139°	+4°
3	Changqing Xianrentai M6	M6:33	1.46	-0.04	2.20	+0.20	0.94	+0.27	3.21	+0.21	0.29 ~ 0.34	+0.07 ~ +0.12	140°	+5°
4	Changqing Xianrentai M6	M6:34	1.28	-0.22	2.23	+0.23	1.07	+0.40	2.86	-0.14	0.25 ~ 0.33	+0.03 ~ +0.11	135°	0°
5	Zhucheng Zangjiazhuang	899	1.44	-0.06	1.97	-0.03	0.85	+0.18	2.84	-0.16	0.24	+0.02	130°	-5°
6	Zhucheng Zangjiazhuang	898	1.44	-0.06	1.74	-0.26	0.88	+0.21	2.51	-0.49	0.18 ~ 0.23	-0.04 ~ +0.01	130°	-5°
7	Tengzhou Xueguo Gucheng M117	Unknown	1.31	-0.19	1.81	-0.19	0.80	+0.13	2.37	-0.63	0.22 ~ 0.23	0 ~ +0.01	130°	-5°
8	Tengzhou Xueguo Gucheng M117	Unknown	1.33	-0.17	1.60	-0.4	0.77	+0.1	2.14	-0.86	0.25	+0.03	134°	-1°
9	Tengzhou Zhuangli Xicun	09376	1.30	-0.20	1.56	-0.44	0.88	+0.21	2.03	-0.97	0.34 ~ 0.37	+0.12 ~ +0.15	143°	+8°

10	Tengzhou Zhuangli Xicun	09375	1.33	-0.17	1.65	-0.35	0.86	+0.19	2.19	-0.81	0.36 ~ 0.49	+0.14 ~ +0.27	137°	+2°
11	Linzi Dafuguan	F30029	1.47	-0.03	2.36	0.36	0.89	+0.22	3.48	0.48	0.25 ~ 0.26	+0.03 ~ +0.04	142°	+7°
12	Linzi Dafuguan	F30045	1.56	0.06	2.11	0.11	0.83	+0.16	3.28	0.28	0.26	+0.04	142°	+7°
13	Linzi Zihedian M2	51:8	1.44	-0.06	2.09	+0.09	0.81	+0.14	3.01	+0.01	0.21	-0.01	133°	-2°
14	Linzi Zihedian M2	51:7	1.54	+0.04	2.07	+0.07	0.88	+0.21	3.20	+0.20	0.23 ~ 0.27	+0.01 ~ +0.05	134°	-1°
15	Linzi Shang Wang M2	F30061	1.36	-0.14	2.06	+0.06	0.87	+0.20	2.81	-0.19	0.20 ~ 0.24	-0.02 ~ +0.02	141°	+6°
Average			1.40	-0.10	1.96	-0.04	0.87	+0.20	2.76	-0.24	0.25 ~ 0.28	+0.03 ~ +0.06	137°	+2°

Table 11. Ratios of Eastern Zhou chime stones excavated from outside Shandong and the record of *Kaogongji Qingshi*

Serial no.	Excavation Location	Specimen no.	*Gushangbian* to *guushangbian*	Difference	*Guushangbian* to *guubo*	Difference	*Gubo* to *guubo*	Difference	*Gushangbian* to *guubo*	Difference	Thickness to *guubo*	Difference	*Jugou* (Vertex angle)	Difference
Kaogongji Qingshi			1.5		2		0.67		3		0.22		135°	
1	Hebi Qixian Songzhuang M4	M4:40	1.46	-0.04	1.64	-0.36	0.63	-0.04	2.40	-0.6	0.22 ~ 0.29	0 ~ +0.07	148°	+13°
2	Hebi Qixian Songzhuang M4	M4:51	1.29	-0.21	1.68	-0.32	0.85	+0.18	2.16	-0.84	0.14 ~ 0.29	-0.08 ~ +0.07	160°	+25°
3	Hebi Qixian Songzhuang M4	M4:39	1.28	-0.22	1.82	-0.18	0.73	+0.06	2.32	-0.68	0.28 ~ 0.32	+0.06 ~ +0.10	153°	+18°
4	Hebi Qixian Songzhuang M4	M4:50	1.23	-0.27	1.72	-0.28	0.83	+0.16	2.11	-0.89	0.32 ~ 0.36	+0.10 ~ +0.14	150°	+15°
5	Hebi Qixian Songzhuang M4	M4:38	1.44	-0.06	1.67	-0.33	0.89	+0.22	2.40	-0.6	0.39 ~ 0.42	+0.17 ~ +0.2	150°	+15°
6	Hebi Qixian Songzhuang M4	M4:49	1.46	-0.04	1.44	-0.56	0.78	+0.11	2.11	-0.89	0.29 ~ 0.32	+0.07 ~ +0.10	160°	+25°
7	Luoyang Zhongzhou Daqu	no.7	1.54	+0.04	1.87	-0.13	0.93	+0.26	2.88	-0.12	0.22	0	144°	+9°
8	Luoyang Zhongzhou Daqu	no.4	1.71	+0.21	1.52	-0.48	0.71	+0.04	2.59	-0.41	0.21	-0.01	151°	+16°

9	Luoyang Zhongzhou Daqu	no.8	1.37	-0.13	1.74	-0.26	0.83	+0.16	2.39	-0.61	0.25	+0.03	140°	+5°
10	Luoyang Zhongzhou Daqu	no.9	1.53	+0.03	1.34	-0.66	0.87	+0.2	2.05	-0.95	0.21	-0.01	150°	+15°
11	Shanxi Jindu Xintian M302	no.94	1.39	-0.11	2.27	+0.27	0.94	+0.27	3.15	+0.15	0.32	+0.10	145°	+10°
12	Shanxi Jindu Xintian M302	no.98	1.50	0	1.73	-0.27	1.04	+0.37	2.60	-0.4	0.28	+0.06	138°	+3°
13	Tomb of Marquis Yi of the Zeng	Lower tier no.3	1.24	-0.26	1.5	-0.5	0.84	+0.17	1.87	-1.13	0.26	+0.04	164°	+29°
14	Tomb of Marquis Yi of the Zeng	Upper tier no.2	1.48	-0.02	1.41	-0.59	0.79	+0.12	2.09	-0.91	0.22	0	160°	+25°
15	Shanxi Lucheng Luhe M7	no.1	1.76	+0.26	1.79	-0.21	0.79	+0.12	3.14	+0.14	0.27	+0.05	130°	-5°
Average			1.45	-0.05	1.68	-0.32	0.83	+0.16	2.42	-0.58	0.26 ~ 0.28	+0.04 ~ +0.06	150°	+15°

The results show that the ratios in *Kaogongji* are an approximate guide for making chime stones, but not a unified standard. Table 10 shows that the ratios of *gushangbian* and *guushangbian* between the Qi state and the *Kaogongji Qingshi (KQS)* are relatively close, the difference in averages being 0.10. It identifies that the ratio of 3/2 in *gushangbian*/*guushangbian* from *KQS* could be reflected in the chime stones of the Qi region in Shandong of northeast China. The average of *guushangbian*/*guubo* has little difference in the ratio of *KQS*, which is 0.04 less than that of the *KQS*.

The ratio of *gubo* and *guubo* is slightly greater than that of *KQS*, with an average of 0.87; 0.20 larger than the *KQS*. From the archaeological record of Qi state chime stones, it appears that the *gubo* in the Qi area of the Eastern Zhou dynasty (770-256 BCE) was relatively smaller than the *guubo*; there is no case that shows the ratio between *gubo* and *guubo* is 1, therefore the widths of the *gubo* and *guubo* are not equal on this occasion.

The average thickness ratio of the Qi area is about 0.03-0.06 higher than that of *KQS*. The difference between the ratio of *gushangbian* and *guubo* is not much different from the *KQS*, with a difference in the average of less than 0.24. The vertex angle in *KQS* is 135 degrees. In table 10, the angle is fairly close, with an average difference of 2°, which is larger than in *KQS*.

Table 11 compares the ratio of *gushangbian* and *guushangbian* between the other areas outside Shandong during the Eastern Zhou period and the *KQS*. The result is closer than in table 10. The average ratio of *gushangbian* and *guushangbian* from selected chime stones is 0.05 less than that of *KQS*. It identifies that the ratio of 3/2 in *gushangbian*/*guushangbian* from *KQS* could be also reflected in the chime stones from other places during the Eastern Zhou period. The average of *guushangbian*/*guubo* has quite a large difference when compared with the ratio of *KQS*, which is 0.32 less than *KQS*.

The average ratio of *gubo* and *guubo* is slightly larger than that of *KQS*, with a difference in the average of 0.16 greater than *KQS*. As before, the length of the *gubo* in other areas outside Shandong during the Eastern Zhou period (770-256 BCE) was relatively smaller than that of the *guubo.* There is no case that shows the ratio between the *gubo* and the *guubo* is 1, therefore the widths of the *gubo* and *guubo* are not equal on this occasion.

The average thickness ratio of the chime stones from other areas is about 0.04-0.06 higher than that of *KQS*, and much thicker than those from the Qi area. The differences between the ratio of *gushangbian* and *guubo* show much discrepancy from the *KQS*, with an average of 0.58 less than the *KQS*. The vertex angles from other locations outside Qi state are relatively bigger than that of *KQS*, with an average of 15° larger than that of the *KQS*. The chime stones from Marquis Yi's tomb have a very wide vertex angle, for example, the specimens in lower tier no. 3 and upper tier no. 2 are 164° and 160°, respectively, which are the 29° and 25° larger than that of *KQS*.

The data in the two tables illustrate a number of differences from the documented standard. Based on the above discussion, the results can be achieved:

Due to the influence of weathering and other factors, the size of the chime stones may differ slightly from the size before the burial, that is, the size may be decreased. However, such deviation is relatively small, and the erosion and spalling of the chime stones should be equal on its whole body and despite this, the scale of the *gu* and *guu* part of Eastern Zhou stones is roughly similar to that contained in *KQS*. In particular, the average vertex angle of chime stone in the Qi area is close to that of *KQS*. Thus, the explanation is that *KQS* is more applicable to the Qi area stones in the Eastern Zhou period.

The *gubo* in the Eastern Zhou dynasty is wider than that of *KQS*, probably because of grinding, and the arching base of the Eastern Zhou chime stones may also be shaped after tuning. The overall thickness of the Eastern Zhou chime stones varies from stone to stone and is often uneven on individual stones; the *KQS* has not explained this factor in much detail. The *KQS* includes the approximate thickness of the chime stone. Actually, the excavated chime stones are thicker than that of *KQS*, which may be to leave space for grinding and tuning. In addition, it is not yet possible to determine the shape of the chime stone accurately by following the scales such as the vertex angle, *gu*, *guu*, *bo* and thickness contained in the *KQS*. Only by adding the angles of the *gushangjiao* and *guushangjiao* can they be accurately formed; there are no records about that in *KQS*. It is interesting to note that both the *gu* part and the vertex angle in the southern region are much bigger than those in the northern area, especially the chime stones from the Marquis Yi's tomb.

In sum, selected examples from the Eastern Zhou (770-256 BCE) show that the chime stones of the Qi realm are roughly similar to that of the *KQS*, while only a small part of the ratios of other individual sites outside the Qi are similar to those of *KQS*. The scales and ratios of the chime stones contained in the *KQS* are the approximate specifications of the semi-finished product. After the process of tuning, their dimensions will be changed. According to Wenren (1984), the *KQS* was compiled in the early period of the Warring States (476-387 BCE). Some experiments also indicate that the dimensions of chime stones depicted in *KQS* are considerably different from those of the Western Zhou period (Fang, 1989; Sun, 2009). The formula in *KQS* is a theoretical summary based on the chime stone manufacturing practice which the Western Zhou craftsman and chime stone maker "Qingshi" (Qing family) had experienced. The manufacture of chime stones in the Eastern Zhou period had evolved from an early stage of empirical design to another phase of theoretical design.

4.3 Inscription, Decoration and Metaphor

Inscriptions are commonly seen on archaeological finds in both the Shang (ca. 1600-1046 BCE) and the Zhou dynasties in ancient China. The earliest inscriptions are known as oracle-bone script which appears in the late Shang dynasty (ca. 1260-1050 BCE) carved on turtles' breastplates. In remote antiquity the overwhelming majority of inscriptions appeared on bronze vessels and other bronze objects including musical bells, although some stone artefacts including chime stones were also inscribed. Inscriptions on bronze vessels dating to the Western Zhou dynasty (1046-771 BCE) revealed that they were not only dedicated to deceased ancestors, but also intended for using as lavish ritual banquet items (Liu, 2011).

As they are musical instruments used to make “metal and stone music”, relevant inscriptions are sometimes seen on chime stones. Some chime stones have inscriptions which record and describe the musical scale, tone names, the reason for making the instruments, the owner of the instruments, or even the historical background. The earliest inscribed chime stone is the late Shang stone excavated from Fu Hao’s tomb (ca. 1200 BCE), as discussed in Chapters 1 and 2. Another example is a set of three late Shang chime stones allegedly found in Henan Anyang, each carved with different Chinese characters: Yongqi 永啟, Yaoyu 夭餘 (fig. 55) and Yongyu 永餘, respectively (Yu, 1976); however these inscriptions have not been explained.

Figure 55. One of three inscribed late Shang chime stones.
Inscribed with “Yongyu”. After Yu, 1976, p. 141.

The 32 chime stones in Marquis Yi’s tomb (433 BCE) are covered with rich inscriptions which number them serially, give the names of the tones they would each emit, and the name of the *twelve-lü* tuning system (Hubei provincial Museum, 1989. fig. 56). Lothar von Falkenhausen points out that “these inscriptions told us the chime stones of the Zeng emitted an unbroken chromatic sequence of tones through three and a half octaves” (Falkenhausen, 1993, p. 270). I will look at the Zeng chime stone inscriptions in detail in Chapter 8.

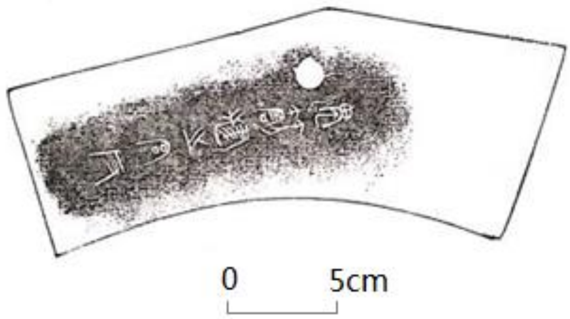


Figure 56. Rubbing of Chime stone from Marquis Yi's tomb.
Early Warring States (433 BCE). After Hubei Provincial Museum, 1989, p. 580, fig. 22.

Dating to the Warring States period (475-221 BCE), chime stones from Luoyang Jincun tomb display inscriptions that show the names of the tones they emitted, and their order for hanging from chime racks (Yu, 1976). In 1995, a chime stone dating to the Warring States period was excavated from a Chu tomb in Henan Shangcai, with inscriptions of "Shang fu zhi Zhi" 商父之徵 along the *guu* part, showing the tone names *shang* (re) and *zhi* (sol) in a traditional Chinese five note scale. They are very similar in shape to the chime stones from Marquis Yi's tomb (fig. 57).

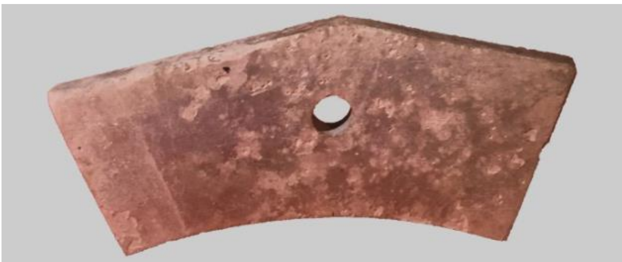


Figure 57. Chime stone from Henan Shangcai Chu tomb.
Warring States (475-221 BCE). After WWDXBJB, 1996a, fig. 1.5.17a.

Inscriptions relating to music are also seen on a Eastern Zhou (770-256 BCE) chime stone found in Shandong Linzi Shaoyuancun, which displays an inscription Yuetang 樂堂[31] (music hall) on the *guu* part. Recently, a new find in Shaanxi Xianyang has been briefly reported, where a number of inscribed chime stones were excavated from a city

31 The inscription could be explained as either Yueshi 樂室 (music room) or Yuetang 樂堂 (music hall).

site of the Qin state, although most of them were broken into pieces (fig. 58). An inscription of the music institution Yuefu 樂府[32] appeared on some of these chime stones, suggesting that the Yuefu was established by the late Warring States period (284-221 BCE. Xu, Zhang & Geng, 2016).

Figure 58. Chime stones inscribed "Yuefu" from Shaanxi Xianyang.
Late Warring States (284-221 BCE). Photo by Xu Weihong.

In a Luozhuang Western Han tomb, inscriptions on chime stones also reflect stone suspension orders, serial numbers, and historical information (JNKGS et al., 2004). Similarly, chime stones in private collections dating to the late Western Han period from Guo Handong in Guangdong Zhuhai display an explanation of tone names and titles of music compositions (fig. 59). I will discuss these further in Chapter 8.

Figure 59. Chime stone collected by Guo Handong.
Western Han (202 BCE-8 CE). After WWDXBJB, 2010, fig. 1.8.3b.

Colin Renfrew and Paul Bahn state, "Art is not, of course, restricted to the depiction of

32 The word Yuefu has two meanings, it can be understood to mean Chinese poetry composed in a folk song style but here it refers to an important music institution in the royal court which appeared as early as the Qin dynasty.

scenes or objects. The decoration of pottery and other artefacts with abstract patterns must not be overlooked" (Renfrew & Bahn, 2004, p. 423). In ancient China, bronze objects served as a means of communicating with invisible spirits, this was at least partially through mystical decorations, particularly zoomorphic images such as Taotie (an imaginary animal mask design), a dragon pattern and so on. Therefore, inscriptions and animal patterns on bronze objects were reflecting both their practical uses and ritual functions in ancient times.

As well as chime stones with inscriptions, examples with other ornamentation have been found. Chime stones exhibiting decoration in the form of an engraved motif or a painted pattern occur during the period from the late Shang (ca. 1260-1050 BCE) to the Warring States (475-221 BCE) although no decorated Western Han (202 BCE-8 CE) examples exist. Decoration reemerges on some specimens during the Qing dynasty (1636-1911 CE. Fang, 2011).

By far the earliest ornamented chime stone appeared in Fu Hao's tomb (ca. 1200 BCE), where a single chime stone was found carved with an owl-like design (fig. 60). The Chinese classical text *Shi Jing* says that "the mysterious bird is an ancestor of the Shang dynasty"[33], and this owl-patterned chime stone might have communicated good fortune for the dead, wishing for an auspicious life in another world. The incised decoration of the Shang chime stones can be divided into two types, those that depict real animals and those that depict imaginary animal-like patterns. The former means that images of tigers, fish and other real animals are depicted, the latter refers to imaginary or legendary animals such as dragon and the *Kui* 夔, half snake and half bird.

33 *Shi Jing: Shang Song* "Xuan Niao". For the Chinese version, see Ruan, 1980, p.622.

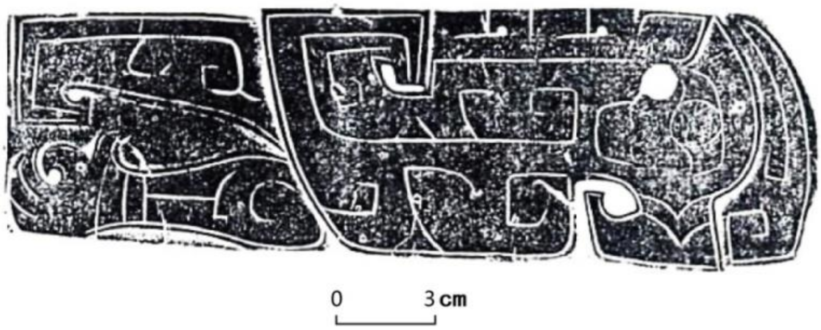


Figure 60. Rubbing of the owl-like decorated chime stone from Fu Hao's tomb.
Late Shang (ca. 1200 BCE). After ZSKKGS, 1980, p. 199, fig. 99.

In the Central Plain area, tiger decorations are found occasionally. In Anyang Wuguancun, for example, a chime stone decorated with a tiger was excavated from a large tomb which dated to the late Shang period (see Chapter 2, fig. 8). In the southwest region, tiger designs have been found on the musical instrument *ling* clapper-bell. In the southern area, the tiger appeared on chime bells and other bronze-made musical instruments, such as the big bell *bo* (Fang, 2006). In classical literature, people from the ancient Ba tribe regarded the tiger as a totem animal[34], probably heralding the auspicious and warding off bad luck. Decoration on musical instruments is not only a visual beautification, but also carries metaphoric and symbolic meaning.

Chime stones with fish decorations have also been found in the Central Plain area in China. An example is the chime stone excavated from the tomb M1769 at the west district of Yinxu in Henan Anyang dating to late Shang period (see Chapter 3, fig. 37-3). Fish are also sacred animals in Chinese culture, for example in *Huai Nan Zi*, the Hou Ji is referred to as a legendary ancestor of the Zhou people, that came alive magically after death, and became a half-fish man[35].

Dating to the late Shang period (ca. 1260-1050 BCE), a chime stone engraved with sunken lines that resemble the image of a dragon, was found in Yinxu Huanshui Nan'an near the site of a palace building (ZSKKGSAYFJD, 1976). Originally, the excavators

34 See *Nanman Xi'nanyi Liezhuan* in *Houhanshu* vol. 86, p.837.
35 See *Huai Nan Zi* "Dixing".

regarded this ornamental decoration motif (fig. 61) as looking like a tiger, but later Fan Yuzhou argued that according to the profile and facial features, the carved pattern is not a tiger design but a dragon image (Fan, 1982). This zoomorphic decoration is shown on both sides of the chime stone.

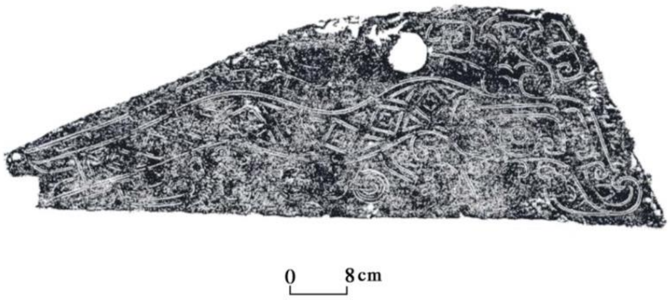


Figure 61. Rubbing of chime stone with dragon ornamentation from Yinxu Huanshui Nan'an.
Late Shang (ca. 1260-1050 BCE). After ZSKKGSAYFJD, 1976, p. 16, fig. 3.

Dragon images on other artefacts appeared as early as the late Neolithic Age, in Xiangfen Taosi, for example, a dragon patterned ceramic plate dating to approximately 2400-2300 BCE was buried with a chime stone and crocodile-skin drum in the large tomb M3072 (fig. 62). In *Zuo Zhuan Zhaogong 29 years*, it suggests that a "dragon is an aquatic animal"[36], and in *Guan Zi,* the "dragon is a water based animal with five colours on its body."[37] Both classical texts associate the dragon with water. As a sacred imaginary animal, the dragon is an ancestor of the Chinese people, and symbolizes the power and majesty of the royal court in ancient society.

36 *Zuo Zhuan* "Zhaogong ershijiu nian". For the Chinese version, see Ruan, 1980, p. 2123.
37 *Guan Zi* "Shuidi". For the Chinese version, see Guan, 1968, Chapter 39.

Figure 62. Ceramic plate with dragon pattern from M3072 in Xiangfen Taosi.

Early Taosi culture (ca. 2400-2300 BCE). After ZSKKGS & SXLFWWJ, 2015, p. 616, fig. 4-119.

Sarah Allan suggests that the decorations on bronze vessels of the Shang dynasty (ca. 1600-1046 BCE) were indirectly related to the real world, and relate rather to a virtual world. She also points out that the principal meaning of these decorations was the metaphor of death and transformation:

> I have argued that these motifs derive their meaning not as representations of any particular creatures or gods but as more generalized allusions to the consumption of sacrificed animals and humans, the passage to the other world, and those who inhabit it (Allan, 2007, p. 10).

In the Zhou dynasty, especially in the Western Zhou period (1046-771 BCE), the *Kui* pattern (half-snake and half-bird) dominated in the decoration of bronze bells and chime stones. For example, chime stones carved with *Kui* motifs were discovered in Shaanxi Fufeng Shaochen Yiqu dated to the mid- to late Western Zhou period (976-771 BCE. Luo, 1987, fig. 63).

Figure 63. Chime stones carved with *Kui* patterns from Fufeng Shaochen Yiqu.
Mid- to late Western Zhou (976-771 BCE). Photo by Fang Jianjun.

According to *Lüshi Chunqiu*, the Kui is associated with music:

> Long ago, Shun wanted to use music to transmit his teachings to the whole world, so he ordered Zhong Li to select Kui from among the "jungle" people and promote him. Shun made him rectifier of music [an officer who in charge of music]. Kui thereupon rectified [corrected] the six pitch-standards and harmoniously tuned the five tones, circulating the winds of the eight directions and thus caused the whole world to submit generally to Shun's rule (Knoblock & Riegel, 2000, p.583. For the Chinese version, see *Lüshi Chunqiu* "Cha Zhuan", Chen, 1984, p. 1526-1527).

It is therefore understandable that Western Zhou (1046-771 BCE) musical bells and chime stones were ornamented with the *Kui* pattern.

By far the earliest painted patterns or images on the surfaces of chime stones appeared in the Yinxu culture Period IV of the late Shang dynasty (ca. 1097-1050 BCE); later than chime stones with inscriptions. Anyang Yinxu Xiqu M93 contained five such chime stones but it is unclear what the images on them represent, although the excavation report regards them as some kind of animal (see Chapter 2, fig. 10). Chime stones with painted motifs appeared commonly in the Eastern Zhou period (770-256 BCE). In Anhui Shucheng Jiulidun, five chime stones with drawn cloud patterns on the surface were excavated from a tomb of the Zhongli state which was dated to the late Spring and Autumn period (546-476 BCE, fig. 64). One Warring States (475-221 BCE) example of a decorated chime stone came from Hubei Jiangling Jinancheng, the capital of the Chu state at that time; unusually, red, yellow, blue, green, and golden colours were used to depict a phoenix theme (fig. 65).

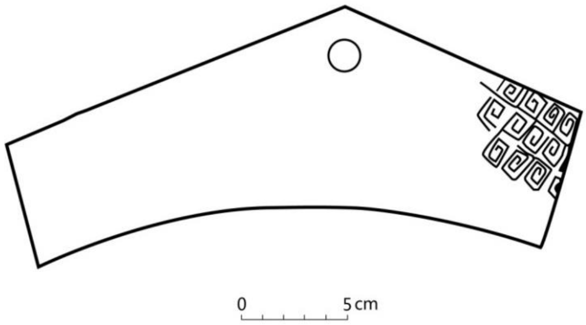


Figure 64. The chime stone with drawn cloud pattern from Shucheng Jiulidun.
Late Spring and Autumn (546-476 BCE). After AHGZD, 1982, p. 237, fig. 8. Redrawn by Xueyang Fang.

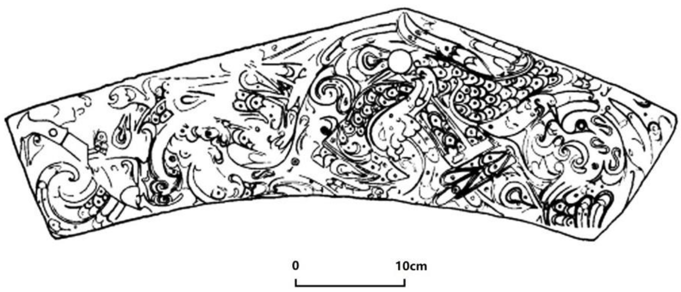


Figure 65. The chime stone with phoenix-design decoration from Jiangling Jinancheng.
Warring States period (475-221 BCE). After Hubei Provincial Museum, 1972, p. 43, fig. 3. Redrawn by Xueyang Fang.

These cases reveal that chime stones with decorations may have reflected the social status of their owner at that time; decorated chime stones often reference sacred animals, and seem to indicate particularly high status. The large number of funerary objects found in tombs that include chime stones (e.g. Fu Hao’s tomb), suggests that the occupants were wealthy and had political or military power. Carved and drawn patterns on chime stones from such tombs suggest a particular symbolic meaning.

4.4 Summary

The new typological system presented here distinguishes between two main types of chime stones: A (A-1, A-2) and B (B-1, B-2, B-3). By using this distinction, I examine the origin and shape evolution of chime stones. In particular, the ratios illustrated in the ancient book of *Kaogongji Qingshi* was verified by conducting quantitative analysis on chime stones from different regions. The results show that the ratios of the Qi state chime stones were closest to those of *KQS* and with regard to the specifications for making chime stones, the Qi state stones are similar to those of *KQS*. This further proved that the *KQS* was an official record in relation to the Qi state in northeast China of the early Warring States period (476-387 BCE) of the Eastern Zhou dynasty (770-256 BCE). Inscriptions, decorations and metaphors are also discussed with their cultural background. It appears from current information that inscriptional chime stones appeared earlier than decorated stones, and that the general trend of inscriptions evolved from simple characters to those such as musical tones, musical temperaments and the order of suspension. Detailed information on inscriptions will be further discussed in Chapter 8. The following chapter will concentrate on detailing the manufacture of chime stones.

Chapter 5: The Manufacture of Chime Stones

5.1 Materials

Most chime stones are made of limestone. Limestone has a medium density and a relatively strong structure (Feng, 1993). In the Neolithic period, as well as limestone, chime stone makers also chose hornfels and siltstone as manufacturing materials, both of which have a higher density; these chime stones were often crudely flaked. Five Neolithic chime stones from Xiangfen Taosi were made of hornfels or siltstone, and showed blasto-psammitic texture under microscopic observation (ZSKKGS & LFWWJ, 2015; table. 12).

Table 12. Lithic materials for making chime stones from the late Neolithic Age to the Shang dynasty

Site/Tomb	Date	Specimen no.	Material
Shanxi Xiangfen Taosi M3015	Late Neolithic, early Taosi culture	M3015:17	hornfels
Shanxi Wenxi Nansongcun	Late Neolithic, early Taosi culture	-	limestone
Shanxi Wutai Yangbai	Late Neolithic, early Longshan culture	87SWYH111:1	slate
Shanxi Xiaxian Dongxiafeng	Dongxiafeng type of Erlitou culture, Xia dynasty	74SW26H15:60	sandstone
Shaanxi Lantian Huaizhenfang	Early Shang, the upper layer of Erligang culture	-	limestone
Henan Anyang Wuguancun M1	Late Shang, Yinxu culture II	WKGM1	marble
Kalaqin Xifu, Inner Mongolia	Lower Xiajiadian culture, approximately contemporary with late Shang	-	siltstone

The manufacturing materials of chime stones during the Shang (ca. 1600-1046 BCE) and the Western Zhou dynasties (1046-771 BCE) were primarily limestone, including some in marble. After the Western Zhou dynasty, almost all chime stones used limestone as manufacturing material. During the Eastern Zhou dynasty (770-256 BCE), limestone was commonly used in sculptures because of its suitability for carving (Zhai, 2014). For example, two chime stones separately excavated from a large tomb in Yinxu Wuguancun (Henan, the late Shang period) and the tomb M157 (Jingshu's tomb, late

Western Zhou, 877-771 BCE) in Chang'an Zhangjiapo (Shaanxi) are made of marble. Marble is a form of limestone, both have the same chemical component $CaCO_3$. Limestone, as Wang Shanyou, Zhu Guangyao, Tang Hong, Kan Xuhang and Zhou Qun (2013) point out, has a medium density between hornfels and siltstone, while marble has the highest density and strongest structure of these materials. From the Eastern Zhou (770-256 BCE) through to the Western Han (202 BCE-8 CE), limestone was mainly adopted as the material for making chime stones, for example, the 32 chime stones from the tomb of Marquis Yi of the Zeng, and 107 chime stones from the Zhangqiu Luozhuang Western Han tomb are all made of limestone. One reason is that limestone is widely distributed in the region of the Yellow and Yangtze River valley in China, and is therefore convenient to obtain. Nevertheless, it is unclear whether chime stones found in various locations were made from locally quarried limestone.

Some scholars have analysed the characteristics of the different materials that chime stones are made of and concluded that there is a relationship between the lithic materials and the pitch of chime stones (Wang, Zhu, Tang, Kan, & Zhou, 2013). Table 13 lists four types of lithic materials and compares their features (Feng, 1993, p. 52-61, 186). According to Wang Shanyou et al, marble, although also a form of calcium carbonate, is very strong and has a high density that can produce a higher pitch, while the texture and density of limestone is weaker so that the pitch from a limestone chime stone is lower than one made of marble (Wang et al., 2013). However, it is the dimensions of a chime stone which have the most direct influence on pitch. As a plate-like vibrational instrument, the pitch or frequency is determined by size and thickness, as well as the material of construction. Some stone does not ring, whilst dense stone like limestone and flint is more likely to ring. Chime stone is idiophonic vibrational instrument; ordinarily, the thicker and smaller it is, the higher the frequency. Wang and other scholars only choose a few individual cases to explore pitch data, analysing their lithologic character but not considering their dimensions and therefore providing limited evidence of the significance of material on pitch.

Table 13. Characteristics of four sorts of lithic materials

Petrography of lithic products	Compressive strength（MPa）	Pitch
Siltstone	100-140	high
Limestone	100-120	medium
Hornfels	>60	medium
Marble	>limestone	high

The manufacture, sound quality, and especially sound timbre is influenced by the different lithic materials. Limestone was the main material used during the Shang (ca. 1600-1046 BCE), Zhou (1046-256 BCE) and Western Han dynasties (202 BCE-8 CE). The advantages of limestone are that it is widely distributed and easily acquired, it is easily worked and can be polished; these properties make it highly suitable for the process of manufacturing chime stones. The disadvantage of limestone from a research point of view is that it is easily eroded by water, and sound properties might be influenced by aging (Feng, 1993). To take the Western Zhou (1046-771 BCE) chime stones as an example, more than half of them are incomplete due to erosion; their poor condition prevents pitch measurement and sound experimentation.

Jae-hyun Ahn and Richard Dudas believe that the tuning of stone-made *pyeongyeong* (the Korean chime stone, brought from China) is not greatly affected by temperature or humidity when compared with instruments made from other natural materials such as wood and natural fibres (Ahn & Dudas, 2015). The pitch of chime stones is seldom influenced by temperature and humidity; however, if chime stones of limestone were buried in tombs and immersed in water, erosion effects could result in a reduction of sound quality and tone pitch. In general, as all chime stones were under the same circumstances and conditions when interred in tombs, their relative pitches or intervals should remain unchanged.

In Shanxi Xiangfen Daguduishan, a large-scale stone tool manufacturing site with some workshops was archaeologically excavated (Wang, Li, & Tao, 1987). Dating to the late

Neolithic (early Taosi culture, ca. 2400-2300 BCE), large amounts of stone-made products (including fragments) survived at this site and it was likely a site of manufacture. Significantly, a partially completed chime stone without a suspension hole was found (fig. 66), which resembles the shape of another chime stone (M3015:17) from a site in Xiangfen Taosi (Tao, 1988, 1991). Both chime stones were made of hornfels, and the two sites are six kilometres apart, suggesting that the Taosi chime stone might have been made at the Daguduishan stone tools manufacturing site.

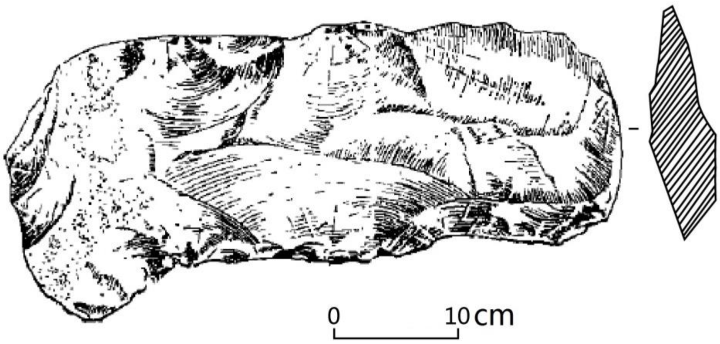


Figure 66. Part completed chime stone from Shanxi Xiangfen Daguduishan.
Late Neolithic Age, Taosi culture (ca. 2400-2300 BCE). Length: 49.8 cm. After Tao, 1991, p. 3, fig.3-1. Redrawn by Xueyang Fang.

William Andrefsky Jr. explores the relationship between the knappable quality of lithic raw materials and stone tool technology in hunter gatherer populations, and shows how the geological occurrence of lithic raw materials' size, shape and quality play an important role in the technological strategies employed by hunter gatherers who made and used stone tools (Andrefsky Jr., 1994). John Webb, Anne Ford and Justin Gorton reveal the influences on the selection of lithic raw material sources during the Neolithic Age at the Huizui archaeological site located near the modern village of Huizui in Henan Yanshi in China. They point out,

> "It would appear that the choice of raw materials used at Huizui was a reflection of proximity to source, functional properties and extraction in an appropriate form for tool manufacture. The stone tool producers at Huizui were making cost efficient decisions based on more than one criterion"

(Webb, Ford, & Gorton, 2007, p. 86).

Archaeological sites for manufacturing lithic products such as chime stones have certain relationships. For example, the raw materials of chime stones from Xiangfen Taosi were probably obtained from Daguiduishan, and the people of the Taosi area in ancient times may have promoted the rapid development of their own economy by controlling stone resources, as no other places close to Daguduishan were found to use the same stone sources. Raw materials from different geological sources can influence the manufacturing of stone tools and since chime stones have their own characteristics in different locations, the local geological sites and raw material selection could be elements that affect their sound.

Material selection is a historical process. In the earliest periods of production, such as the Neolithic, Xia (ca. 2070-1600 BCE) and Shang dynasty (ca. 1600-1046 BCE), more than one form of material was chosen, suggesting that ancient craftsmen were exploring appropriate materials in practice. As Fang Jianjun describes, "The material selection was based on the sounding of inartificial stone" (Fang, 2006). From around the late Shang dynasty (ca. 1260-1050 BCE), the dominant lithic material for crafting chime stones was limestone, with some marble, and from the Western Zhou (1046-771 BCE) onward, the manufacturing material of chime stones had become exclusively limestone.

5.2 Designing Chime Stones

After material selection, the next manufacturing process to consider is the design of the chime stone. In the Neolithic Age, almost all chime stones were flaked or chipped to shape without further process (e.g. polishing technology). It could be assumed that the stone makers firstly chose a flakeable stone that sounded sonorous, and then they used a simple procedure for roughly chipping and trimming parts of the surface and rim without much attempt at design. During this period, the chime stone was irregularly shaped and without much processing and precise design.

In contrast, during the Xia (ca. 2070-1600 BCE) and Shang dynasties (ca. 1600-1046 BCE), there were specific design approaches to chime stones. For example, Type B chime stones are shaped with an angular top, and eventually this became the only shape of chime stone from the Eastern Zhou period (770-256 BCE). In this type, the triangle-shaped chime stone may have some relation to the later convex pentagonal shaped chime stones, which eventually became the unified type. The chime stones unearthed in Liaoning Beipiao (see Chapter 3, fig. 38-2) and Hebei Gaocheng Taixi (see Chapter 3, fig. 38-1) are all triangular shaped in design.

The type B chime stone (whether with a straight or curved base) may have been designed by using an obtuse triangle as an initial frame, then cutting both the ends to complete the process. A set of three late Shang chime stones inscribed with characters Yongqi 永啟, Yaoyu 夭餘 and Yongyu 永餘 are examples that were possibly made in this way (fig. 67; Li, 1996). Such a design intention can also be observed on the late Western Zhou (877-771 BCE) chime stones from Shanxi Tianma Qucun M8 (the Marquis Su's tomb of the Jin state), the middle Warring States (386-285 BCE) chime stones from Shandong Zhangqiu Nülangshan M1, and the early Western Han (187-180 BCE) chime stones from Shandong Zhangqiu Luozhuang Han tomb (fig. 68). There is probably an evolutionary relationship between the obtuse triangle and the convex pentagonal shape, which eliminated the two acute angles on both sides of the chime stones.

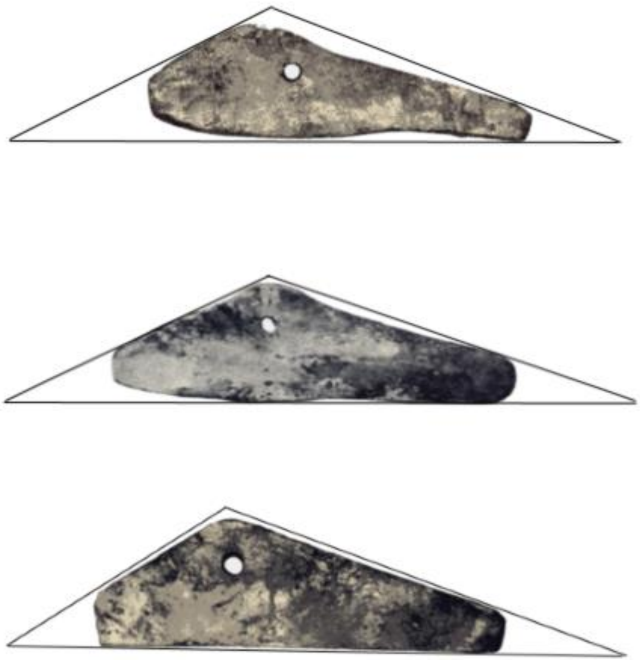


Figure 67. A set of three late Shang chime stones and their design intention.

Possibly from Henan Anyang. Drawn by Xueyang Fang.

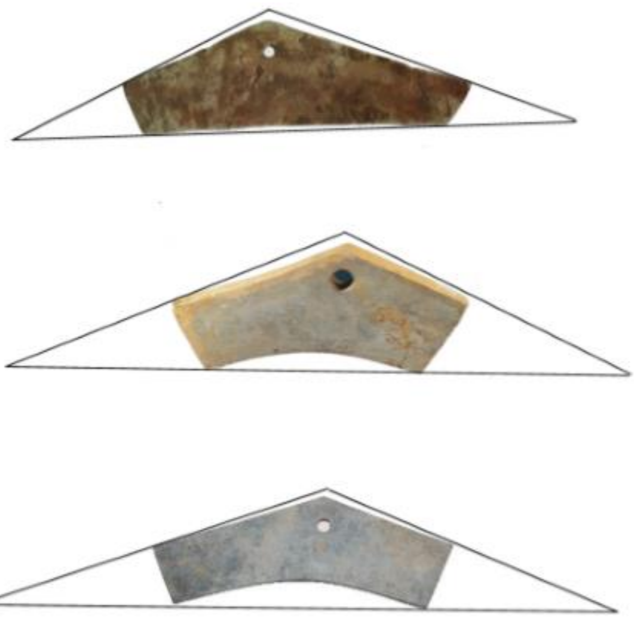


Figure 68. Three chime stones dating to different dynasties and their designs.

Upper: from Shanxi Tianma Qucun M8, late Western Zhou (877-771 BCE); middle: from Shandong Zhangqiu Nülangshan M1, middle Warring States (386-285 BCE); lower: from Shandong Zhangqiu Western Han tomb (187-180 BCE). Drawn by Xueyang Fang.

The pitch of chime stones also needs to be set. During both the Eastern Zhou (770-256 BCE) and Western Han dynasties (202 BCE-8 CE), the shape of chime stones was unified and production was carefully designed to match the required pitch and timbre so as to function in ensemble performance with other musical instruments. It appears, therefore, that the manufacturing and designing of chime stones had reached a high standard by the Western Han dynasty (202 BCE-8 CE). However, evidence as to how the pitch of chime stones was effected has not yet been discovered archaeologically or through documents. Ancient people may have had limited mathematical or geometrical knowledge, and depended primarily on personal experience. To a degree, the dimensions of the chime stone are relative to pitch; the larger and thinner the stone is, the lower the pitch and vice versa. Nevertheless, this is not absolute. Chapter 9 will discuss issues regarding the correlation between the dimensions and pitch of chime stones.

5.3 Tools and Techniques

One way that archaeologists have studied the manufacture of chime stones is by exploring the tools and techniques that were used when they were made. Lin Huixiang (1934) examined tools and techniques according to the chronological sequence of archaeological finds. In the 1950s, An Zhimin (1955) studied raw materials and techniques as well as conducting experiments on the drilling process. More recently, scholars have also made efforts to research manufacturing tools and techniques (Zhai, 2014, 2015). In her study, Zhai Shaodong (2015) introduces the purpose, methods, processes and results of experimental replication of stone tools from the Xiangfen Taosi archaeological site. The research shows that procedures to make ground stone tools[38] were time consuming but simple; an inexperienced flint knapper in this experiment could succeed in making all the ground stone tools attempted. Based on this reconstructive experiment, she believes that the techniques for making ground stone

38 The chime stones are a type of ground stones, they are shaped by rubbing against another more rough stone called a tool stone. cf. Tool stone. (2019). In *Wikipedia*. Retrieved July 20, 2019, from https://en.wikipedia.org/wiki/Tool_stone).

tools are simple and easy to replicate.

Judging from archaeological evidence, it is likely that the techniques and tools for making ground stone objects were also used in making chime stones, especially in later periods. Although, grinding techniques were more advanced on other Neolithic artefacts than they were on chime stones.

During the Neolithic, the processing steps of chime stone manufacture are thought to be sound choice, material and shape selection, flaking and drilling. At first, ancient craftsmen might choose a natural lithic material with a sonorous sound, and then fashion it by removing some pieces through the process of lithic reduction. Starting from the late Shang dynasty (ca. 1260-1050 BCE), advanced technologies such as the grinding process were applied to making chime stones, especially during the Western Zhou dynasty (1046-771 BCE), when the technique became more advanced. By the Shang dynasty (ca. 1600-1046 BCE), the manufacturing process may have been sound choice, material and shape selection, chipping or flaking, carving, grinding, drilling, and sometimes decorating (drawing or engraving ornamentation on both sides of the chime stone), whereas from the Western Zhou onward, tools and technologies were improved further and fine grinding was added.

In their article, Douglas Bamforth and Nyree Finlay (2008) propose a range, with archaeological correlates, of skills in flint knapping from novice to expert. They detail the archaeological correlates of five aspects of tool manufacture, which relate to raw material quality, manufacturing stages, performance, social context and product. Every process ranges from simple to complex. The skill spectrum they have laid out can be applied as a reference for understanding the process of making chime stones in ancient times. The procedure of manufacturing chime stones is complicated work, and it is certain that chime stones have value far beyond their simple playing purpose in ceremonial events in ancient times (see further discussion in Chapter 10).

In the Neolithic Age, all chime stones were knapped-stone artefacts. One of the flaking methods was to strike a particular point on the stone to shape it; this procedure removes a flake and leaves behind signs of the process. One singly used chime stone from Xiangfen Taosi (M3002: 6) is a typical example, which shows the ripples formed on its surface through this procedure. Lines of ripples can be seen radiating from the point of percussion on the base to a position near the vertex angle of the chime stone (see fig. 3 in Chapter 2). Another example is the chime stone (H15:60) unearthed from Shanxi Xiaxian Dongxiafeng, where the traces of two distinct points of percussion and associated ripples are clear on the surface, you can also see the scars left behind when the flakes were removed (see fig. 36-6 in Chapter 3). Judging from the shape of the suspension hole of the chime stone, the process for boring the hole was first to choose the hole's position, then to chisel it from both sides, and finally to drill it thoroughly. As a result, the hole has a pitted area surrounding it where the stone was chipped away on both sides. Some chime stones have two holes, perhaps because of playing requirements (i.e. different hanging arrangements), but this may also be evidence of attempting to balance of the chime body (Li, 1996). One example of this is the chime stone (M3016: 39) from Xiangfen Taosi which has two drilled holes (see fig. 36-1 in Chapter 3).

In the Xia (ca. 2070-1600 BCE), Shang (ca. 1600-1046 BCE) and early Western Zhou periods (1046-977 BCE), the chime stone had two methods of manufacture and was either simply flaked or ground, or both. However, from the late Western Zhou (877-771 BCE) to the Western Han dynasty (202 BCE-8 CE), all chime stones were made by using grinding and polishing processes. The smoothness of the polished surface of the chime stone is not only for beautification but also for better sound production. Grinding stones dating back to the Shang dynasty have been found archaeologically in Henan province. Furthermore, tools made by grinding, such as stone knives and stone sickles were found to be widespread in the ruins of Anyang Yinxu (ZSKKGSAYFJD, 1979). Grindstones, usually made from sandstone, are also used in the manufacture of jade implements, this can be seen on animal patterned jade ware unearthed from Ningxiang

Huangcai Wangjiafen in Hunan (Yu, 2013).

The tools used to drill the hole on stone implements could be various. According to Cui Tianxing and Zhang Jian (2017), the process of drilling holes was common on polished stone tools in the past. Drilling technology can be divided into four main methods: tubular-drilling, awl-drilling, knock-drilling and hole-slicing. Cui and Zhang suggest that using a bamboo tube combined with a copper tube to drill a hole is possible. However, whether ancient people used a bronze drill or a bamboo tube together with a copper drill still has yet to be established from archaeological evidence. Tubular drilling is an effective way to drill a hole, as it makes a hole with parallel sides.

Engraving techniques used on chime stones commenced in the Shang dynasty (ca. 1600-1046 BCE). The tools used for engraving ornamentations and inscriptions could be knives made of bronze, jade or stone. Bronze knives used as engraving tools, were excavated from tomb M539 in Anyang Dasikongcun (ZSKKGSAYFJD, 1992). Similarly, a “Hetian” jade knife from Fu Hao’s tomb in Anyang Yinxu was likely used for fine engraving during the late Shang period (ca. 1260-1050 BCE. ZSKKGS, 1980). Chime stones with engravings were also found in the two tombs, which may indicate that knife engraving was used on chime stones.

The manufacturing technologies of chime stones may have regional differences, for example in southern and northern areas of China. The qualities of chime stones could also be diverse depending on the different identities of the tomb occupants, for example, the chime stones belonging to kings, marquises, and superior nobles may have had enhanced qualities and be more durable to play.

5.4 Pitch Tuning

Neolithic chime stones were made only by roughly sculpting the shape and perhaps only served as a rhythmic instrument. In such a situation, there may have been little or no tuning or the tuning process may have been simple. However, the stone makers would have also considered the harmonic relationship to other musical instruments.

For the sets of chime stones that emerged in the Shang dynasty, the tuning process was more complex and precise. The stones were tuned by reducing their size and increasing their thickness to raise the pitch (*Kaogongji Qingshi*. Also see Chapter 4). One example that shows this tuning process was a set of three chime stones inscribed with Chinese characters Yongqi, Yaoyu and Yongyu, respectively (see fig. 67 above). The grinding traces on both sides and rims of the first two stones suggest that they had been tuned many times, unlike the third one, which may have been used as a tuning point reference. At this early period, tuning positions were undefined, and, although the whole body of the chime stone could be ground to achieve the purpose of calibrating the pitch, this could make the stone look misaligned and uneven (Fang, 1996).

During the Western Zhou dynasty (1046-771 BCE), partially decorated chime stones were a convex pentagon-shape, and the pitch is determined by the thickness of the main body (Fang, 1996). The base of the chime stone is straight or very slightly curved, it is not clear whether the process of tuning was conducted by grinding the base.

From the Eastern Zhou period (770-256 BCE) onward, the chime stones had a definite curved base, the bottom of which was ground down to tune them (Fang, 1989a). Together with differences in thickness, this became the method of tuning. The volume *Qingshi* (Qing family) of the classical text *Kaogongji* (The records of examination of craftsmen) describes the tuning method. It states, "When pitch is too high, then grind both sides of the stones (making it thinner and reducing the frequency); when pitch is too low, then grind both ends of stones (making it relatively smaller and thicker, getting a higher pitch)."[39] This appears a reasonable explanation of the tuning process of chime stones during the Eastern Zhou period.

39 For the Chinese version, see Ruan, 1980, p. 923-924.

Fritz Kuttner (1990) proposes a hypothesis to explain the manufacturing process of curved based chime stones. He suggests that the lithophones being made on one grinding stone were first put on the edge of a smaller grinding wheel, circularly grinding the stone's base at the same time as each other, in order to fashion a group of curved based chime stones. However, this was conjecture. An experiment with stone implements conducted by Zhai Shaodong (2015) suggests that a range of skills may have been used in making a curved based chime stone. From viewing ten ground stones, she suggests that the grinding tool could be a kind of whetstone (a flat Hornfels sharpening stone)[40]or a circular grindstone (as suggested by Kuttner)[41].

Figure 69 is a chime stone from Shandong Zhangqiu Nülangshan M1 which dates to the Warring States period (475-221 BCE). The red dotted line on the left picture could be the original bottom line from which the curved base was formed; no matter how curved the base is, both the *gu* and *guu* part will remain unchanged. On the contrary, if one keeps grinding horizontally from the flat base upward, such as the right picture shows, the size and shape of both ends would be altered, which would not be acceptable. Perhaps this is the reason why the base of chime stones becomes curved; the arched base may have been the best choice for tuning made by ancient craftsmen.

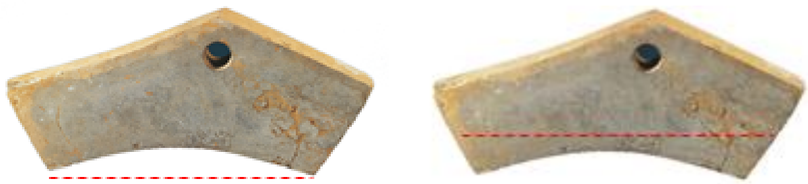


Figure 69. Schematic diagram of pitch tuning through grinding the base.

Chime stones dating back to the Warring States period have been excavated from a pit C1M395 of funerary objects in Henan Luoyang Jiefanglu, among the total of 23 pieces some of which are possibly semi-finished productions (fig. 70). Two specimens (fig. 70-1, 4) have an arched base, but another two (fig. 70-3, 5) are straight based, which

40 A fine-grained stone used for sharpening cutting tools.
41 A grindstone is a round sharpening stone or whetstone used for grinding or sharpening metal tools such as knives.

may imply that the process of tuning was unfinished. Another chime stone (fig. 70-2) has a long notch and a small pitted indentation on the *guu* part, and an oval indentation on the middle of one side. The base has not been completely ground, suggesting that the manufacturing process of this chime stone may also have not been finished.

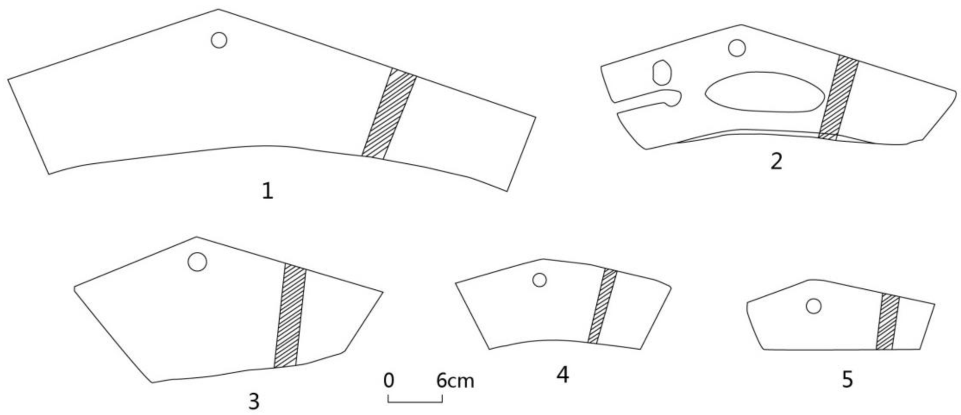


Figure 70. Chime stones found in Henan Luoyang Jiefanglu.
Warring States (475-221 BCE). 1. M395: 49; 2. M395: 47; 3. M395: 42; 4. M395: 52; 5. M395: 55. After LYWGD, 2002. p. 371, fig. 17. Redrawn by Xueyang Fang.

Alternatively, the long notch could be possibly part of a kind of animal design. Similar examples were found in Anhui Bengbu Shuangdun M1, in this case, the *guu* part was in the shape of a dragon head (see fig. 33 in Chapter 2 and fig. 39-4 in Chapter 3). Tone measurement suggests that this kind of shaping does not affect the sound or pitch of the instrument, and relates to a certain status and identification of the tomb owners (Wang et al., 2013). From my perspective, such a dragon head shaped chime stone may be just a pattern or style of ornamentation.

5.5 Summary

In Chapter 5, I have explored the nature of the materials of chime stones and suggested plausible ways in which they were designed. Material selection was a long process in historical terms; after a period of trial and error, it was found that limestone was the best material for manufacturing, although interestingly stones were most often made with hornfels or siltstone in early times. Limestones is widely distributed in China and easy to access, although not all types of limestone ring so it is likely that unvoiced or inferior stones were eliminated after screening. So far there is no evidence to suggest that the materials used to make chime stones came from particular and known sources. Because of the proximity of the sites of Daguduishan and Xiangfen Taosi, archaeologists inferred that the Taosi chime stone might have been made at the Daguduishan stone tools manufacturing site or quarry. Some chime stones may have originally been associated with triangular shapes, which is supported by the discovery of several triangular chime stones. However, not all chime stones from varied locations necessarily follow this design principle. Manufacturing techniques were also explored, with two methods involved. The first was a flaking method and the second a grinding technique. The tuning position on chime stones evolved from grinding anywhere on the stone to there being a fixed position on the bottom of the chime stone which was ground to adjust the pitch. Having established how they were made, we will now explore chime stone performance.

Chapter 6: Chime Stone Performance

Chime stones in the ancient royal court were hung from a wooden rack by a cord through a hole near their apex and struck at one end with a wooden mallet, but most racks were found to be decayed when excavated, thus we know very little about how to suspend chime stones from the rack. The set of 32 chime stones from the tomb of Marquis Yi of the Zeng was unusual in using a bronze ring and a hook system which was used to suspend stones from an entirely bronze-made rack. Stones in other contexts were possibly suspended using cord which has since decayed, but with a lack of evidence we cannot be certain of this. Research on ancient chime racks, suspension methods, beating mallets and striking point, as well as the positions of the performers' are discussed in the following text.

6.1 Chime Stone Racks

Remains of Neolithic chime racks have not yet been found, although since Neolithic chime stones have holes they may well have been suspended when played. Chime stone racks survive from the late Shang dynasty (ca. 1260-1050 BCE) in tomb M1 at Wuguancun in Anyang, M1001 and M1217 at the Shang Kings' mausoleum district in Anyang Houjiazhuang. Traces of a wooden carved chime rack from Wuguancun were found under and beside the burial position of the tiger motif chime stone discussed in the previous chapter (Guo, 1951). M1001, probably the Shang king Wu Ding's tomb, has also revealed rotted chime racks (Liang & Gao, 1962). In the tomb M1217, one single chime stone and one crocodile skin drum were found with traces of chime stone racks and drum stands. Fang Jianjun (1988) has tried to reconstruct the shape of these racks, which had two standing columns and one beam, but the method of hanging the chime stones is still unclear. There are currently no archaeological records of Western Zhou (1046-771 BCE) chime racks, but several chime racks belonging to the Eastern

Zhou (770-256 BCE) and the Western Han (202 BCE-8 CE) have been archaeologically discovered; whilst some of them are only scant remains, some are relatively complete, allowing a good chance of reconstruction or replication.

In most cases the chime racks have only one tier although in a few cases there are two. Some hanging racks were delicately adorned. Usually, the chime racks were lacquered or carved with extensive patterns on the standing columns and horizontal beams, especially those found in large, wealthy and aristocratic tombs. The tomb of Marquis Yi of the Zeng state, for example, contained chime stones with a two-tier bronze rack, showing two engraved bird-like monsters on the bottom of the supports, and with elaborate decorations cast on the rack, such as geometric patterns, cloud scrolls, and a dragon pattern (Hubei Provincial Museum, 1989; fig. 71). In some other tombs, such as the Zhangqiu Luozhuang Western Han tomb, the wooden hanging racks were poorly preserved probably due to the humid environment of the tomb. The rotted traces of chime racks could be clearly distinguished but it is difficult to judge the accurate size overall and the detail of ornamentations on the rack (JNKGS et al., 2004).

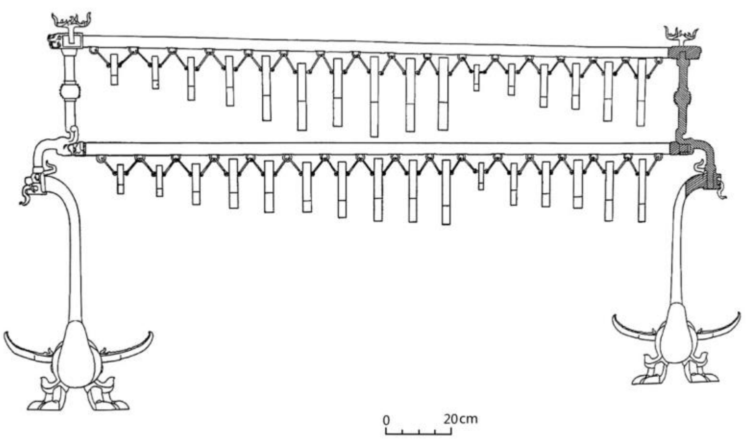


Figure 71. Chime stones and bronze rack from tomb of Marquis Yi of the Zeng.
Early Warring States (433 BCE). After Hubei Provincial Museum, 1989, p. 134, fig. 59. Redrawn by Xueyang Fang.

Li Chunyi asserts that the chime stone racks of the Eastern Zhou dynasty (770-256 BCE) appeared in two categories, bronze and wood (Li, 1996), however thus far the chime stone rack from the tomb of Marquis Yi of the Zeng is the only one found made of bronze; all of the other chime racks are made of wood. The wooden chime rack found in the tomb M1 of the Chu state at Tianxingguan in Chu's capital Jiangling (Hubei) was one example (JZ Museum, 1982). This chime rack consists of four vertical columns, two beams and two circular bases. It measures 0.95 metres in height and is 2.09 metres wide. The patterns such as triangular and rhombic decorations are the same as on a chime bell rack also unearthed in this tomb. Another example was the chime-stone rack found in tomb M2 of the Chu state at Changtaiguan in Xinyang (Henan), as seen in figure 72. Two beams are allocated to suspend 18 chime stones with the upper beam measuring 2.6 metres in length and the lower beam measuring 2.27 metres. The vertical stands are 1.08 metres in height. The main decorations on this chime rack are clouds and triangular patterns (HNWYS, 1986; fig. 72).

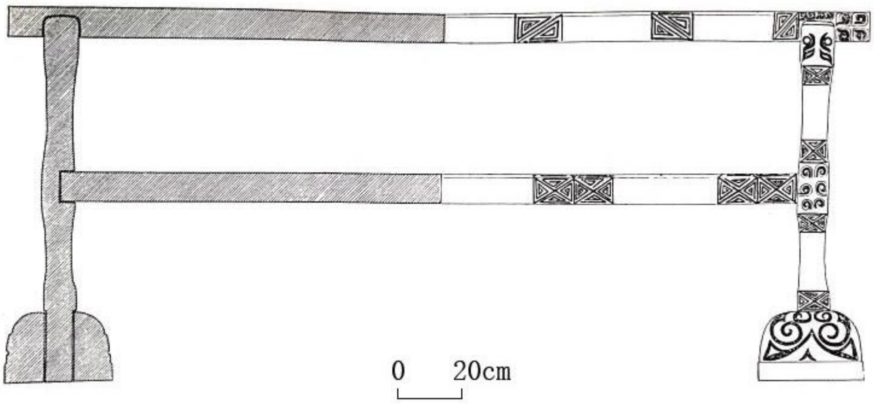


Figure 72. Wooden chime rack from Henan Xinyang Changtaiguan M2.
Warring States (475-221 BCE). After HNWYS, 1986, fig. 60. Redrawn by Xueyang Fang.

There are some descriptions of bell and chime stone racks in the volume *Qing Shi* (Qing family), part of the classical text *Kaogongji*. In the section "Zi Ren makes racks" 梓人為筍虡, it illustrates elaborate decorations patterned onto racks with various animal mask motifs (Ruan, 1980, p. 924-925). Zi Ren was a professional carpenter, and excelled at making chime-racks for hanging musical bells and stones. The term Sun 筍 is used to refer to the horizontal beams of the rack, and Ju (虡) refers to the vertical columns to support the beams.

However, the description regarding chime racks in *Kaogongji* is very brief and only discusses decoration; other details such as how to construct chime racks are absent, and there are no details of materials, dimensions and shape. Table 14 is a compilation of archaeological information about chime stone racks so as to understand their construction and shape (table. 14).

Table 14. Chime stone racks from Eastern Zhou to Western Han period

Sample of chime stone rack	Height (m)	Width (m)	Beam (m)	Material	Chime stone
Henan Anyang Wuguancun M1, late Shang	-	-	-	wood	1
Henan Anyang Houjiazhuang M1001, late Shang	-	-	-	wood	Broken pieces
Henan Anyang Houjiazhuang M1217, late Shang	1.1	1.95	2.25	wood	1
Henan Xinyang Changtaiguan Chu tomb M2, Warring States	1.08	-	Upper 2.6 Lower 2.27	wood	18
Hubei Zaoyang Jiuliandun Chu tomb M2, Warring States	0.66	1.71		wood	19
Hubei Jiangling Tianxingguan Chu tomb M1, mid-Warring States	0.95	2.09	-	wood	Broken pieces
The tomb of Marquis Yi of the Zeng, early Warring States	1.09	2.15	Upper 1.975 Lower 1.85	bronze	32
Shandong Zhangqiu Luozhuang Western Han tomb	0.86 (incomplete)	-	2.3	wood	20 in first set

Hunan Changsha Mawangdui Western Han tomb M3	0.22	-	0.47	wood	10
Jiangsu Xuyi Dayunshan Western Han tomb M1	1.74	2.73	3.03	Perhaps wood	20

The racks from both Wuguancun M1 and Houjiazhuang M1001 are decayed, and their size is unknown. Changsha Mawangdui M3 contained ten wooden substitutions of chime stones, that were not playable instruments but the *mingqi* imitation. The wooden rack from this tomb is a miniature model and therefore too small to be used for hanging chime stones. A chime stone rack was also found in Shaanxi Hancheng Liangdaicun M28, although it was rotted and placed in the same location as a bell rack, so the excavators could not identify them from each other.

From the table above, it is apparent that wood is the usual material for chime rack making, except for the one bronze example from Marquis Yi's tomb. All racks are frame-shaped, two examples use double beams; one from the Marquis Yi's tomb and the other from Xinyang Chu tomb M2. The height of the stands of these chime racks are around 1.2 metres on average, in some cases less than 1 metre. At such a height, performers would need to be kneeling to play the instrument assuming the rack was placed on the ground. Some Warring States (475-221 BCE) representations of musical performance show the images of musicians playing in this way, for example, on a pictorial bronze vessel *dou* 豆 from an aristocratic tomb of Zhongshan state in Hebei Pingshan Sanji (fig. 73), a bronze vessel *jian* 鑒 from tomb M84 in Shanxi Changzhi Fenshuiling (fig. 74), and a terracotta figure from Shandong Zhangqiu Nülangshan (fig. 75). All show that the musicians were kneeling to play chime stones. In the Hebei Pingshan Sanji picture, besides chime stones, performers were playing bells, a pole drum and a pellet drum (鞀鼓 *taogu*), and two other musicians seem to be playing wind instruments, probably *sheng* or *yu*. A bronze vessel *jian* from Changzhi Fenshuiling M84 shows two people playing chime bells and one person playing *sheng*. The chime stones and bells in these depictions are symbolic not realistic in appearance; for example, the terracotta figure from Zhangqiu Nülangshan only shows two chime stones, although the rack has two tiers.

The width of chime stone racks is usually about 2 metres (only the rack from Dayunshan M1 is almost 3 metres) suggesting that at least nine or ten chime stones could be suspended from each rack (see table. 14 for the number of chime stones found with each rack). In Anyang Houjiazhuang M1217, however, only one chime stone has survived because the tomb was robbed many times. We do not know the original number of chime stones although, as the rack is 1.95 metres wide, it seems unlikely this held only one stone.

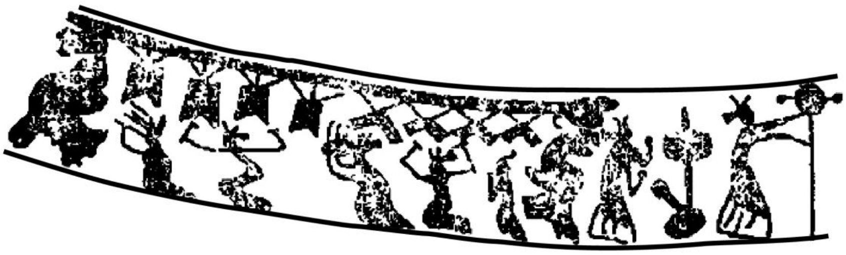


Figure 73. Facsimile of a pictorial bronze vessel *dou* (a bronze vessel used to contain food) from an aristocratic tomb of Zhongshan state in Hebei Pingshan Sanji.
Early Warring States (476-387 BCE). After HBWYS, 1987, p. 178, fig. 29. Redrawn by Xueyang Fang.

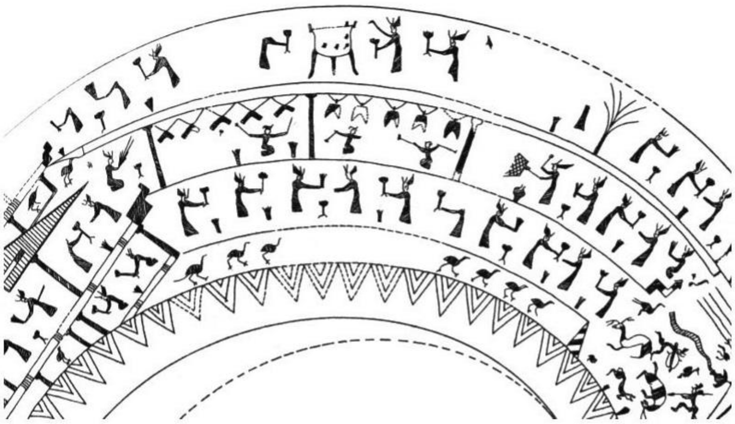


Figure 74. Facsimile of a pictorial bronze vessel *jian* (A bronze vessel used to contain water) from Shanxi Changzhi Fenshuiling M84.
Middle Warring States (386-285 BCE). After SXKGS et al., 2010, p. 288, fig. 101C. Redrawn by Xueyang Fang.

Figure 75. Terracotta figures from tomb in Shandong Zhangqiu Nülangshan.
Warring States (475-221 BCE). After WWDXBJB, 2001, fig. 2.1.1g.

6.2 Suspending Chime Stones

During the period from the Neolithic to the Western Zhou dynasty (1046-771 BCE), a lack of evidence from the archaeological record means that the method of hanging chime stones in this period is unknown. However, depending on the shape of the chime stone, the longer part (*gu*) would be slanting downward (fig. 76). Only if the hole is at a central balance point will both ends be parallel after hanging (see fig. 35-5 in Chapter 3). From the Eastern Zhou dynasty (770-256 BCE) onward, the shape of chime stones is more consistent so that the hole is close to the top angle and on one side, and the *gu* part hangs naturally lower when suspended (fig.77).

Figure 76. Suspending a late Shang chime stone.
Anyang Museum (A01609). Photo by Xueyang Fang.

Figure 77. Suspending a set of chime stones from Qixian Songzhuang M4.
Late Spring and Autumn (546-476 BCE). Photo by Xueyang Fang.

There are some unusual cases dating from the late Neolithic to the Western Zhou period (1046-771 BCE), for example a double-hole suspension, namely one chime stone with two hanging holes (see Chapter 2, fig. 10-1 and Chapter 3, fig. 36-1, fig. 37-5, and fig. 38-1). The reason for this might be to allow a particular playing position, to make it easier to play. Or perhaps one of the holes was not appropriate for hanging and the chime stone maker drilled another, or maybe the two holes were used simultaneously for suspension.

The method of suspension from the late Western Zhou (877-771 BCE) to the Eastern Zhou period (770-256 BCE) commonly involves a slanted *gu* section. The unearthed chime rings and hooks from the tomb of Marquis Yi of the Zeng state make the method of suspension much clearer: the *gu* part of the chime stone is hangs lower with a suspension hole near their vertex angle. A similar suspension style continued throughout the Western Han period (202 BCE-8 CE).

In the developmental stage of the early time periods, suspension styles could be varied; double-holes and single holes in different positions occur. In the late Western Zhou (877-771 BCE) through Eastern Zhou (770-256 BCE) and Western Han (202 BCE-8 CE), the manner of suspension was unified with only a single hole near the vertex angle, with the *gu* part slanting downward when hanging.

6.3 The Beating Mallet

There is no archaeological evidence related to Neolithic chime stone mallets or other methods of performance. However, several specimens of mallets have been found archaeologically in the Eastern Zhou, for instance, six wooden mallets of the same size were found in tomb M1 of the Chu state at Tianxingguan in Jiangling (Hubei). T-shaped mallets for beating chime stones were usually made of wood, which protects the body of the chime stones from damage. Usually more than 20 cm in length, the chime mallet constitutes an integral part of the "metal and stone music" in a tomb. With a cylindrical handle and oval mallet head, one specimen (no. 100) is 31 cm long with a head that is 9.6 cm wide (JZ Museum, 1982).

In Marquis Yi's tomb, two wooden mallets were buried together with a set of 32 chime stones. One specimen (c. 71) was found to be broken when excavated, another (c. 204) was complete. The handle of the latter was shaped to be rectangular, and the head was octagonal. The mallet is 52 cm in length with its head 7 cm in length; the longest diameter of the head measures 1.8 cm and the shortest diameter 1.5 cm (fig. 78). The whole length of this mallet is close to that of an adult's arm; the forearm plus the hand of an adult being 45 cm long on average, according to research (Stoudt, 1973). The chime mallet is like an extension of the human arm.

Figure 78. A wooden mallet from Marquis Yi's tomb (c. 204)
Early Warring States (433 BCE). After WWDXBJB, 1996c, fig. 3.8.14.

Most mallets were made of hard wood; a hard mallet is used with many percussion instruments. As N. H. Fletcher and Thomas Rossing stress:

> Striking a marimba or xylophone with a hard mallet, for example, produces a sound rich in overtones that emphasizes the woody character of the instrument. A soft mallet, on the other hand, which excites only the harmonically tuned lower partials, gives a dark sound to the instrument" (Fletcher & Rossing, 1993, p. 639).

Similarly, as a percussion instrument, the chime stone matched with a hard mallet will resonate with long sustain and result in rich overtones.

The wooden mallet is the most common type found in ancient tombs in China, however there are other materials found in neighbouring countries. For example, a bone-made mallet was used for performing with stone instruments in Korean court music (Dudas

& Ahn, 2015). Worldwide, the shape of mallet used with lithophones can vary; the mallet displayed in Keswick Museum (fig. 79) has two round hammer heads on one stick, and another stick with a single hammer head.

Figure 79. A beating mallet preserved alongside the musical stones of Skiddaw with padded ends from Keswick Museum in the UK.
Photo by Xueyang Fang.

In Marquis Yi's tomb, there were two wooden mallets, suggesting that one player might have used both mallets in his/her right and left hands. Figures 73-75 show players beating chime stones using both hands. The two tones (an interval) could be sounded simultaneously from two pieces of chime stones in a set, or this could allow the musician to play faster or more smoothly.

6.4 Striking Point

Theoretically, it is possible to determine the striking point on a chime stone through use-wear observation and analysis, but no such research has been successfully carried out. In Sudan, some rock gongs have so-called "cup marks" on them. Kleinitz and Till (2015) analysed the position, shape and depth of the percussion zones and cup marks to assess their possible means of performance in the past. It is difficult to distinguish striking traces on the weathered surface of a chime stone and also, in their early period the surface of the chime stones was uneven, the shape was irregular, and different pitches could be emitted by striking different parts.

Use-wear analysis has been applied in the study of other types of stone artefacts and their usage and functions. Through analysis of five kinds of stone tools found in Xiangfen Taosi (Shanxi), Cai Ming has identified that stone knives were used to harvest grasses and rice, and may also have been used to scrape wood (Cai, 2014). E.C. Blake and Ian Cross apply use-wear analysis to conduct experiments on the musical use of flints (Blake & Cross, 2008). These studies have shown that use-wear analysis can be applied to archaeological research and is an effective method to judge the function of stone tools; it would be a useful technique to apply to chime stones in a future study.

Although chime stones have not been used as objects in use-wear experiments, their function and usage can be determined by other methodologies: archaeological context, excavation condition, assemblage, inscription and within historical literature. This subject is discussed in Chapter 10.

Following experiments sounding the stones, scholars believe that the end of the *gushangjiao* (the upper angle of the *gu* part) on Eastern Zhou (770-256 BCE) chime stones is the striking point for producing the best sound (Hubei Provincial Museum & ZKYWWYS, 1984; fig. 80). Regular shaped chime stones produce single-tones in contrast to stones from earlier times with irregular shapes.

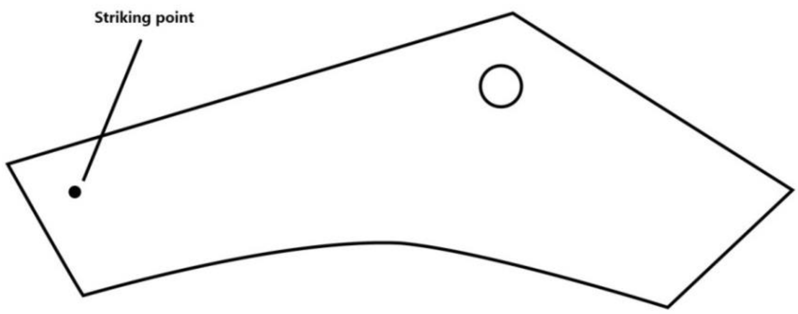


Figure 80. Diagram of striking point on Eastern Zhou chime stone.
Drawn by Xueyang Fang.

We know little about the techniques used by ancient musicians for playing chime stones. Possibilities include a continuous beat for yielding a sustained sound, and two tones played in harmonic intervals.

6.5 Performance Position

To take the chime bells from the tomb of Marquis Yi of the Zeng as an example, judging from the number of bell-striking mallets and poles in the central chamber of the tomb, Robert Bagley surmises that five performers stood on both sides of the bell rack and played the 45 bells in the middle and lower tiers (Bagley, 2000).

> Two in front of the stand played the large bells in the lower tier; three behind the stand played three distinct subsets of bells in the middle tier. The middle-tier bells were struck with mallets, the lower-tier bells with long poles of lacquered wood. The players behind the stand used two mallets each; six mallets were found in the tomb. Two poles for the two players in front were found leaning against the stand (Bagley, 2000, p.35).

This supposition provides a vivid picture of the performance of chime bells in ancient times. When one shifts attention to chime stones from Marquis Yi's tomb, they are "suspended from a bronze rack and were played, likely by one person, with two mallets" (Furniss, 2008, p. 217). The suspension paradigm of Marquis Yi's chime stones could be 16 plus 16 according to the excavation report, meaning that the upper tier could be arranged with 16 chime stones, the same as the lower tier. Because of the rack's height (1.09 m) and the excavated two mallets, it is likely that one musician would play the two-tiers of chime stones while kneeling on the ground.

Apart from a kneeling performance position, music iconographic sources also indicate a standing position for playing chime stones, mainly on pictorial bronze vessels dating to the Warring States period (475-221 BCE). These bronzes were adorned with engraved sunken lines that separate iconographic scenes of musical performance. Musical instruments and their players are shown as a series of lively images of a musical occasion in ancient times. In Sichuan Chengdu Baihuatan M10, a pictorial bronze pot shows instrument players in a standing position in the second tier of the images; two performers are playing five chime stones, and the other two are playing four chime bells.

Beside them, four persons in a kneeling position are likely playing *sheng* or *yu*, one person is standing and playing a pole drum (Sichuan Museum, 1976; Tian & Lu, 1990; fig. 81). Similar images appear on a bronze pot housed in the Palace Museum in Beijing, but the persons playing bells are kneeling (fig. 82). In Henan Huixian Zhaogu M1, a bronze vessel *jian* carved with sunken line ornamentation depicted images of suspended chime stones and two standing players on the second tier of the image; the players seem to be striking chime stones and dancing at the same time (fig. 83).

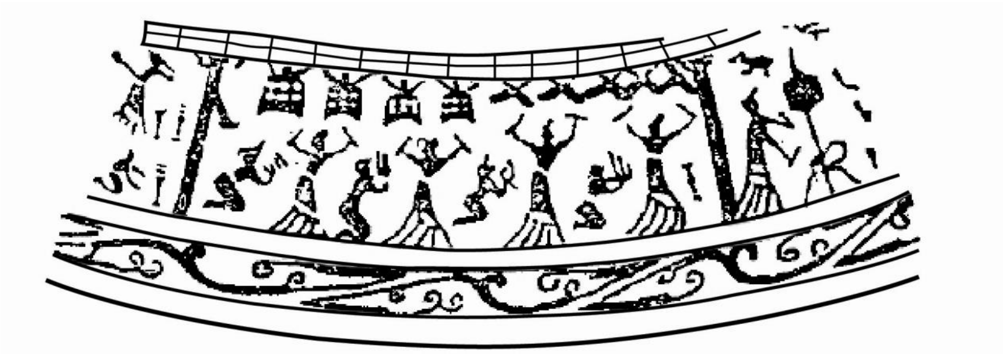


Figure 81. Facsimile of a pictorial bronze pot in Sichun Chengdu Baihuatan M10.
Warring States (475-221 BCE). After Sichuan Provincial Museum, 1976, plate 2. Redrawn by Xueyang Fang.

Figure 82. Facsimile of a pictorial bronze pot housed in Palace Museum in Beijing.
Warring States (475-221 BCE). After WWDXBJB, 1996e, fig. 2.1.2b. Redrawn by Xueyang Fang.

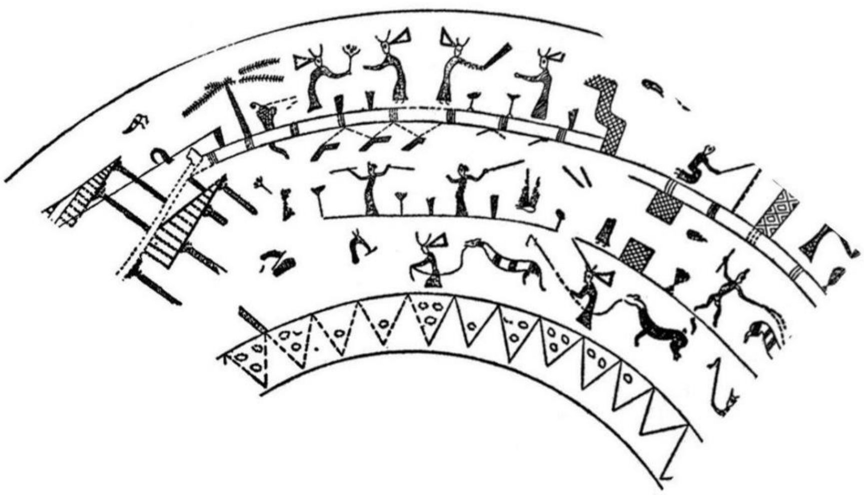


Figure 83. Facsimile of a bronze *jian* in Henan Huixian Zhaogu M1.
Warring States (475-221 BCE). After ZSKKGS, 1956, p. 116, fig. 138. Redrawn by Xueyang Fang.

The above pictorial bronzes display instrumental and dance performance in the royal court. Musicians are striking chime bells and stones using two mallets, they look as if they are playing and dancing. Other instruments such as drums and mouth organs are being played in accompaniment, suggesting that a complex royal court performance is taking place. From these images, we can see different positions for playing chime stones and bells, such as standing, bending, and beating them using two hands. The performance position, whether standing or kneeling, depends on the height of the racks, although of course these racks could be built to accommodate particular performance position traditions.

6.6 Summary

This chapter has addressed issues of performance, including tools for playing, the suspension rack for hanging chime stones, the method of suspension, the striking point and performance positions. As discussed above, two wooden mallets and a wooden rack were commonly employed in performing. According to some pictorial bronze vessels, the kneeling position was common in playing chime stones. Research suggests that the *gushangjiao* is the best striking point for producing sound. It is also important to know more about the musical combination of chime stones. The next chapter focuses on assemblages of chime stones.

Chapter 7: Assemblage of Chime Stones

Bronze bells and chime stones were found to co-exist in many tombs. Not only are they part of Chinese “metal and stone music”, but they both have symbolic meanings in ritual ceremonies. Some archaeological finds provide detailed information about their assemblage. Neolithic chime stones always appear singly, not in sets. Parts of chime stones have been unearthed from tombs in or near Shanxi Xiangfen Taosi and several of them were found in the Yellow River basin area. At this point, few were buried with additional instruments, except for in those tombs excavated from Shanxi Xiangfen Taosi (ZSKKGS, 1983), which belong to the Taosi culture and date to ca. 2400-2300 BCE. In the Taosi site, four large tombs each contained a single chime stone accompanied with other instruments namely crocodile skin and pottery drums.

In the late Shang period (ca. 1260-1050 BCE), the chime stone first appeared in sets in Anyang, the capital city of the dynasty, where it coexisted with solely used single stones, although single stones disappeared by the end of the Western Zhou dynasty. After this, the practice of using sets of chime stones developed throughout the Western Han (202 BCE-8 CE). As time went on, the number of stones in the assemblages increased, and their musical functionality and acoustic properties were enhanced and reached a peak of quality. The 107 chime stones found in the Western Han tomb at Zhangqiu Luozhunang (Shandong) represents one typical example in a period of great prosperity. This chapter mainly explores the assemblage circumstances of the chime stones from the Shang (ca. 1600-1046 BCE) to the Western Han dynasties (202 BCE-8 CE).

7.1 Three Pieces in a Set

The tomb of Fu Hao, dating to the late Shang in the second period of Yinxu culture (ca. 1230-1120 BCE), contained a set of three chime stones and two single ones accompanying other musical instruments such as a set of five *yong*-bells (庸, normally called *nao* 鐃) and three clay ocarinas. The chime stones excavated from Fu Hao's tomb are the earliest dated set of stones known, unfortunately all of them were poorly preserved, thus we do not know their sound.

In the western district of Anyang Yinxu, five chime stones were excavated from the tomb M93, which also dates to the late Shang period, but from the later fourth period of Yinxu culture (ca. 1097-1050 BCE). In this tomb, the specimens of M93:2 and M93:3 were placed on the south platform of the secondary layer in the coffin pit and superposed; the other two specimens (M93:5 and M93:6) were placed on the same platform but in the opposite position. One chime stone was placed alone on the west platform of the secondary layer (fig. 84). Based on pitch measurement studies in Chapter 8, of these five chime stones, some of them are probably chime stones in a group while others may have been used as single chime stones, but it is still unclear if the set of chimes comprised three or four pieces of stone.

A set of three chime stones dating to the late Shang period, on the surface of which were inscribed the Chinese characters Yongqi, Yaoyu and Yongyu, were probably unearthed from a pit in Anyang. These three specimens belong to a set of chime stones (see Chapter 8), although they lack detailed archaeological context.

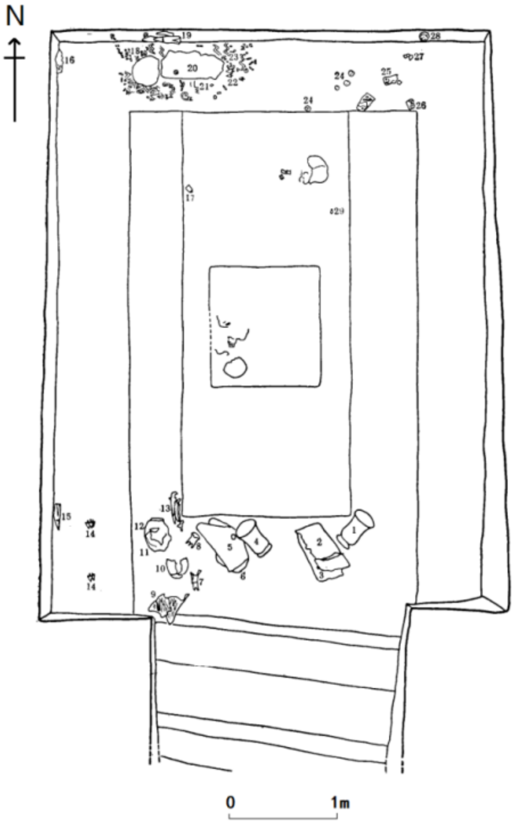


Figure 84. **Diagram of Yinxu Xiqu M93.**
Late Shang Yinxu culture Period IV (ca. 1097-1050 BCE). After ZSKKGSAYFJD, 1979, p. 54, fig. 40 A.

Interestingly, during the late Shang (ca. 1260-1050 BCE) to early Western Zhou period (1046-977 BCE), excavations have shown that most late Shang *yong*-bells and early Western Zhou *yongzhong*-bells (甬鐘) comprise three in a tomb (except ones from Fu Hao’s tomb), and that they constitute a definite tone series. This assemblage of late Shang *yong*-bells can be seen from Huayuanzhuang M54 (ZSKKGSAYGZD, 2004), Dasikongcun M663 (ZSKKGSAYGZD, 1988), Guojiazhuang M26 (ZSKKGSAYGZD, 1998), Qijiazhuang M269 (AYWGD, 1991), and Yinxu Xiqu (western district) M699 in Anyang (ZSKKGSAYFJD, 1979). The early Western Zhou *yongzhong*-bells in a set of three can be seen in Baoji Zhuyuangou M7 (Lu & Hu, 1988), Rujiazhuang M1 (Lu & Hu, 1988), and Chang’an Puducun Changfu (長由) tomb in Shaanxi (SXWGW,1957).

Late Shang clay ocarinas also appeared in the form of three in a tomb: one being larger, the other two smaller but the same size as each other. Three ocarinas unearthed from Fu Hao’s tomb and the Henan Huixian Liulige tomb M150 exemplify this kind of assemblage. Beside considering the musical factors such as different keys (pitch standard) and timbres in these two types of ocarina, the number three has probably signified a lucky number of instruments in the Shang (ca. 1600-1046 BCE) through early Western Zhou periods (1046-977 BCE), but any further specific meaning is still unknown. However, it seems likely that since there are three ocarinas and three stones, that these instruments were matched up in some way; there may have been three musicians, or both instruments may have been played in sets of three together in an ensemble.

7.2 Ten Pieces in a Set

Chime stones in sets of ten pieces emerged in the late Western Zhou (877-771 BCE) to the Western Han (202 BCE-8 CE). More than 30 examples of this assemblage have been found archaeologically from during that time. The earliest assemblages of ten-part stones, dating back to late Western Zhou, were uncovered from the cemeteries of Marquis Jin and Guo state. In the tomb M8 of Marquis Su of Jin, ten chime stones were buried with 16 inscribed bronze *yongzhong*-bells. The tomb occupant was Su who was a Marquis of Jin state approximately at the time of King Xuan (827-782 BCE, BDKGXX et al.,1994a)[42].

Another set of ten chime stones was discovered from the tomb M2009 in Sanmenxia Shangcunling (Henan), contemporary with the tomb of Marquis Su. The set was interred with eight bronze *yongzhong*-bells and eight *niuzhong*-bells (see appendix 1). Recent archaeological excavation found a similar assemblage of ten chime stones in Rui state tombs M27 and M28 in Hancheng Liangdaicun (Shaanxi). Dating back to the end of Western Zhou (877-771 BCE) or the beginning of the Spring and Autumn period (770-686 BCE), chime stones from both tombs were a little later than those from the

42 According to Carbon-14 dating, this tomb belonged to 808 ±8 BCE.

Jin and Guo states tombs.

The above finds suggest that the number of pieces in a set of Western Zhou (1046-771 BCE) chime stones had increased to ten, although a set of ten stones has not been found in the political central area of the Zhou realm (i.e. today's Shaanxi). Since more Eastern Zhou (770-256 BCE) chime stones in sets of ten have been found from a large number of tombs, we have reason to believe that this type of chime stone assemblage had become increasingly standardized in the late Western Zhou period (877-771 BCE).

In the Eastern Zhou period, ten-part chime stones were increasingly widespread. In particular, this assemblage of chime stones was commonly distributed along the Yellow River region. Some examples belonging to the Spring and Autumn period (770-476 BCE) have been found in Gansu Lixian Dapuzishan (EQARG, 2007), Henan Zhongzhou Daqu (HNWHJWGD, 1960), Shanxi Changzhi Fenshuiling M269 (Shanxi Changzhi Museum et al., 1974), Shanxi Houma Shangmacun M13, M5218 and M1004 (WWDXBJB, 2000), Shandong Changqing Xianrentai M6 (SDKGX, 1998) and Shandong Yishui Jiwanggu M1 (SDWYS, 2013). The Warring States (475-221 BCE) examples are those found in Henan Shaanxian M2040 (ZSKKGS, 1994), Shanxi Lucheng Luhe M7 (SXKGS & SXJDNWHJ, 1986), Shanxi Taiyuan Jinshengcun M88 (WWDXBJB, 2000), Shanxi Changzhi Fenshuiling M25 (SXKGS et al., 1964) and Henan Jixian Shanbiaozhen M1 (Guo, 1959). It is noteworthy that chime stones found as an assemblage of ten pieces make up around 40% of the total number of chime stones found from this period (excluding disarrayed and broken pieces), making it the most common combination in this period (see Chapter 2 for details of the finds).

In the Western Han (202 BCE-8 CE), this assemblage was relatively rare although some cases have been found. The wooden *mingqi* (grave good) chime stones excavated from Hunan Changsha Mawangdui M3 (Hunan Museum et al., 2004) and glass-made chime stones from Jiangxi Nanchang Haihunhou M1 (Zhang & Ke, 2019) are illustrations of this type of assemblage.

7.3 Thirteen Pieces in a Set

In Eastern Zhou times (770-256 BCE), as well as ten-part sets of chime stones, thirteen-part chime stone sets also existed and these were commonly distributed along the middle and lower Yellow River regions. Upon archaeological excavation, sets of 13 chime stones belonging to the middle and late Spring and Autumn period (685-476 BCE) have been unearthed from Shanxi Taiyuan Jinshengcun M251, the Zhao Qing's tomb (although most chime stones here were damaged. SXKGS & TYWGH, 1989) and Shandong Tengzhou Jiangtunzhen Zhuangli Xicun , the Teng state tomb (WWDXBJB, 2001).

Warring States (475-221 BCE) examples have been found in King Cuo's tomb of the Zhongshan Kingdom (313 BCE) in Hebei Pingshan Sanji (HBWYS, 1996); a burial pit in Shandong Yangxin Chengguanzhen Xibeicun (HMWPD &YXWHG, 1990); tomb M1 in Shandong Tancheng Erzhong, buried with ceramic products dating from the early to middle Warring States (476-285 BCE. Liu & Feng, 1996); a burial pit in Shandong Zhucheng Zangjiazhuang, although 11 stones were damaged (Shandong Zhucheng Museum, 1987); and the Ying state tomb M25 and M11 in Henan Pingdingshan (WWDXBJB, 1996a).

In southern Eastern Zhou vassal states, for example, the Chu and Wu states, sets of 13 chime stones were also utilized in ensemble. The Chu tombs such as Henan Xichuan Xiasi M1, M2 and M10, each contained 13 chime stones, dating to the Spring and Autumn period (770-476 BCE. DJWFD, 1980). Other examples are the Shangcai Guozhuang (Xu, 2012) and the Xinyang Xibeicun in Henan dating to the early Warring States period (475-387 BCE. WWDXBJB, 1996a). In the Wu state tomb, 13 chime stones were discovered in Jiangsu Pizhou Jiunüdun M3 (Kong & Chen, 2002), dating to the late Spring and Autumn period (546-476 BCE). Chime stones transferred from the Central Plain area to the region of the Yangtze River in the Eastern Zhou period (770-256 BCE).

In the Western Han dynasty (202 BCE-8 CE), a set of 13 chime stones was excavated from a burial pit (no.14) of Lü Tai's tomb (186 BCE) in Shandong Zhangqiu Luozhuang; thirteen-part chime stones sets are only one type of assemblage of six sets which have in total 107 stones (JNKGS et al., 2004).

Among the finds cited above, the vast majority of thirteen-part sets were found in the northern part of China (north of the Yangtze River). By contrast, only one case was located in the southern area: chime stones from the tomb of the Wu state. Thus, it seems likely that thirteen-part sets of chime stones were more popular in the north than in the south.

7.4 Twenty Pieces in a Set

Twenty porcelain *mingqi* chime stones dating to the Warring States period were excavated from the Yue state tomb in Jiangsu Wuxi Hongshan. In burial pit no.14 of the Shandong Zhangqiu Luozhuang Western Han tomb, a large number of chime stones were found. By analysing the inscriptions on some of the stones it was possible to organise a number of them into four sets, each set having 20 stones.

Set One were all inscribed "Lujia" (鲁加) with unknown meaning (probably the name or label of the set); other inscriptions include "left" and "right" on every single stone, from which one may divide this set into two groups—left group and right group, each having ten stones. Moreover, the chime stones were inscribed with numbers ranging from one to ten in a regular sequence (see table. 15). It is clear that characters "left" or "right" indicate the direction of left side or right side that the chime stones ought to be suspended from the chime rack, while the numbers denote the hanging order. The assemblage of 20 chime stones in two groups of ten discussed above was prevalent during Eastern Zhou times (770-256 BCE).

Table 15. Chime stones Set One from pit 14 of the Western Han tomb in Luozhuang

Excavation no.	Inscription	Group	Order
P14C：31	Lujia, Left, One	Left	1
P14C：29	Lujia, Left, Two	Left	2
P14C：30	Lujia, Left, Three	Left	3
P14C：28	Lujia, Left, Four	Left	4
P14C：27	Lujia, Left, Five	Left	5
P14C：36	Lujia, Left, Six	Left	6
P14C：35	Lujia, Left, Seven	Left	7
P14C：34	Lujia, Left, Eight	Left	8
P14C：33	Lujia, Left, Nine	Left	9
P14C：32	Lujia, Left, Ten	Left	10
P14C：41	Lujia, Right, One	Right	1
P14C：40	Lujia, Right, Two	Right	2
P14C：39	Lujia, Right, Three	Right	3
P14C：38	Lujia, Right, Four	Right	4
P14C：37	Lujia, Right, Five	Right	5
P14C：25	Lujia, Right, Six	Right	6
P14C：26	Lujia, Right, Seven	Right	7
P14C：24	Lujia, Right, Eight	Right	8
P14C：22	Lujia, Right, Nine	Right	9
P14C：23	Lujia, Right, Ten	Right	10

Set Two has inscriptions with “Yiwa” (益瓦) on each stone, and like Set One, “left”, “right” and one to ten numbers also, so it is straightforward to classify them into two groups. Set Three are inscribed “Xi” (息) on each stone, whereas there is no “left” or “right” inscription on the stones. Among the 20 stones, ten have numbers from one to ten, so apparently belong to an integral group. The other ten stones, however, have only an engraved character “Xi” and likely belong to another group. In Set Four, only two stones have inscriptions with numbers “one” and “ten” respectively, but they do not correspond to the correct order of one and ten positions within a single group (see Chapter 8), even so, this set also consists of two groups.

7.5 Thirty-two Pieces in a Set

In the tomb of Marquis Yi of the Zeng, a set of 32 chime stones was suspended from a two tier rack, 16 chime stones were hung on each of the upper and lower tiers. Additionally, three chime boxes accompanied them (fig. 85), each has inscriptions (Hubei Provincial Museum, 1989, p. 146-148):

> Guxi, ten and three stones in this box (specimen no. 9)
>
> Jianyin, ten and four stones in this box (specimen no. 7)
>
> Xinzhong and Shaoyu's octave, ten and four stones in this box (specimen no. 8)

The chime box inscriptions demonstrate that 41 stones were stored in the boxes, but only 32 were suspended from the rack. The other nine pieces may have been used as supplementary chimes.

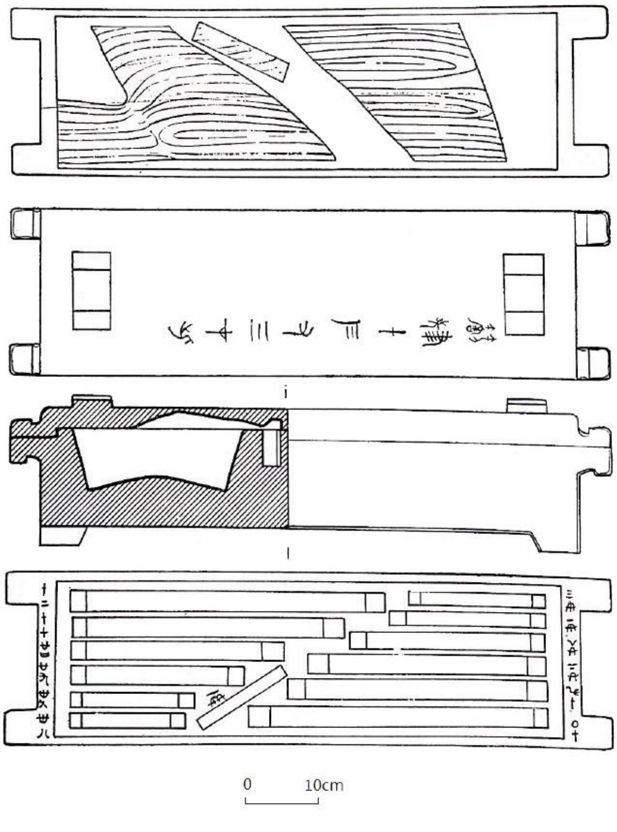


Figure 85. Chime stones boxes from Marquis Yi's tomb.
Early Warring States (433 BCE). After Hubei Provincial Museum, 1989, p.146, fig. 66.

This set of 32 chime stones consists of two groups of 16 on the rack. However, the 16 chime stones can also be divided into two subgroups—six plus ten, confirmed by study of their inscriptions (Li, 1983), although all the chime stones were poorly preserved and could not be measured for their sound and tone pitch.

7.6 Other Forms of Combination

There may be other numeral possibilities for the combination of chime stones. In the Western Zhou period (1046-771 BCE), for instance, four chime stones have been uncovered from the Ying state tomb M95 in Henan Pingdingshan. Since this tomb was not previously looted, the four chime stones might have been a possible form of combination.

In the late Western Zhou (about the King Li period, 877-841 BCE) inscriptions on a bronze vessel Shihui (師𩛥) *gui* (food container), say that Bo Hefu bestowed Shihui "one bell, five chime stones, and bronzes" (ZSKKGS, 2001, p. 439). In short, between the sets of three and ten chime stones that commonly appeared from the late Shang (ca. 1260-1050 BCE) to the Western Zhou, chime stones might have existed in sets of four and five in the late Western Zhou.

In the Eastern Zhou period (770-256 BCE), as well as assemblages of ten and thirteen chime stones, other forms of combination could be used practically in performance. The nine chime stones dating to late Spring and Autumn (546-476 BCE) unearthed from tomb M4 in Henan Hebi Qixian Songzhuang (HNWYS, 2015) may have two possible combinations—nine or ten (see Chapter 8).

Apart from a set of nine pieces, Warring States (475-221 BCE) examples of seven chime stones from the Xue state tomb M117 in Shandong Tengzhou (WWDXBJB, 2001) and eight from Shandong Linzi Shifotang were unearthed (WWDXBJB, 2001). There are also examples of possible twelve stone sets in the Eastern Zhou period (770-256 BCE), such as those from tombs in Shanxi Xiangfen Zhaokang M2 (WWDXBJB, 2000), Shandong Linzi Yujiazhuang (WWDXBJB, 2001), Henan Xichuan Heshangling M2 (WWDXBJB, 1996a), Jiangsu Dantu Beishanding (JSDTKGD, 1988), and Anhui Bengbu Shuangdun M1 (AHWYS & Bengbu City Museum, 2010). Additionally, a set of 14 chime stones was excavated from pit 14 of the Western Han tomb in Shandong Luozhuang (JNKGS et al., 2004).

Those tombs in which four, seven, eight, nine, twelve and fourteen chime stones appeared were mostly robbed, or the stones are without detailed archaeological context or badly preserved. The formal excavation reports have not yet been published, so it is difficult to assess how many of the listed extra sets of chime stones were real assemblages which occurred in musical performance in ancient times; more archaeological finds would be useful in this assessment.

7.7 Summary

This chapter describes the combinations in which chime stones were arranged. As time progressed, the size of chime stone sets increased, from sets of three, to sets of ten, thirteen and twenty. Thirty-two pieces in one group is the maximum number of chime stones found in a set. Chime stones were often found with bronze bells, as well as with other instruments such as mouth organs and drums. Having identified the assemblage conditions of chime stones, further research on pitch measurement and music theory is necessary.

Chapter 8: Pitch Measurement and Music Theory

8.1 Methods

Tone measurement is a term commonly used by Chinese scholars when studying chime stones. Because this project explores the whole frequency spectrum of the stones, it is suggested that pitch measurement is a more relevant term. It involves trying to understand the pitch produced by a musical instrument. This project will extend this principle to studying the sound produced by stones, including their frequency spectrum, not merely their fundamental pitch. Initially, researchers took tone measurement by using hardware. For example, Fritz Kuttner (1953) once used a stroboscope to give the readings in terms of cents, or hundredths of an equal temperament semi-tone. One limitation of using such hardware is that the equipment is rather heavy and not easily portable. Today, sound analysis can be conducted by using computer software.

In China, most researchers prefer to use GMAS software[43]. In her study on late Shang (ca. 1260-1050 BCE) musical instruments, Liu Xinhong (2006) examined a single chime stone and three bronze *yong*-bells unearthed from the tomb M54 in Henan Anyang. She conducted tone measurements on them by using GMAS and discusses the single chime stone in some detail, exploring the frequency and sound spectrum produced. Fang Jianjun also conducted complex experimentation through the GMAS system to identify the sound properties of six sets of chime stones excavated from the Luozhuang Western Han tomb in Shandong Zhangqiu (Fang, 2010a). Fang asserts that the sound produced from stones is dependent on the striking strength and the striking position. Other research using computer and data acquisition systems to analyse tones (Zhang, Xu, Chu & Han, 1983), is based on results from an outdated computer system

43 General Music Analysis System (version 2.0) was created by the Research Institute of Music at China Arts Academy.

now more than 30 years old.

The other advanced technology used by Chinese scholars is Nearfield Acoustical Holography. This is a new acoustical imaging technique and is developed from traditional acoustic holography. Cheng Jianzheng and Zhang Dejun (2000) have used this method to research the vibration modes of excavated chime stones.

Other types of computer software have been used by researchers outside China, for example, Sonic Visualiser, an application for visualising and analysing the sound of music audio files (Cannam, Landone, & Sandler, 2010). Of the software Adobe Audition (Audition), Tony Nunes describes its concept: “An impressive feature in this software is that you can make frequency-specific selections within Audition’s Spectral view. You can view amplitude, fundamental frequency and pitch” (Nunes, 2004). The last piece of software widely used is Izotope RX6 Audio Editor (RX) which is mainly used in my study.

> It features an advanced spectrogram display that is capable of showing greater time and frequency resolution than other spectrograms, allowing you to see an unprecedented level of detail when working with audio. The spectrogram displays the audio signals by time and by frequency, showing the frequency components that make up the signal (Anonymous, 2018. http://help.izotope.com/docs/rx/pages/userguide_spectrogramwaveformdisplay.htm).

From my perspective, although different analytical tools and methods exist, all can be utilised for sound analysis. In my research, I mainly use RX and combine this with some theoretical and practical methods to conduct pitch measurement and analysis. The rationale of using RX will be further discussed later in this chapter.

8.1.1 The Measuring Procedure

During my fieldwork, I used audio recording, and photography equipment for collecting audio, video and visual data. This includes a Roland R-26 portable recorder (ver.1.02), HISS Schertler DYN P Set (Ser.-Nr.7917) contact microphone, DT 150 headphones, DPA 4011AS/N 3116748 microphones (cardioid), a recording pen (Hnsat DVR-260), a tuning fork and a digital camera (Nikon D50, AF-S 18-55mm,3.5-5.6G). The method and sequence of measuring the dimensions of chime stones were as follows.

The chime stones were laid on a large piece of paper one by one; their profiles were drawn and then measured. The dimensions of the stones, including thickness, length, height, angle and so forth were measured in situ by using appropriate tools including a vernier calliper, protractor, ropes and a level ruler. To play the chime stones for sound recording, I took a T-shaped wooden mallet and used it as striking tool, which is somewhat similar to previously discussed archaeological chime stone mallets.

In order to play the chime stones in an appropriate way to make pitch measurements, all the chime stones were suspended from a beam similar to an excavated chime rack, and each stone was then struck carefully, several times, with a wooden mallet (fig. 86). The single irregular-shaped chime stone that was studied had to be struck on the slanting part *gu* when hanging. For chime stones with a regular shape, the best striking point should be at the *gushangjiao*, an angle connecting both sides of the *gushangbian* and *gubo* of the chime stone, which emits a better quality sound than other parts (Hubei Provincial Museum & ZKYWYS, 1984).

Figure 86. This author was playing chime stones excavated from the Luoyang Zhongzhou Daqu

At the same time, audio and video recordings were made and photographs were taken. By means of computer software, I conducted pitch measurement acoustic analysis of the chime stones which included exploring their pitches and examining spectrograms, from which I obtained accurate scientific sonic data. However, aural experience is also crucial when taking pitch measurements, since it is important to understand how the instruments are heard. We need therefore to play them in sequence and listen so as to understand pitch information in conjunction with the computer data.

8.1.2 The Application of Four Different Computer Software Packages

Each different computer software package has its own features and advantages. Therefore, I chose four software packages to conduct my research, with comparative analysis on the results obtained from the four packages. I chose specimen no.7 from a set of chime stones found in Luoyang Zhongzhou Daqu as a sample.

At first, I was planning to use Sonic Visualiser for testing, but it did not show specific data, identifying small frequency ranges or "bins" instead of specific frequencies. However, the visual use of Sonic Visualiser was effective (see Chapter 9, figs. 95 & 96).

The software I used instead was Adobe Audition. From experiments, the fundamental frequency of no.7 was 612.42 Hz, the pitch was $^{\sharp}D_5$-27 cents. The second partial was approximately 1612.60 Hz with the pitch G_6+48. An impressive feature in Audition is that one can make frequency-specific selections within Audition's Spectral view. One can view amplitude, fundamental frequency and pitch, but when analysing partials, one can only edit them by isolating out each of the partials from a recording and then analysing them. It can produce accurate results for each partial, but it is difficult and inconvenient to access this data.

Compared with Audition, GMAS is more complicated to use. Since the original sound recording sample cannot be loaded into the GMAS system directly, the original sound sample needs to be simultaneously uploaded and recorded again through the recorder function inside GMAS. Consequently, the results are less accurate as it may result in unwanted noise from the computer.

Peak Analyzer (Peak) developed by Frederic Dufeu was also trialled. This software is based on Fast Fourier Transform (FFT) and it can rapidly calculate the pitch, frequency and decibel level of a number of partial frequencies for each chime stone. Nevertheless, the frame in Peak is broad and it cannot precisely locate the peak value of resonances in the stones. Dufeu acknowledges that this is only a draft version of the software and it needs further improvement.

RX is precise and convenient. As a spectral-based audio editor, it can visualise and edit audio in both the time and spectral dimensions. This cutting-edge software can identify each partial of a resonant sound such as that of a chime stone (Anonymous, 2018)[44]. Unlike Audition in which the sound being analysed needs to be isolated, RX seems fast, reliable and simple to operate. Results for pitch and frequency are listed in table 16.

44 Anonymous, 2018. https://www.izotope.com/en/learn/products/rx/using-rx-7-for-music.html

Table 16. The results of pitch, frequency and partial tests on chime stone no.7 from Luoyang Zhongzhou Daqu

Audition				GMAS			
Fundamental frequency (Hz)	Pitch (cent)	Partial 2 frequency (Hz)	Pitch 2 (cent)	Fundamental frequency (Hz)	Pitch (cent)	Partial 2 frequenc y (Hz)	Pitch 2 (cent)
612.42	$^{\sharp}D_5$-27	1612.6	G_6+48	612.23	$^{\sharp}D_5$-36	1612.07	G_6+40
Peak				RX			
Fundamental frequency (Hz)	Pitch (cent)	Partial 2 frequency (Hz)	Pitch 2 (cent)	Fundamental frequency (Hz)	Pitch (cent)	Partial 2freque ncy (Hz)	Pitch 2 (cent)
623.21	$^{\sharp}D_5$+2	1631.04	G_6-32	612.28	$^{\sharp}D_5$-28	1612.1	G_6+48

Note: Sonic Visualiser was not used in this comparison as it could not show specific data.

The results seen from the data are similar for two of the software packages, Audition and RX, which thus seem reliable. The results from GMAS are close but 8 or 9 cents different. The results from Peak seem less accurate. Overall, the ratio between fundamental tone and partial are decimal but not in integer multiple relations, an inharmonic relationship. In sum, from examining four different computer software packages, the results show that the best choice for detecting sound properties is the RX software, partly because of its ease of use, but also because of its accuracy.

8.2 Tone Pitches

The singly used chime stone, *Te Qing*, as a rhythm percussion instrument, can only emit one tone. Some measurement research has shown that two tones are obtainable by striking two different points on each stone, for example, the chime stones in Xiangfen Taosi (tables. 17 and 18)[45]. Single chime stones *Te Qing* from the period between the

45 Pitch measurement data in this thesis, apart from my own, comes from WWDXBJB (1996a, b, c, d, e; 1998;2000;2001;2006;2008;2010), Li Chunyi (1996) and Fang Jianjun (2006, 2011).

Neolithic and Western Zhou (1046-771 BCE) were quite large (see table. 17), the surfaces are uneven and the thicknesses differ. Given these features, these stones may produce diverse tones when hitting different parts, which is exactly the characteristic of any similarly irregularly shaped plate percussion instrument with a sectionalised vibrating pattern.

Table 17. The dimensions of single chime stones from the Neolithic period to the Western Zhou dynasty

Specimen	Date, Culture	Whole length (cm)	Height (cm)	Thickness (cm)
Shanxi Xiangfen Taosi M3002:6	Early Taosi culture	95	32	2-6.5
Shanxi Xiangfen Taosi M3015:17	Early Taosi culture	79	32	1-5.5
Shanxi XiangfenTaosi M3016:39	Early Taosi culture	44	19	3.5
Lanzhou Yuzhong Majiawa	The Qijia culture	74	33.5	2.3-3.5
Anyang Yinxu Dasikongcun M991	Late Shang, Yinxu culture II	62.5	29.5	3
Hubei Suizhou Maojiachong	The middle Western Zhou	64.5	-	2.0
Shandong Jiaoxian Zhangjiazhuang	The middle Western Zhou	82	42	5.0

Table 18. Data of tone measurement on single chime stones from the Neolithic to the Western Zhou period

Site/Tomb	Specimen no.	Date, Culture	Pitch	Register
Shanxi Xiangfen Taosi tomb	M3002:6	Neolithic, Taosi culture	C_5-23, C_5-18	two-lined octave
Shanxi Xiangfen Taosi tomb	M3015:17	Neolithic, Taosi culture	$^\sharp F_5$-23, E_6-11	two- to three-lined octave
Shanxi Xiangfen Taosi tomb	M3016:39	Neolithic, Taosi culture	$^\sharp G_6$-23, B_5+1	two- to three-lined octave
Shanxi Xiangfen Taosi tomb	M3072:10	Neolithic, Taosi culture	A_6+7, $^\sharp C_7$+27	three- to four-lined octave
Henan Yuxian Yanzhai tomb	YHY83T11M14	Neolithic, Longshan culture	D_7+27	four-lined octave
Shanxi Wutai Yangbai	H111:1	Neolithic, Longshan	D_5-8	two-lined octave

Site/Tomb	Specimen no.	Date, Culture	Pitch	Register
		culture		
Shanxi Wenxi Nansongcun		Neolithic, Longshan culture	A_5-13	two-lined octave
Henan Yanshi Erlitou	K3:21	Xia dynasty	G_5+39	two-lined octave
Shanxi Xiaxian Dongxiafeng	H15:60	Xia dynasty	$^{\sharp}C_4$	one-lined octave
Henan Zhengzhou Xiaoshuangqiao	ZSXT189 ③:1	Early Shang, Erligang culture	$^{\sharp}G_6$-12	three-lined octave
Shaanxi Lantian Huaizhenfang		Early Shang, Erligang culture	$^{\sharp}F_5$+13	two-lined octave
Anyang Yinxu Wuguancun tomb M1, tiger-designed chime stone	WKGM1	Late Shang, Yinxu culture	$^{\sharp}C_4$+1	one-lined octave
Anyang Yinxu Huanshui Nan'an, dragon designed chime stone		Late Shang, Yinxu culture	A_4-16	one-lined octave
Anyang Yinxu Fu Hao's tomb	AXTM5:2	Late Shang, Yinxu culture	B_5	two-lined octave
Anyang Yinxu Fu Hao's tomb	AXTM5:316	Late Shang, Yinxu culture	$^{\sharp}A_5$-11	two-lined octave
Anyang Yinxu Xiqu tomb	M991:20	Late Shang, Yinxu culture	$^{\sharp}C_5$-42, G_5-13	two-lined octave
Anyang Yinxu Guojiazhuang tomb	M160:6	Late Shang, Yinxu culture	$^{\sharp}G_5$-8, $^{\sharp}A_5$-33	two-lined octave
Anyang Yinxu Xiqu tomb	M701:72	Late Shang, Yinxu culture	F_5-42	two-lined octave
Anyang Yinxu Xiqu tomb	M93:3	Late Shang, Yinxu culture	F_5-6	two-lined octave
Anyang Yinxu Xiqu tomb	M93:5	Late Shang, Yinxu culture	$^{\sharp}A_4$-8	one-lined octave
Anyang Yinxu Xiqu tomb	M93:6	Late Shang, Yinxu culture	F_5+26	two-lined octave
Anyang Yinxu Xiqu tomb	M93:20	Late Shang, Yinxu culture	E_5-16	two-lined octave
Anyang Angang Zhongban tomb	M1769:1	Late Shang, Yinxu culture	A_5+24	two-lined octave
Anyang Yinxu Dasikongcun	M539:11	Late Shang, Yinxu culture	G_6+23	three-lined octave
Liaoning Shuiquan		Lower Xiajiadian culture	C_6-43	two-lined octave
Liaoning Beipiao		Lower Xiajiadian culture	A_5+8	two-lined octave
Shaanxi Fufeng Qinzhencun	87F:400	Middle Western Zhou	$^{\sharp}F_5$+47	two-lined octave
Shaanxi Baoji Shangguancun	2212.IL.3	Late Western Zhou	E_5-18	two-lined octave
Shaanxi Fufeng Yuntang	82FY:1	Late Western Zhou	$^{\sharp}A_5$+39	two-lined octave

In the Neolithic Age, as shown in table 18, the pitch registers of chime stones range from two to three-lined octaves and occasionally to a four-lined octave[46].

During the Shang (ca. 1600-1046 BCE) and Western Zhou dynasties (1046-771 BCE), singly used chime stones remained primarily in the register of a two-lined octave, with a few cases of one-lined and three-lined octaves. Apparently, a rhythmically used chime tone was a treble instrument rather than a bass instrument in this period.

Of chime stones found in the late Shang (ca. 1260-1050 BCE) Yinxu Xiqu tomb M93, five stones were buried in total, one (no.2) of which was smashed. Nos.5 and 20 produce an augmented fourth, while nos.20 and 3 as well as no.6 are a minor second. However, the interval between no.5 ($^{\sharp}A_4$-8 or $^{\flat}B_4$-8, both are enharmonic tones) and no.6 (F5+26) are the perfect fifth; the same interval of perfect fifth can form in between stones no.5 and no.3. Stones no.3 and no.6 have the same pitch, with only 20-cent difference. Given these properties, they may have been two stones arranged in a chime set (either no.5 and no.6 or no.5 and no.3). Nevertheless, since the five stones were placed in different positions within the tomb and have different shapes, it is uncertain whether this group of stones belonged to only one set, or possibly included a singly used stone (*Te Qing*).

From the Eastern Zhou (770-256 BCE) to Western Han dynasties (202 BCE-8 CE), singly used chime stones disappeared and instead, sets of chime stones appeared. Chime stones range from a one-lined to a four-lined octave (see the following section on Scales and Modes).

From examining 66 chime stones that have been subjected to measurement so far in my fieldwork, I first established all the fundamental frequency pitches. There are subtle differences between each fundamental in cents, but here I discount cents. The following fundamental pitches are present:

---

46 "The notes from middle C to B of the 3rd staff-line belong to the one-lined octave. The notes from C, written on the staff's third space, up to the note B, written in the space over the first ledger-line above the staff, belong to the two-lined octave" (Sembos, E.C, 2006, p. 18-19).

G_4, A_4, B_4

C_5, $^\sharp C_5$, D_5, $^\sharp D_5$, E_5, $^\sharp F_5$, G_5, $^\sharp G_5$, $^\sharp A_5$, B_5

C_6, $^\sharp C_6$, D_6, $^\sharp D_6$, E_6, F_6, $^\sharp F_6$, G_6, $^\sharp G_6$, A_6, $^\sharp A_6$, B_6

C_7, $^\sharp C_7$, D_7, $^\sharp D_7$, E_7, F_7, $^\sharp F_7$, G_7, $^\sharp G_7$, $^\sharp A_7$

From G_4 to $^\sharp A_7$, we can see the tone distribution is rather wide, and can reach three octaves on the piano keyboard (such as G_4—G_7). Only a few pitches have not appeared, such as F_5, A_5 and A_7. The lowest pitched stone was from M7983:11 in Henan Tanggong Xilu, and the highest pitched stone was from M1:01 in Henan Luoyang Baihuo Gongsi. This presents some issues which need to be clarified. On one hand, many chime stones were broken and imperfectly preserved either in the tomb or exposed in the air after excavation. The chime stones may experience chemical efflorescence and become distorted in their sound qualities. On the other hand, the range of these pitches are limited as I found from my fieldwork. A large number of pitches have emerged in data from excavation reports which encompasses the three missing pitches. The range of pitches reported ranges from $^\sharp C_4$ up to C_8. The lowest pitched chime stone in this data was found in Shanxi Xiaxian Dongxiafeng H15:60, and the highest pitched stones were found separately in Marquis Yi's tomb (Group one no.6) and Luozhuang Western Han tomb (Group five no.112). With further archaeological excavations in the future, more stones with more pitches can be expected to be found. Figure 87 shows the pitch distribution from the Shang (ca. 1600-1046 BCE) to the Western Han dynasties (202 BCE-8 CE) according to my fieldwork, accompanied by accurate frequencies and dates (fig. 87).

The archaeological pitch range of existing chime stones is from $^\sharp C_4$ to C_8; converted to $^\sharp C^1$-C^5, which covers four octaves. Generally, the range of pitch is rich in the period from the Shang to the Western Han dynasties.

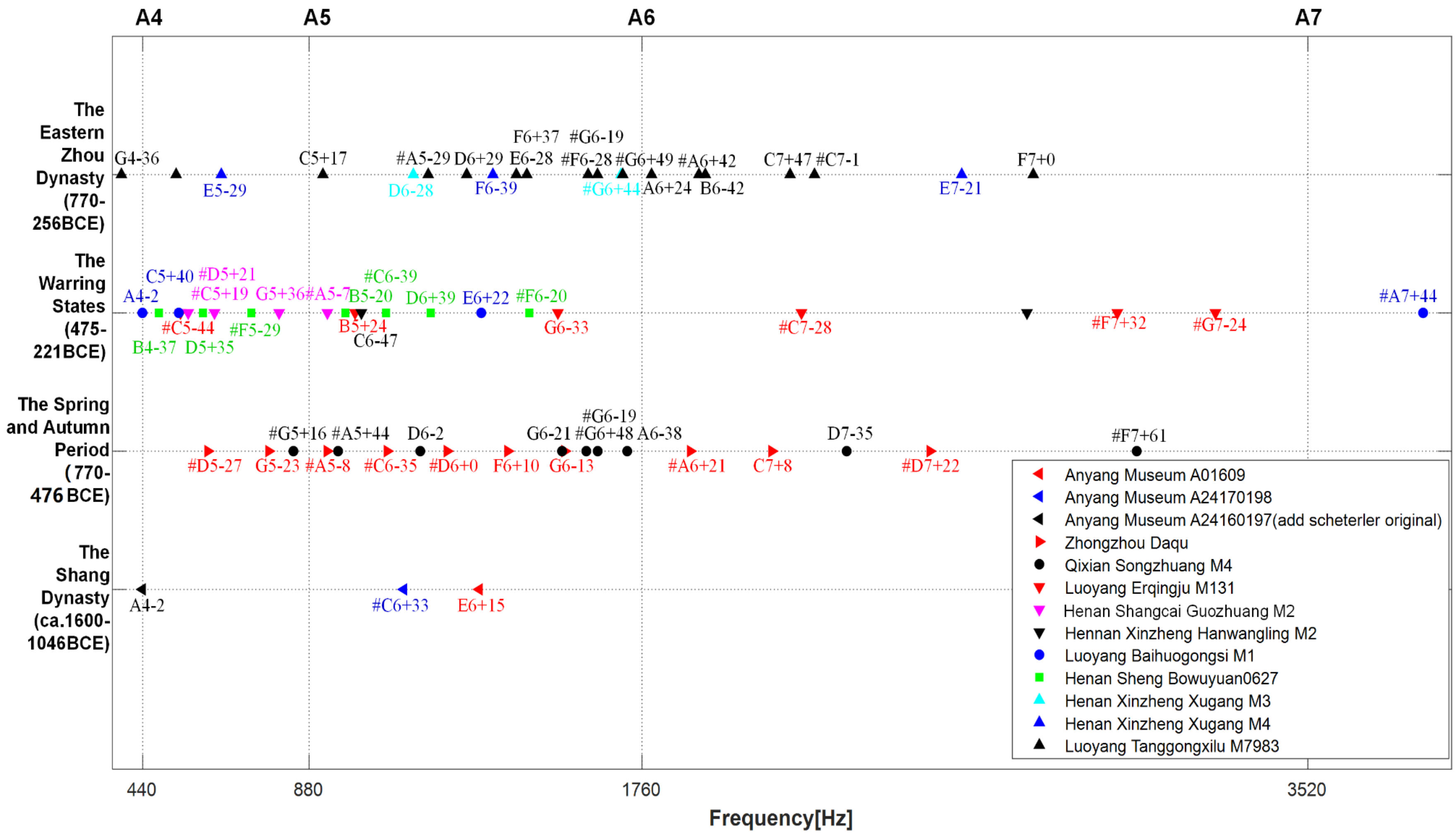


Figure 87. The pitch distribution of chime stones from the Shang to the Eastern Zhou period

8.3 Scales and Modes

Scales with specific modes and note frequencies have different characters. A scale with five notes per octave (frequency doubling) with specific interval patterns is the pentatonic scale, seen widely in the oriental music of ancient China. Chime stones which are typical for the period from the Shang (ca. 1600-1046 BCE) to the Western Han dynasty (202 BCE-8 CE), and which are complete, are considered in this chapter, which covers the measurement of scales, modes and sound. The absence of notated composition is an obstacle to studying the sound of ancient chime stones, but we may examine their possible scales and modes through measurement of the frequencies of individual chime stones, and transcribe their frequency and pitch distribution using modern notation. Though it is imprecise, utilisation of the musical stave is an effective and direct way to present the notes that chime stones produce. However, ancient Chinese musical instruments are not in equal temperament, thus pitches, such as C4 or middle C, are augmented by adding details of how far away from the pitch centre the note is in hundredths of a semi-tone, or cents.

In this section, I will use musical stave notation to illustrate various kinds of scales and modes that the ancient chime stones formed. As William Duckworth points out: "There are, of course, obvious advantages to being able to write down your musical ideas on these musical staves. To use musical staves to represent these notes in a line of scale is necessary" (Duckworth, 2014, p. 77). The advantages of using musical staves are apparent; the sound of chime stones can be transcribed as a symbol or text for analysis, and understood in relation to contemporary musical structures. The aim of this section is to better understand the musical scales and modes of chime stones.

8.3.1 Three-Tone Series

Chime stones from the late Shang (ca. 1260-1050 BCE) to the Western Han (202 BCE-

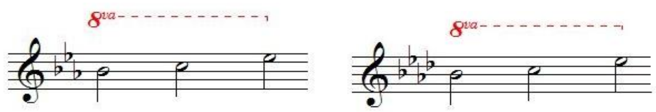
8 CE) construct specific scales and modes; these can be illustrated using examples of typical chime stones from that period.

Sets of three chime stones appeared in the late Shang period. Two sets have been found, including one in Fu Hao’s tomb which is of poorly preserved condition, which prevents sound recording. The other set found in Anyang was well preserved, these are well-known chime stones with inscriptions of Yongqi, Yaoyu and Yongyu. In the Western Zhou period (1046-771 BCE), there are no complete sets of three chime stones, since the majority of the stones were broken into pieces. The pitch data from the three inscribed chime stones from Anyang is as follows:

Yongqi $^{\sharp}A_5+30$

Yaoyu $C_6\pm0$

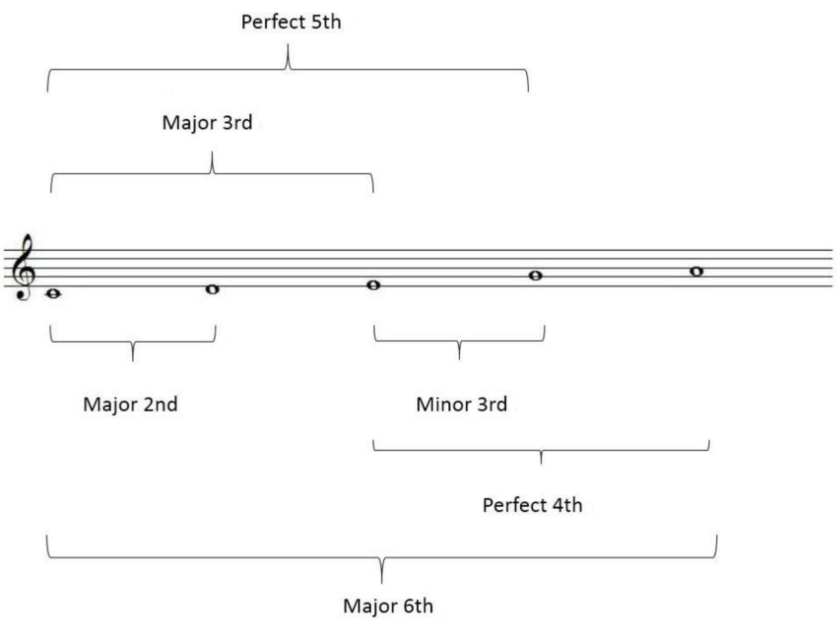
Yongyu $^{\sharp}D_6+47$

They form a three-tone series, which can be defined traditionally as either the Chinese *zhi* 徵 mode with a three-tone series *zhi-yu-gong* (徵-羽-宫), which corresponds to sol-la-do in the modern tonic *sol-fa* system, or the *shang* 商 mode with *shang-jue-zhi* (商-角-徵), which is equivalent to re-mi-sol. Both have different **do**, harmonic root, or in Chinese the *gong*, namely a different tonality, see example 1.

Example 1. Transcription of three-tone series inscriptional chime stones from Anyang

The three-tone series contains the first, second and third note of a pentatonic scale starting on a ^{b}B, with intervals including a major second, minor third and perfect fourth. Traces of heavy grinding on the surfaces and rims of stones suggest that they may have been processed in order to tune them to a specific pitch standard and intonation. What we see is evidence that these stones played a scale that we would find quite familiar, some 3000 years ago.

8.3.2 Pentatonic Scale

Pentatonic scales have five notes. "The word 'pentatonic' comes from the Greek word 'pente', meaning five. They are very common in folk music from around the world and are a useful basis for improvising in Jazz, pop and rock music as they work well over several chords" (Winterson & Harris, 2014, p. 46). In traditional Chinese music, pentatonic is the basic scale, and is still widely used today. The pentatonic scale omits the fourth and seventh degrees (example. 2) of a standard Western scale. The intervals include perfect fourth and fifth, major sixth, major and minor third, as well as major second. Ancient Chinese music theory nomenclature of the five notes is *gong* 宫, *shang* 商, *jue* 角, *zhi* 徵, *yu* 羽, which approximately corresponds to do, re, mi, sol, and la, respectively, in the modern tonic *sol-fa* system, a root note, major 2nd, major 3rd, perfect 5th and major 6th.

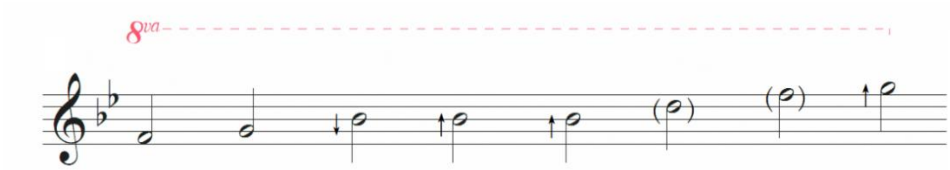


Example 2. The structure of pentatonic scale

From the late Western Zhou (877-771 BCE) throughout Eastern Zhou (770-256 BCE) and Western Han periods (202 BCE-8 CE), sets of chime stones pitched as pentatonic scales were quite common. In general, a set of chime stones can be composed of a two-tone or three-tone series, a four-note or pentatonic scale. Due to most Western Zhou (1046-771 BCE) chime stones being broken or badly preserved, only specimens from three excavated sites have their tonality explored here. First of all, I will consider the finds from the marquis cemetery of the Jin state; they are M8—the tomb of Marquis Su, M64—the tomb of Marquis Bang Fu, and M93—the tomb of another Marquis of Jin. These three tombs were all located in Shanxi Tianma Qucun and dated to the late Western Zhou period. Tomb M64 had at least 18 musical stones surviving but most were severely broken into pieces. Of M8 and M93, each contained ten chime stones, however, the three tombs were robbed several times and the chime stone assemblage was surely incomplete, we hence tentatively take them as a reference. Table 19 lists the measurement data of chime stones from the three tombs.

In tomb M8, we have the tunings of six chimes (of the other four stones, two were broken and two unknown). They are able to form a four-note scale *gong-jue-zhi-yu*, the possible structure is as follows (example. 3):

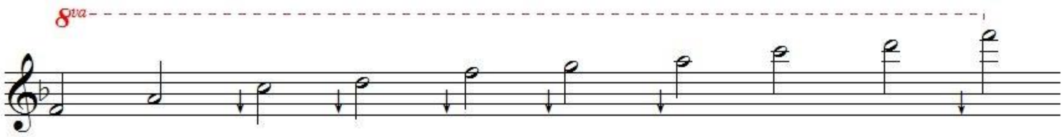
zhi-yu-↓gong-↑gong-↑gong-(jue)-(zhi)- ↑yu

sol-la-↓do-↑do-↑do-(mi)-(sol)- ↑la

Example 3. Transcription of chime stones from the Marquis Su's tomb (M8)

The ten chime stones from M93 may construct a pentatonic scale as below (example. 4):

gong-jue-↓zhi-↓yu-↓gong-↓shang-↓jue-zhi-yu-↓gong

do-mi-↓sol-↓la-↓do-↓re-↓mi-sol-la-↓do

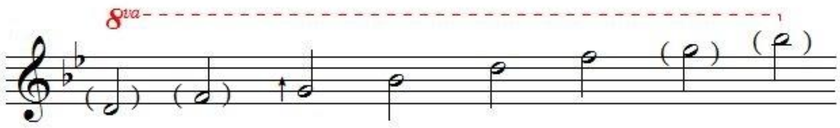


Example 4. Transcription of chime stones from the Marquis tomb of Jin (M93)

Eight of the chime stones from M64 may presumably be a four-note scale but with structure of *jue-zhi-yu-gong* (example. 5):

(jue)-(zhi)-↑yu-gong-jue-zhi-(yu)-(gong)

(mi)-(sol)-↑la-do-mi-sol-(la)-(do)



Example 5. Transcription of chime stones from the Marquis Bang Fu's tomb (M64)

Table 19. Tone measurement data of chime stones from M8, M93 and M64 in the Marquis cemetery of the Jin state

Chime stones from M8										
Specimen no.	M8:11	M8:15	M8:12	M8:57	M8:14	M8:13	Unknown	M8:16	M8:54	M8:53
Pitch	broken	F_5-16	G_5+53	$^\sharp A_5$-15	B_5-28	B_5+22	broken	Unknown	Unknown	A_6+43
Chime stones from M93										
Specimen no.	M93:83	M93:84	M93:78	M93:85	M93:81	M93:87	M93:79	M93:80	M93:86	M93:82
Pitch	F_5-31	A_5-38	B_5+23 (C_6-77)	$^\sharp C_6$+33 (D_6-67)	E_6+4 (F_6-96)	$^\sharp F_6$+2 (G_6-98)	$^\sharp G_6$+2 (A_6-98)	C_7+14	D_7-33	D_7+29 ($^\flat E_7$-71)
Chime stones from M64										
Speciment no.	M64:77	M64:81	M64:76	M64:80	M64:75	M64:79	M64:74	M64:78		
Pitch	broken	broken	A_5+0 (G_5+200)	$^\sharp A_5$-4 ($^\flat B_5$-4)	D_6-23	F_6-26	broken	broken		

Among the above mentioned chime stones, those from M8 and M64 have probably lost some of their tone. I have tried to recover their sound according to the regularity and structure of the pentatonic scale, combined with the dimensions of the chime stones and accounting for possible missing stones. The tones shown in brackets represent the possible missing notes and the arrows are tones of not accurate pitch. The ascending arrow indicates that the present-day tone is a little higher than the ideal sound is may have produced, whilst the descending arrow indicates a tone that is lower than the ideal. Thus, the given scales show the ideal sound that the chime stones could have produced. The chime stones found in tomb M93 are relatively complete; the pentatonic consists of a four-note scale do-mi-sol-la, and the five notes do-re-mi-sol-la. This is problematic if the *shang* 商 (re) note really occurred and was played in ritual performance in the Western Zhou (1046-771 BCE) court music.

In an ancient Chinese historical context, not only was Shang a dynasty, but also one of five notes in the pentatonic system (Anonymous, probably 3rd century BCE [1980], *Zhou Li Chun Guan*). According to historical documentation, the Shang were conquered in the Central Plain region by the Zhou, an ethnic group from north-western China. The Shang dynasty was then replaced by the Western Zhou (Sima, 145 or 135-90 BCE [1993]). In the record of *Yue Ji* (Record of music), Confucius (551-479 BCE) talks about music with Binmu Gu, which involves issues of the *shang* (supertonic) note:

> Binmu Gu was serving Confucius, and sitting beside him, Confucius talked about music with Bin…, and asked a question: "The tones were more elaborate including *shang* note, why was that?" Bin answered: "It was not the music of *Wu* 武." Confucius added: "If not the *Wu*, what was it?" Bin answered: "The *Wu* was lost by Yousi, otherwise, the ambition that King Wu had established was almost forgotten" (for the Chinese version, see Ruan, 1980, p. 1542).

The above quotation tells us a story that *Wu*, or *Da Wu* 大武 (great Wu) was a distinguished composition of ritual music for eulogizing King Wu, who defeated the Shang dynasty and built the new Western Zhou dynasty. The music that Confucius listened to in the Spring and Autumn period (770-476 BCE) was not the *Wu*, because *Wu* lacked the *shang* note. According to Binmu Gu, the reason for this is that Yousi failed to hand down the *Wu* to the following generations. In the Western Zhou (1046-

771 BCE) court music *Wu* did not have the *shang* note.

Based upon classical texts, some scholars (Gao, 2004; Yang, 2007) believe that the *shang* note could not have existed during the Western Zhou period, as the *shang* symbolised the enemy that could destroy the nation of Western Zhou. They conclude that musical performance was limited during the Western Zhou dynasty owing to the lack of the *shang* note. However, it is merely a supposition, since new music archaeological evidence such as the chime stones from M93 of Shanxi Tianma Qucun have proven the existence of the *shang* note during that period. According to Fang Jianjun (2008), the sounding result of the Western Zhou clay ocarina from Luoyang Beiyao provided another indication of the *shang* note used in ritual music during the Western Zhou period. The ocarina has five finger holes, which produce a pentatonic scale, including the *shang* note.

Dating to the end of the Western Zhou period, a set of ten chime stones found in tomb M27 of the Rui state in Shaanxi Hancheng Liangdaicun also support the notion that the *shang* note was used in Western Zhou court music. Among the stones, five were completely preserved; others were broken to different degrees but have since been glued very effectively. Almost all glued chime stones emit good sound except the third example (M27:1049. See table. 20).

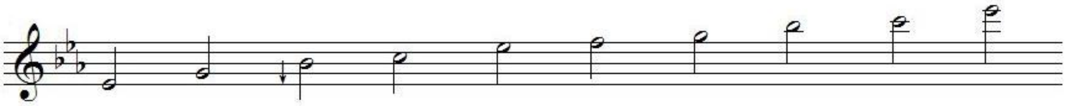
Table 20. Data of tone measurement of chime stones from Hancheng Liangdaicun M27

Order	Specimen no.	Pitch	Comments
1	M27:1047	$^{\#}D_4$+39	Broken and restored
2	M27:1046	G_4+45	
3	M27:1049	A_4+32	Broken and restored
4	M27:1042	$^{\#}C_5$-48 (C_5+52)	A little break
5	M27:1048	$^{\#}D_5$+19	Broken and restored
6	M27:1043	$^{\#}F_5$-24 (F_5+76)	

Order	Specimen no.	Pitch	Comments
7	M27:1044	G_5+24	Broken and restored
8	M27:1045	B_5-31 ($^\sharp A_5$+69)	A little weathering on the surface
9	M27:1041	C_6+48	
10	M27:1050	E_6-48 ($^\sharp D_6$+52)	Broken and restored

From the tone distribution, it appears that the ten chime stones may construct a pentatonic scale with the *gong* (do) mode through two octaves (example. 6). Furthermore, the auditory sense also supports such a scale structure.

gong-jue-↓zhi-yu-gong-shang-jue-zhi-yu

do-mi-↓sol-la-do-re-mi-sol-la-do

Example 6. Transcription of the ten chime stones from Hancheng Liangdaicun M27

This shows that at least some musical instruments including a clay ocarina and some chime stones could play the *shang* note in the Western Zhou period (1046-771 BCE).

Assemblages of ten-part chime stone sets from this include both a four-note scale and a pentatonic scale. The finds excavated from a burial pit in Lixian Dapuzishan (Gansu) are a good complete example, dating from the early Spring and Autumn period (770-686 BCE), in which ten chime stones were arranged in line but placed out of sequence, and divided into two groups, each group having five stones (table. 21).

Table 21. Data of tone measurement of chime stones from Lixian Dapuzishan

Unearthed Order	Specimen no.	Pitch
1	K5:15	E_5-42
2	K5:16	B_5-25
3	K5:17	E_6-17
4	K5:18	B_6+16
5	K5:19	E_7+0
6	K5:20	$^{\#}G_5$-49
7	K5:21	$^{\#}C_6$-30
8	K5:22	$^{\#}F_6$+0
9	K5:23	$^{\#}G_6$-16
10	K5:24	$^{\#}C_7$+9

This set of chime stones were well-preserved, and provide accurate pitch information. Group one consists of stone nos. 1 to 5, group two nos. 6 to 10, the two groups create different types of tonal series:

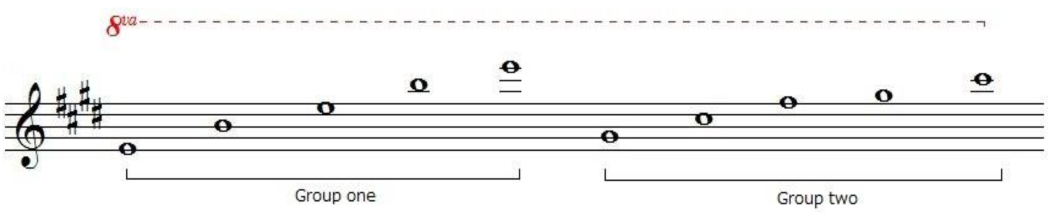
Group one: *gong-zhi-gong-zhi-gong*

do-sol-do-sol-do

Group two: *jue-yu-shang-jue-yu*

mi-la-re-mi-la

In group one, a two tone-series is developed alternately with a sequence of *gong-zhi* (do-sol), and the *gong* (**do**) tends to be a tonic (mode) within two octaves. By using *yu* as tonic (mode), group two adds a *shang* note on the basis of alternate sequence in *jue-yu* (mi-la) (see example. 7).

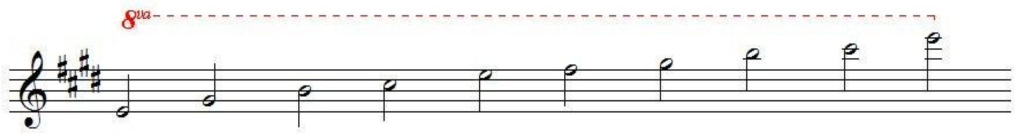


Example 7. Tone-series in two groups of chime stones from Lixian Dapuzishan

A secondary formation of these stones can be created by discounting the excavated order of the stones and reorganising the two groups of stones in sequence according to pitches ranging from lower to higher; then the pentatonic scale will be constructed as below (see example. 8):

gong-jue-zhi-yu-gong-shang-jue-zhi-yu-gong

do-mi-sol-la-do-re-mi-sol-la-do



Example 8. Pentatonic scale of chime stones from Lixian Dapuzishan

Such an arrangement offers various possibilities for practical performance. The ten-part chime stones may have been used either as one combined group or two separate groups.

The assemblage and tone series/scales of the Dapuzishan chime stones are significant for understanding other sets of ten-part chime stones from the Eastern Zhou period (770-256 BCE). Several sets of ten chime stones have been discovered in the Central Plain region, such as those from Shanxi Changzhi Fenshuiling M269 and M25, Shanxi Linyi Chengcun M1001 and M1002, Shanxi Houma Shangma M13 and M1004, where the chime stone sets were separately placed in two halves and piled up in tombs, each having five stones. Other archaeological finds such as those of Henan Luoyang Zhongzhou Daqu, Henan Shaanxian Houchuan M2040, Shanxi Jiaokou Yaowacun, and Shanxi Wenxi Qiujiazhuang, had a less clear position in tombs; the suspension order, however, can be considered with the pitches arranged from lowest to highest.

Chime stones from Houma Shangma M13, for example, were in the tomb in two groups of five, they were piled up according to size in descending order. In his *Zhongguo shanggu chutu yueqi zonglun*, Li Chunyi refers to the location where the chime stones were placed in tomb M13, explaining that the ten-part chime stone sets could be divided into two groups, each of five (Li, 1996). It turns out, through analysing data of tone measurement, the tone series and scales of chime stones from M13 were also in a five-plus-five arrangement. The aforementioned finds from Lixian Dapuzishan have supported Li's conclusion.

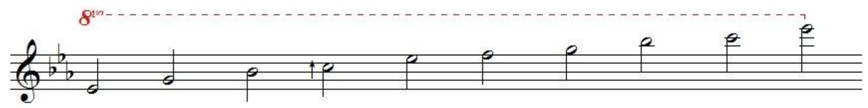
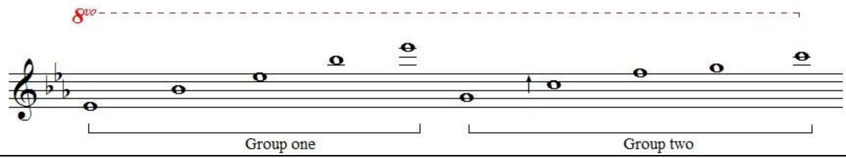
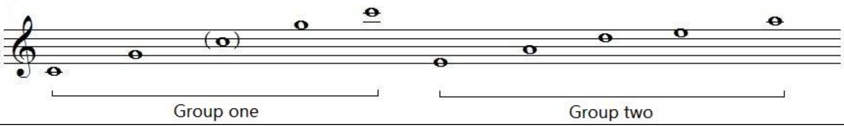
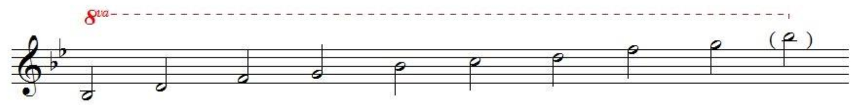
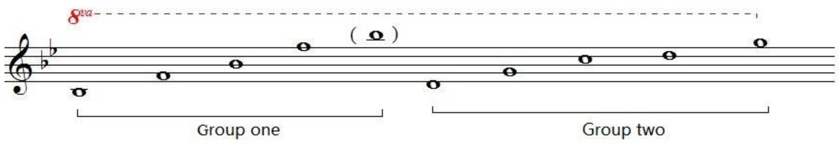
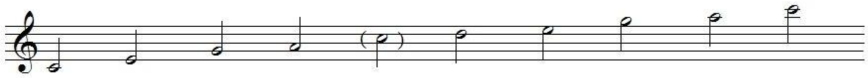
There are several well preserved sets of Eastern Zhou (770-256 BCE) ten-part chime stones which are appropriate for comparing with those found in Lixian Dapuzishan. Three examples were those uncovered from the late Spring and Autumn (546-476 BCE) tomb in Henan Luoyang Zhongzhou Daqu, the Eastern Zhou tomb in Shanxi Wenxi Qiujiazhuang, and the Warring States (475-221 BCE) tomb M2040 in Shaanxian

Houchuan. Table 22 illustrates that they all form a pentatonic scale if the pitches are arranged in order from lowest to highest pitch, the same as the Dapuzishan chime stones. Furthermore, like the Dapuzishan chime stones, they can be divided into two parts within a five-plus-five paradigm, and the structure of the tone series is the same as that from Dapuzishan (example. 9).

Table 22. Tone measurement data of ten-part chime stones in Eastern Zhou period

Tomb	Specimen/Serial no.	Pitch	Comments
Henan Luoyang Zhongzhou Daqu, without tomb number, dating to the late Spring and Autumn period (data from my fieldwork)	no. 7	$^\sharp D_5$-27	
	no. 4	G_5-23	
	no. 8	$^\sharp A_5$-8 ($^\flat B_5$+92)	
	no. 3	$^\sharp C_6$-35	Broken and restored
	no. 9	$^\sharp D_6$+0	
	no. 2	F_6+10	
	no. 10	G_6-13	
	no. 1	$^\sharp A_6$+21	
	no. 5	C_7+8	
	no. 6	$^\sharp D_7$+22	
Shanxi Wenxi Qiujiazhuang, Eastern Zhou tomb	no.1	C_4-24	
	no.2	E_4-33	
	no.3	G_4-9	
	no.4	A_4-32	
	no.6	Unknown	Broken
	no.5	D_5+0	
	no.7	E_5-4	
	no.8	G_5+14	
	no.9	A_5+22	
	no.10	C_6-20	
Henan Shaanxian Houchuan, tomb M2040, Warring States period	M2040:1	$^\sharp A_4$+8	
	M2040:2	$^\sharp C_5$+8 (D_5-92)	
	M2040:3	F_5+8	
	M2040:4	G_5+18	
	M2040:5	B_5-22 ($^\sharp A_5$+78)	
	M2040:6	$^\sharp C_6$-25 (C_6+75)	
	M2040:7	D_6+41	
	M2040:8	F_6+4	
	M2040:9	Unknown	Broken
	M2040:10	$^\sharp G_6$-16 (G_6+84)	

Example 9. The scales of three sets of ten chime stones from Eastern Zhou period

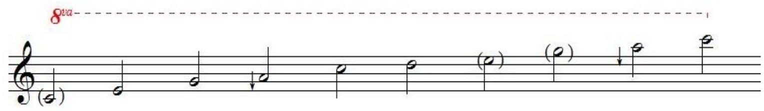
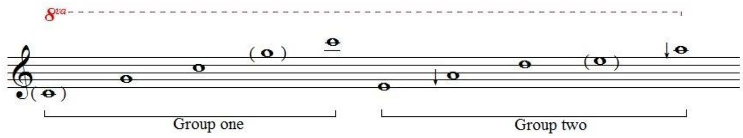
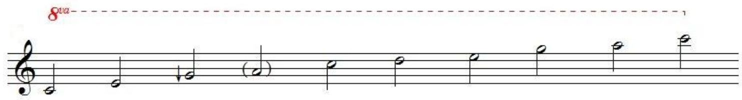
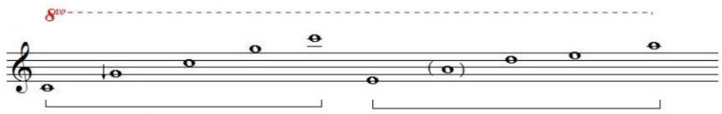
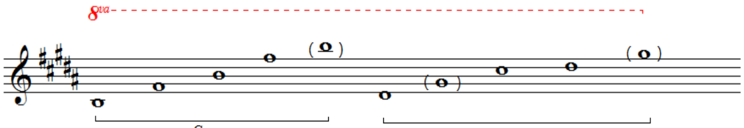
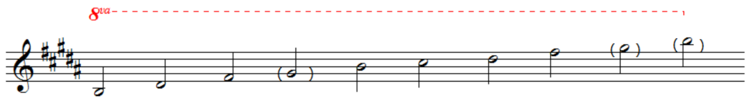
Ten chime stones from Luoyang Zhongzhou Daqu (data from my fieldwork)	
Ten-part paradigm	
Five-plus-five paradigm	
Ten chime stones from Shanxi Wenxi Qiujiazhuang	
Ten-part paradigm	
Five-plus-five paradigm	
Ten chime stones from Henan Shaanxian Houchuan M2040	
Ten-part paradigm	
Five-plus-five paradigm	

These cases make it possible to reconstruct the original scales of those ten-part chime stones sets that are not as well preserved. Nevertheless, some prerequisites are needed when recovering their original pitch series. First, one cannot work out their pitch series if all ten stones are broken, or if only a very few (one or two) stones can be acoustically measured. However, if just a few individual stones were fragmentary, it would still be possible to reconstruct the original pitch distribution of the set by comparing with the cases discussed above.

Ten chime stones unearthed from Shanxi Houma Shangma M13, for example, have three stones (nos. 1, 7, and 8) broken into pieces so it is impossible to play and measure their individual pitches. Nonetheless, by arranging the rest of the complete stones in sequence, and comparing them with the ten-part chime stones mentioned previously, it is possible to suggest their original scale structure (table. 23, example. 10). Other similar cases are the ten chime stones found in the Warring States (475-221 BCE) tomb in Shanxi Jiaokou Yaowacun, and in the Eastern Zhou (770-256 BCE) tomb in Henan Sanmenxia. Among the specimens in Yaowacun, one stone was transferred to another museum so could not be studied, another two (nos. 2 and 3) produce the same pitch, while no. 3 should be the third note in the scale compared with other sets of ten-part chime stones. This example forms a pentatonic scale with a tendency towards the *gong* (do) mode (table. 23, example. 10). As for chime stones from Sanmenxia, two (no. 8 and 9) were broken without pitch data, but their pitches could be calculated by means of the same comparative study (table. 23, example. 10).

Table 23. Three sets of fragmentary chime stones from the Eastern Zhou period

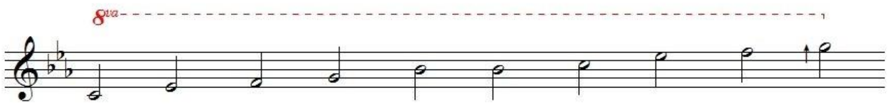
Tomb	Specimen/ serial no.	Pitch	Comments
Shanxi Houma Shangma, tomb M13, mid- to late Spring and Autumn period	no. 1	Unknown	Broken
	no. 2	E_5-1	
	no. 3	G_5+30	
	no. 4	$^\sharp G_5$+26	Broken and restored
	no. 5	C_6+30	
	no. 6	D_6+20	
	no. 7	Unknown	Broken
	no. 8	Unknown	Broken
	no. 9	$^\sharp G_6$+49 (A_6-51)	Broken and restored
	no. 10	C_7+34	
Shanxi Jiaokou Yaowacun, Warring States tomb	no. 1	C_5-26	Broken and restored
	no. 3	E_5+0	Broken and restored
	no. 2	E_5+28	
	no. 10	Unknown	Lent to other museum
	no. 5	C_6-12	
	no. 4	D_6+14	Broken and restored
	no. 6	E_6-20	
	no. 7	G_6-1	
	no. 8	A_6-35	
	no. 9	C_7-19	
Henan Sanmenxia No. 0627 (legendary location), Eastern Zhou tomb (data from my fieldwork)	no.1	B_4-37	Good
	no.2	D_5+35 ($^\sharp D_5$-65)	Good
	no.3	$^\sharp F_5$-29	Good
	no.9	Unknown	Broken
	no.4	B_5-20	Good
	no.5	$^\sharp C_6$-39	Good
	no.6	D_6+39 ($^\sharp D_6$-61)	Good
	no.7	$^\sharp F_6$-20	Good
	no.8	Unknown	Broken

Example 10. Recovered scales of three sets of fragmentary chime stones from the Eastern Zhou period

Ten chime stones from Shanxi Houma Shangma M13	
Ten-part paradigm	
Five-plus-five paradigm	
Ten chime stones from Shanxi Jiaokou Yaowacun	
Ten-part paradigm	
Five-plus-five paradigm	
Ten chime stones from Henan Sanmenxia No. 0627 Eastern Zhou tomb (data from my fieldwork)	
Ten-part paradigm	
Five-plus-five paradigm	

The above discussion and analysis has shown that from the late Western Zhou (877-771 BCE) to the Warring States period (475-221 BCE), sets of ten-part chime stones were popular in the region of the Yellow River valley, and most of them construct pentatonic scales in a *gong* mode. Ten stones may usually divide into two groups and form the five-plus-five assemblage paradigm, one group emits a two-tone series with *gong* (do)-*zhi* (sol), whilst the other produces a three-tone series with *shang* (re)-*jue* (mi)-*yu* (la). Such a scale formation or tone series may have been the common combination for most sets of ten chime stones during the Eastern Zhou period (770-256 BCE).

In addition to the aforementioned ten-part chime stones, some sets of ten chime stones in the Eastern Zhou period formed other possible scale formations. In the Shandong Changqing Xianrentai tomb M6, for example, ten chime stones dating to the early Spring and Autumn (770-686 BCE) were found. Most had good sound quality, although a few were corroded to a certain degree. From the data obtained from tone measurements, this set of ten chime stones differs from those discussed above (see table. 24).

Table 24. Tone measurement data of chime stones from Shandong Changqing Xianrentai M6

Tomb	Specimen no.	Pitch	Comments
Shandong Changqin Xianrentai, tomb M6, early Spring and Autumn period	M6:35	C_5-2	
	M6:36	$^{\sharp}D_5$+44	
	M6:33	F_5+19	Broken and restored
	M6:34	G_5-46	
	M6:31	$^{\sharp}A_5$-26	
	M6:27	$^{\sharp}A_5$-4	decomposed
	M6:32	C_6+16	decomposed
	M6:28	E_6-49 ($^{\sharp}D_6$+51)	decomposed
	M6:30	F_6+39	decomposed
	M6:29	$^{\sharp}G_6$+19	decomposed
Notation			

It seems likely that the ten stones could be divided into two groups of five, with the scales as follows:

Group one *yu-gong-shang-jue-zhi*

la-do-re-mi-sol

Group two *zhi-yu-gong-shang-↑jue*

sol-la-do-re-↑mi

If the two groups are combined together, then the following scale structure (see table. 24: “notation”) is constructed:

yu-gong-shang-jue-zhi-zhi-yu-gong-shang-↑jue

la-do-re-mi-sol-sol-la-do-re-↑mi

From which we can observe that these two groups of chime stones may constitute a pentatonic scale, but the first notes are different from each other, they are *yu* (la) and *zhi* (sol), respectively.

Some sets of 13 chime stones have been found, but most have broken stones, and thus the reported tone measurements are not reliable, only one set so far known in Shandong Tengzhou Zhuangli Xicun is adequately complete for constructing a scale. Apart from two fragmentary stones, the others are well preserved and can produce a measurable sound (see table. 25). Based upon the data of tone measurement, this thirteen-part set of chime stones may constitute a pentatonic scale with the first note *zhi* (sol), the range has over two octaves:

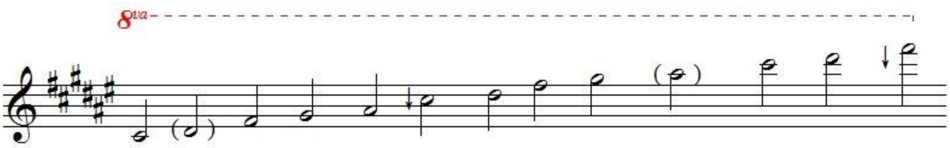
zhi-(yu)-gong-shang-jue-↓zhi-yu-gong-shang-(jue)-zhi-yu-↓gong

sol-(la)-do-re-mi-↓sol-la-do-re-(mi)-sol-la-↓do

Table 25. Tone measurement data of thirteen chime stones from Shandong Tengzhou Zhuangli Xicun

Order	Specimen no.	Pitch	Comments
1	00791	$^{\sharp}C_5$-7	
2	Unknown	Unknown	Broken
3	00789	F_5+47 ($^{\sharp}F_5$-53)	
4	00790	G_5+50 ($^{\sharp}G_5$-50)	
5	00788	$^{\sharp}A_5$-24	
6	00787	B_5+36 ($^{\sharp}C_5$+164)	
7	00786	$^{\sharp}D_6$+3	
8	00785	$^{\sharp}F_6$-12	
9	00784	$^{\sharp}G_6$-37	
10	Unknown	Unknown	Broken
11	00783	D_7-43 ($^{\sharp}C_7$+57)	
12	00782	$^{\sharp}D_7$+34	
13	00781	F_7-6 ($^{\sharp}F_7$-106)	

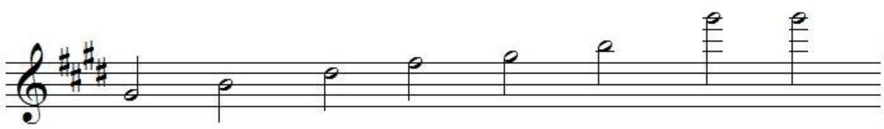
Two broken stones, although their sound is lost, may be inserted into the order (see notes in brackets); also stones no. 6 and 13 pitched a little lower in tone. The whole tone distribution could be transcribed in a notation with a scale formation as follows (example. 11).



Example 11. Pentatonic scale of chime stones from Tengzhou Zhuangli Xicun

Besides sets of ten-part and thirteen-part chime stones, some unusual examples are some sets of eight and nine chime stones. On the eight-part assemblages, one case from Shandong Linzi Shifotang is interesting (table. 26). This set of chime stones constructs a four-note scale la-do-mi-sol-la-do-la-la, but the last two stones are the same pitch (la), and a major sixth interval is produced between the sixth and seventh stones, suggesting that at least one stone may have been missing, and also that the pitch intonation is possibly not accurate in the last two stones.

Table 26. Data of tone measurement of eight chime stones from Shandong Linzi Shifotang

Specimen no.	30046	30045	30048	30049	30051	30050	Unknown	Unknown
Pitch	G_4+37($^{\#}G_4$-63)	B_4-23	$^{\#}D_5$-43	$^{\#}F_5$-14	$^{\#}G_5$-47	$^{\#}A_5$+34(B_5-66)	$^{\#}G_6$-1	$^{\#}G_6$-19
Tonic Sol-fa	la	do	mi	sol	la	do	la	la
Chinese five notes	yu	gong	jue	zhi	yu	gong	yu	yu
Notation								

Dating to late Spring and Autumn (546-476 BCE), another case involves nine chime stones from the tomb M4 in Henan Hebi Qixian Songzhuang. Judging from their pitch measurement (table. 27), the pitch distribution of the chime stones is as follows (data from my fieldwork):

re–mi–sol–do–re–$^{\#}$do–re–sol–do

Corresponding to D-E-G-C-D-#C-D-G-C

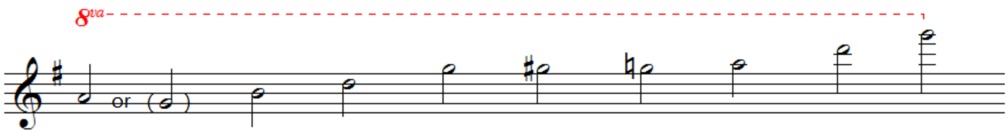
Such a scale formation is based on the pentatonic but without the sixth degree *yu* (la), and is most like the Chinese *shang* (re) mode:

shang–jue–zhi–gong–shang–bianshang–shang–zhi–gong

or *gong* mode:

gong-jue-zhi-gong-shang-bianshang-shang-zhi-gong

The final note in the fixed-doh system (where *doh* is always C)[47] is G, so we may suppose that *gong* is equal to G (example. 12). *Yu* (la) is not shown in this scale. The tone series of these chime stones may form a pentatonic scale, but without the note *yu* (la). Thus, it seems appropriate to regard it as a four-note scale in a pentatonic scale mode: *shang–jue–zhi–gong* (re-mi-sol-do).



Example 12. The scale of chime stones from Qixian Songzhuang M4

This assemblage from M4 in Henan Hebi Qixian Songzhuang is unusual for having nine stones, ordinarily, as I discussed above, sets of ten-part chime stones were the most common formation during the Spring and Autumn period (770-476 BCE). The pitch distribution is arranged as do–mi–sol–la–do–re–mi–sol–la–do. On the other hand, a five-plus-five paradigm could also form do–sol–do–sol–do, and mi–la–re–mi–la. As the group of tombs in Qixian Songzhuang were looted before excavation, it is possible that this set of chime stones was incomplete.

Over time, chime stones which had been buried underground may experienced chemical efflorescence. Some of them became eroded and their sound quality was imperfect. For instance, one chime stone specimen (M4:48) shows poor preservation condition. However, using Sonic Visualiser to measure the tones of each chime stone reveals the original musical scale (see Chapter 9 for details). At least the first five stones fit the scale: re–mi–sol–do–re. As for the rest of the stones, it is supposed to be: do–re–

47 A term applied to the harmonic system in which C is called doh in whichever key it appears (and D is called re, etc.). Arnold 1983, 682.

$\boxed{\text{mi}}$–sol–do. The first two notes with an underline are chime stones that were not well-preserved, while one might suggest the third is the chime stone that was missing, perhaps robbed from the tomb. There are a few examples of other sets of nine chime stones dating to the Spring and Autumn period (770-476 BCE), one case is the set found in tomb M1 in Anhui Fengyang Bianzhuang, however, after making a comprehensive analysis of the chime stones found in tomb M4, I consider that their original total was probably not nine.

Table 27. Pitch measurement data of chime stones from Qixian Songzhuang M4 (data from my fieldwork)

Order	Specimen no.	Pitch	Comments
1	M4:40	$^{\sharp}G_5+16$	
2	M4:51	$^{\sharp}A_5+44$	
3	M4:39	D_6-2 ($^{\sharp}C_6+98$)	
4	M4:50	G_6-21($^{\sharp}F_6+79$)	
5	M4:38	A_6-38($^{\sharp}G_6+62$)	
6	M4:49	G_6+48	Smooth but has poor tone quality
7	M4:37	$^{\sharp}G_6-19$	Surface weathering
8	M4:36	D_7-35 ($^{\sharp}C_7+65$)	
9	M4:48	$^{\sharp}F_7+61$	Broken and restored

Another interesting example is that of the 32 chime stones from the Marquis Yi's tomb of Zeng, many of which were found broken into pieces, so it was not possible to conduct tone measurement. Fortunately, inscriptions on the stones provide epigraphic evidence of the order numbers for suspension and the tone names that each stone would produce. Moreover, most unusually, it was found that the stones were accompanied by three chime stones boxes for storing 41 stones, although only 32 stones were found and would have been hung from a two-tier rack. According to inscriptions on both the stones themselves and the chime boxes, the 32 stones were divided into two groups and suspended from upper and lower tiers of the rack, each had 16 stones, and the extra nine stones in chime boxes were reserved for other purposes, probably for playing music with different tonalities or in other words, for modulations.

Chinese archaeologists have speculated on the tone distribution and scale structure of these chime stones, and musicologists have also participated in examining the arrangement of the tone series, but neither have made final conclusions to date. Li Chunyi explains the inscriptions of tone names on chime stones, provides their suspension arrangement and reconstructs the scale formation (Li, 1983, p. 17); this is particularly convincing (see table. 28).

Table 28. Reconstruction of scales of chime stones from the tomb of Marquis Yi of the Zeng state

Group	Left group						Right group									
Order	1	2	3	4	5	6	1	2	3	4	5	6	7	8	9	10
upper tier	$^{\sharp}F_5$	B_5	$^{\sharp}F_6$	B_6	$^{\sharp}F_7$	B_7	$^{\sharp}G_4$	$^{\sharp}C_5$	$^{\sharp}D_5$	$^{\sharp}G_5$	$^{\sharp}C_6$	$^{\sharp}D_6$	$^{\sharp}G_6$	$^{\sharp}C_7$	$^{\sharp}D_7$	$^{\sharp}G_7$
lower tier	G_5	C_6	G_6	C_7	G_7	C_8	A_4	D_5	E_5	A_5	D_6	E_6	A_6	D_7	E_7	A_7

According to Li, Marquis Yi's chime stones have different tonalities in the upper and lower tiers. Those from the upper tier use B as the tonic note *gong* (do), while the lower use C as the tonic note, the two are separated by a semitone (minor second) difference. This provides two different tunings of a pentatonic scale.

However, the stones could be organised in different ways. 16 stones, whether on upper or lower tiers, could be divided into left and right groups. The left has two notes *zhi* (sol)-*gong* (do) alternately, which actually is the variation of two notes *gong* (do)-*zhi* (sol) in the left group of the ten-part chime stone set discussed previously. On the other hand, the right group in Marquis Yi's chime stones constructs the three-tone series *yu* (la)-*shang* (re)-*jue* (mi), which in fact develops from *jue* (mi)-*yu* (la)-*shang* (re) in the right group of other ten part sets. The specific tone structure is listed as below:

Left group (Zeng chime stones)	*zhi-gong-zhi-gong-zhi-gong*
	sol-do-sol-do-sol-do
Left group (sets of ten chime stones)	*gong-zhi-gong-zhi-gong*
	do-sol-do-sol-do
Right group (Zeng chime stones)	*yu-shang-jue-yu-shang-jue-yu-shang-jue-yu*
	la-re-mi-la-re-mi-la-re-mi-la

Right group (sets of ten chime stones) *jue-yu-shang-jue-yu*

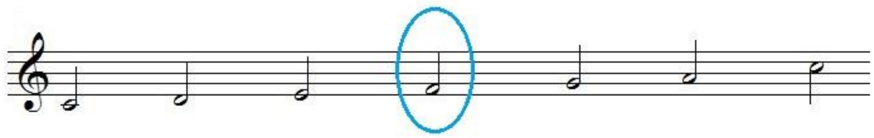
mi-la-re-mi-la

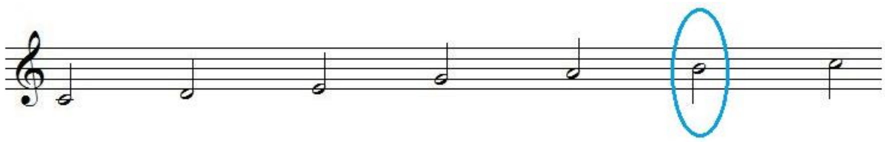
It would form a pentatonic scale if the 16 chime stones were mixed in one group. Furthermore, if the chime stones from the upper and lower tiers were put together, the 32 stones would construct ten successive semitones, in which the Zeng chime stones could have performed music beyond the pentatonic, possibly even music compositions with modulation. Either arrangement offers a range of musical possibilities.

8.3.3 Hexatonic and Heptatonic Scales

Hexatonic (six note) and heptatonic (seven note) scales are extensions of the pentatonic scale. Either a 4th or 7th, an F or B, is added to a pentatonic scale to form a hexatonic scale. If another of these notes is added to the pentatonic scale, a heptatonic scale is constructed.

The hexatonic scale is usually shown as follows (example. 13):



Or

Example 13. The structure of Hexatonic scale

In traditional Chinese music, the fourth degree often appears as *bianzhi* 變徵 (sharp fa or $^{\sharp}$fa) instead of using the original note fa. The seventh degree has a proper term *biangong* 變宮 (si). An example of chime stones with hexatonic scale can be seen from the Shandong Changqing Xianrentai tomb M5, where 14 stones were excavated in good condition (table. 29).

Table 29. Tone measurement data of 14 chime stones from Changqing Xianrentai M5

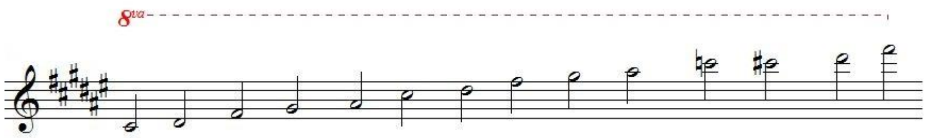
Order	Specimen no.	Pitch
1	M5:5	$^{\sharp}C_5$ +24
2	M5:9	$^{\sharp}D_5$-26
3	M5:6	$^{\sharp}F_5$+12
4	M5:10	$^{\sharp}G_5$+0
5	M5:11	A_5+44 ($^{\sharp}A_5$-54)
6	M5:7	$^{\sharp}C_6$+39
7	M5:12	$^{\sharp}D_6$-10
8	M5:8	$^{\sharp}F_6$+16
9	M5:37	$^{\sharp}G_6$-10
10	M5:36	$^{\sharp}A_6$+16
11	M5:13	C_7-21
12	M5:29	$^{\sharp}C_7$+42
13	M5:38	E_7-45 ($^{\sharp}D_7$+55)
14	M5:14	G_7-2 ($^{\sharp}F_7$+98)

This set of 14 chime stones may constitute a hexatonic scale with the first note *zhi* (sol), shown as follows:

zhi-yu-gong-sang-jue-zhi-yu-gong-shang-jue-bianzhi-zhi-yu-gong

sol-la-do-re-mi-sol-la-do-re-mi-$^{\sharp}$fa-so-la-do

The transcription of this arrangements of notes is shown in example 14:

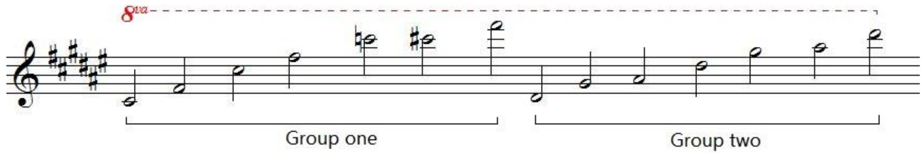


Example 14. Scale of chime stones from Changqing Xianrentai M5

Another possibility is that this set of chime stones might have been divided into two groups, each of seven, and become an example of a seven-plus-seven paradigm. Below is the pitch distribution (example. 15):

Group one sol-do-sol-do-$^{\sharp}$fa-sol-do (*zhi-gong-zhi-gong-bianzhi-zhi-gong*)

Group two la-re-mi-la-re-mi-la (*yu-shang-jue-yu-shang-jue-yu*)



Example 15. Scale of two groups of chime stones from Changqing Xianrentai M5

The most convincing examples of chime stones with hexatonic scales are the six sets of chime stones from Zhangqiu Luozhuang Western Han tomb. Table 30 presents data for the first set of Luozhuang chime stones (table. 30).

Table 30. First set of chime stones from Luozhuang Western Han tomb

Group	Order	Specimen no.	Inscription	Pitch	Comments
Left	1	P14C:31	Lujia left one	G_4+27	Broken and restored
Left	2	P14C:29	Lujia left two	$^{\sharp}A_4$-45(A_4+55)	Broken and restored
Left	3	P14C:30	Lujia left three	D_5-23	Broken and restored
Left	4	P14C:28	Lujia left four	D_5+35($^{\sharp}D_5$-65)	Broken and restored
Left	5	P14C:27	Lujia left five	$^{\sharp}G_5$-38(G_5+62)	
Left	6	P14C:36	Lujia left six	D_6-18	Broken and restored
Left	7	P14C:35	Lujia left seven	Unknown	Broken and restored
Left	8	P14C:34	Lujia left eight	Unknown	Broken and restored
Left	9	P14C:33	Lujia left nine	D_7+18	Broken and restored
Left	10	P14C:32	Lujia left ten	F_7+32	
Right	1	P14C:41	Lujia right one	B_4+49	Broken and restored
Right	2	P14C:40	Lujia right two	E_5+18	Broken and restored
Right	3	P14C:39	Lujia right three	$^{\sharp}F_5$+37	Broken and restored
Right	4	P14C:38	Lujia right four	A_5+31	Broken and restored
Right	5	P14C:37	Lujia right five	B_5+20	Broken and restored
Right	6	P14C:25	Lujia right six	F_6-44 (E_6+56)	
Right	7	P14C:26	Lujia right seven	$^{\sharp}F_6$-12	Broken and restored
Right	8	P14C:24	Lujia right eight	$^{\sharp}A_6$-5 (A_6+95)	
Right	9	P14C:22	Lujia right nine	C_7-25 (B_6+75)	
Right	10	P14C:23	Lujia right ten	$^{\sharp}F_7$-42	

The first set has 20 stones in total, each inscribed “Lujia” 鲁加, moreover, inscriptions of “left” and “right” show the division of the two groups, and numbers from one to ten indicate the suspension order. The ten stones in the left group may form a four-note scale by using G as a tonic *gong* (principal do) with *gong* (do) mode:

gong-shang-bianzhi-zhi-gong-bianzhi-(zhi)-(gong)-zhi-gong

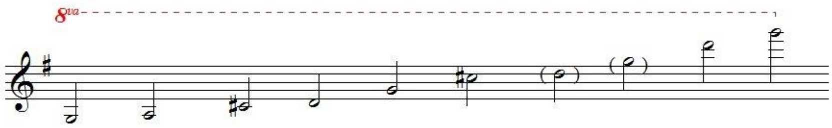
do-re-$^{\#}$fa-sol-do-$^{\#}$fa-(sol)-(do)-sol-do

The notes in brackets are deduced based on the tone data from another three sets of stones (detailed discussion follows). In the right group, the ten stones may construct a four-note scale with a tendency towards *zhi* mode, and the A is the tonic *gong* note:

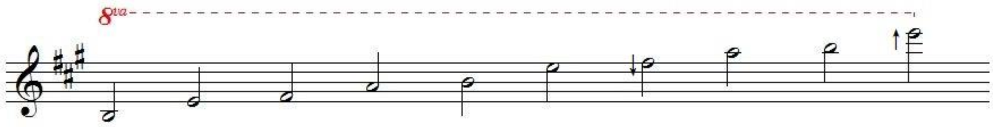
shang-zhi-yu-gong-shang-zhi- ↓yu-gong-shang- ↑zhi

re-sol-la-do-re-sol- ↓ la-do-re- ↑ sol

Scales of chime stones in both groups may be shown in the following notations (example. 16-17):



Example 16. Scale of the left group of chime stones in the first set from Luozhuang Western Han tomb



Example 17. Scale of the right group of chime stones in the first set from Luozhuang Western Han tomb

Nevertheless, chime stones in the right group may constitute a four-note scale with the *yu* (la) mode, if we regard them as having the same tonality as those in the left group, namely, both groups use G as the same principal *gong* (do).

jue-yu-biangong-shang- jue-yu- ↓biangong-shang-jue- ↑yu

mi-la-si-re-mi-la- ↓ si-re-mi- ↑ la

This form of scale has many possibilities. As we know, sets of ten chime stones had two groups with a five-plus-five paradigm from the late Western Zhou period (877-771 BCE) onward. The Luozhuang chime stone set, although the arrangement is enlarged to 20 pieces, is similar to the five-plus-five paradigm in sets of ten chimes. In other words, the scale in the left group of Luozhuang chime stones evolved from do-sol-do-sol-do, but added two extra notes—re and ♯fa; while the right group resembled mi-la-re-mi-la, but added a note "si" in the scale. By combining the two groups of Luozhuang chime stones, one could make up an ancient Chinese heptatonic scale including *bianzhi* (♯fa) and *biangong* (si), that is do-re-mi-♯fa-sol-la-si. Such a scale was traditionally named *yayue*, which can mean elegant music or musical scale (Miao, 1998). Of course, it is possible that the measurement of pitch of these stones is inaccurate, as they are broken and restored.

Three more sets of chime stones from this tomb are divided into two groups, left and right groups, and each has ten stones. Table 31 provides data for these sets in order to compare their scales with the first Lujia set.

Table 31. Second to fourth sets of chime stones from Luozhuang Western Han tomb

Set	Group	Order	Specimen no.	Inscription	Pitch	Comments
Second	Left	1	P14C:75	Yiwa left one	B_4+39	Broken and restored
Second	Left	2	P14C:74	Yiwa left two	♯C_5+22	Broken and restored
Second	Left	3	P14C:73	Yiwa left three	F_5+21	
Second	Left	4	P14C:72	Yiwa left four	♯F_5+12	Broken and restored
Second	Left	5	P14C:71	Yiwa left five	C_6−24	
Second	Left	6	P14C:77	Yiwa left six	F_6+23	
Second	Left	7	P14C:69	Yiwa left seven	G_6−45	Broken and restored
Second	Left	8	P14C:68	Yiwa left eight	C_7−8	
Second	Left	9	P14C:66	Yiwa left nine	G_7−33	
Second	Left	10	P14C:67	Yiwa left ten	A_7+22	Broken and restored
Second	Right	1	P14C:84	Yiwa right one	E_5−44	
Second	Right	2	P14C:85	Yiwa right two	♯G_5+48	
Second	Right	3	P14C:82	Yiwa right three	♯A_5+10	Broken and restored
Second	Right	4	P14C:83	Yiwa right four	♯C_6+23	Broken and restored
Second	Right	5	P14C:81	Yiwa right five	E_6−21	

Set	Group	Order	Specimen no.	Inscription	Pitch	Comments
Second	Right	6	P14C:79	Yiwa right six	$^{\sharp}G_6+47$	Broken and restored
Second	Right	7	P14C:80	Yiwa right seven	B_6+20	
Second	Right	8	P14C:70	Yiwa right eight	D_7-33	
Second	Right	9	P14C:78	Yiwa right nine	E_7-12	
Second	Right	10	P14C:76	Yiwa right ten	G_7-32	Broken and restored
Third	Left	1	P14C:42	Shanggong, one, xi	B_4-4	
Third	Left	2	P14C:43	Two, xi	$^{\sharp}C_5-32$	Broken and restored
Third	Left	3	P14C:44	Three, xi	E_5+47	Broken and restored
Third	Left	4	P14C:45	Four, xi	$^{\sharp}F_5-25$	Broken and restored
Third	Left	5	P14C:46	Five, xi	B_5-42	Broken and restored
Third	Left	6	P14C:47	Six, xi	F_6-24	
Third	Left	7	P14C:48	Seven, xi	$^{\sharp}F_6-7$	
Third	Left	8	P14C:49	Wa, eight, xi	B_6-3	
Third	Left	9	P14C:50	Nine, xi	$^{\sharp}F_7+5$	
Third	Left	10	P14C:51	Ten, xi	B_7-19	Broken and restored
Third	Right	1	P14C:52	Xi, six, wa, xi	$^{\sharp}D_5-36$	
Third	Right	2	P14C:53	Xi	$^{\sharp}G_5-49$	Broken and restored
Third	Right	3	P14C:55	Xi	$^{\sharp}A_5-26$	
Third	Right	4	P14C:54	Xi	$^{\sharp}C_6-35$	Broken and restored
Third	Right	5	P14C:56	Xi	D_6+45	Broken and restored
Third	Right	6	P14C:59	Xi	$^{\sharp}G_6-45$	Broken and restored
Third	Right	7	P14C:57	Xi	$^{\sharp}A_6-16$	
Third	Right	8	P14C:58	Xi	$^{\sharp}C_7+2$	
Third	Right	9	P14C:60	Xi	$^{\sharp}D_7-23$	
Third	Right	10	P14C:61	Xi	$^{\sharp}G_7+42$	
Fourth	Left	1	P14C:104		$^{\sharp}G_4-39$	Broken and restored
Fourth	Left	2	P14C:103		A_4+24	Broken and restored
Fourth	Left	3	P14C:102		$^{\sharp}C_5+10$	Broken and restored
Fourth	Left	4	P14C:98	One	$^{\sharp}D_5-31$	
Fourth	Left	5	P14C:97		$^{\sharp}G_5-34$	Broken and restored

Set	Group	Order	Specimen no.	Inscription	Pitch	Comments
Fourth	Left	6	P14C:99		D_6+40	Broken and restored
Fourth	Left	7	P14C:100		D_6-47	Broken and restored
Fourth	Left	8	P14C:101		$^\sharp G_6+9$	
Fourth	Left	9	P14C:105		F_7-9	
Fourth	Left	10	P14C:96		A_7+31	
Fourth	Right	1	P14C:92		C_5-26	
Fourth	Right	2	P14C:93		Unknown	Broken, sound distortion
Fourth	Right	3	P14C:91		G_5-45	
Fourth	Right	4	P14C:90	Ten	$^\sharp A_5-14$	Broken and restored
Fourth	Right	5	P14C:94		C_6-48	Broken and restored
Fourth	Right	6	P14C:89		F_6-20	
Fourth	Right	7	P14C:88		G_6-47	Surface weathering
Fourth	Right	8	P14C:87		$^\sharp A_6-7$	
Fourth	Right	9	P14C:95		$^\sharp D_7-16$	
Fourth	Right	10	P14C:86		C_7-10	

All chime stones in the second set have inscribed characters “Yiwa” 益瓦 (unknown meaning), additional inscriptions include “left” and “right”, designating their group, and then the numerical order from one to ten.

Each stone in the third set has an inscription “Xi”息 but without “left” or “right”. However, it seems that in this case the lower pitches are usually placed in the left group. Among all 20 stones, ten in the left group are inscribed with numbers from one to ten, while the stones in the right group are not numbered.

In the fourth set, there are only two stones inscribed “one” and “ten”, respectively, but their order does not match their sizes. However, this set of chime stones produce good sound and a regular note series, so it appears that they have not been put together at random.

Comparing these three sets of chime stones with the first set, one may suggest that they are almost identical in scale structure, even the tonality in the second and third sets is the same by using B as *gong* (do). Nevertheless, the tonality in the first set differs from that in the fourth, the former *gong* note is G, the latter is $^{\sharp}$G, they have a minor second difference. Some stones in the second set and the fourth set were broken, one (P14C:93) in the fourth set was particularly affected, although it had been glued completely; the intonation was changed, yet once played and measured in sequence the scale was unaffected.

The fifth set from this tomb has 13 chime stones, as seen in table 32.

Table 32. Fifth set of chime stones from Luozhuang Western Han tomb

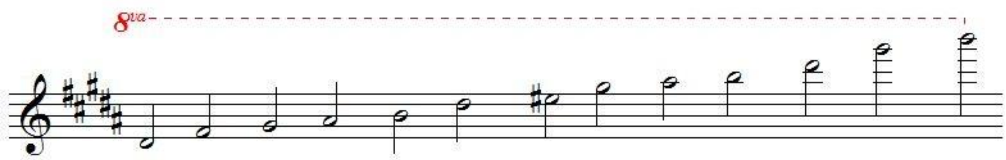
Order	Specimen no.	Inscription	Pitch	Comments
1	P14C:113		$^{\sharp}D_5$−8	
2	P14C:107		$^{\sharp}F_5$−27	
3	P14C:114		$^{\sharp}G_5$−39	
4	P14C:106		$^{\sharp}A_5$+23	
5	P14C:115	Eight	$^{\sharp}D_6$+10	
6	P14C:110		B_5−28	Broken and restored
7	P14C:109		F_6−10	Broken and restored
8	P14C:116	Zui, one	$^{\sharp}G_6$+8	Broken and restored
9	P14C:108		$^{\sharp}A_6$+15	Broken and restored
10	P14C:111		B_6−28	
11	P14C:117		$^{\sharp}D_7$+40	
12	P14C:112		C_8+12	
13	P14C:118		$^{\sharp}G_7$−23	Broken and restored

It is not certain whether this set of chime stones can be divided into two groups like the others, since only two stones have simple inscriptions. The 13 stones may at least constitute a heptatonic scale including notes *bianzhi* ($^{\sharp}$fa) and *biangong* (si), which apply B as *gong* (do) and with the tendency towards the *jue* (mi) mode:

jue-zhi-yu-biangong-gong-jue-bianzhi-yu-biangong-gong-jue-yu-gong

mi-sol-la-si-do-mi-♯fa-la-si-do-mi-la-do

A transcription is provided in example 18:



Example 18. Scale of fifth set of chime stones from Luozhuang Western Han tomb

The fifth set of chime stones has another possible scale formation which uses ♯F as *gong* (do) and constitutes a heptatonic scale:

yu-gong-shang-jue-qingjue-yu-biangong-shang-jue-qingjue-yu-shang-qingjue

la-do-re-mi-fa-la-si-re-mi-fa-la-re-fa

Stone nos. 5 and 8 have inscriptions “eight” and “one”, but these do not fit the tone order in such a scale, therefore it is still uncertain whether the fifth set of chime stones were originally a coherent set or made up of different parts.

The sixth set has 14 chime stones, listed in table 33. There are some contradictions in the inscriptions on the sixth set of chime stones, the majority of them have the carved character “right”, only two have “left”. Furthermore, six stones have the same text inscriptions. From this information it may be that the 14 stones do not belong to one set; or one could consider dividing the 14 stones into two groups of seven according to their inscriptions and sizes.

Table 33. Sixth set of chime stones from Luozhuang Western Han tomb

Group	Order	Specimen no.	Inscription	Pitch	Comments
One	1	P14C:123	Xi right seven	B_5+23	
One	2	P14C:119	Xi right six	C_6-32	
one	3	P14C:120	Xi right five	♯C_6+44	
One	4	P14C:124	Xi right four	G_6-47	
One	5	P14C:131	Xi right three	A_6-27	

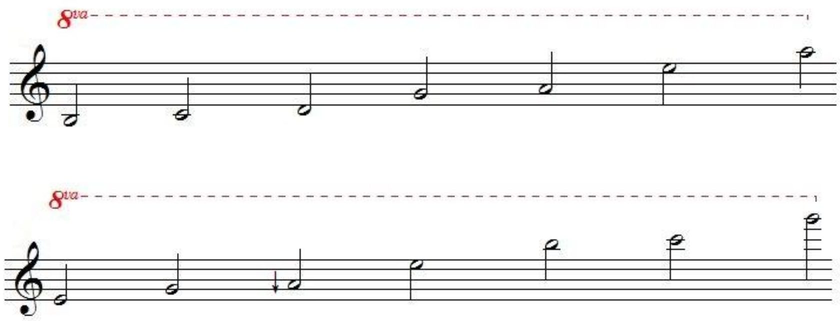
Group	Order	Specimen no.	Inscription	Pitch	Comments
One	6	P14C:130	Xi right two	E_7−24	
One	7	P14C:126	Xi right one	B_7−21	
Two	1	P14C:127	One, xi right six, qi	E_5−49	
Two	2	P14C:122	Xi right eight, six left	$^\sharp F_5$+1	Broken and restored
Two	3	P14C:128	Two, xi right five	A_5−49	
Two	4	P14C:129	Xi right four	E_6−41	
Two	5	P14C:121	Xi right three	B_6+31	
Two	6	P14C:125	Xi right two	C_7−24	
Two	7	P14C:132	Xi left one	$^\sharp A_7$−18	

They can form the following scale mode (example. 19):

Group one *biangong-gong-shang-zhi-yu-jue-yu*

si-do-re-sol-la-mi-la

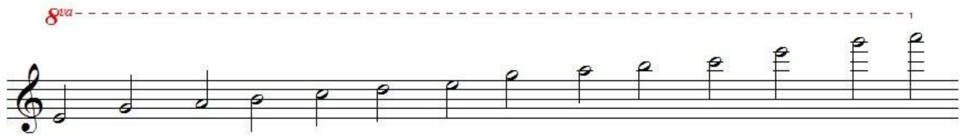
Group two *jue-zhi-* ↓ *yu-jue-biangong-gong-zhi*

mi-sol- ↓ la-mi-si-do-sol

Example 19. Scale of the sixth set of chime stones from Luozhuang Western Han tomb (Upper: group one; lower: group two)

Both groups make C as *gong* (do). Group one constructs a hexatonic scale including *biangong* (si), while the note *shang* (re) is absent in group two. They would form a hexatonic with *jue* (mi) as the first note, if combining the two groups together (example. 20):

jue-zhi-yu-biangong-gong-shang-jue-zhi-yu-biangong-gong-jue-zhi-yu

mi-sol-la-si-do-re-mi-sol-la-si-do-mi-sol-la



Example 20. Scale of the sixth set of chime stones from Luozhuang Western Han tomb

Nevertheless, according to their tone distribution and interval relationship, the sixth set of chime stones also have the possibility of forming another scale:

Group one *jue-qingjue-zhi-gong-shang-yu-shang*

mi-fa-sol-do-re-la-re

Group two *yu-gong-shang-yu-jue-qingjue-gong*

la-do-re-la-mi-fa-do

Both groups use $^\sharp$F as *gong* (do) note. If combining all 14 stones together and arranging them along with pitch from lower to higher, then the scale structure would be the following hexatonic scale:

yu-gong-shang-jue-qingjue-zhi-yu-gong-shang-jue-qingjue-yu-gong-shang

la-do-re-mi-fa-sol-la-do-re-mi-fa-la-do-re

As a further example of a hexatonic scale, 14 chime stones were excavated from tomb M5 in Shandong Changqing Xianrentai, which belonged to the remains of the Shi state and dated to late Spring and Autumn period (546-476 BCE). Chime stones from M5 may construct a hexatonic with *zhi* mode, which is quite different from that of the sixth set in Luozhuang.

To conclude, during the historical dynasties of Shang, Zhou, and Western Han in ancient China, chime stones were made to construct specific tone series, scales and modes, which include four-note scale, pentatonic, hexatonic, heptatonic, and even ten sequential semitones (such as in the Marquis Yi's chime stones), for possible modulation in performance. However, the three-tone series and a four-note scale or pentatonic scale seem to have been used as the main melodic scales in compositions. Other scales, such as hexatonic and heptatonic, besides five notes do-re-mi-sol-la, contain the fourth degree fa or sharp fa, and the seventh degree si. Nevertheless, both degrees were regarded as *pianyin* 偏音 (remote note or incidental note), which were "coloured tones" (tones which are bright and become a splash of colour in a scale) in ancient music (Miao, 1998). In general, playing the chime stones may have often involved pentatonic tunes according to their scale structure, just as a vast majority of traditional Chinese music is limited to the range of a pentatonic scale. In the *Guo Yu* (Discourses of the states, attributed to Zuo Qiuming, probably fourth century BCE), different forms of musical instruments have their own functions: "metal and stone instruments (percussion) played for strengthening rhythm, while silk and bamboo (strings and winds) for the melody"[48]. Apparently, bronze bells and chime stones primarily played the *gong-shang-jue-zhi-yu* (do-re-mi-sol-la) five notes in ancient music rather than the remote notes *pianyin*, including *qingjue* (fa), *bianzhi* (♯fa) and *biangong* (si). Therefore, the pentatonic scale played a predominant role in both the present and antiquity, as Falkenhausen points out: "the fact is that most present-day Chinese music continues to be essentially pentatonic. Pentatonic is suggested by the evidence from lithophones, which were used in conjunction with bell-chimes" (Falkenhausen, 1993, p. 267).

8.4 Inscriptions and Music Theory

8.4.1 Traditional Chinese *twelve-lü*

The traditional Chinese *twelve-lü* is an ancient musical temperament in China. In it, a chromatic scale is made up of all the twelve notes in an octave and is formed entirely of semitones (Winterson & Harris, 2014, p. 45). Each of these semitones has its own name which are consecutively shown as Huangzhong 黃鐘, Dalü 大呂, Taicu 太簇,

48 *Guo Yu* "Zhou Yu". For the Chinese version, see Xu, 2002, p.111.

Jiazhong 夾鐘, Guxi 姑洗, Zhonglü 仲吕, Ruibin 蕤賓, Linzhong 林鐘, Yize 夷則, Nanlü 南吕, Wuyi 無射, and Yingzhong 應鐘.

According to *Guo Yu*, the names of the *twelve-lü* first appeared in the Zhou court around 522 BCE [49], and *twelve-lü* and its terminology seem to have originated from Zhou musical culture. Subsequently, the classical text *Lüshi Chunqiu* (249-237 BCE) depicted the principle from which the *twelve-lü* temperament was formed:

> Yellow Bell generates Forest Bell. Forest Bell generates Great Budding. Great Budding generates Southern Regulator. Southern Regulator generates Maid Purity. Maid Purity generates Resonating Bell. Resonating Bell generates Luxuriant. Luxuriant generates Great Regulator. Great Regulator generates Equalizing Rule. Equalizing Rule generates Compressed Bell. Compressed Bell generates Tireless. Tireless generates Mean Regulator (Knoblock & Riegel, 2000, p. 157).

The cited text explains the order in which the *twelve-lü* is produced: the first pitch Huang Zhong produces Lin Zhong, Lin Zhong then produces Tai Cu, Tai Cu produces Nan Lü and so forth; this was based on the method of circle-of-fifths in ancient China. The names and their corresponding notes of the *twelve-lü* can be charted in figure 88.

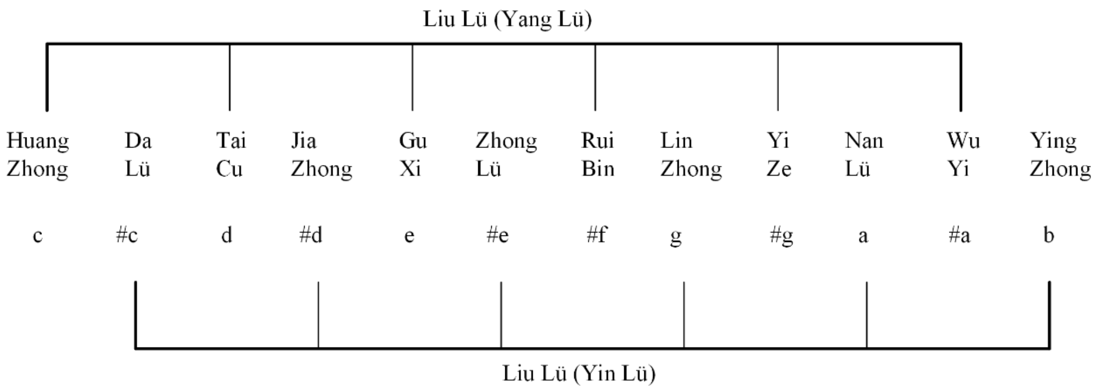


Figure 88. Ancient Chinese *twelve-lü*

The *twelve-lü* tuning system was generated during the early Eastern Zhou dynasty, however, although epigraphic evidence appeared on bronze bells of the Marquis Yi of the Zeng, no unified names of *twelve-lü* were used in different states during the early Warring States period (476-387 BCE); some local kingdoms kept using their own

49 *Guo Yu* “Zhou Yu” (Xu, 2002, p. 113-121).

names of the *twelve-lü* tuning system.

Like the musical bells in Marquis Yi's tomb, the Zeng chime stones were carved with the same names of the *twelve-lü* tuning system, but they differ from those in the states of Zhou, Chu, Jin, Qi, and Shen. Basically, the Zeng *twelve-lü* names are borrowed from Zhou and Chu, and mixed together as its own music theoretical system. In line with the Zeng inscriptions, the terms of *twelve-lü* of Zeng and five other states are listed in table 34 (Li, 2005), showing the different systems of names used for notes. By the early Warring States (476-387 BCE), the nomenclature of the *twelve-lü* system varied from one vassal state to another. There were no uniform standards for their musical theory, especially the tuning system.

Table 34. Nomenclature of *twelve-lü* of Zeng and five other states

Pitch name	*Guoyu Zhouyu*	Zeng	Zhou	Chu	Jin	Qi	Shen
C	Guxi	Guxi Xuanzhong (octave)		Lüzhong	Liuyong (octave)		
♯C	Zhonglü			Zhuopinghuang			
D	Ruibin	Ruibin		Pinghuang			Yize
♯D	Linzhong			Zhuowenwang			
E	Yize	weiyin		Wenwang			
F	Nanlü			Zhuoxinzhong			
♯F	Wuyi	Wuyi Yingsi (octave)		Xinzhong		Lüyin	
G	Yingzhong			Zhuoshouzhong			
♯G	Huangzhong	Huangzhong Yingyin (octave)	Yingyin	Shouzhong			
A	Dalü			Zhuomuzhong			
♯A/♭B	Taicu	Taicu Muyin (octave)	Ciyin	Muzhong	Banzhong (octave)		
B	Jiazhong	Zhuoguxi		Fuyusu (?)			

Apart from Zeng bells and chime stones, inscriptions with names from the *twelve-lü* system were also found in the tomb of Luoyang Jincun, where the chime stones had carved characters such as “jiazhong right eight”, “guxi right six”, and “guxi qizhi left ten”. The words “left” and “right”, like inscriptions on chime stones from the Luozhuang Western Han tomb, suggest the groups and orientations of the hanging rack, numbers such as “eight”, “six” and “ten” show the suspension order, and the terms of “jiazhong” and “guxi” belong to *twelve-lü*. With regard to the “qizhi”齊屋, Li Chunyi states that “qi” means “next”, and “zhi” denotes rack, and so “qizhi” presumably indicates chime stones from the next chime rack (Li, 1996, p. 59).

According to bamboo slips in the archaeological finds from the Qin state in Gansu Tianshui Fangmatan, the names of the *twelve-lü* system were unified by the end of Warring States period (284-221 BCE). The texts written on the bamboo slips show that the *twelve-lü* names in the Qin state were the same as those in the Zhou court; in addition, the tuning system was the same as in *Lüshi Chunqiu*, as I cited above. This suggests that the Zhou *twelve-lü* system continued to be practiced in the Qin musical culture, from then onward the traditional Chinese *twelve-lü* has been used.

8.4.2 Tuning Nomenclature

The Chinese pentatonic scale mode has five notes and specific tone names—*gong* 宫*, shang* 商*, jue* 角*, zhi* 徵*,* and *yu* 羽. In ancient China, the five notes and their tone names had symbolic meanings. According to *Yue Ji* (Record of music, probably edited in the Warring States period), “*gong* acts as the monarch, *shang* as the officials, *jue* as the people, *zhi* as the affairs, and *yu* as the substances (both animate and inanimate). If five notes were chaotic, the nation would be destroyed soon”[50]. These five notes were regarded as crucial and related to particular subjects and objects.

Inscriptions on bronze bells and chime stones from Marquis Yi’s tomb of the Zeng, as well as the five notes, includes the nomenclature of chromatic tones and octaves. The term *he* 龢 in Zeng inscriptions is the fourth degree note fa, which appears in classical texts as *qingjue* 清角. Another term *mu* 穆 in Zeng inscriptions is equivalent to the traditional note *run* 閏, the flat note of seventh degree (♭si). The major third above certain notes has proper names such as *jue* 角, *fu* 䪗, and *zeng* 曾, for example, *gongjue*

50 For the Chinese version, see Ruan, 1980, p. 1528.

宫角 is the major third above *gong* (i.e. the mi). The octave of certain notes is named *fan* 反, and *gongfan* 宫反 means the octave of *gong* (do). Although the pitch names from Zeng inscriptions are absent from historical literature, these texts help to enrich our further understanding of ancient Chinese music theory.

With regard to the practical use of *bianzhi* ($^\sharp$fa), the historical documentation *Zhan Guo Ce Yance* (*Yance* in *Episodes from the Warring States*, edited by Liu Xiang, 77-6 BCE) tells a story that during the Warring States period (475-221 BCE), a distinguished warrior Jing Ke in the Yan state intended to kill the Emperor Qin. The Yan state Prince and other friends were bidding farewell to Jing Ke when he left for Qin state:

> The prince and guests who knew of the mission were all dressed in white mourning robes and caps to see him off. They went with him as far as the Yi River. He made sacrifice to the gods of the place to grant him a good journey. Kao Chien-li [Gao Jianli] struck the strings of his lute [the instrument *zhu* zither] and Ching K'o [Jing Ke] joined him, singing in a sad, minor key [*bianzhi* note]. All the officers who heard wept. Then he walked away singing: "Hsiao-hsiao soughs the wind, oh- Cold the waters of the Yi. The knight who leaves you now, oh- You shall nevermore see." After this he sang the "Song of the Generous Knight" [*yu* note]; the eyes of all the officers grew angry and they bristled with resentment. Ching K'o walked to his carriage and left without a further backward glance (Crump, 1996, in the chapter of *The book of Yen*, p. 508-809. For the Chinese version, see Ji, 1980, p. 61).

The above quotation[51] describes the use of special notes *bianzhi* and *yu*. Archaeologically found chime stones, such as those unearthed from the Luozhuang Western Han tomb, display the *bianzhi* note, suggesting that ancient music was sometimes composed in that period with the note $^\sharp$fa. The *bianzhi* ($^\sharp$fa) also appears in today's traditional Chinese music, such as the *yuju* opera in Henan and *qinqiang* opera in Shaanxi.

It is also interesting that the diviner or soothsayer in ancient China saw a connection between the five notes and musical instruments, for example, the *zhi* note thus corresponds to *xiao* 箫 (a vertical bamboo flute), and *yu* note is equal to string

51 Square brackets are my notes.

instruments such as *guzheng* 古箏 and *guqin* 古琴 zithers. This divination imparts qualities describing the volume or timbre of certain sounds (see Chapter 19 *Yue Ji* in *Li Ji*).

In the *Guo Yu*, there is a description which explains how some of the eight materials of sound (*Ba Yin*) were allotted to the five notes. It states:

> The zithers *qin* and *se* exalt the *gong* note. Bells exalt the *yu* note. Ringing-stones exalt the *jue* note. Instruments of gourd and bamboo exalt the note which is appropriate to them (*shang* or *zhi*). The lowest note is not over the *gong*, and the highest note not beyond *yu*. The *gong* is the tonic of all notes (Needham & Wang, 1962, p. 151. *Guo Yu* "Zhou Yu". For the Chinese version, see Xu, 2002, p. 110).

Also the terms of *gong*, *shang*, *jue*, *zhi* and *yu*, as Joseph Needham and Wang Ling state, would later refer to particular instruments related to music and dance (Needham & Wang, 1962, p. 159).

8.4.3 The Repertoire

The private collection of 14 chime stones housed at Handong Museum in Zhuhai (Guangdong) by Guo Handong are well-preserved although without archaeological context such as site location and excavation date, as well as whether any other funeral objects were present (Li, 1997). Dating to the late Western Han dynasty, these chime stones have inscriptions relating to repertoire performed in ancient times. The chime stones also have some inscriptions relevant to tone names, *twelve-lü* terms, left or right groups and numbers, as well as having chime racks, similar to those found in Marquis Yi's tomb, Luoyang Jincun, and the Luozhuang Western Han tomb.

In the Handong Museum collection, 11 of 14 chime stones have engraved inscriptions. These describe details of music and dance repertoire for ritual performance, including *Jiazhi* 嘉至 (welcome god), *Yong'an* 永安 (peaceful forever), *Anshi* 安世(safe world), *Wude* 武德 (martial virtue), *Wuxing* 五行 (five elements including metal, wood, water, fire, and earth), and *Sishi* 四時(four seasons). All of these can be seen in the volume *Liyue Zhi* (The bibliographical treatise on ritual music) in *Han Shu* (Official history of Western Han dynasty). In addition to these compositions, epigraphic sources also show some of the posthumous names of ancestral temples of the emperors in the Han dynasty, such as 高寢 Gaoqin (256-195 BCE), Xiaowu 孝武 (156-87 BCE), Xiaozhao 孝昭 (94-74 BCE), and Xiaoxuan 孝宣 (91-49 BCE). They were the only chime stones belonging to emperors so far excavated and undoubtedly, the six music and dance repertoires were performed in ritual events in the Han royal court. The inscriptions also provide evidence for dating the chime stones, at least the upper date at 49 BCE. However, despite being grouped together in the collection, the 14 stones were from different ancestral temples. Unsurprisingly they are not arranged in order (Wang, 1997). They therefore do not make up a complete set and probably contain stones from several sets.

8.5 Summary

This chapter describes the methods of measuring pitch by means of computer software packages. After comparing four different packages, the software RX was chosen. Researching tone pitches and scales is complex; to infer various scales and modes that chime stones may form, we have seen how the notes on a stave form a scale. This showed that pentatonic scales appear to be common during the time of the Eastern Zhou dynasty (770-256 BCE), as the shape of chime stones became stabilised. The sound register of the chime stones widely ranged from a one-lined to four-lined octave. By studying inscriptions on the surface of the stones, is was possible to explain the tuning systems of some typical examples, and gain further information about various musical theories through inscriptions and the names of scales, whilst recovering some scales and modes that possibly conformed originally. Such analysis of pitch is interesting and useful, but has restrictions as it does not explore the range of frequencies present when playing a chime stone. This is addressed in the next chapter.

Chapter 9: Acoustic Properties and Sound Experimentation

A spectrogram is a visualization of a particular acoustic spectrum, showing a range of frequencies, the lowest at the bottom of the display and the highest at the top, with time displayed across. It also shows the loudness of events at different frequencies by applying different colours to the different amplitudes of signals. In this chapter, I mainly use RX to present spectrograms, along with other software such as Sonic Visualiser, to demonstrate the entire range of sound of chime stones. In order to find a clearer relationship between, for example, frequencies of different partials and various measurements of chime stones, statistical software Statistical Package for the Social Sciences (SPSS) is employed. For detecting correlation coefficients, Dr. Dara Mojtahedi collaborated to generate quantitative data analysis.

9.1 The Sound Spectrum

9.1.1 Fundamental Tone and Partials

Most Chinese "tone measurement" of chime stones has focused on the fundamental tone of each chime stone, but has ignored other frequency partials. In this section, I will examine the frequency spectrum of chime stones. From spectrograms one can easily identify the features of each chime stone and explore consonant and dissonant chime stone sounds from different historical periods and geographical areas.

For testing the spectrum of sound that each stone produces, field work recordings were used. The first specimen is from Henan Qixian Songzhuang tomb M4 (excavation no. M4:51).

Figure 89 shows its spectrogram. Each spectrogram in this thesis uses the same settings in RX; the FFT size is 8192 and a Hann window is used. RX shows the fundamental pitch as $^{\sharp}A_5$+44 and frequency as 956.6Hz. From this spectrogram of, one can clearly identify at least five strong partials appearing horizontally with an orange colour. The pitch and frequency of these partials are B_6+37, 2018.1Hz; $^{\sharp}D_7$-40, 2431.9Hz; B_7-30, 3882.7Hz; $^{\sharp}C_8$+32, 4517.3Hz and G_8-20, 6199.5Hz.

The partials are inharmonic with the fundamental tone, for example, P2=2018.1Hz; P3=2431.9Hz. The fundamental frequency is 956.6Hz. The result is P2≈2.1F, P3≈2.5F, since 2.1 for example is not an integer, the partials are inharmonic with the fundamental tone. Figure 90 shows the frequency spectrum of the sound of the chime stone with partials showing as peaks. The largest peak with the lowest frequency is generally thought of as the fundamental tone. The rest of the higher peaks are different partials one after the other. The X axis refers to frequency in Hz, and the Y axis is amplitude in dB. There are a number of problems with assumptions about the fundamental frequency. When does a frequency become a peak? At what point is a peak too small to be heard or perceived as a partial? Is it the lowest, loudest, or longest partial that is heard as the fundamental? What if the lowest partial is not loudest or longest? What if two partials are present at equal volumes, are two pitches heard? This is the case if two stones are played together so why not if two partials are heard? How much louder does a frequency have to be than the rest of the spectrum to be a partial? The inharmonic nature of the partials that are present complicates matters, as usually the harmonic relationships of the partials would help to identify the fundamental pitch.

These depictions illustrate the richness of partials that are present, and provide a way to analyse aspects such as timbre, any correlation between each partial and the dimensions of the chime stone, or the relationships between fundamental tone and dimensions.

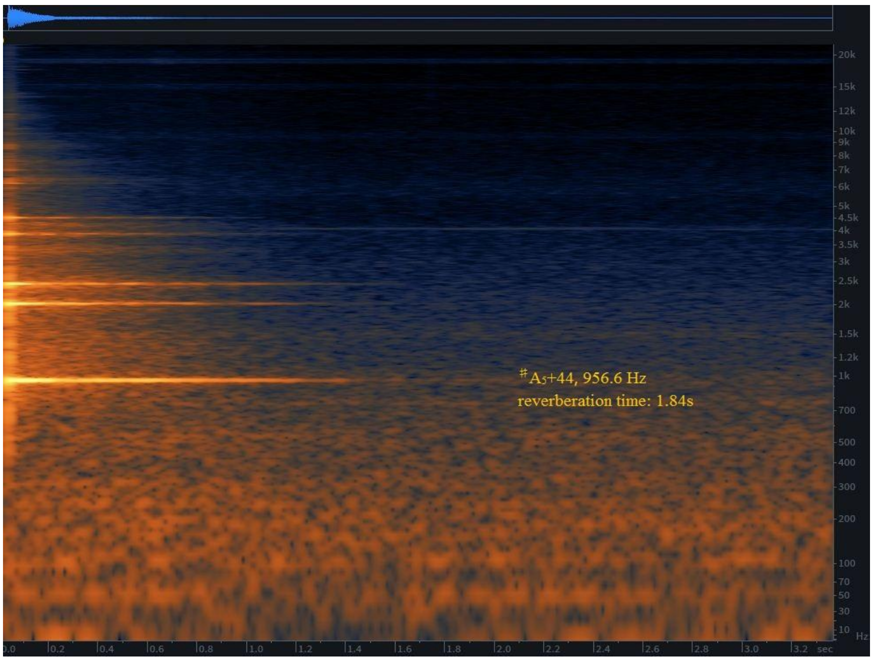


Figure 89. Spectrogram of chime stone M4:51 from Qixian Songzhuang M4

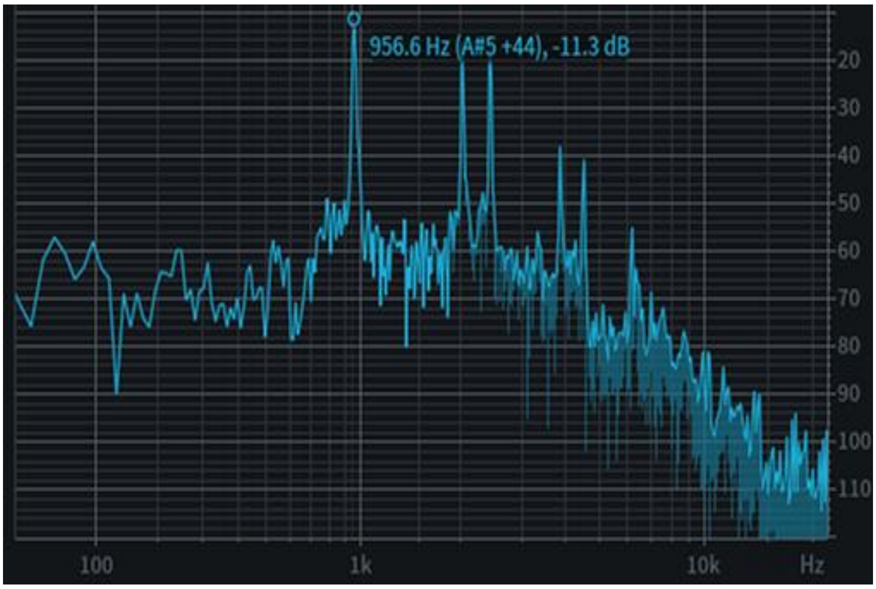


Figure 90. Spectrogram Analyser on chime stone M4:51 from Qixian Songzhuang

Another experimental approach was to research the relationships of amplitude and frequency through spectrograms. Taking ten chime stones from Luoyang Zhongzhou Daqu (data obtained from my fieldwork) as an example, 50 partials of the ten chime stone set were examined in total, each of them were found to have different amplitudes. To take stone no.7, which was the largest stone, as an example, as the partial frequency increases, volume or amplitude decreases (fig. 91). That is to say, the frequencies and volumes are not in direct proportion and do not increase simultaneously. The amplitude will become weaker successively as frequency increases, which is common for chime stones, but not always the case. In the case of no.8 chime stone, partial 3 was louder than partial 2 (figs. 92 & 93). In another example from Qixian Songzhuang M4 (M4:40), partial 2 was louder than the fundamental (fig. 94). There is no obvious reason why some partial tones with high frequencies were louder or stronger than the first partial (fundamental tone). According to this sound experimentation, not all fundamentals had the highest volume in the compound tone of a chime stone. Perhaps the acoustics of the recording environment, the strength with which the stone was hit or some other elements were influential factors. The sound of chime stones is often made up of more than one pitch being present. Interestingly, chime bells have been found in some cases to have more than one pitch when struck in different positions (WWDXBJB, 1996a,b,c,d,e).

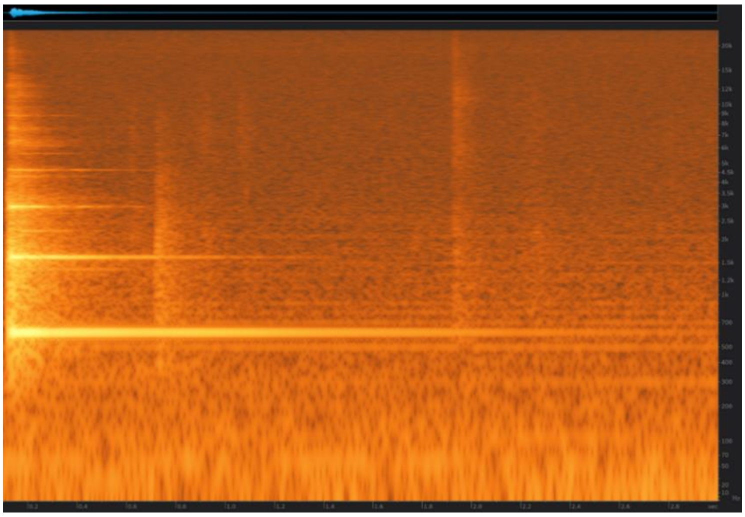


Figure 91. Spectrogram of chime stone no.7 from Luoyang Zhongzhou Daqu.

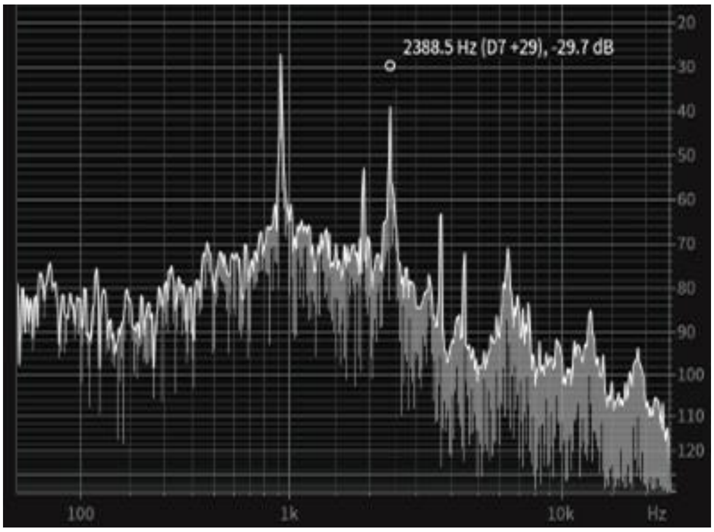


Figure 92. First spectrogram of chime stone no.8 from Luoyang Zhongzhou Daqu.

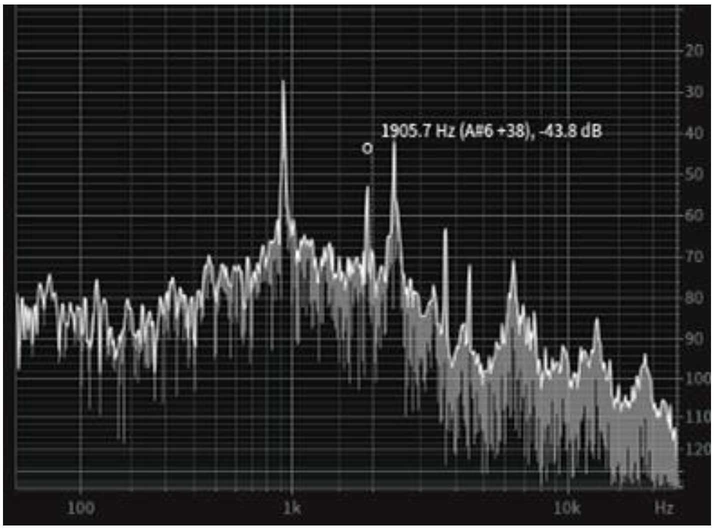


Figure 93. Second spectrogram of chime stone no.8 from Luoyang Zhongzhou Daqu.

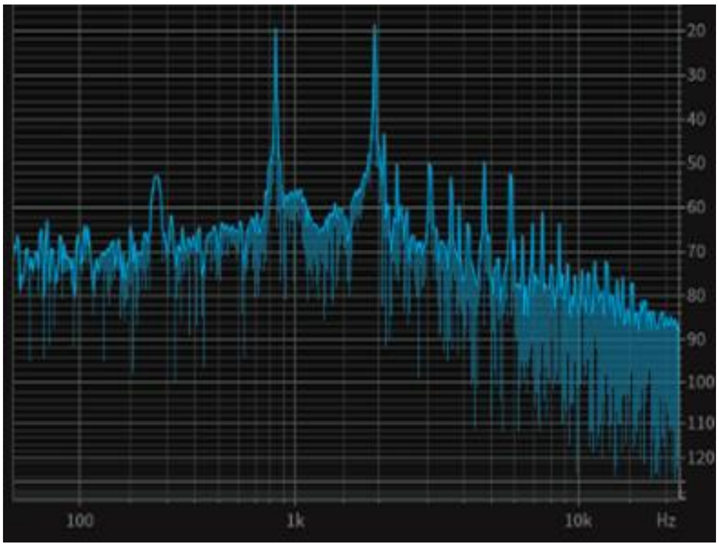


Figure 94. The spectrogram of chime stone no. M4: 40 from Qixian Songzhuang.

For the purpose of providing an overview of the whole sound range of a group of chime stones, here I present some sample images and figures generated from Sonic Visualiser. Two figures (95 & 96) show Sonic Visualiser in use, with a monophonic music audio file loaded. Figure 95 is a spectrogram of a number of chime stones, totalling a set of nine pieces from Qixian Songzhuang M4, each recorded three times; figure 96 shows sound from these nine chime stones recorded and tested one by one in sequence. The horizontal axis is time and the vertical axis represents frequency. From these spectrograms, we can see that the harmonics at two or more frequencies are often of almost equal volume, with a number of smaller and higher frequency harmonics. In figure 96, the spectrogram shows the resonance of many individual frequencies in chime stones, indicating how long individual frequencies are sustained.

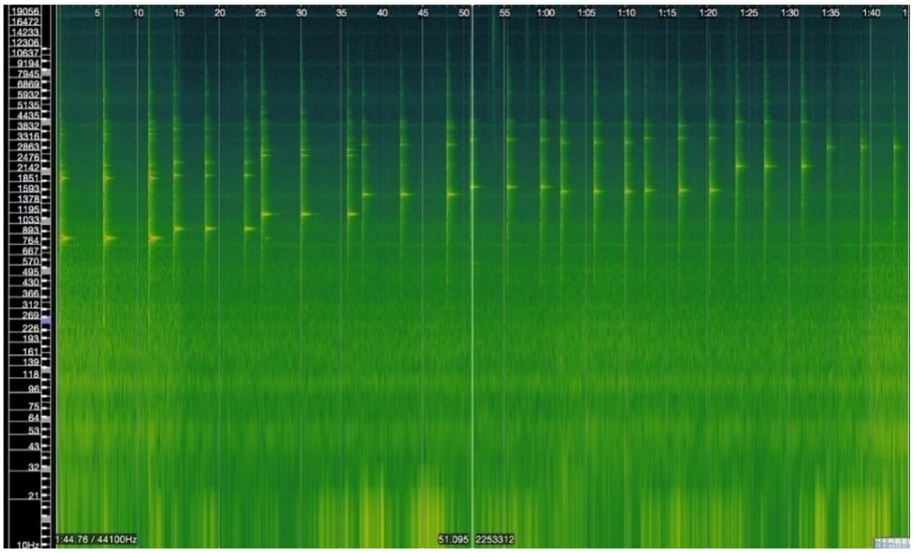


Figure 95. Sonic Visualiser generated spectrogram of the nine chime stones from Qixian Songzhuang M4 response (each chime stone was recorded three times).

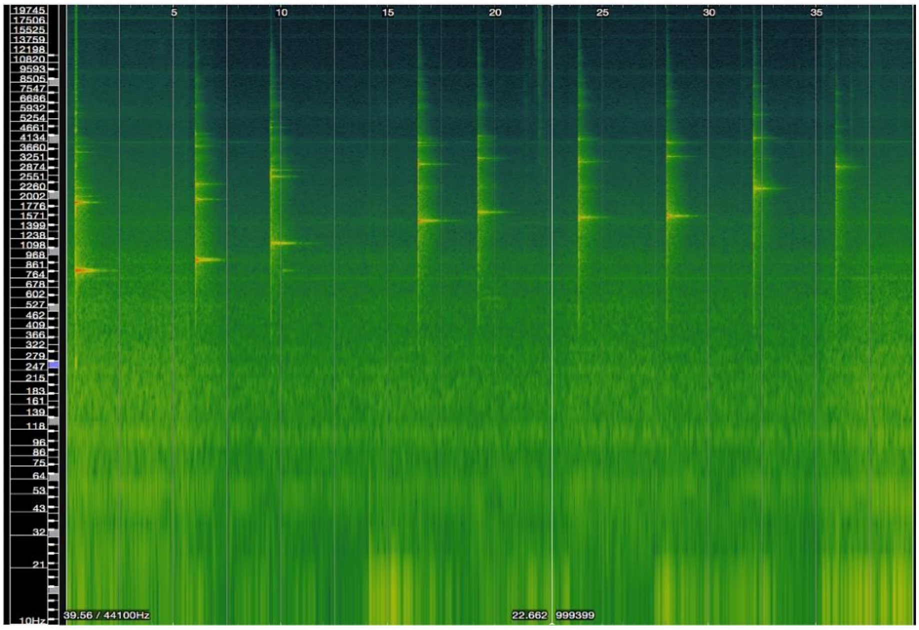


Figure 96. Sonic Visualiser generated spectrogram of the nine chime stones from Qixian Songzhuang M4 response (nine chime stones were tested in sequence).

The fact that the sounds of chime stones appear to have two or three different strong partials indicates that there exists one basic tone (fundamental tone) and many overtones (tones above fundamental), and the partials are not necessarily harmonically related, as they might be for example in the strings of a stringed instrument. For example, the partials here are not octaves or fifths of one another; the relationship between these partials is more complex, and this is what gives the chime stones their characteristic sound. The corresponding data of P1 to P5 frequencies is listed in table 35. A more detailed study is needed to understand the complexities of sounds produced, especially since the notes do not conform to equal temperament, and the relationship between different harmonics has not been studied here in detail. Some low frequency content is shown in figure 97, from approximately 30 Hz to 150 Hz, but this may be due to background noise.

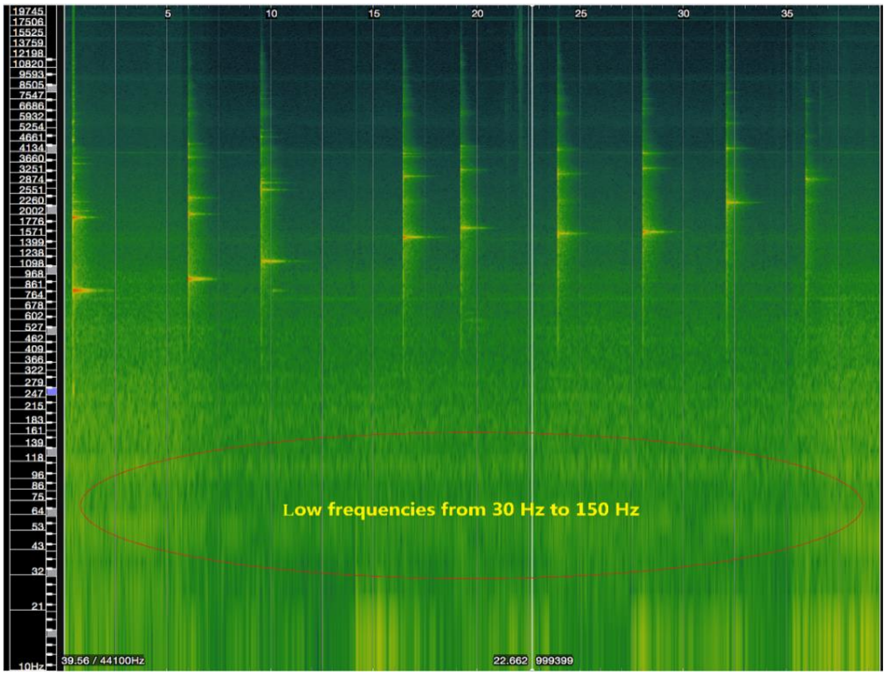


Figure 97. Low frequencies from 30 Hz to 150 Hz are shown in Sonic Visualiser (nine chime stones were recorded in sequence)

Table 35. Individual frequencies of P1-P5 frequencies by using RX on nine chime stones from Qixian Songzhuang M4

Order	Excavation no.	P1	P2	P3	P4	P5
1	M4:40	838.66	1941.3	2321.5	3046.3	3613.5
2	M4:51	956.6	2018.1	2431.9	3882.7	-
3	M4:39	1174	2670.1	2892.2	4895.4	-
4	M4:50	1548.7	3113.6	-	-	-
5	M4:38	1720.9	3550.4	-	-	-
6	M4:49	1612.8	3211.8	-	-	-
7	M4:37	1642.9	3411.7	-	-	-
8	M4:36	2301	4300.6	-	-	-
9	M4:48	3067.77	-	-	-	-

Note: P=Partial, P1 is the fundamental frequency, P2 is the second partial. Due to the number of partials, the table only shows the partials which are ≧ 50 dB louder than the background.

9.1.2 Relationships Between Timbre and the Different Base Shapes of Chime Stones

As Needham and Wang point out, "We regard timbre as that which distinguishes one note from another not by volume or pitch but by complex blends of overtones" (Needham & Wang, 1962, p. 141). Timbre is the phenomenon that takes into account spectral patterns (Lerch, 2012).

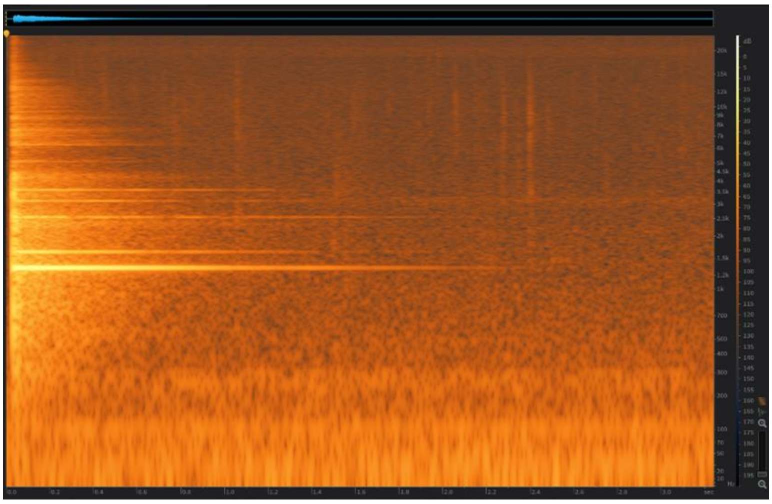
Scholars have arrived at different conclusions when exploring the reason why chime stones in the later period were made with a curved base. Fritz Kuttner (1990) proposes that the curved base of a chime stone was for improving the acoustic qualities of the stone. He suggests that the Chinese instrumental craftsmen had specific aims. The first was to take the precise pitch into account and then, to consider the elimination or limitation of disturbing overtones since they were not always in harmonic relation with the fundamental tone. All these factors can be improved by changing the stone's shape; such as the angle, the height, and the curvature of base, claims Kuttner. However, he adds, it is impossible to keep a balance between more than one or two factors. That is to say, refining one factor is likely to impair the others. Zhu Guowei (2010) alleges that it reduces the overtones of lower frequencies when a chime stone has a curved base; increasing the curvature of the bottom edge can promote the fundamental frequency and make a much clearer sound.

Both scholars emphasize the importance of the curved base of the chime stone; they have the common idea that a curved base chime stone can produce a better sound. However their approaches are theoretical, without physical evidence. In this section, I will explore this issue through experiment and demonstrate whether the curved base could influence the sound of a chime stone.

Stones with two different bases, straight and curved, were chosen for comparative studies. Selected from different areas and from different historical periods, the purpose is to find their timbral diversity and the relationships between timbre and the base shape.

Three chime stones in good condition from different locations and eras were considered. These chime stones have either similar sizes in terms of their whole length (around 55cm), the length of their bottom line (around 40 cm) or *gushangbian* (around 35 cm). I chose a late Shang dynasty (ca. 1260-1050 BCE) singly used chime stone with a straight base from Henan Anyang, which is housed in Anyang City Museum with specimen number A01609 (figs. 98a, b). The fundamental pitch of this chime stone is E6+15, frequency 1330.1 Hz. The second stone is from Shaanxi Hancheng Liangdaicun M27, with specimen number M27:1043, which has a pitch of $^{\sharp}F_5$-21 and 730.92 Hz frequency. This straight base chime stone dates to the Western Zhou dynasty (1046-771 BCE. figs. 99a, b). The third stone has a curved base, found in Henan Qixian Songzhuang M4 dating to the late Spring and Autumn period (546-476 BCE. figs. 100a, b). The fundamental pitch of this stone (M4: 40) is $^{\sharp}G_5$+16, 838.66 Hz.

(a)



(b)

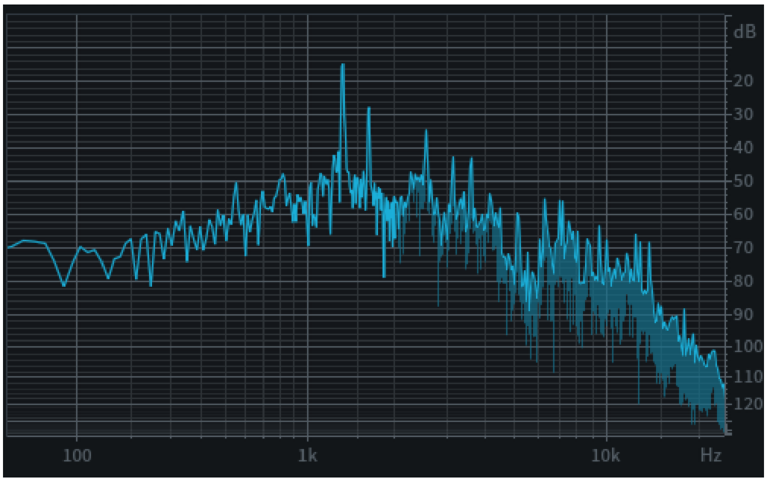
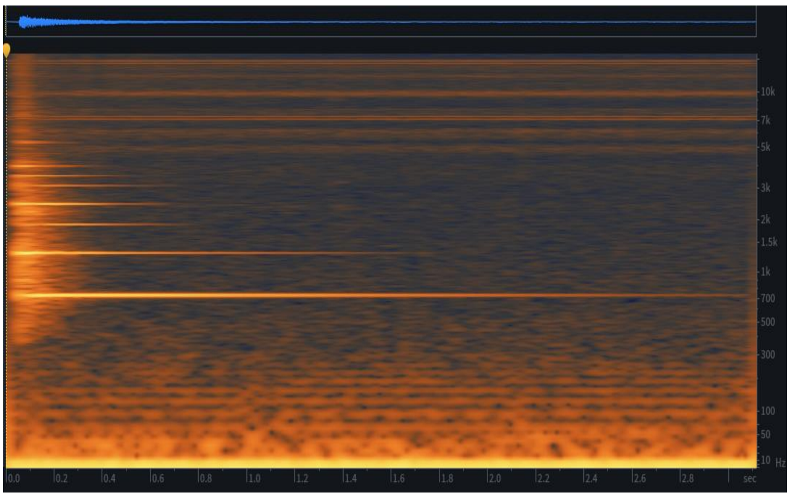


Figure 98 (a) Spectrogram of A01609 from Henan Anyang, late Shang period (ca. 1260-1050 BCE). (b) Spectrogram Analyser on A01609.

(a)



(b)

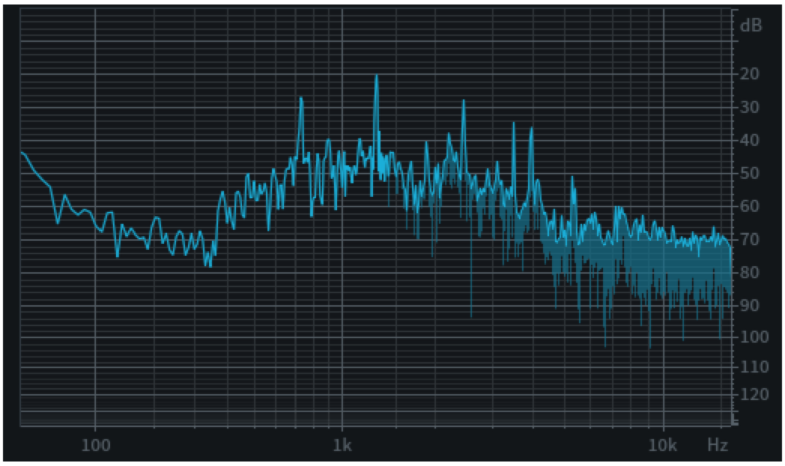
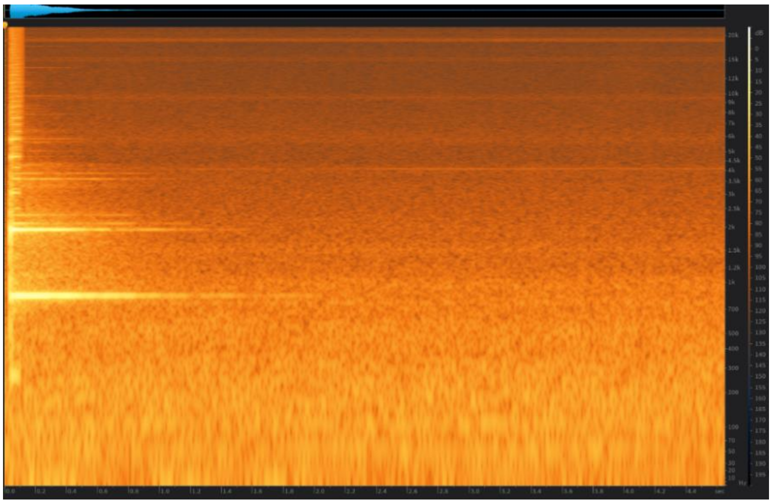


Figure 99 (a) Spectrogram of straight base chime stone M27:1043 from Shaanxi Hancheng Liangdaicun M27, the Western Zhou dynasty (1046-771 BCE). (b) Spectrogram Analyser on M27:1043.

(a)



(b)

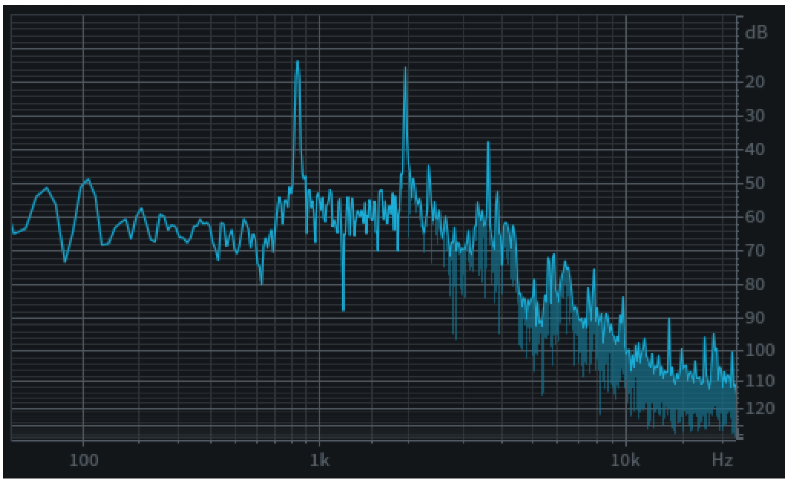


Figure 100 (a) Spectrogram of curved base chime stone from Qixian Songzhuang M4 (M4:40), the late Spring and Autumn period (546-476 BCE). (b) Spectrogram Analyser on M4:40.

From the logarithmic spectrograms above, we can observe the significant partial tones of each chime stone. The straight based stones do in this case produce more partials, giving a less pure tone than those with a curved base; the partials on stone A01609 and M27:1043 are much richer than that of M4:40, with more partials gathered in the middle frequency range. A base level of decibels was chosen in order to analyse the sound spectrum because of the large number of partials produced by chime stones. Partials which were strong, easy to identify and that were above or equal to 50 dB were selected[52]. Thus the chime stone from Anyang has five partials (fig. 98b) and Shaanxi Hancheng Liangdaicun M27 eight partials (fig. 99b), whilst the chime stone from Qixian Songzhuang M4 only has four partials (fig. 100b). From these examples we can make an initial judgment that a relationship probably exists between timbre and base shape when the whole length, the length of baseline and *gushangbian* are similar in dimension.

However, the initial results are insufficient to be sure about this relationship. Due to differences and imbalances in manufacturing technology, craftsmen, and regions, there will be diversities in timbre. Furthermore, the sound property of chime stones is not only connected to shape, but also relates to the density of the stone and their raw materials. Therefore, further examples are required.

Two chime stones with a similar pitch but from different areas and historical periods, are A01609, the single chime stone with a straight base from Henan Anyang (fig. 98b) discussed above, and a chime stone with a curved base picked from a set of chime stones belonging to the Warring States period (475-221 BCE), found in Luoyang Baihuo Gongsi M1 (M1:04, figs. 101a, b). Examined with RX, the fundamental pitch and the frequency of chime stone M1:04 were found to be E6+22 and 1335.2 Hz. The chime stone A01609 has a similar pitch, which is E6+15 and 1330.1 Hz.

From figure 101b (M1:04), it is clear that partial 2 at 2547.3 Hz is somewhat far from the fundamental, and quite a pure tone. In figure 98b (A01609), partial 2 is much closer in frequency to the fundamental. Both have decimal relations with the fundamental frequency, $P2 \approx 1.9F$, $P2 \approx 1.2F$ and are inharmonic. This example of a curved base chime stone has less partials than the example with the straight bottom and this result supports

52 The audio files are all standardised (‘normalised’ in Adobe Audition) so that they could be compared.

the hypothesis that stone makers were shaping the stones not just for pitch but also for timbre, creating a purer fundamental tone with partials which are far away from the first partial, quieter, and mostly gathered into the higher register; a little like the sound of a vibraphone[53]. The stone from Anyang in figure 98b sounds more metallic, as partials are present in both middle and higher registers and are much closer to the fundamental, thus producing a less pure sound, sounding unstable and more noisy. It seems that the sound emitted from the curved base chime stone is much purer and clearer in sound quality than that produced by the straight based chime stone.

(a)

(b)

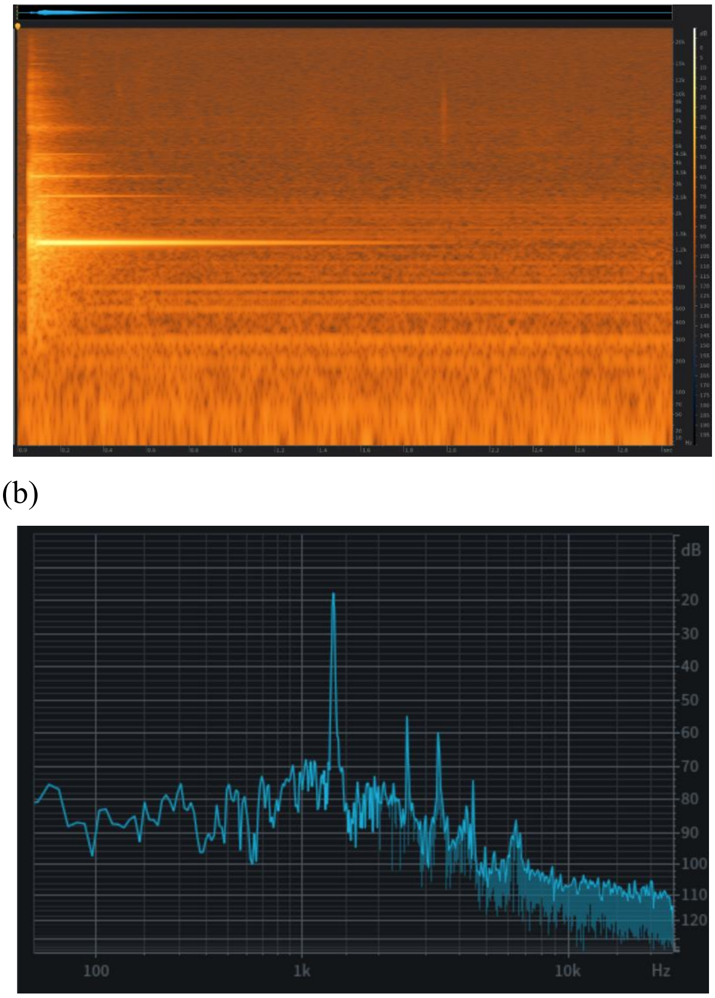


Figure 101. (a) Spectrogram of chime stone M1:04 with curved base chosen from a set of chime stones found in Luoyang Baihuo Gongsi M1, Warring States period (475-221 BCE) (b) Spectrogram Analyser on M1:04.

To provide further evidence that the sound from a curved base stone is purer and clearer, two more samples, each with a curved base, are compared. The first is a chime stone

53 The vibraphone is a musical instrument in the struck idiophone subfamily of the percussion family.

(M4:51) from the Qixian Songzhuang tomb M4, dating to the late Spring and Autumn period (546-476 BCE), with fundamental pitch and frequency of $^{\#}A_5$+44 and 956.6 Hz (fig. 102). The second is a chime stone numbered P14C:106 from the Zhangqiu Luozhuang Western Han tomb, which was measured as $^{\#}A_5$+23 and 944.83 Hz (fig. 103).

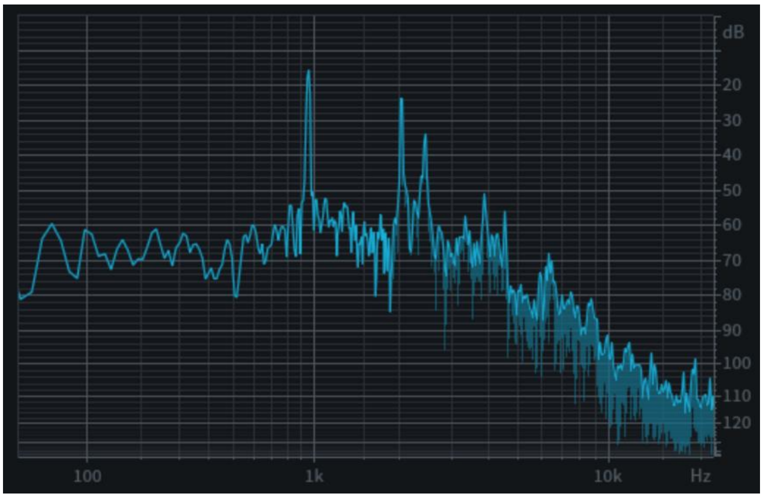


Figure 102. Spectrogram of chime stone M4:51 with curved base found in Qixian Songzhuang, the late Spring and Autumn period (546-476 BCE).

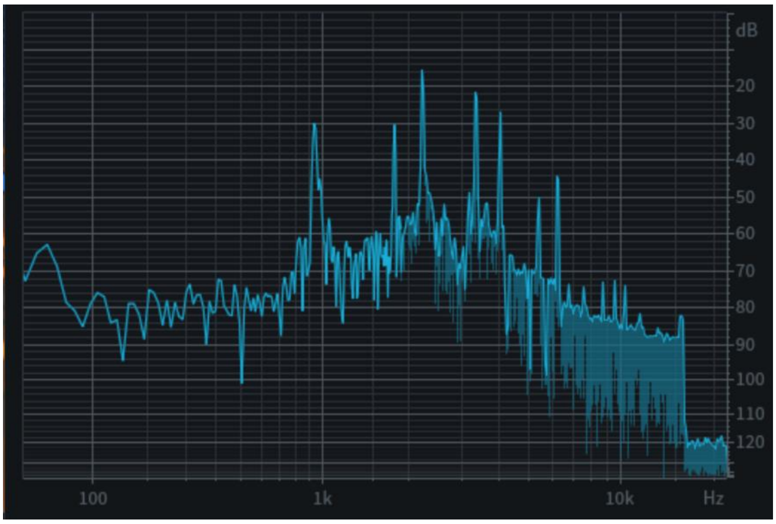


Figure 103. Spectrogram of chime stone P14C:106 with curved base found in Zhangqiu Luozhuang, the Western Han period (187-180 BCE).

There are fewer loud partials from chime stone M4:51 compared to P14C:106. More overtones appear in the middle register (approximately from 900 to 5000 Hz in this spectrum) on the Western Han chime stone. Additionally, more partials can be seen on the spectrogram of chime stone M4:51 compared with that of M1:04 from Luoyang Baihuo Gongsi (fig. 101). Therefore, we cannot assert that chime stones with curved base always produced a sound that was pure.

Based on the above analysis, the straight based chime stones produce more partials when compared to those with a curved base. Whether this is a universal phenomenon still requires the accumulation of more audiometric data and quantitative analysis and therefore, systematic research has been conducted. Table 36 below shows partial statistics on chime stones from the Shang (ca. 1600-1046 BCE) to the Western Han dynasty (202 BCE-8 CE). The samples were chosen from 86 chime stones found in various archaeological sites.

Table 36. Numbers of partials of 86 chime stones from Shang to Western Han dynasty

Partial numbers (≧50 dB, including fundamental)	Shang dynasty chime stones total: 2	Western Zhou chime stones total: 10	Spring and Autumn chime stones total: 19	Warring States chime stones total: 23	Eastern Zhou chime stones[54] total: 21	Western Han chime stones total: 11
5 or 5⁺	2	7	2	5	2	9
4	-	2	1	3	2	1
3	-	1	10	7	4	1
2	-	-	5	1	7	-
1	-	-	1	6	6	-
Average number of partials	7	5.8	2.8	3.5	2.5	6.9

Table 36 shows how many chime stones dating to different periods are in accordance with specific partial numbers. We find that the Shang dynasty (ca. 1600-1046 BCE) chime stones produced more than five partials, but there are only two examples[55]. In the Western Zhou period (1046-771 BCE), 70% of stones had five or more partials. Chime stones in the Eastern Zhou dynasty (770-256 BCE), including Spring and Autumn (770-476 BCE) as well as Warring States periods (475-221 BCE), have fewer partials, most commonly having three and a small average number. In the Western Han dynasty (202 BCE-8 CE), 80% of the chime stones had more than five strong partials; this may be because Western Han stones have a shorter baseline. Table 37 shows five sample groups of stones with numbers of their partials.

54 Eastern Zhou chime stones without a detailed period division are considered as belonging to the Eastern Zhou dynasty.

55 There are a limited number of Shang dynasty chime stones analysed here, due to difficulties in accessing enough chime stones to be measured.

Table 37. The comparison of partials between five groups of chime stones[56]

Date	Tomb	Specimen no.	Pitch	Partial numebrs	P(1&2)diff.	Base shape
Western Zhou dynasty	Shaanxi Hancheng Liangdaicun M27	M27:1046	G4+47	6	2.6	Straight
		M27:1049	A4+32	7	1.8	Straight
		M27:1042	#C5-45	6	1.8	Straight
		M27:1043	#F5-21	6	1.8	Straight
		M27:1044	G5-8	8	1.8	Straight
		M27:1047	#G5+13	6	1.6	Straight
		M27:1045	B5-30	4	1.4	Straight
		M27:1041	C6+48	8	1.8	Straight
		M27:1050	E6-45	5	1.8	Straight
		M27:1048	G6-50	3	1.4	Straight
Spring and Autumn period	Luoyang Zhongzhou Daqu	No.7	#D5-27	3	2.6	Curved
		No.4	G5-23	3	2.3	Curved
		No.8	#A5-8	3	2.1	Curved
		No.3	#C6-35	3	2.2	Curved
		No.9	#D6+0	3	1.8	Curved
		No.2	F6+10	3	1.8	Curved
		No.10	G6-13	3	1.8	Curved
		No.1	#A6+21	3	1.8	Curved
		No.5	C7+8	2	1.7	Curved
		No.6	#D7+22	2	1.6	Curved
Spring and Autumn period	Qixian Songzhuang M4	M4:40	#G5＋16	5	2.3	Curved
		M4:51	#A5＋44	6	2.1	Curved
		M4:39	D6-2	5	2.3	Curved
		M4:50	G6-21	2	2	Curved
		M4:49	G6＋48	3	2	Curved
		M4:37	G#6-19	3	2.1	Curved
		M4:38	A6-38	2	2	Curved
		M4:36	D7-35	2	1.8	Curved
		M4:48	G7-39	2	1.6	Curved
Warring States period	Luoyang Erqingju M131	M131:35	#C5-44	3	2.1	Curved
		M131:36	B5+24	3	1.9	Curved
		M131:37	G6-33	2	1.5	Curved
		M131:40	#C7-28	2	1.5	Curved
		M131:39	#F7+32	3	1.9	Curved
		M131:38	#G7-24	2	1.3	Curved
Western Han dynasty	Luozhuang Han tomb P14C	group5:113	#D5-8	7	1.9	Curved
		group5:107	#F5-27	10	1.9	Curved
		group5:114	#G5-39	10	1.9	Curved
		group2:82	#A5＋10	9	2.1	Curved
		group5:110	B5-28	7	2	Curved
		group5:115	#D6+10	7	1.9	Curved
		group2:77	F6+23	10	1.9	Curved
		group2:79	#G6+47	7	1.9	Curved
		group6:125	C7-24	8	1.8	Curved
		group6:132	#A7-18	4	1.7	Curved
		group5:112	C8+12	3	1.5	Curved

Note: diff. = difference. P (1 & 2) means the ratio of fundamental frequency and P2 frequency.

In table 37, the first group is ten chime stones from M27 dating to the Western Zhou dynasty (1046-771 BCE). The second group shows ten chime stones from Zhongzhou Daqu dating to the late Spring and Autumn period (546-476 BCE). The third group contains nine chime stones from the Qixian Songzhuang M4, also from the late Spring

56 This table contains chime stones from the Western Zhou to the Western Han dynasty. Incomplete stones and those without background information are not listed here. Except for the Western Han stones, the other stones are all complete sets. The Western Han stones are chosen from three different groups from within one tomb. Western Zhou dynasty stones are referenced from Fang, 2008. The rest of the stones are from my fieldwork data.

and Autumn period. The fourth group is a set of six chime stones from Luoyang M131 dated to the Warring States period (475-221 BCE). The last group is 11 of 107 chime stones selected from mixed groups of stones from the Luozhuang Western Han tomb (187-180 BCE). The first four groups are complete sets, while the last group is chosen from three different groups from the Luozhuang Western Han tomb.

From the table it can be seen that the number of partials decreases with the increase of pitch. Also, as pitch increases, the ratio of P2 and fundamental frequency becomes smaller, which means a closer distance between P2 and P1. P1 and P2 ratios are different among these five groups. In each of the first four sets, the lowest pitched stones have a higher partial ratio, and the partial ratio becomes lower as the pitch of the set becomes higher in most cases, despite the difference in pitch of the fundamental. The Western Han stones are a mixed selection; they do not operate in this way because they are not from the same set. These results imply that during the Western Zhou dynasty there began a consideration of the timbre of stones rather than just pitch. Singly used chime stones from the Shang period (ca. 1600-1046 BCE) are an exception to this, as their individual sound property was regarded as important rather than the distribution of tones in sets.

From the above case studies, we may come to some conclusions. Firstly, from the late Shang (ca. 1260-1050 BCE) to the Western Zhou, straight based chime stones have more partials and less distance between P1 and P2 when compared to those of the Eastern Zhou period (770-256 BCE). The sound of chime stones from the late Shang to the Western Zhou has a less pure quality and the fundamental pitch is less clear. As time went by, less partials were distributed in the intermediate range of frequencies, and the partials are found further from the fundamental. This creates a more pure and clear timbre particularly in chime stones of the Eastern Zhou period although this continues to be seen until the Western Han dynasty (202 BCE-8 CE).

Secondly, the early curved base chime stones dating to the Eastern Zhou dynasty (770-256 BCE) had comparatively fewer partials than the late curved base chime stones of the Western Han dynasty (202 BCE-8 CE). The Eastern Zhou chime stones are more likely to have three to four partials on average. As time went on, the number of partials increased, so that the timbre of chime stones became richer during the Western Han period.

Thirdly, in the Western Han dynasty (202 BCE-8 CE), chime stone design was improved with an abundant number of partial tones. However, the rich partials of the Western Han chime stones were different from those of the late Shang (ca. 1260-1050 BCE) and Western Zhou periods (1046-771 BCE). In particular, the chime stones of the Shang dynasty (ca. 1600-1046 BCE) were at an early stage in the evolution of chime stones, and the process of making a chime stone was simple and crude; the partial frequencies of these stones were gathered more in the lower register than those of the Western Han period. The sound of early straight base chime stones is less pure and significantly different compared with the sound characteristics of the Western Han curved base chime stones.

In addition to factors relating to different eras, the timbre of chime stones has regional differences. It is also true to say that the materials used for making chime stones and the technologies used for manufacture all affect the sound quality of chime stones. Additionally, the financial resources of a tomb occupant and the level of their status would also affect the quality of chime stones recovered, whilst, in research, the striking strength and environment when making measurements are also factors. All of these factors affect and increase the diversity of timbre of chime stones.

9.1.3 Relationships Between Dimensions and Timbre

Statistical Package for the Social Sciences (SPSS) is a software package used for statistical analysis, and it is used in the following section to explore the relationships between physical dimensions of chime stones and their sound. The software was used in order to provide an answer to a number of questions: is there a relationship between geographical location and timbre, as measured through P1-6 frequency and P2-6 amplitude? Are there any relationships between P1 frequency and any of the surface measurements, individually or collectively? Are there any relations between P2-P6 frequency or amplitude and any of the measurements? Are the partial frequencies of a chime stone related to the degree of its vertex angle?

The SPSS form for analysis has eight sub forms, the data content includes excavated locations, time periods, specimen numbers, P1-P6 frequencies, P2-P6 amplitudes, whole lengths, heights, *gushangbian*, *guushangbian*, *gubo*, *guubo*, baseline, vertex angles, *gushangjiao*, *guushangjiao*, *guxiajiao*, *guuxiajiao*, thicknesses, diameter of suspension holes and condition. Among these parameters, there are nine locations separately distributed at Qixian Songzhuang, Luoyang Zhongzhou Daqu and Luoyang Erqingju, Anyang, Henan Shangcai Guozhuang, Xinzheng Hanwangling, Xinzheng Xugang, Henan Tanggong Xilu (Luoyang Wangcheng square), Luoyang Baihuo Gongsi and Henan Sanmenxia. All nine locations are in Henan province, but spread widely across the area (spreadsheet1). The chime stones are displayed in chronological sequence, from the Shang dynasty (ca. 1600-1046 BCE) to the Eastern Zhou period (770-256 BCE).

This part of the study aimed to find which factor or elements of the chime stones' dimensions have the strongest correlation with timbre. I worked closely with statistical expert Dara Mojtahedi to examine these relationships. Several auxiliary graphs and pictures created in Microsoft Excel are also presented. Various experimental samples, totalling 65 chime stones from different sites and dates, are selected from my fieldwork.

Table 38. Correlations between dimensions and partial (P1 & P2) frequencies from 65 chime stones

Dimensions	P1	P2
	Correlation	*Correlation*
Whole length	-.51*	-.56*
Height	-.43*	-.57*
Gushangbian	-.59*	-.67*
Guushangbian	-.27	-.32*
Gubo	-.46*	-.57*
Guubo	-.35*	-.48*
Baseline	-.52*	-.59*
Vertex angle	.49*	.61*
Gushangjiao	-.19	.31
Guushangjiao	-.29	-.42*
Guxiajiao	.15	.14
Guuxiajiao	.24	.36*
Thickness	.08	.05
Suspension hole	-.09	-.16

Note: *significant relationship. P1 Frequency refers to fundamental frequency and P2 Frequency is the second partial frequency.

Table 38 illustrates the correlation between each measurement and both P1 and P2 frequencies. All values that have an asterisk next to them are significant relationships and those without were insignificant. To interpret these values, the closer a value is to +/-1 the stronger the relationship (see table. 39) and if the value is negative, this means that there was a negative correlation. For example, if the whole length had a -.51 and the height had a -.43 relationship with P1, this means that there was a significant negative moderate relationship between the variables and therefore, in this case, the larger the size of the whole chime stone, the lower the P1 frequency. The higher the value of correlation coefficients (no matter if positive or negative), the stronger the relationship.

Table 39. Common standard correlation in SPSS[57]

	Positive	Negative
No correlation	0	0
Weak correlation	0 to 0.3	0 to -0.3
Medium correlation	0.3 to 0.5	-0.3 to -0.5
Strong correlation	0.5 to 0.7	-0.5 to -0.7
Very strong correlation	0.7 to 1	-0.7 to -1
Perfect correlation	1	-1

The size of *gushangbian* is one of the strongest parameter correlations. The variable *gushangbian* explained 35.5% of the variance in P1 frequency ($F(1, 46) = 24.72$, $p < .001$). The relationship between *gushangbian* and P1 frequency was significant ($\beta = -.59$, $p < .001$). However, P2 frequency had a slightly better correlation to measurement parameters than P1 frequency. The variable *gushangbian* explained 44.8% of the variance in P2 frequency ($F(1, 46) = 36.58$, $p < .001$). The relationship between *gushangbian* and P2 frequency was significant ($\beta = -.67$, $p < .001$). P (probability) $< .001$ means there is 99.9% certainty that the result is significant. Other parameters such as thickness have a weak correlation to both P1 and P2, because the uneven characteristic of chime stones' thickness would result in an imprecise expected value through SPSS. Thickness, as *Kaogongji* depicted, is a significant parameter in making a chime stone.

It is interesting to consider which correlations are closer for P2 than for P1. *Guushangjiao* and *guuxiajiao* are both correlated to P2, and have a far weaker correlation to P1. These angles are related to the secondary partials. Other parameters such as the whole length, height, *guushangbian*, *guubo* and baseline are also more correlated to P2 than P1. In other words, the short top edge of the chime stone

57 Referenced from Rumsey, D. J. (2010).

(*guushangbian*), an angle connecting both sides of the *guushangbian* and *guubo* of chime stones (*guushangjiao*), the short and straight side on the part of *guu* of chime stone (*guubo*) as well as an angle connecting both sides of the *guubo and guuxiabian* of chime stone (*guuxiajiao*) have much stronger correlation with P2. The above four parameters with double "uu" are all correlated to P2, and either not correlated to P1 or the correlations are much weaker (table. 38). As discussed in Chapter 4, this provides further evidence that changes in the design of the stone can affect the number of partials present.

Further analysis was carried out to find if the other partial frequencies and amplitudes had additional effects. A hierarchical multiple regression analysis indicated that when controlling for P1 frequencies, none of the other frequencies or amplitudes made any additional contributions to explaining the relationship between measurements and timbre. This is partly because most of the frequencies highly correlated with each other. There seems to be some relationships between partials, but these relationships are complicated and it would be worth additional study. Although beyond the scope of this study, further research would be invaluable that aimed to define these relationships.

The above results in table 38 illustrate that P2 has a slightly stronger relationship to various measurements than P1, and that stone shape affects the timbre of chime stones as well as pitch. The short section of the stone tunes the second partial frequency and the long section of the stone tunes the fundamental frequency (first partial frequency). This suggests that stone makers were interested not just in fundamental pitch but also the second partial, and they would tune the P2 by deliberately adjusting the shorter part of the stone. On the other hand, they were also concerned with fundamental frequency; SPSS results show that this is more closely related to the longer section of the stone. In general, the evidence shows that both the first two partials were being considered when stones were being manufactured and tuned.

From SPSS, other conclusions have been reached. A one-way Multivariate Analysis of Variance (MANOVA) was conducted to see if there were any differences in P1-P6 frequencies between stones of different preservation conditions. The results were insignificant [$F(36, 244.28) = .66$, $p > .05$; Wilk's $\Lambda = .67$, partial $\eta 2 = .06$] suggesting no significant differences in any of the P1-P6 frequencies between the varied preservation conditions. Another MANOVA was conducted to see if there were any differences in P2-P6 amplitudes between the different preservation conditions. The results were also insignificant [$F(30, 226) = .53$, $p > .05$; Wilk's $\Lambda = .76$, partial $\eta 2 = .05$] again suggesting no significant differences in any of the P2-P6 amplitudes between the varied preservation conditions. This suggests that the preservation condition of chime stones, even if they are broken and glued together or repaired, will not significantly change the timbre.

Analysis of the relationship between location and timbre as measured through P1-6 frequencies showed no significant correlation [$F(48, 264.85) = 1.36$, $p > .05$; Wilk's $\Lambda = 0.34$, partial $\eta 2 = .17$]. Also, the relationship between location and timbre as measured through P2-6 amplitude showed no significant correlation [$F(40, 238.18) = 1.38$, $p > .05$; Wilk's $\Lambda = 0.4$, partial $\eta 2 = .17$].

Analysing the relationship between measurements and time period, we found that the stones from the Shang dynasty (ca. 1600-1046 BCE) seemed to have significantly larger scores on the majority of measurements, in comparison to the other stones. A series of Analyses of Variance (ANOVAS) were used to investigate this relationship. Measurements that were significantly related to period are listed below:

Height [$F(3, 46) = 14.53$, $p < .05$; partial $\eta 2 = .5$] Post hoc analyses indicated that the stones from the Shang dynasty (ca. 1600-1046 BCE) had a significantly larger height than the stones from the Spring and Autumn period (770-476 BCE), the Warring States (475-221 BCE) and the Eastern Zhou dynasty (770-256 BCE).

Gushangbian [$F(3, 46) = 9.48$, $p < .05$; partial $\eta 2 = .4$] Post hoc analyses indicated that the stones from the Shang dynasty had significantly larger measurements of the long top edge than the stones from the Spring and Autumn period, the Warring States and the Eastern Zhou dynasty.

Guushangbian [$F(3, 46) = 5.29$, $p < .05$; partial $\eta 2 = .27$] Post hoc analyses indicated that the stones from the Eastern Zhou dynasty had significantly larger measurements of the short top edge than the stones from the Spring and Autumn period and the Warring States.

Gubo [$F(3, 46) = 7.9$, $p < .05$; partial $\eta 2 = .36$] Post hoc analyses indicated that the stones from the Shang dynasty had significantly larger measurements of the end of the long side of the stone than the stones from the Spring and Autumn period, the Warring States and the Eastern Zhou dynasty.

Guubo [F (3, 46) = 5.7, $p < .05$; partial $\eta 2 = .29$] Post hoc analyses indicated that the stones from the Shang dynasty had significantly larger measurements of the end of the short side of the stone than the stones from the Spring and Autumn period, the Warring States and the Eastern Zhou dynasty.

Baseline [F (2, 30) = 5.73, $p < .05$; partial $\eta 2 = .36$] Post hoc analyses indicated that the stones from the Shang dynasty had significantly larger measurements of the baseline than the stones from the Spring and Autumn period, the Warring States and the Eastern Zhou dynasty.

Vertex angle [F (2, 20) = 25.1, $p < .05$; partial $\eta 2 = .72$] Post hoc analyses indicated that the stones from the Spring and Autumn period had significantly larger measurements of the vertex angle than the stones from the Warring States and the Shang dynasty. The stones from the Warring States also had significantly larger measurements than the stones from the Shang dynasty.

Gushangjiao [F (2, 20) = 19.52, $p < .05$; partial $\eta 2 = .66$] Post hoc analyses indicated that the stones from the Shang dynasty (ca. 1600-1046 BCE) had a significantly larger measurement than the stones from the Spring and Autumn period (770-476 BCE) and the Warring States (475-221 BCE).

Guushangjiao [F (2, 20) = 58.88, $p < .05$; partial $\eta 2 = .86$] Post hoc analyses indicated that the stones from the Shang dynasty had significantly larger measurements than the stones from the Spring and Autumn period and the Warring States.

Guuxiajiao [F (2, 30) = 8.67, $p < .05$; partial $\eta 2 = .37$] Post hoc analyses indicated that the stones from the Shang dynasty had significantly larger measurements than the stones from the Spring and Autumn period and the Warring States.

When analysing the relationship between measurements and location, the results were as follows, in short, the measurements of the stones from Anyang seemed to be significantly different to the measurements of the stones from the other locations.

ANOVA tests were conducted and the measurements that were significantly related to location are listed below:

Height [F (3, 19) = 7.47, p < .05; partial η2 = .54] Post hoc analyses indicated that the stones from Anyang had a significantly larger height than the stones from Qixian Songzhuang, Zhongzhou Daqu & Luoyang Erqingju, and Luoyang Baihuogongsi.

Gushangbian [F (3, 19) = 4.92, p < .05; partial η2 = .44] Post hoc analyses indicated that the stones from Anyang had significantly larger measurements of the *gushangbian* than the stones from Qixian Songzhuang, Zhongzhou Daqu and Luoyang Erqingju.

Gubo [F (3, 19) = 9, p < .05; partial η2 = .59] Post hoc analyses indicated that the stones from Anyang had significantly larger measurements of the *gubo* than the stones from Qixian Songzhuang, Zhongzhou Daqu & Luoyang Erqingju, and Luoyang Baihuogongsi.

Baseline [F (3, 19) = 4.42, p < .05; partial η2 = .41] Post hoc analyses indicated that the stones from Anyang had a significantly larger base measurement than the stones from Qixian Songzhuang, Zhongzhou Daqu and Luoyang Erqingju.

Vertex angle [F (3, 19) = 15.9, p < .05; partial η2 = .72] Post hoc analyses indicated that the stones from Anyang had a significantly smaller angle measurement than the stones from Qixian Songzhuang, Zhongzhou Daqu & Luoyang Erqingju, and Luoyang Baihuo Gongsi. The stones from Qixian Songzhuang also had a significantly larger measurement than the stones from Zhongzhou Daqu and Luoyang Erqingju.

Gushangjiao [F (3,29) = 17.99, p < .05; partial η2 = .65] Post hoc analyses indicated that the stones from Anyang had significantly larger measurements of *gushangjiao* than the stones from Qixian Songzhuang, Zhongzhou Daqu & Luoyang Erqingju, and Luoyang Baihuo Gongsi.

Guushangjiao [F (3,29) = 40.13, p < .05; partial η2 = .81] Post hoc analyses indicated that the stones from Anyang had significantly larger measurements of the *guushangjiao* than the stones from Qixian Songzhuang, Zhongzhou Daqu & Luoyang Erqingju, and Luoyang Baihuo Gongsi.

Guuxiajiao [F (3,29) = 5.96, p < .05; partial η2 = .38] Post hoc analyses indicated that the stones from Anyang had significantly larger measurements of the *guuxiajiao* than the stones from Qixian Songzhuang, Zhongzhou Daqu and Luoyang Erqingju.

Multiple regression was performed to investigate the ability of P2-6 frequencies to predict P1 frequency. Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity and homoscedasticity. The 5 independent variables explained 86.8% of variance in P1 frequency ($F(5, 66) = 79.99$, $p < .001$). In the final model only three predictor variables were statistically significant (P2, P3, P6), with P3 recording a higher Beta value ($\beta = .648$, $p < .05$) than P2 ($\beta = .646$ $p < .05$) and P6 ($\beta = -.291$, $p < .05$). All significant predictors were positively correlated with P1.

Multiple regression was performed to investigate the ability of P2-6 amplitudes to predict P1 frequency. Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, and homoscedasticity. The 5 independent variables explained 65.6% of variance in P1 frequency ($F(5, 66) = 23.28$, $p < .001$). In the final model, only P3 amplitude could significantly predict P1 frequency ($\beta = -.69$, $p < .001$). P3 was negatively correlated with P1 frequency. P3 amplitude is the best predictor of P1 frequency. This is a very powerful and negative correlation with 99% significance and strong probability: as P3 amplitude increases, P1 frequency is likely to decrease.

On the whole, Shang dynasty (ca. 1600-1046 BCE) stones have a larger *gushangbian*, *gubo*, *guubo*, *gushangjiao*, *guushangjiao*, *guuxiajiao*, baseline and height than those of the other dynasties. Stones from different dynasties have their own design traditions, with subtle differences; for example, some stones have large angles and some have large baselines. In general, the overall size of stones became smaller over time; although there are variation, for example, stones from the Spring and Autumn period (770-476 BCE) had a significantly larger vertex angle than the stones from the Shang dynasty.

After analysing all 65 chime stones with SPSS, it was also interesting to look at scatter graphs to explore the relationships between the fundamental frequency and stone dimensions. The following case study is an example of this.

In 1958, ten chime stones were accidentally found in Luoyang Zhongzhou Daqu (Henan) in the process of conducting an architectural project, and without detailed archaeological context. According to a brief archaeological report, the chime stones date to the late Spring and Autumn period (546-476 BCE) and they seem to be exceptionally well preserved. There were no co-existent remains surviving, so it is not clear if these chime stones were buried in a tomb or a pit. To date, only one article has discussed these finds (Fang, 1989). Sound recording and data collection on these chime stones in my fieldwork adds to current information.

Below, scatter diagrams illustrate length, height and frequency (figs. 104 &105).

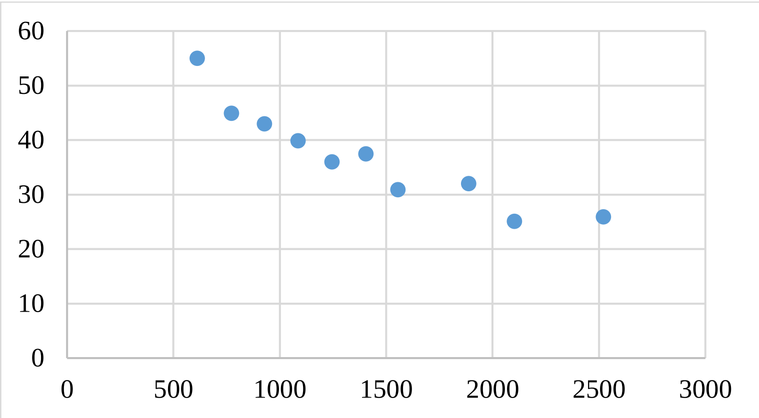


Figure 104. The correlation between fundamental frequency and whole length of ten chime stones from the Luoyang Zhongzhou Daqu

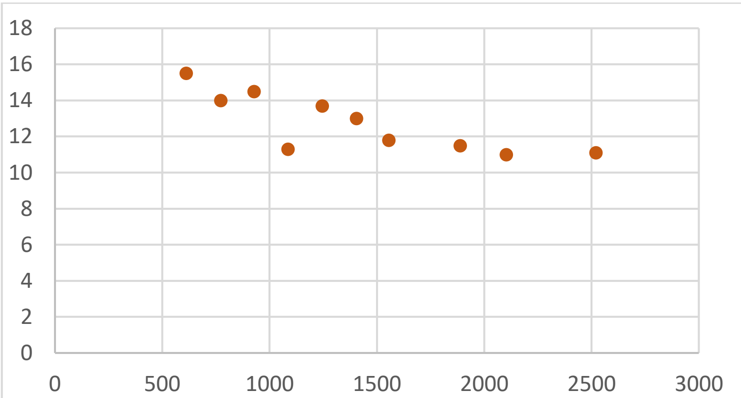


Figure 105. The correlation between fundamental frequency and height of ten chime stones from the Luoyang Zhongzhou Daqu

The dots represent the ten chime stones. In figure 104, they represent frequency (X axis) and whole length (Y axis); in figure 105, the dots refer to frequency (X axis) and height (Y axis). They show that as frequency increases, the whole length and height decrease in most cases, although there are exceptions that show that it is a combination of dimensions that affect pitch. Some of the chime stones are quite small in height, and height does not always have an effect on pitch. Generally, the height has less effect on pitch compared to the whole length.

The section above illustrates that P2 has a slightly stronger relationship to measurements than P1. P2 frequency and amplitude is key in setting the timbre of the chime stones. In this section, I will explore the second partial in more detail, using the ten stones from Luoyang Zhongzhou Daqu for example.

In figure 106, frequencies of partials from P2 to P6 are described for the chime stones from Luoyang Zhongzhou Daqu and are arrayed in sequence from the largest to the smallest. The specimen numbers are successively ordered from lower to higher pitches, shown as no.7, no.4, no.8, no.3, no.9, no.2, no.10, no.1, no.5 to no.6.

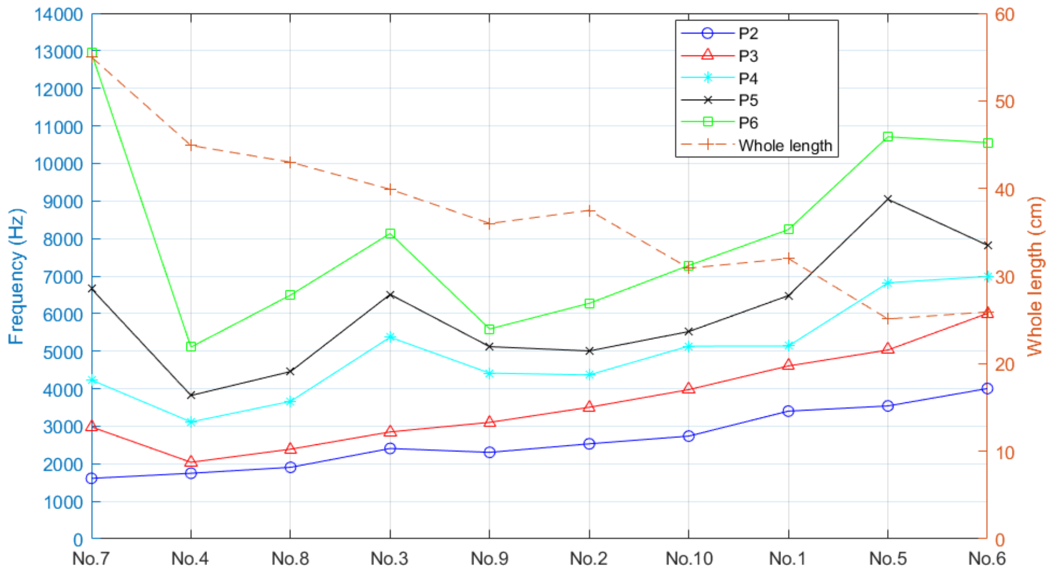


Figure 106. The correlation between P2-P6 partial frequencies and whole length of ten chime stones from the Luoyang Zhongzhou Daqu

P6 represents the highest partial frequency, while P2 is the lowest. This can also be applied to other chime stones according to the partials data in statistic form (spreadsheet 1). Stone no.7 has the highest partial frequency in P6, at approximately 13000 Hz. There is a sharp fall to 5020 Hz on the second chime stone. Then frequencies increase steadily, but in some cases frequencies of higher partials decrease as P2 increases. This is perhaps because the expected P3 is low in amplitude in these cases. This phenomenon indicates that partial frequencies and amplitudes are not always in a simple relationship with each other.

9.1.4 The Relevance of Vertex Angle to Frequency

The data from SPSS indicates a correlation between vertex angle and frequency, a medium correlation for P1 (0.01 less than strong correlation), and a strong correlation for P2. The geometrical experiments undertaken by Junehee Yoo and Thomas D. Rossing (2006) showed different results. They chose Chinese chime stones and Korean *pyeongyeong* for comparison. *Pyeongyeong* are Korean chime stones dating to the 17th century (approximately equal to the time of the Ming and Qing dynasty). They are an L-shaped form of chime stone adopted from China for ceremonial use, with an angled base rather than curved. Chime stones located in Korea and China show different characteristics: Korean *pyeongyeong* are each a similar size with different thicknesses, whereas ancient Chinese chime stones are varied in size and thickness. Yoo and Rossing's experiment suggest that frequency (referring to the fundamental frequency) has close relationship with the vertex angle and that increasing the angle produces a lower frequency of the chime stone.

For Chinese chime stones, tuning is not controlled solely by the vertex angle. Table 40 compares the vertex angle and fundamental frequency for chime stones found in the tomb of Jiangsu Dantu Beishanding (see table. 40).

Table 40. Vertex angle and fundamental frequency of the Eastern Zhou chime stones from the tomb of Jiangsu Dantu Beishanding[58]

Excavation no.	Vertex angle	Fundamental frequency
M:55	141°	497.0
M:54	142°	612.5
M:53	142°	825.0
M:57	141°	850.5
M:56	142°	1112.5
M:61	140°	1237.5
M:58	139°	1280.2
M:63	140°	unknown
M:60	142°	2250.0
M:64	143°	1850.0
M:62	149°	2290.4
M:59	140°	3025.0

58 Note: The frequency datum was not measured on M:63. The frequency data were all converted from cent to Hz to make the results more intuitive. These data were taken from the excavation report of Dantu Beishanding.

The Eastern Zhou (770-256 BCE) chime stones in table 40 had similar vertex angles, between 139 and 149 degrees, and yet have very variable frequencies.

Some Western Han chime stones are similarly compared which also show little relation between vertex angle and fundamental frequency (see table. 41).

Table 41. Vertex angle and fundamental frequency of chime stones from Luozhuang Western Han tomb (187-180 BCE)[59]

Excavation no.	Vertex angle	Fundamental frequency
First set P14C:31	145˚	398.4
First set P14C:29	144˚	454.4
First set P14C:41	140˚	508.3
First set P14C:30	145˚	579.9
First set P14C:28	142˚	599.5
First set P14C:40	140˚	666.5
First set P14C:39	138˚	756.4
First set P14C:27	142˚	812.9
First set P14C:38	142˚	896.0
First set P14C:37	142˚	999.5
First set P14C:36	144˚	1162.8
First set P14C:25	142˚	1362.6
First set P14C:26	144˚	1470.5
First set P14C:24	143˚	1859.8
First set P14C:22	142˚	2064
First set P14C:33	144˚	2374.9
First set P14C:32	140˚	2847.1
First set P14C:23	144˚	2889.6

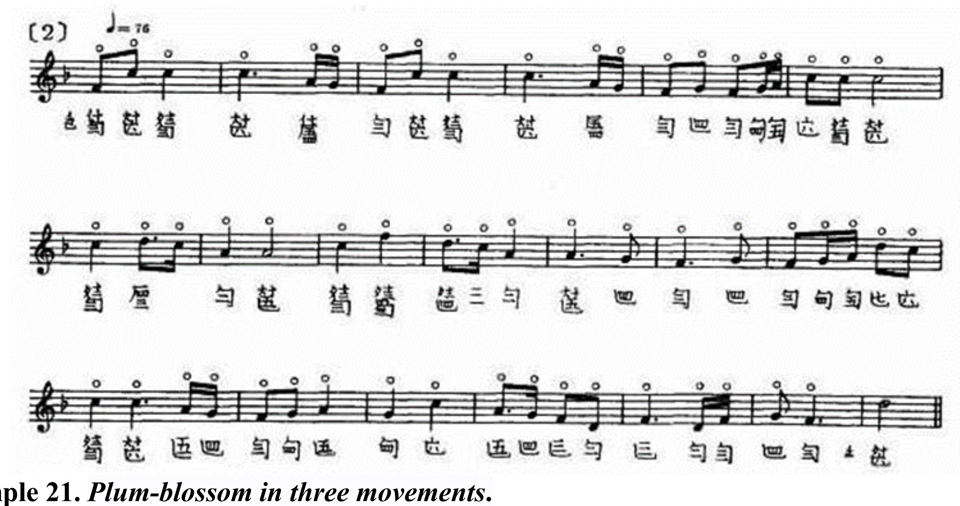
From table 41 it can be seen that in these stones some of the vertex angles are large, but they have a high frequency. Meanwhile, other stones with the same vertex angles have different frequencies because of varied other dimensions. Comparing the vertex angle with frequency on each chime stone, the angle does not seem to be as important as Yoo and Rossing suggest.

59 Note: Stones 34 and 35 were broken.

Yoo and Rossing's experiment depends on a small number of chime stones; in order to draw more accurate conclusions, we have to comprehensively consider all aspects, and carry out quantitative research.

9.2 Compositional Experimentation

In this section I describe an experimental approach which uses a sound sampler to capture the original timbre of chime stones, chime bells, clay ocarinas, Chinese *di* bamboo flute and *guzheng* zither, and combine these sounds as a sample of Chinese traditional music. This is to demonstrate an effective ancient musical performance and present it to contemporary audiences. Another purpose is to explore the role and meaning of chime stones in ancient China.

In this experiment, I used a sampler plug-in in Logic Pro X music software to edit sounds. To recreate a piece of Chinese melody from ancient times, I created a sound library of chime stones from original sound recordings made in Qixian Songzhuang, and using the same pitches as those instruments listed above. The sounds of chime bells and clay ocarinas originate from the Luozhuang Han tomb (Shandong) and Luoyang Beiyao (Henan). The other sounds are standard sampler provided sounds. The original score for the melody *Meihua Sannong* 梅花三弄 (Plum-blossom in three movements) is shown in below (example 21):

Example 21. ***Plum-blossom in three movements.***

From ZYYJYYYS. (2004). *Guqin quji* (The music score of *qin*). Beijing: Renmin Yinyue Chubanshe, p. 51.

The original version of this tune is said to have been composed by Huanyi in the Jin dynasty (265-420 CE), a tune played by *di* flute. However, it was later adapted for the *qin* during the Tang dynasty (618-907 CE). The theme of this tune *Plum-blossom in three movements* is to pay a tribute to people who have integrity and who are noble and moral (Liu, Z. S., 2006). This tune is sometimes performed by ensembles; for example, a *qin* zither combined with a Chinese flute. The piece notated is *qin* tablature (also known as abbreviated character notation), this kind of notation was popular in the Tang dynasty, *qin* tablature shows finger positions and playing techniques, rather than notes. A recording of the piece accompanies this thesis.

9.3 Temperament: the Application of the Method of circle-of-fifths in *twelve-lü* Tuning System

The examples listed in section 8.3 show the use of different scales. Some of these scales have a tuning system originating from the circle-of-fifths method. The samples chosen for experiment from my fieldwork data were all dated to the Eastern Zhou dynasty (770-256 BCE) and their pitches were all generated by using the circle-of-fifths.

9.3.1 Case Study One: An Analysis of Ten Chime Stones of the Spring and Autumn Period (770-476 BCE) from Luoyang Zhongzhou Daqu

What follows is a study of the tuning of ten chime stones from Luoyang Zhongzhou Daqu, with three tables listed.

Table 42. Pitch and frequency measurement of chime stones from Luoyang Zhongzhou Daqu

Specimen no.	Pitch (cent)	Frequency (Hz)	Comments
No.7	$^{\sharp}D_5$-27 (D_5+73)	612.42	-
No.4	G_5-23 ($^{\sharp}F_5$+77)	773.26	-
No.8	$^{\sharp}A_5$-8 (A_5+92)	927.8	-
No.3	$^{\sharp}C_6$-35 (C_6+65)	1086.46	restored
No.9	$^{\sharp}D_6$+0	1244.99	-
No.2	F_6+10	1405.18	-
No.10	G_6-13 ($^{\sharp}F_6$+87)	1555.83	-
No.1	$^{\sharp}A_6$+21	1887.79	-
No.5	C_7+8	2103.16	-
No.6	$^{\sharp}D_7$+22	2521.3	-

Table 43. Interval calculations for chime stones from Luoyang Zhongzhou Daqu

Specimen no.	Number of cents each stone is above equal temperament	Difference from +46 cents, the average tuning	Pitches relative to tuning to $^{\sharp}D_6$ rather than the frequency $^{\sharp}D_4$=311.13Hz (+16va)	Cents above reference frequency note	Frequency Ratio
No.7	73	27	$^{\sharp}D_5$-27	-1227	0.49
No.4	77	31	G_5-23	-823	0.62
No.8	92	46	$^{\sharp}A_5$-8	-508	0.75
No.3	65	19	$^{\sharp}C_6$-35	-235	0.87
No.9	0	-46	$^{\sharp}D_6$	0	1.00
No.2	10	-36	F_6+10	210	1.13
No.10	87	41	G_6-13	387	1.25
No.1	21	-25	$^{\sharp}A_6$+21	721	1.52
No.5	8	-38	C_7+8	908	1.69
No.6	22	-24	$^{\sharp}D_7$+22	1222	2.03
Total	455	-	-	-	-
Average	46	-	-	-	-

Table 44. Comparison of the Luoyang Zhongzhou Daqu chime stone frequency ratios with the *twelve-lü* tuning system. Grey fill indicates where a stone is present

Frequency Ratios in *twelve-lü*	Frequency Ratios in *twelve-lü* as Numbers	*Twelve-lü* Pitch Names	Chime Stones Specimen Numbers	Chime Stones Frequency Ratio	Closest Western Pitch
	0.45	Wu Yi			♯C
	0.475	Ying Zhong			D
	0.5	Huang Zhong	No.7	0.49	♯D
	0.535	Da Lü			E
	0.565	Tai Cu			F
	0.605	Jia Zhong			♯F
	0.635	Gu Xi	No.4	0.62	G
	0.675	Zhong Lü			♯G
	0.71	Rui Bin			A
	0.75	Lin Zhong	No.8	0.75	♯A
	0.80	Yi Ze			B
	0.845	Nan Lü			C
	0.90	Wu Yi	No.3	0.87	♯C
	0.95	Ying Zhong			D
1	*1*	Huang Zhong	No.9	1	♯D
2187/2048	1.07	Da Lü			E
9/8	1.13	Tai Cu	No.2	1.13	F
1968/1638	1.21	Jia Zhong			♯F
81/64	1.27	Gu Xi	No.10	1.25	G
1771/1311	1.35	Zhong Lü			♯G
729/512	1.42	Rui Bin			A
3/2	1.50	Lin Zhong	No.1	1.52	♯A
6561/4096	1.6	Yi Ze			B
27/16	1.69	Nan Lü	No.5	1.69	C
5905/3277	1.8	Wu Yi			♯C
243/128	1.9	Ying Zhong			D
2	2	Huang	No.6	2.03	♯D

Table 42 shows the pitch measurement data of chime stones from Luoyang Zhongzhou Daqu. In the temperament of *twelve-lü*, most of the intervals between notes are different sizes (unlike western european equal temperament where each note is equidistant). The intervals calculations are illustrated in table 43. Table 42 shows the musical pitches and frequencies of the chime stones in cents and Hz respectively. Although frequencies are the most accurate and least culturally loaded way to describe the pitch of sounds made by chime stones, since they vary in a logarithmic rather than a linear manner, it is difficult to understand how a sequence of frequencies relates to one another in a musical scale. To use pitches such as the names of musical notes is equally problematic, because they might be taken to imply equal temperament descriptions (modern terminology). For this reason, I describe both frequency and pitch information, and explain how these frequencies relate to the notes of scales in the equal temperament tuning system which may be most familiar to a broad range of readers. The first column of table 43 shows the specimen number of the chime stones. Column two shows how many cents each stone is above the closest equal temperament, this is in order to produce a set of positive values that could be easily averaged.

Using A440 Hz, the modern tuning reference, makes no sense when looking at these notes, instead in this project we will look for a different tuning reference based on the frequencies present in the stones.

Firstly, the average distance above equal temperament of this set of chime stones was 46 cents. No pitches in table 43 are similar to 46 cents, so using an average to find a reference pitch was not a particularly successful approach, therefore, stone no.9 was chosen as it is the central example of ♯D, the note which is the *gong* or home pitch of the scale.

In table 43, the final column indicates the frequency ratios of stones in relation to the central reference pitch. Table 44 shows in the first column the ratios of frequencies of the *twelve-lü* tuning system (see section 8.4), with decimal equivalents in column 2. These are the ratios that should be present if the stones are in tune in the *twelve-lü* system, and column 5 shows the actual measured ratios of the stones. The ratios present matched very accurately to the *twelve-lü* tuning system. Whereas the stones are mostly a number of cents out of tune with equal temperament, they are accurately tuned in this ancient Chinese system. The stone in the middle had a ratio of 1, which is almost equal to the 1 of *twelve-lü*. Other stones were even closer, 0.49 and 0.5; 0.62 and 0.635; 0.75 and 0.75; 0.87 and 0.90; 1.13 and 1.13. 1.25 and 1.27; 1.52 and 1.50; 1.69 and 1.69; 2.03 and 2. These results are remarkably accurate, at most the ratio is 0.03 out, it is notable how accurately the chime stones map onto the *twelve-lü* tuning system ratios.

The poor condition of specimen no.3 might mean that the actual tuning pitch should be C rather than ♯C, which would fit in better with a pentatonic scale.

It is interesting to note that if we chose stone no.7, a ♯D an octave lower than no.9, as a reference note, or set the reference note as the last stone no.6, an octave higher than no.9, they would not be so accurately in tune. From this comparative experiment, it seems that the most accurate approach was to choose the middle stone no.9 as a reference note. It seems that the chime stone maker would make the first stone, the central "tonic" or *gong*, and then tune the other chime stones from this reference.

These ten chime stones are perfectly in tune according to the *twelve-lü* tuning system, containing five notes in a pentatonic scale. In this case, $^\sharp D_4 = ^\sharp D_6 \div 4 = 311.2475$ Hz. The frequency ratio f2/f1=1.414214, f2=A_4, f1=$^\sharp D_4$. Thus $A_4 = 311.2475 \times 1.414214 = 440.171$ Hz. The standard pitch A_4 of this set is 440.171 Hz which is close to 440 Hz in modern concert pitch.

9.3.2 Case Study Two: An Analysis of Six Chime Stones of the Warring States period (475-221 BCE) from Luoyang Erqingju M131

Table 45. Data of pitch measurement on chime stones from Luoyang Erqingju M131

Specimen no.	Pitch (cent)	Frequency (Hz)
M131:35	$^\sharp C_5$-44 (C_5+56)	540.18
M131:36	B_5+24	1001.56
M131:37	G_6-33 ($^\sharp F_6$+67)	1537.70
M131:40	$^\sharp C_7$-28 (C_7+72)	2181.55
M131:39	$^\sharp F_7$+32	3016.48
M131:38	$^\sharp G_7$-24 (G_7+76)	3275.76

Table 46. Interval calculations for chime stones from Luoyang Erqingju M131

Specimen no.	Number of cents each stone is above equal temperament	Difference from +55 cents, the average tuning	Pitches relative to tuning to $^{\#}C_5$-44 rather than the frequency $^{\#}C_4$=277.18 Hz (+8va)	Cents above reference frequency note	Frequency Ratio
M131:35	56	1	$^{\#}C_5$	0	1
M131:36	24	-31	C_6-32	1068	1.85
M131:37	67	12	G_6+11	1811	2.85
M131:40	72	17	$^{\#}C_7$+16	2416	4.04
M131:39	32	-23	G_7-24	2976	5.58
M131:38	76	21	$^{\#}G_7$+20	3120	6.06
Total	327	-	-	-	-
Average	55	-	-	-	-

The average distance above equal temperament of the set of chime stones in table 46 was 55 cents. One of the stones (M131:35) is at exactly this average tuning, so this stone has been chosen to be used as a tuning reference. Trying to construct a scale based on equal temperament and tuning to the modern reference frequency of $^{\#}C_4$=277.18 Hz is problematic as already discussed. I chose in this case $^{\#}C_5$-44 cents, or 540.18 Hz instead, the lowest pitched stone in this set. Column three of table 46 shows how many cents out of tune each note is to our new reference pitch of 540.18 Hz. This pitch note is almost one octave above $^{\#}C_4$= 277.18 Hz; the same octave equivalent would be 270.09 Hz. Stone M131:35 is effectively our pitch tuning reference; in modern musical terminology, we would say the chime stone set is tuned to 270.09 Hz. When constructing a musical scale, one always begins from a fixed point, the harmonic centre or in western language "tonic" note.

After subtracting 55 cents from each stone's pitch to recalibrate the tunings of the stones to this new reference, the differences of cents of each of the six chime stones from what would be expected if the tunings were in equal temperament were recalculated, and these values can be seen in the third column of table 46. The six pitches of the chime stones, relative to $^{\#}C_5$-44 were calculated and can be seen in column four, and the frequency ratios present can be seen in column six. When calculating the number of cents from the root pitch, the frequency ratios were laid out using a cent-frequency ratio conversion calculator.[60] I compared the frequency ratios of the six chime stones being

60 Conversion of Cents-Frequency ratio. (n.d.). Retrieved from <http://www.sengpielaudio.com/calculator-centsratio.htm>

studied to the *twelve-lü* tuning system standard form. I used frequency ratios rather than absolute pitches or frequencies, in order to compare to the tuning system rather than any individual tuning reference.

Once the frequencies were presented in this way, the ratios present once more matched very accurately to the *twelve-lü* tuning system, as can be seen in table 47. Whereas the stones are mostly a number of cents out of tune with equal temperament, they seem mostly accurately tuned to this ancient Chinese system. The largest stone had a ratio of 1, as it is the tuning reference in *twelve-lü*. Other stones were also close, 1.85 and 1.90; 2.85 and 2.84; 4.04 and 4; 5.58 and 5.68; 6.06 and 6. These results are again remarkably accurate, it is notable how accurately the chime stones map onto the *twelve-lü* tuning system ratios. In this smaller set it seems the stone maker first made the lowest tuned stone, and then tuned the rest of the set to it.

Table 47. Comparison of the Luoyang Erqingju M131 chime stone frequency ratios with the *twelve-lü* tuning system. Gray fill indicates where a stone is present

Frequency Ratios in *twelve-lü*	Frequency Ratios in *twelve-lü* as Numbers	*Twelve-lü* Pitch Names	Chime Stones Specimen Numbers	Chime Stones Frequency Ratio	Closest Western Pitch
1	*1*	Huang Zhong	M131:35	1	♯C
2187/2048	1.07	Da Lü			D
9/8	1.13	Tai Cu			♯D
1968/1638	1.21	Jia Zhong			E
81/64	1.27	Gu Xi			F
1771/1311	1.35	Zhong Lü			♯F
729/512	1.42	Rui Bin			G
3/2	1.5	Lin Zhong			♯G
6561/4096	1.6	Yi Ze			A
27/16	1.69	Nan Lü			♯A
5905/3277	1.8	Wu Yi			B
243/128	1.9	Ying Zhong	M131:36	1.85	C
2	2	Huang Zhong			♯C
	2.14	Da Lü			D
	2.26	Tai Cu			♯D

	2.42	Jia Zhong			E
	2.54	Gu Xi			F
	2.7	Zhong Lü			♯F
	2.84	Rui Bin	M131:37	2.85	G
	3	Lin Zhong			♯G
	3.2	Yi Ze			A
	3.38	Nan Lü			♯A
	3.6	Wu Yi			B
	3.8	Ying Zhong			C
	4	Huang Zhong	M131:40	4.04	♯C
	4.28	Da Lü			D
	4.52	Tai Cu			♯D
	4.84	Jia Zhong			E
	5.08	Gu Xi			F
	5.4	Zhong Lü			♯F
	5.68	Rui Bin	M131:39	5.58	G
	6	Lin Zhong	M131:38	6.06	♯G
	6.4	Yi Ze			
	6.76	Nan Lü			
	7.2	Wu Yi			
	7.6	Ying Zhong			

Table 47 shows these notes within the *twelve-lü* tuning system. Their accuracy is especially notable when you consider the simple tools used to tune the stones. It seems that these notes form a pentatonic scale, but it is an unusual one, six notes ♯C-C-G-♯C-G-♯G. There are two octaves: ♯C-♯C and G-G. The important issue from this sample is that octaves are always accurate; it may be that there are stones missing.

To compare different examples, the tuning standard compared to A_4 in this set of chime stones can also be calculated.

First of all, the frequency ratio f2/f1=1.587401 is calculated, because the cent distance from $♯C_4$ to A_4 is 800 cents. Here, f1=$♯C_4$=270.09 Hz, f2=A_4 (a standard note in this set of chime stones). f2=f1×1.587401=270.09×1.587401=428.741 Hz. Therefore, the frequency of A_4 in this set of chime stones is 428.741 Hz, which is some distance from 440 Hz in modern standard pitch, and certainly a long way from our previous example.

9.3.3 Case Study Three: An Analysis of Seven Chime Stones of the Warring States Period (475-221 BCE) from the Henan Sanmenxia No.0627

The section below describes chime stones from Henan Sanmenxia. Similarly, three tables are presented.

Table 48. Data of pitch measurement of chime stones from Henan Sanmenxia No.0627

Specimen no.	Pitch (cent)	Frequency (Hz)	Comments
no1	B4-37 ($^\sharp A_4$+63)	483.2	-
no2	D_5+35	599.6	-
no3	$^\sharp F_5$-29 (F_5+71)	727.57	-
no4	B5-20 ($^\sharp A_5$+80)	976.28	Restored, lack of *gushangjiao*
no5	$^\sharp C_6$-39 (C_6+61)	1083.5	-
no6	D_6+39	1201.5	-
no7	$^\sharp F_6$-20 (F_6+80)	1462.4	-

Table 49. Interval calculations for chime stones from Henan Sanmenxia No.0627

Specimen no.	Number of cents each stone is above equal temperament	Difference from +61 cents, the average tuning	Pitches relative to tuning to $^\sharp C_6$-39 rather than the frequency $^\sharp C_4$=277.18 Hz (+16va)	Cents above reference frequency note	Frequency Ratio
no1	63	2	B_4+2	-1398	0.45
no2	35	-26	$^\sharp D_5$-26	-1026	0.55
no3	71	10	$^\sharp F_5$+10	-690	0.67
no4	80	19	B_5+19	-181	0.90
no5	61	0	$^\sharp C_6$	0	1
no6	39	-22	$^\sharp D_6$-22	178	1.11
no7	80	19	$^\sharp F_6$+19	519	1.35
Total	429	-	-	-	-
Average	61	-	-	-	-

Table 50. Comparison of the Henan Sanmenxia No.0627 chime stone frequency ratios with the *twelve-lü* tuning system. Gray fill indicates where a stone is present

Frequency Ratios in *twelve-lü*	Frequency Ratios in *twelve-lü* as Numbers	*Twelve-lü* Pitch Names	Chime Stones Specimen Numbers	Chime Stones Frequency Ratio	Closest Western Pitch
	0.45	Wu Yi	0627no1	0.45	B4
	0.475	Ying Zhong			C5
	0.5	Huang Zhong			♯C5
	0.53	Da Lü			D5
	0.56	Tai Cu	0627no2	0.55	♯D5
	0.6	Jia Zhong			E5
	0.63	Gu Xi			F5
	0.68	Zhong Lü	0627no3	0.67	♯F5
	0.71	Rui Bin			G5
	0.75	Lin Zhong			♯G5
	0.8	Yi Ze			A5
	0.84	Nan Lü			♯A5
	0.9	Wu Yi	0627no4	0.9	B5
	0.95	Ying Zhong			C6
1	*1*	Huang Zhong	0627no5	1	♯C6
2187/2048	1.07	Da Lü			D6
9/8	1.13	Tai Cu	0627no6	1.11	♯D6
1968/1638	1.21	Jia Zhong			E6
81/64	1.27	Gu Xi			F6
1771/1311	1.35	Zhong Lü	0627no7	1.35	♯F6
729/512	1.42	Rui Bin			G6
3/2	1.5	Lin Zhong			♯G6
6561/4096	1.6	Yi Ze			A6
27/16	1.69	Nan Lü			♯A6
5905/3277	1.8	Wu Yi			B6
243/128	1.9	Ying Zhong			C7

In this archaeological site, nine chime stones were unearthed without additional background information. However, two of them cannot produce any sound. The data above shows the seven chime stones that remained.

From table 50, we find that the frequency ratios of the seven chime stones are very accurate, and exactly the same as the frequency ratios in *twelve-lü*. Stone no.5 is the tuning reference. Other stones were: 0.45 and 0.45; 0.55 and 0.56; 0.67 and 0.68; 0.90

and 0.90; 1.11 and 1.13; 1.35 and 1.35. The pitches we have are: B_4, $^\sharp D_5$, $^\sharp F_5$, B_5, $^\sharp C_6$, $^\sharp D_6$ and $^\sharp F_6$. The reference note $^\sharp C_6$ in this scale belongs to the note *shang* based on Huangzhong system, B is the *gong*, root, or harmonic centre. Thus, it can form the scale of do-mi-sol-do-re-mi-sol, which converts to C-E-G-C-D-E-G. This forms part of the pentatonic scale, there is no $^\sharp G$.

The result of calculations are $^\sharp C_4 = {}^\sharp C_6 \div 4 = 1083.5 \div 4 = 270.875$ Hz. The frequency ratio $f2/f1 = 1.587401$, $f2 = A_4$, $f1 = {}^\sharp C_4$. Thus $A_4 = 270.875 \times 1.587401 = 429.987$ Hz. The standard note A_4 of this set is 429.987 Hz which is similar to the previous example.

The aim of the analysis above is to verify that chime stones in ancient were accurately tuned. The results from this experiment suggest that chime stones were accurately tuned to the ancient *twelve-lü* tuning system. After being buried underground for around 2000 years, these stones still appear to be accurately tuned when unearthed. Although a great deal more research would be needed to be sure, a tentative suggestion is that of the Eastern Zhou dynasty in ancient China, chime stones were tuned to the equivalent of A 430 Hz.

9.4 Summary

This chapter begins by describing the fundamental pitch and other partials in the sound spectrum of chime stones, and exploring the relationships between timbre and the different base shapes of the chime stones. The SPSS statistical package was used throughout to study the relationship between dimensions and pitches. This suggested that, through examination of 65 chime stones, the first two partials had strong correlations with the dimensions of the chime stone. P2 has a slightly stronger relationship to measurements than P1, and correlated more with the shorter sections of the chime stone. This suggests that stone makers were interested in not just fundamental pitch but also the second partial and that they would tune the second partial by adjusting the shorter part of the stone. In addition, it was demonstrated that stones from a later period with a curved base could emit a much purer sound, in particular in the Eastern Zhou period (770-256 BCE). In a later section of this chapter it was detailed how a trial was carried out, using the sampled sound of chime stones, chime bells, clay ocarinas and *guzheng* zither as well as *di* flute, to recreate a traditional Chinese melody.

Furthermore, I explored the temperament of chime stones by using three different sample sets and concluded that after being buried underground for around 2000 years, these stones still appear to be accurately tuned to the ancient *twelve-lü* system, with two of the sets tuned to the equivalent of A 429-430 Hz.

Chapter 10: Chime Stone Use and Function

10.1 Chime Stones in Ensemble Performance

The chime stone as a musical instrument was primarily played in ensemble performances. There is no textual or archaeological evidence that the chime stone functioned as a solo musical instrument.

Tombs containing chime stones and other coexisting percussive musical instruments were found during the Neolithic Age but limited to the region of the Yellow River valley. In the Xiangfen Taosi site, chime stones accompanied by crocodile skin drums and pottery drums were excavated from four of five large tombs in M3002, M3015, M3016 and M3072. The fifth tomb M3073 contained a crocodile skin drum and a pottery drum, but no chime stones. Of the four tombs, three contained two crocodile skin drums and one pottery drum, whilst tomb M3072 had one crocodile skin drum and one pottery drum. These assemblages suggest that chime stones and drums may have been one instrumental combination at this time. So far, no wind or string instruments have been discovered in combination with chime stones during the Neolithic, suggesting that percussion was the main type of instrument and that the chime stone likely served only as a rhythm instrument during this period.

In the Shang dynasty (ca. 1600-1046 BCE), different combinations of musical instruments including percussion and wind appeared. Chime stones were mainly popular in northern China, where they are often found with bells, although plenty of single used large bells were found in the Yangtze River valley area. For instance, three *yong*-bells were found with one chime stone in each of these tombs: Henan Anyang Huayuanzhuang M54, Guojiazhuang M160 and Shandong Qingzhou Subutun M8, whilst five chime stones were found accompanied by three clay ocarinas *xun* and five *yong*-bells in Fu Hao's tomb (ZSKKGSAYGZD, 2004; ZSKKGS, 1998; SDWYS et al., 1989; ZSKKGS, 1980).

The three *yong*-bells from Huayuanzhuang M54 produce F_5+7, $^\sharp G_5$-26, and $^\sharp C_6$-44 respectively (Liu, X.H., 2006)[61], which can form the tone series mi-so-do, the tonic *do* is $^{\sharp}$C. Whereas the chime stone from this tomb produces C_5+37, it is likely that this is not the original pitch given its broken condition. As mentioned previously, chime stones used singly were rhythm instruments, therefore it is uncertain whether the single stone (*Te Qing*) needed to match the pitch of other melodic instruments in the ensemble.

A similar instrumental assemblage appeared in other late Shang (ca. 1260-1050 BCE) tombs. In Guojiazhuang M160, for example, the single stone emits $^{\sharp}G_5$-8 or $^{\sharp}A_5$-33 when beating two different positions, the coexistent *yong*-bells produce $^{\sharp}D_5$+31, $^{\sharp}F_5$+2, and C_3+29 respectively (WWDXBJB, 1996a, p. 76). In Fu Hao's tomb, only two stones have pitch data among a total of five pieces (Fang, 2006, p. 105), they are B_5 (M5:2) and $^{\sharp}A_5$-11 (M5:316); the rest of the stones are in poorly preserved condition. Five chime bells in the same tomb produce G_5, A_5, C_6, E_6 (possibly), and G_6 respectively (Li, 1996, p. 119). Other coexistent wind instruments included three clay ocarinas; according to Li, one of the ocarinas and the chime bells are in tune (Li, 1996, p. 402). Judging from the pitches of the instruments in Fu Hao's tomb, the chime stones, bells and ocarinas may have been played in an ensemble. Thus, "metal and stone music" as a form of performance could be dated as early as the late Shang period.

Chime stone and drum combinations were encountered during the late Shang period, similar to those from the Neolithic. A chime stone accompanied by one crocodile skin drum and a drum rack was found in tomb M1217 in Anyang Houjiazhuang, whilst the assemblage of one *ling* clapper-bell, two crocodile skin drums and one chime stone was found in both M4 and M210 of Tengzhou Qianzhangda. Wind instruments in most cases form this period are represented by clay ocarinas or *xun*. Apart from the aforementioned Fu Hao's tomb, one clay ocarina and one bone ocarina were excavated in association with a chime stone from Anyang Houjiazhuang Xibeigang M1001. Since the chime stones was broken into pieces, we have no way to explore its musical relation with the ocarinas (Liang & Gao, 1962).

61 The ancient Chinese musical bell can produce *two-tone* 雙音. The first tone is heard when the bell is struck in the centre above the mouth and the second tone is produced when it is struck to the right (sometimes the left) of this area; this is referred to as one bell with *two-tone* phenomenon. In the late Shang dynasty, the *yong*-bells normally comprised of three and occasionally five in a set, but the second notes from these bells are not coherent or unclear, suggesting that only the first notes may have been used in bells from the late Shang period. In this thesis I have therefore chosen the first notes for discussion.

In ancient documents, the assemblage of instruments described in ensembles of the Shang dynasty (ca. 1600-1046 BCE) was much richer than present archaeological finds suggest. A famous passage from the *Na* (Fine) Ode in *Shi Jing* describes a ritual orchestra in the Shang court:

> Oh, fine, oh, lovely!
> We set up our tambourines and drums.
> We play on the drum loud and strong,
> To please our glorious ancestors.
> The descendent of Tang has come;
> He has secured our victories.
> There is a din of tambourines and drums;
> A shrill music of flutes,
> All blend in harmony,
> With the sound of our stone chimes.
> Magnificent the descendent of Tang;
> Very beautiful his music.
> Splendid are the gongs and drums;
> The Wan dance, very grand.
> [Waley, *The book of songs*, no. 213 (Shang Hymn, "Fine"). p. 225.
> For the Chinese version, see Ruan, 1980, p. 620]

The *gongs* in the original poem are *yong*-bells not circular *gongs*, suggesting that chime stones were associated with bells, drums and flutes, comprising a ritual orchestra to accompany the ceremonial dance in the Shang court. Stringed instruments like *qin* and *se* zithers dating to the Shang dynasty have not been uncovered archaeologically so it is likely that the musical combination of chime stones and stringed instruments appeared after the Shang dynasty.

From the Western Zhou dynasty (1046-771 BCE), three *yongzhong*-bells combined with several chime stones were found in Shaanxi Chang'an Zhangjiapo M163. Due to the poor condition of these instruments, there is no sonic or pitch comparison. Other bell-stone combinations also exist, such as the example of sixteen *yongzhong*-bells and ten chime stones were excavated from Shanxi Tianma Qucun M8, in the tombs of Marquis Su of the Jin state. The chime stones here can form scales using the B as tonic **do** (*gong* note), corresponding to one set of eight-part chime bells from the sixteen, showing that they may have been used in ensemble performed (BDKGXX et al.,1994a).

Besides bell-stone combinations, some tombs also contained wind, string and other kinds of percussion instrument in this era, for instance, six *yong*-bells, five bone panpipes and one chime stone in Henan Luyi Taiqinggong Changzikou's tomb; several chime stones accompanied with two *se* zithers and a pole drum stand from Hubei Zaoyang Guojiamiao M1. Bell and chime stone racks survived in this tomb, but bells were missing because of severe looting (Fang, 2015). From this it can be deducted that the bell-stone combinations began to appear in southern China during the Western Zhou period. In Shaanxi Hancheng Liangdaicun M27, one *chunyu*, one *zheng,* one pole drum, one small drum, and eight chime bells combined with ten chime stones were a good example of the assortment of instruments found together at this time (SXKGYJY et al., 2007). It seems that the ritual orchestra from M27 of the Rui state is relatively complete and substantiated. The key signature of the chime stones and chime bells matched well, to $^{\#}$D. They have the same tonality, with the same pitch of tonic *gong* note, which means they can constitute a musical ensemble (Fang, 2008).

Results detailed in Chapter 2 suggest the bell-stone combination during the Eastern Zhou period (770-256 BCE) was the most common association, both in the Yellow and Yangtze River valley areas. Furthermore, it appears musical ensembles contained highly complicated and varied instruments, as evidenced by the finding of wind, string, drum, bell sets and chime stones in one tomb; strings in particular are found in southern China. In the north, stringed instruments like *qin* and *se* zithers have been rarely discovered; one possible reason being that the burial environment in the northern area was too dry to preserve the wooden soundbox of the zithers.

From the funeral pit K5 in Gansu Lixian Dapuzishan, a set of ten chime stones, an eight-part *yongzhong*-bell set and three large *bo*-bells seem to compose an instrumental ensemble. The two sets of bells have the same tonic **do**; the key signature is C (Fang, 2010b). The ten chime stones, however, do not easily fit in with the musical ensemble because of different key signatures, from which the tonic **do** is at the position of E. It is not known whether the chime stones were interred with the wrong bells, or perhaps were to be used for playing musical tunes in another key.

In the south, ritual orchestras which included wind, string and percussion instruments have been excavated from several vassal states, for example Wu, Chu and Zeng states. The Wu state tomb in Jiangsu Dantu Beishanding contained 12 chime stones, 12 bronze bells (five *bo*-bells plus seven *niuzhong*-bells), three *chunyu*, one *zheng* and drum accessories (a suspension ring and a beating mallet). The poor condition of the bells and chime stones distorted the sound, and the resulting pitch analysis seems to be chaotic. *Chunyu* and *zheng* were played as bronze percussion instruments within ritual orchestras in earlier periods; according to classical texts *Guo Yu* (Discourses of the States)[62] they were subsequently used in warfare as signalling instruments or sound makers to beat a marching rhythm.

In Hubei Jiangling Tianxingguan Chu tomb M1, chime stones were found buried with a varied assortment of additional instruments. Besides the remains of several incomplete chime stones, four *niuzhong*-bells, five *se* zithers, six *sheng* mouth organs, one bird-and-tiger drum, one small wooden drum, one bell rack and one chime stone rack, six chime stone mallets, two bell mallets and two drum mallets have survived. The bell rack has twenty-two square holes for inserting each suspension loop of bells, showing that the original number of bells could be twenty-two, however, the tomb was robbed many times so the assemblage of musical instruments is incomplete.

Another Chu tomb in Hubei Zaoyang Jiuliandun M2 contained percussion, wind and string instruments, including nineteen chime stones, eleven chime bells, two drums (one bird-and-tiger drum), one *ya* (wooden percussion), one *zhu* (wooden percussion), one *chongdu* (bamboo percussion), four *chi* transverse bamboo flutes, two *paixiao* bamboo panpipes, four *sheng* mouth organs, five *se* zithers, one chime stone rack with two mallets, and one bell rack with four mallets. Unfortunately, most of the chime stones were broken into pieces, even so, they added to this display of the Chu ritual orchestra instrumentation.

62 *Guo Yu* "Jin Yu" and "Wu Yu". See Xu, 2002, p. 379, 550.

The most complex instrumental ensemble was discovered in 1978 in the tomb of Marquis Yi of the Zeng state; it reveals an astonishing understanding of the interplay between music capabilities, physics, acoustics, metallurgy and manufacture. Some 125 instruments, including one set of 65 tuned bells and a set of 32 chime stones suspended from ornate tiered racks, two *chi* transverse flutes, two bamboo panpipes, six *sheng* mouth organs, two *qin* and twelve *se* zithers, as well as four drums, were found. This comprised an ensemble that is the most sophisticated known from the early Warring States period (476-387 BCE). According to tone measurement of the chime bells (Hubei Provincial Museum, 1989, p. 110-115) and the inscriptional tone names on chime stones, bells and chime stones have the same *gong* note C (i.e. the tonic **do**). In such an ensemble, bronze bells and chime stones could therefore be played together in the same tonality. Most likely, wind, string and percussive instruments were accompanied by bells and chime stones in ensemble performance, although bamboo flutes, panpipes and zithers were all poorly preserved when excavated.

As introduced in Chapter 2, Western Han (202 BCE-8 CE) chime stones were found with musical bells, wind and stringed instruments excavated from four large tombs: the Luozhuang Han tomb in northeast Shandong, the tomb of Marquis Haihun in Jiangxi Nanchang, the Dayunshan Han tomb M1 in Jiangsu Xuyi, and the Nanyue King's tomb in Guangzhou Xianggangshan. The last three are all in the region of the Yangtze River valley. Except for the chime stones from Luozhuang, they were found in poorly preserved condition and their sounds could not be recorded and measured. It is therefore difficult to explore the musical relation between chime stones and other kinds of instruments in the orchestras found here. Fortunately, six sets of chime stones from the Luozhuang Han tomb provide us with extremely rich data of tone measurement (see Chapter 8), which allows discussion of interaction with other musical instruments. Some percussion and stringed instruments, such as drums, *qin* and *se* zithers, were found to be decomposed when unearthed. However, other percussion usually used as rhythm instruments in ensemble performance, such as *ling* clapper-bells, rattles, bronze *chunyu* and *zheng*, were in well preserved condition.

The chime bells from Luozhuang were an important component of bell-stone assemblage or "metal and stone music". According to tone measurement, the *gong* note (the tonic **do**) of the tuned bells is $^{\#}$D (Fang, 2011). It is strange that none of the six sets of chime stones is in tune with the chime bells, therefore, both kinds of instruments from Luozhuang could not be played in ensemble performance. Perhaps bells and chime stones were casually put together as grave goods; in spite of this, their coexistence in this tomb remains valuable for understanding instrumental combinations in the Western Han ritual orchestra.

To sum up, during the Neolithic period the chime stone was used singly as an instrument which was sometimes played with other percussion, such as the crocodile skin and pottery drums found at the Taosi site. It is also possible that a chime stone placed alone in a tomb without any other accompanying instruments may have also served as a sound tool or signalling instrument. During the Shang dynasty (ca. 1600-1046 BCE), instrumental combinations became variable. In addition to drums, chime stones were frequently found together with wind instruments such as clay ocarinas and percussion instruments such as *yong*-bells and *ling* clapper-bells. The *ling* was primarily used as a sound maker in ancient times, but it also served as an ornamental object for chariots and sacrificial animals, for example, the late Shang (ca. 1260-1050 BCE) tombs in Henan Anyang Yinxu Xiqu contained *ling* clapper-bells which were fastened onto the necks of dogs (ZSKKGSAYGZD, 1979).

During the Western Zhou dynasty (1046-771 BCE), a variety of musical instruments appeared in the ritual orchestra. Percussive instruments became more common; for example, *chunyu*, *zheng*, *bo*-bells and pole drums were all associated with chime stones. According to *Shi Jing* (The book of songs: the ancient Chinese classic of poetry, 900-700 BCE), the Western Zhou instruments might have included wind and strings:

> Din of drums and bells,
>
> Sound of the small zither, the great.
>
> Reed-organ and stone chimes make music together.
>
> There are songs of the capital [*Ya*], songs of the south [*Nan*],
>
> And flute[*yue*] unfaltering.
>
> (Waley, p.140, no.141.
>
> Note: Ya and Nan were probably the percussion instruments,
>
> and yue was not a flute but a panpipe)

Apparently, *se* and *qin* zithers, *sheng* mouth organ and *yue* 籥 were in the ensemble.

In both Eastern Zhou (770-256 BCE) and Western Han periods (202 BCE-8 CE), a large number of instruments made up a magnificent orchestra, showing that ancient Chinese instruments had developed in a prosperous phase. The best known example of such an orchestra was excavated from the tomb of Marquis Yi of the Zeng, which showed that chime stones could combine with many different types of instruments in ensemble performance. The presence of various sorts of instruments may also have been allocated according to the preferences of the tomb owners, and to denote prestige. From the late Shang (ca. 1260-1050 BCE) to the Western Han (202 BCE-8 CE), wind instruments including clay ocarinas, transverse flutes, panpipes and mouth organs became more common. The clay ocarina appeared more frequently than other wind instruments in the northern area, whereas in southern areas, transverse flutes, panpipes and mouth organs are more regularly found. Various categories of combinations could achieve a higher level of expressiveness in musical performance, and chime stones were indispensable in the ensembles of the ancient court.

10.2 Chime Stones in Ritual Music

Chime stones and bronze bells, as ritual and musical instruments of "metal and stone music", constitute a ritual orchestra together with wind instruments, strings and other percussion. In the process of ritualization, music, sound and dance were the intermediary for communicating between human beings and gods, and instrument playing had become an important component of rites of passage and ritual performance. This section will address the employment of chime stones in ritual activities, with particular focus on sacrificial occasions in the courts of ancient China.

In the periods of Shang and Zhou, as the *Zuo Zhuan* records, sacrificial and military events affected the whole country and played an important role in social and political life[63]. In ancient China, the sacrificial objects were comprised of items representing the heaven, earth and human beings, which corresponded with the god (deity), earth spirit, and the ancestor. During sacrifices, instrument playing was combined with other ritual

63 *Zuo Zhuan*: "Cheng Gong shisannian". See Ruan, 1980, p. 1911

performances and behaviours.

It is difficult to determine the ritual function of chime stones. Most of the remains found through excavation are bronzes and other vessels, although musical instruments are found. Textual sources are also limited, meaning that much detailed information about ritual procedures, participants and instrumental ensembles is impossible to obtain. Archaeological finds do however give us a ‘visual’ experience and their material presence can often compensate for a lack of documentary evidence, so we may still rely on unearthed instruments and those ancient textual sources that do exist to tentatively explore the ritual function of chime stones and other instruments.

Bruno Nettl has argued that the use of music to communicate with the supernatural appears to be a universal feature. In his words, “Universals in the conceptualization of music and in musical behavior are harder to isolate…Surely significant among them must be the association of music with the supernatural. All known cultures accompany religious activity with music” (Nettl, 2005, p. 46). Ancestor worship was the socialised belief system and the ideological foundation of the Shang (ca. 1600-1046 BCE) and Zhou dynasty and ancestral cults featured heavily in many ritual activities.

Some examples of chime stones from the period of the Neolithic to the Western Han (202 BCE-8 CE) were found: one in an early Shang (ca. 1600-1300 BCE) site, the palace and ancestral temple building in Henan Zhengzhou Xiaoshuangqiao; one engraved with a dragon decoration, buried near the site of the palace and ancestral temple building of the late Shang (ca. 1260-1050 BCE) in Anyang Yinxu Huanshui Nan’an; and one engraved with *kui* ornamentation was excavated from the site of the palace and ancestral building in Fufeng Zhouyuan Shaochen Yiqu (HNWYS, 1993; ZSKKGSAYFJD, 1976; Luo, 1987). These finds suggest that chime stones were most likely played in palaces and ancestral temples.

The features and functions of these chime stones are closely related to the nature or function of the palace and ancestral temples themselves, which were a religious site for sacrifices to the ancestors; one manifestation of ancestor worship. The ancestral temple was where ancestral cult activities took place in the Shang and Zhou dynasties. Objects such as chime stones being found at the site of ancestral temples reveals that they functioned ritually and that music and sound was used to communicate between ritual participants and ancestral deities. These were high status ritual objects used in temples and palaces, not everyday objects found in ordinary homes.

According to *Zhou Li*, instrumental music accompanied with singing and dancing was performed in the ancestral temple during rites of sacrifice to the ancestors (Ruan, 1980, p. 787-790)[64]. In this text, instruments including drum, bamboo flute, *qin* and *se* zithers are mentioned, but chime stones and musical bells are omitted. "metal and stone music", however, was an integral part of ritual music performance, both in elegant music *yayue* in the court, and music in the rites of ancestral cults. In the classic poem *Shi Jing*, the chime stone appears several times, whilst Kern asserts "The 'fixed and repeatable' nature of poetry is well demonstrated by the preservation of the *Shi Jing* itself. This corpus of musical poems and ancestral hymns was intended for memorization from an early age" (Kern, 2008, p. 260). The poem also reflects the ancestral cult of the Zhou court, for instance, *Shi Jing* "Zhousong Zhijing" describes a ritual for the sacrifice of the Wu Wang, King Wu 武王 of the Western Zhou dynasty (1046-771 BCE):

> Terrible in his power was King Wu;
>
> None so mighty in glory.
>
> Illustrious were Cheng and Kang
>
> Whom God on high made powerful.
>
> From the days of that Cheng, that Kang,
>
> All the lands were ours.
>
> Oh, dazzling their brightness!
>
> Let bell and drum blend,
>
> Stone-chime and pipes echo,
>
> That rich blessings may come down,
>
> Mighty rich blessings come down.
>
> Every act and posture has gone rightly,
>
> We are quite drunk, quite sated;
>
> Blessings and bounties shall be our reward

64 *Zhou Li: Chunguan* "Dasiyue".

(Waley, 1937, p. 230, no.222.

For the Chinese version, see Ruan, 1980, p. 589).

In this verse, an instrumental ensemble, including chime bells, drums, chime stones and flute, performed during the sacrificial ceremony. The descriptive poem in Chinese contained onomatopoeic words such as “huanghuang” and “qiangqiang” to simulate the sounds of bells, drum, chime stones and flute; it suggests a spectacular scene of ritual performance.

In *Shi Jing* “Zhousong Yougu”, chime stones are played in an ensemble in the temple courtyard during a ritual ceremony of the ancestor cult:

Blind men, blind men

In the courtyard of Chou.

We have set up the cross-board, the stand,

With the upright hooks, the standing plumes.

The little and big drums are hung for beating;

The tambourines and stone-chimes, the malletbox and scraper.

All is ready, and they play.

Pan-pipes and flute are ready and begin.

Sweetly blend the tones,

Solemn the melody of their bird-music.

The ancestors are listening;

As our guests they have come,

To gaze long upon their victories

(Waley, p. 218, no. 205.

For the Chinese version, see Ruan, 1980, p. 594-595).

In this ensemble, various instruments are played for the ancestors’ in the Zhou court.

Burying musical instruments in tombs was a kind of funeral fashion in ancient China. According to *Lüshi Chunqiu*, the bigger the state, the richer the home, and the richer the funerary objects. The pearls of the deceased, the jade clothes they wore, their treasures, musical instruments and weapons were countless. The burial objects also include devices for health care (Chen, 1984, p. 525). Besides various funerary objects and musical instruments, human and animal sacrifices were also buried in tombs. For example, in the Shang kings' mausoleum, young boys and girls, horses and dogs were buried alive with the dead in the tomb of M1001, M1004 and WKGM1, all of which contained musical instruments. The late Western Zhou (877-771 BCE) tombs M8, M64 and M93 in Shanxi Tianma Qucun contained chime stones and other instruments as well as several funeral pits for sacrifices in front of the main burial chambers. In the chariot pit attached to M8, horses, cows, dogs and young boys were buried (Li, 1997).

This phenomenon is evidence of the belief system that the soul is immortal after death. The ancient Chinese believed that the dead person would live in the other world as in real life. To transfer the supplies of the living world into the underground was an effective way for the deceased to continue enjoying the luxuries of when they were alive. When chime stones and other instruments are placed into the side compartment of the tomb, they pass into the afterlife with the tomb owner. As Ingrid Furniss describes: "It is the maintenance of deceased comfort and pleasure in the afterlife" (Furniss, 2008, p. 155).

Objects found in sacrificial pits also reflect the worship of ancestors. Dating to the early Spring and Autumn period (770-686 BCE), a sacrificial pit K5 excavated from Qin Gong cemetery in Gansu Lixian Dapuzishan contained only musical instruments without any other artefacts; it included ten chime stones, eight bronze bells, three *bo*-bells as well as bell hooks and chime racks. Bronze bells and chime stones were buried together as if a musical performance was being staged. Surrounded by four human sacrificial pits, K5 is the most important. It is rectangular in shape, 2.1 metres wide and 8.8 metres in length and is located close to tomb M2 where Xian Gong (a king of the Qin state) is buried. As discussed in Chapter 2, a similar funeral instrument pit (P14) was found near to the Western Han tomb in Zhangqiu Luozhuang; it was one of 37 funereal and sacrificial pits around the tomb. Some pits contained pottery figurines and animal sacrifices, pit 14 contained only musical instruments including 107 chime stones, embodying the belief that they functioned as sonic objects to play in the ritual performance of the afterlife, and indicate the tomb occupier's status in the beyond.

The content of bell inscriptions recorded from the Western Zhou (1046-771 BCE) epigraphic *yongzhong*-bells, also indicates their use in ancestral worship. For example, the Lu Yuan-bell 魯原鐘 inscribes that “Lu Yuan made tuneful and harmonious bells for the purpose of sacrifices to the ancestors” (ZSKKGS, 2001, p. 8); and the Shanbo Taisheng-bell 單伯昊生鐘 clarifies that the “[bells] was for the use of making offerings to the ancestors” (ZSKKGS, 2001, p. 48). Similarly, inscriptions on chime stones also reflect ancestral worship. For instance, some of the chime stones from the Qin Gong no.1 tomb in Shaanxi Fengxiang Nanzhihui are inscribed with words about the earliest ancestor Gao Yang 高陽 of the Qin state, the god and the temple, involving sacrificial objects and location (Wang, Jiao & Ma, 1996). In addition, the inscriptions on chime stones housed in Zhuhai Handong Museum reflect that all 14 chime stones came from different ancestral temples, and were kept for the purpose of performance during ancestor cult activities (see also Chapter 8).

“Music has evolved to meet many diverse functions and to show immense cultural diversity” (Mithen, 2006, p. 273). Indeed, instrumental performance was not only used to amuse the ancestral deities during ritual processes, but to entertain the ritual’s participants. Besides the rites of ancestor cults, chime stones accompanied musical bells and many other instruments played in the ritual of *yanyue* banquet music, hence they also had an entertainment function. This practice is mainly evidenced in historical documentation, and few archaeological finds support this idea. Even so, we can still acquire some information from iconographical sources unearthed from tombs. For instance, a Warring States (475-221 BCE) pictorial bronze pot housed in the Palace Museum in Beijing, with a pattern of fishing, hunting and dancing, shows one chime rack suspending five chime stones for the right hand, four chime bells for the left hand, and a *jiangu* pole drum on the right. Together with a feasting scene on the upper tier, they depict a banquet music performance (WWDXBJB, 1996e; see fig. 82 in Chapter 6). Similar banquet music images are also shown on a bronze *jian* in Henan Huixian Zhaogu M1 (see Chapter 6 for details).

10.3 Chime Stones and Cultural Context

As Geoffrey Hindley suggests, “in most regions, both voice and musical instruments have a ritual and symbolic value” (Hindley, 1971, p. 17). In ancient China, the system of ritual and music (*Li Yue* Zhidu) contained two parts: the Li (rites or ceremonies) and

Yue (music). As *Yue Ji* points out, "Music is (an echo of) the harmony between heaven and earth; ceremonies reflect the orderly distinctions (in the operations of) heaven and earth." [65] Although the Li was the hierarchical system in patriarchal society and determined the standing and status of the people, it also incorporated five categories of ritual events including auspicious rites (sacrifice etc.), inauspicious rites (burials etc.), military rites, hosting rites (court audiences etc.), and congratulatory rites (wedding, banquet, celebration, etc.). The Yue (music) specifically put music and dance in close connection with the Li, and affected the orchestral arrangement and the number of dancers present. As *Zuo Zhuan* elaborates, "metal and stone music represents the Li [rituals]"[66], suggesting that, as part of metal and stone music, the chime stone was not only a musical instrument, but also a ritual object with a powerful meaning. The bell sets and chime stones had become a materialised form of the rites and music.

According to *Zuo Zhuan*, these objects convey ritual significance.[67] Archaeological finds provide the evidence that objects such as ritual vessels and musical instruments were associated with social class and the tomb owner's status. For example, nine *ding* 鼎 (tripods) and eight *gui* 簋 (tureens) ritual vessels indicated the privilege of a king of the highest rank. The arrangement of musical bells and chime stones is a more sophisticated indicator of status, as it stipulates the strict suspension regulations in the *Zhou Li: Chun'guan* "Xiaoxu", that

> the Zhou king (wang) was entitled to "palace suspension" (gong-xuan): sets of bells and musical stones on all four sides of the courtyard of the ancestral temple; the Many Lords (zhuhou) governing the states surrounding the royal domain were entitled to "awning suspension" (xuanxuan): bells and musical stones on three sides of the courtyard; the ministers (qing) and magnates (dafu) were entitled to "divided suspension" (panxuan): sets of bells and musical stones on two facing sides of the courtyard; and the noblemen (shi) were entitled to "single suspension" (texuan): bells and musical stones suspended from a single rack on one side of the courtyard (Falkenhausen, 1993, p. 32-33. For the Chinese version, see Ruan, 1980, p. 795).

65 James Legge (translator) (2013). *The book of rites*. p. 174. For the Chinese version, see Ruan, 1980, p. 1530.
66 *Zuo Zhuan:* "Xianggong shiyinian". For the Chinese version, see Ruan, 1980, p. 1951.
67 *Zuo Zhuan:* "Chengong ernian". For the Chinese version, see Ruan, 1980, p. 1894.

Bronze bells and chime stones from Marquis Yi's tomb provide an example of "awning suspension" (xuanxuan) with a three sided arrangement, but a king's "palace suspension" (gong-xuan) has not yet been found archaeologically. The "single suspension" (texuan), has appeared frequently in excavations. Ritual vessels and musical instruments, especially bronze bells and chime stones, had become symbols of social elites, a badge of rank. The chime stones together with musical bells were representations of the upper class, and such a system of ritual and music could consolidate and strengthen the hierarchical system of the feudal society in ancient China. The number of bells and stones you had indicated how high you had risen in the social strata.

As for the performance of ritual dance, the Zhou dynasty also had a stipulation for the number and formation of dancers. According to the regulations, the prince (tianzi) has eight rows, each with eight dancers, totalling 64 ("Ba Yi" 八佾[68]); for the Duke (gong), there are six rows, each with six dancers, totalling 36; the Marquis (zhuhou) has four rows of four dancers, totalling 16. The number of dancers was allocated according to different rank of nobility, just like the arrangement of bells and chime stones in an orchestra.

The system of ritual and music (*Li Yue* Zhidu) is regarded as originating as early as the Western Zhou period (1046-771 BCE). As stated in the *Li Ji* (The book of rites, allegedly compiled by Dai Sheng in the Western Han dynasty), when King Wu died in the early Western Zhou (1046-977 BCE), his son King Cheng was so young that the Zhou Gong (younger brother of King Wen) acted as a king instead. In the sixth year of his reign, Zhou Gong met each Marquis at the Ming Tang temple, and established the system of ritual and music (*Li Yue* Zhidu).[69] So Zhou Gong has been regarded as the founder of this practice.

In fact, the ritual and music culture (*Li Yue* Wenhua) can be traced back to the late Neolithic period, for example with the chime stones, crocodile skin drums, and pottery drums excavated from the large tombs of the Taosi site. Aside from musical instruments, other significant items including a colour-painted ceramic plate with a dragon pattern, found in the tomb M3072, may have contained symbolic meaning as ritual objects, in

68 *Gongyang Zhuan* 公羊傳: *Yingong wunian*. See Ruan, 1980, p. 2207.
69 *Li Ji:* "Mingtang Wei". For the Chinese version, see Ruan, 1980, p. 1488.

a similar way to those bronze vessels that occurred in the subsequent Xia (ca. 2070-1600 BCE) and Shang dynasties (ca. 1600-1046 BCE. ZSKKGS & LFWWJ, 2015). In M3072, some clay artefacts and seashells were found together; one clay utensil with a strange shape was also found to be ornamented with a dragon motif. Furthermore, in M3016, two crocodile drums, one pottery drum, one chime stone and one coloured dragon decorated ceramic plate were placed together, comprising an assemblage of musical instruments and ritual items. These represented the artefacts of the Li and Yue in prehistoric China, suggesting that the chime stone was not only a musical instrument, but also a ritual object at that time, and for many years has been primarily a ritual item that conferred status.

In the Taosi site, more than 1560 funerary objects were excavated from the residential area, with pottery iems being the most common. It included 583 pottery containers for daily life, 181 pottery tools, 432 stone tools, 307 bone tools, and 17 shell tools. Four tombs (M3002:6, M3015:17, M3072:10 and M3016:39), which also contained chime stones and drums, occupied the highest status among all 1300 numbered tombs in the Taosi cemetery[70]. The excavation report reveals that the tomb occupant of M3015 was an adult male around 40 years old. Another younger person aged 22 was buried in tomb M3002. Both tombs have richer funerary paraphernalia (including musical instruments) than many other small tombs in this cemetery, suggesting that the tomb owner was possibly a chief of a tribe. At this time, chime stones, crocodile-skin and pottery drums, along with dragon ornamented ceramic plates, were symbols of power and social standing.

In the late Shang period (ca. 1260-1050 BCE), bronzes and instruments including chime stones were placed together in the tombs of those with titles, from kings to nobles. Judging from the late Shang tombs in Henan Anyang Yinxu, *yong*-bells and chime stones were important ritual objects and instruments symbolizing the social position and status of the tomb owner. Furthermore, both sorts of instruments, as representative of the “metal and stone music” of the upper class, were established with a fixed tradition in the political metropolis of the late Shang capital Anyang.

70 See ZSKKGS & LFWWJ, 2015. In addition, the M3073 was one of the five large tombs in which a crocodile drum was found, the chime stone was probably missing according to the excavation report.

In the Shang dynasty (ca. 1600-1046 BCE), archaeological finds have revealed that ritual objects and musical instruments embodied the relationship between the Li and Yue. In Fu Hao's tomb, for example, musical instruments were buried with 468 bronzes including ritual items and weapons. As Shang king Wu Ding's consort, Fu Hao was a military chief, the musical instruments and ritual bronzes she owned before her death were placed in her tomb so that she would enjoy them in the afterlife. In Fu Hao's tomb, five *yong*-bells and five chime stones is by far the largest number of these instruments of metal and stone music found during the late Shang period. The bell-stone combination conveyed extra-musical significance.

In Henan Anyang Guojiazhuang M160, besides one chime stone and three *yong*-bells, 44 bronze ritual vessels were unearthed. Among them, 41 have inscriptions (ZSKKGS, 1998). The most important bronzes such as the *ding*, *hu* (pot), *jiao* (wine cup) and *fangzun* (wine container) have inscriptions. These significant funerary objects indicate that the tomb owner may have been an aristocrat in the Shang society. As Needham and Wang have highlighted, "When the man of breeding listens to the timbre (of different sorts of instruments) he does not listen merely to their clanging and tinkling, but he is also sensitive to their associations" (Needham & Wang, 1962, p. 153). This shows the importance of the social connections of musical instruments.

According to inscriptions on the ritual vessels and musical instruments, the tomb owner of Guojiazhuang M160 was Ya Zhi, and the tomb owner of Huayuanzhuang M54 was Ya Chang. In the record of *Shang Shu* 尚書 (Venerable documents from antiquity)[71], Ya 亞 refers to a senior military officer in the Shang period[72]. Therefore, the tomb owners from both M160 and M54 are likely to have been military leaders.

The type of burial and accompanying funerary objects can reflect certain institutional norms and ritual significance. In the high status tombs of the Shang dynasty (ca. 1600-1046 BCE), not only instruments were buried, but also other daily necessities enjoyed by the tombs' occupants. The variety of rich funerary objects is an expression of the reverence, love and remembrance that people had for the tomb owners at that time.

71 Also known as *Shu Jing* (Classic of history), allegedly compiled by Confucius. See *Shang Shu:* "Jiugao" and "Mushi".
72 See Ruan, 1980, p. 183, 207.

As described in Chapter 2, the tomb owners had three different hierarchies during the Shang period: the kings, royal family members, and the nobles. Their tombs, in most cases, were found to contain chime stones and various burial furnishings, except for those that were looted before excavation. Therefore, the instruments buried in the tombs are more associated with court music or music in ritual performance rather than folk music.

In sum, the chime stones were a symbol of the identity and status of the tomb occupants, and, in some sense, had also become a constituent part of the paraphernalia of ritual. The high standard late Shang tombs found in the Yinxu ruins mostly included bronze weapons. Some tombs like Fu Hao's tomb, Guojiazhuang M160 and Huayuanzhuang M54 also included the large-sized bronze weapon *yue* 鉞, symbolising that the tomb occupant possessed military power.

In the Western Zhou period (1046-771 BCE), bronze bells and chime stones were the manifest combination of "metal and stone music", which was a significant component of the system of ritual and music (*Li Yue* Zhidu). Zhou Gong created this system, according to historical literature. The system of ritual and music (*Li Yue* Zhidu) may have origins in the late Neolithic and was developed in the Shang dynasty (ca. 1600-1046 BCE). The textual record involving the story of Zhou Gong and *Li Yue* Zhidu may be understood to say that Zhou Gong had not only reformed and updated the system of ritual and music, but that his contribution to ancient Chinese ritual music culture should be approved.

The kings' tombs of the Western Zhou dynasty have not yet been uncovered, so we do not know the assemblage of chime stones and other instruments in the tombs belonging to kings. Nevertheless, some Western Zhou bronze bells found in hoards provide information that the owners of the bells included kings and royal family members; for example, the Wusi Hu 五祀㝬 bell (Mu & Zhu, 1983) and Zongzhou bell 宗周 (ZSKKGS, 2001, p. 226-227) belonged to the King Li of the late Western Zhou (877-841 BCE). Given the importance of "metal and stone music", chime stones were certainly a component of bell-stone combinations in the Zhou kings' ritual orchestra. The tombs of high ranking nobles have included chime stones, bronze bells and many other instruments, which were the possessions of these local rulers. For instance, Changzikou's tomb from Henan Luyi Taiqinggong belonged to the Zi 子(viscount) of the Chang state; the tomb occupants of M91, M64 and M93 from Shanxi Tianma Qucun were the different Marquises of the Jin state from generation to generation. Similarly, the owners of three tombs (M2009, M2001, M2011) from Henan Sanmenxia were the different monarchs arranged according to the rule of the royal system in the Western Zhou dynasty.

Combined with other instruments and ritual vessels, there are a number of chime stones from the Eastern Zhou dynasty (770-256 BCE) located in local rulers' tombs. The most famous examples are the Marquis Yi's tomb of the Zeng state, the Chu state tombs in Henan Xichuan Xiasi and the Jiangling Ji'nancheng, from which large amounts of funerary objects including musical instruments, bronze ritual vessels, ceramics and utensils were excavated. In the Eastern Zhou period, the system of ritual and music (*Li Yue* Zhidu) was not strictly adhered to by some local rulers; they display luxury funeral objects including musical instruments, showing that they enjoyed ritual music beyond regulation during their lifetime. In contrast, some medium and small Chu state tombs in the south only contained a few wind and string instruments, or the signalling bronze percussion instruments (e.g. *zheng* and *chunyu*) without chime stones and bells, suggesting that the occupants of these tombs' were most likely nobles and elites with lower status than tombs which included chime stones and bells.

In large tombs of the Western Han dynasty (202 BCE-8 CE) many chime stones and other instruments were still found, for example, the Luozhuang Han tomb and the Nanyuewang tomb; both tombs' owners were local rulers. The combination of bell-stone instruments embodies "metal and stone music" and the continuation of the ritual music system into this later period. Sometimes the real instruments were not buried as funerary objects, instead the *mingqi* ceramic substitutions of bells and chime stones as well as *se* zithers were placed in the tombs, and sometimes musical instruments merely appeared as visual art, suggesting that ritual customs and practice had changed.

In conclusion, the musical instruments excavated from the tombs of the Shang (ca. 1600-1046 BCE) and Zhou dynasties were practical musical instruments played in daily life, and decorative replica models, such as pseudo instruments were rarely seen. Pseudo musical instruments gradually occurred after the Eastern Zhou dynasty and became more common in the Han dynasty (202 BCE-220 CE). This replacement was the transformation of ritual and burial practice. It made the musical instruments in tombs more symbolic, and showed that the people at that time were more frugal in financial and material resources. Presumably it is the reason that we find increasing numbers of unplayable chime stones appearing from the late Warring States (475-221 BCE) to the Western Han period (202 BCE-8 CE).

The system of ritual and music (*Li Yue* Zhidu) of the Zhou dynasty was founded on the basis of the preceding system of the Shang dynasty. This system is one that strengthens the dominant position of government and consolidates the hierarchy of ancient China. The aim of the *Li Yue* Zhidu was to prevent social and political disorder. As *Xun Zi* 荀子 (Master Xun) claims: "The ancient Kings abhorred such disorder; so they established the regulations contained within ritual and moral principles in order to apportion things, to nurture desires of men, and to supply the means for their satisfaction…" (Knoblock, 1999, p. 10).

Apparently, the earliest combination of bell sets and chime stones as ritual musical instruments formed in northern China during the Shang dynasty, and then gradually spread into southern China from the late Shang (ca. 1260-1050 BCE), and flourished in the Eastern Zhou period (770-256 BCE). As a part of "metal and stone music" in ancient China, chime stones represented the hierarchy of social elites with high-ranking status, especially in pre-imperial China. With an extra-musical function, chime stones had become a symbol of power, standing and wealth in ancient Chinese society.

10.4 Summary

Chapter 10 discusses the ensemble circumstances of chime stones in ritual music and cultural context. My study suggests that chronologically there were different ensemble modes or combinations of instruments. As a part of "metal and stone music", chime stones frequently coexisted with other musical instruments. Together with chime bells, they represented the high status of tomb occupants in ancient China.

Chapter 11: Conclusions

Chapter 11 summarises the study, its contributions to the field, with a view to future research, and draws conclusions.

11.1 Summary of the Thesis

The chime stone is one of the oldest musical instruments in ancient China. In the late Neolithic period, the chime stone coexisted in the same tombs with the crocodile-skin drum and pottery drum, constructing a percussive musical ensemble. Bronze Age chime bells first appeared during the Shang dynasty (ca. 1600-1046 BCE), together with chime stones they were the representation of "metal and stone music" in pre-imperial China. Chime stones and chime bells were the leading and most commonly seen musical instruments in the ancient royal court, and they constructed a ritual orchestra with other kinds of musical instruments, creating an ensemble of ritual music.

Archaeological evidence shows that chime stones appeared as early as the late Neolithic in the region of the Yellow River valley, however they were separately distributed and found mainly in the middle and upper area of the basin. The majority of the Shang dynasty chime stones were found in its capital city of Anyang, as well as adjacent areas including the Shanxi, Shaanxi and Shandong provinces, where a number of tombs containing chime stones and other instruments have been archaeologically excavated. In the north and north-east of China, chime stones belonging to the Lower Xiajiadian culture have been uncovered from the western part of Liaoning, the eastern part of Inner Mongolia and the northern part of Hebei. The date of this archaeological culture is approximately contemporary with the end of the Shang dynasty and the beginning of the Western Zhou dynasty (1046-771 BCE) in the Central Plain area.

During the late Shang dynasty (ca. 1260-1050 BCE), the distribution of chime stones widened, from areas in the north to include the Yangtze River basin of southern China, although they were rarely found in Sichuan and Hubei provinces. Western Zhou (1046-771 BCE) chime stones were mainly found in its political centre and metropolitan area of Shaanxi, and also some vassal states at its peripheries. In addition to the Shaanxi

Fufeng Zhouyuan, where the royal court was located, other vassal states around this area like Jin, Guo and Chang also had chime stone finds. In the south, a few of the Zeng state's chime stones were excavated from Hubei. During the Eastern Zhou period (770-256 BCE), chime stones were widely distributed in the Yellow River and Yangtze River basins, and there were large number of discoveries. In the north, chime stones were primarily found in the vassal states of Zhou, Jin, Han, Rui, Ying, Qin, Zhongshan, Qi, Ju, Shi, Teng and Xue; in southern China, they were mainly distributed in the vassal states of Chu, Zeng, Zhongli, Wu and Yue. Following the Warring States (475-221 BCE), in the Western Han era (202 BCE-8 CE) chime stones continued to be used and developed. Due to changes in funeral customs, burial of the practical instruments themselves gradually declined, and instead *mingqi* unplayable instruments such as ceramic chime bells, pottery chime stones and clay *se* zithers were used as funerary objects. During the Eastern Han dynasty (25-220 CE), real musical instruments were rarely seen in tombs and largely disappeared in funerary practice. Conversely, musical iconographic sources like stone carving, wall painting and terracotta figurines depict images and scenes of real instrumental performances, changing and replacing the traditions of burial. Overall, this research suggests that chime stones originated from the Yellow River valley and spread out into the Yangtze River valley in particular, before spreading across China and beyond.

With regard to the utilization of manufacturing materials, the chime stones are usually made in stone. There were some *mingqi* pseudo versions such as ceramic and wooden productions, and the substitution of porcelain or glass-made chime stones, which may have been used in performance, but this needs further experiment for evaluation. This thesis focuses only on the stone-made chime stones. From a typological perspective, I divided the chime stones dating from the Neolithic period to the Western Han dynasty (202 BCE-8 CE) into two types, each of which is further divided into subtypes. My classification criteria are mainly based on the shape of the top edge of the stone, which falls into two categories of type A and type B. Type A has an irregular shape with two subtypes: A-1 (the straight top) and A-2 (the non-straight top). Type B is shaped with an angular top, and has three subtypes of B-1 (the straight base), B-2 (the curved base) and B-3 (the angled base). In the examples that were studied for this research, there are only one musical chime stone that has been found with angular rather than straight or curved bases, however, unearthed pseudo-wares, as well as images that relate to chime stones, do have this type of base, and the much-later chime stones of the Ming (1368-1644 CE) and Qing dynasties (1636-1911 CE) all had angular bases. It seems that this was the final evolved shape of chime stones.

The earliest stones found appeared in the Neolithic and were singly used chime stones of an irregular shape and large size. This shape was the most common until the late Western Zhou dynasty (877-771 BCE) and then disappeared. Chime stones shaped with an angular top appeared in the Xia dynasty (ca. 2070-1600 BCE) and extended to the Western Han dynasty (202 BCE-8 CE). The subtype of B-1 (the straight base) was popular from the late Shang (ca. 1260-1050 BCE) to the end of the Western Zhou, and it then disappeared at the beginning of the Spring and Autumn period (770-686 BCE). The curved base of subtype B-2 occurred from the Spring and Autumn period (770-476 BCE) and persisted till the late Western Han dynasty. This subtype became the established form of chime stones, culminating in both the Eastern Zhou (770-256 BCE) and Western Han dynasties (202 BCE-8 CE). This new typology helps to better understand the main developments in chime stone design, providing a clearer way to group the different shapes.

Chime stones probably originated in the region of Yellow River valley, and their creation may be related to a particular functional tool. Some slab-shaped stone tools can be struck to produce sound, which may have motivated people of this period to play them as sound tools or musical instruments. In the course of the development of this instrument, two periods were thus differentiated, with the coexistence of a Multi-type period and Uni-type period. The former ran from the Neolithic period to the Western Zhou dynasty (1046-771 BCE), while the latter, the unified pentagonal shaped chime stones, were established from the late Shang to the Western Han dynasty. In the early stage of the Uni-type period, the unified type of chime stones was shaped with a straight base, which was gradually replaced by curved based chime stones in the Spring and Autumn period (770-476 BCE). The reason why the type B-2 superseded other types is that this type has unique advantages and characteristics: the *gu* part is naturally slanted when suspended, with a relatively uniform angle of inclination for easy striking. In addition, the curved bottom edge can be ground as a part of the tuning process.

This thesis also compares the ratios of various parts of chime stones recorded in the classical text *Kaogongji* with the real objects that have been unearthed. After mathematically calculating and comparing, it can be seen that the *Kaogongji* contains general specifications on making chime stones, but does not provide a unified standard. It is likely that the specifications recorded in the *Kaogongji* produce a semi-finished stone, which after grinding and tuning has different measurements and ratios than those specified in *Kaogongji.* Having said this, on examination, the ratios of Qi state chime stones were found to be very similar to the *Kaogongji* and some scholars propose that the classical text *Kaogongji* is an official book recording the production of the Qi handicraft industry, thus it is referenced in some detail. The ratios of chime stones in other regions were also close to that of the *Kaogongji,* indicating that the manufacturing industry in the Eastern Zhou period (770-256 BCE) was relatively uniform. Nevertheless, chime stones from different regions and vassal states have certain differences in shape. For example, the chime stones of the Qin state show a curved *gushangbian* and *guushangbian*, while the chime stones of the Zhongli state have an imitation of the shape of an animal's head in the *gu* part. Also from the late Shang dynasty (ca. 1260-1050 BCE), inscribed chime stones began to appear. Some had inscriptions relating to historical events, others involved the division of groups and the hanging positions of chime stones from the rack, or indicated musical theories including pitch names and the nomenclature of the *twelve-lü* tuning system. The surfaces of chime stones evolved from the early period with no decoration to include ornamentation (painting or engraving) in later periods. Zoomorphic patterned ornamentation on the surface of chime stones includes real world animal images such as tigers and fish, as well as fictitious animal images. These decorative motifs on chime stones may have some metaphoric meaning to symbolize the rebirth of the deceased.

Chime stones were made from a range of materials in the early developmental stage from the late Neolithic period to the Shang dynasty (ca. 2400-1046 BCE); craftsmen chose different stone materials. The main issues were whether the sounds of stone materials were suitable to be used, and then whether the material was suited to simple processing. At this time, the flaking method was mainly used, and as a result, the appearance of knapped-stone artefacts is irregular and rough; this manufacturing method lasted into the Western Zhou dynasty (1046-771 BCE). From the late Shang period (ca. 1260-1050 BCE), limestone was commonly used, based on a long term tradition of manufacturing and performance practice. Such calcareous material is chosen since it is widely distributed and easy to obtain, especially in the Yellow River and Yangtze River areas. Limestone properties of medium density and easily flaked-off layers corresponded with the demand for manufacturing slab-shaped chime stones.

The design and manufacture of type B chime stones may have some ties with triangular shapes. It has been speculated that the material of flaky limestone was selected first, then a triangle was used as the frame with the two acute angles cut off, until the eventual convex pentagonal shaped chime stone was formed.

Polished chime stones appeared in the late Shang period, a manufacturing method which utilised a grinding method was used thereafter. Although the grinding method became common, flaked chime stones did not disappear immediately. Instead, they lasted for a long time into the late Western Zhou period (877-771 BCE), when some flaked chime stones were still found. Tools used for grinding stone utensils used in daily life had appeared extensively in the late Neolithic, but chime stones were still being made by the flaking method; so it is likely that chime stones may have had a certain hysteresis in their manufacturing technique compared with other stone artefacts at that time. Whether the chime stones were roughly produced or finely crafted may have been a result of their relationship with either the wealth or status of the tomb occupant. Moreover, there were also certain imbalances in the chime stones' craftsmanship employed in various regions. These are some of the reasons why the early chime stones, especially the singly used ones, show different qualities of manufacture.

After groups of chime stones appeared, their sound properties improved. In order to maintain accurate pitches in a set of chime stones and to play with other instruments in an ensemble, the pitches need to be fine-tuned. The initial tuning process relied mainly on the grinding of the chime stone body. The aim was to change their size and thickness, but at this point in time there was no fixed tuning position to grind. After the Spring and Autumn period (770-476 BCE), tuning was concentrated on grinding the bottom edge, as a result, the chime stone developed from a flat to an arched base.

Chime stones in most cases were suspended from a single tier wooden rack, or uncommonly a bronze one. The frame of a chime stone rack is generally about one metre in height; musicians performed while kneeling on the ground. Such a playing position is supported by some pictorial bronze vessels. The tool for playing chime stones is the wooden T-shaped mallet, musicians could use one or two mallets, in one hand or both, to beat chime stones while performing. According to acoustic experimentation, the best striking point on chime stones when they are suspended is the *gushangjiao*.

In the Neolithic period, all chime stones were singly used rhythm instruments. During the Shang dynasty (ca. 1600-1046 BCE), groups of chime stones began to appear, which coexisted with the single chime stone till the late Western Zhou dynasty (877-771 BCE). Three in a group was the earliest combinational form, and ten in a set appeared in the late Western Zhou times. Since most of the Western Zhou (1046-771 BCE) chime stones were in a state of decay when unearthed, it was difficult to determine their combinations by making pitch measurements. Therefore, there may be other combinations to be made between three and ten, which will be subject to future archaeological discoveries and research. From the Eastern Zhou (770-256 BCE) to the Western Han period (202 BCE-8 CE), ten chime stones in a set became the widely popular form of combination. At the same time, 13 and 20 (or rather a 10+10 combination mode) chime stones in a set began to appear. The largest number of chime stones is a set of 32 pieces unearthed from the Marquis Yi's tomb. With a two-tier bronze chime rack, 16 pieces (6+10 mode) are suspended from both upper and lower tiers. In addition, a number of combinations such as seven, eight, nine, twelve, and fourteen has also been found, but each is a single case.

Through fieldwork investigations on a number of excavated chime stones, I measured their sizes, recorded their sound and obtained pitch and frequency data of their fundamental pitch and other partials. From the Neolithic period to the Shang dynasty, the sound of singly used chime stones ranged across three octaves. Although the size of these single chime stones is larger than those of the Eastern Zhou (770-256 BCE), it is still a high-pitched musical instrument. The sound register of the chime stones in the Eastern Zhou is also across three octaves; as a melodic instrument, the sound register is rather wide.

Chime stones have particular scale structures and mode tendencies. These developed from a three note series in the late Shang (ca. 1260-1050 BCE) to the pentatonic scale in the late Western Zhou period (877-771 BCE). After the Eastern Zhou dynasty, some sets of chime stones could construct a heptatonic or hexatonic scale, but the pentatonic was the main scale structure of chime stones both in the north and south of China. Some scale structures of chime stones contained *qingjue* 清角(fa), *biangong* 變宮(si) and chromatic notes such as *bianzhi* 變徵 (sharp fa or $^\sharp$fa), but they are relatively rare, and are not the common components of scales; they may instead be related to local music traditions. Some inscriptions are engraved on chime stones with the names of the *twelve-lü* and the pentatonic scale, as well as the names of some chromatic tones. In particular, a large number of inscriptions reflecting the rich content of ancient Chinese music theory appeared on the Zeng Houyi chime stones. Despite there being inscriptions of the *twelve-lü*, the nomenclature of *twelve-lü* in the various vassal states in the early Warring States period (476-387 BCE) is still unclear. The inscriptions on chime stones of the Western Han dynasty (202 BCE-8 CE) also contained details of ritual music and dance performed in royal court, which could be confirmed with ancient documents. Research on the different scales and modes of chime stones constitutes a relatively new area for studying and better understanding the scale structure of different eras.

Analysing acoustic properties is an important part of sound research. By describing the fundamental tone and partials in the sound spectrum and exploring the relationships between timbre and the different base shapes of chime stones, some conclusions have been drawn. SPSS statistical analysis was used throughout to aid the research into relationships between dimensions and pitch. Experiments examining 65 chime stones showed that the first two partials had strong correlations with the dimensions of the chime stones. P2 has a slightly stronger relationship to measurements than P1 and correlated more with the shorter sections of the chime stone. It was also demonstrated that stones from the later period with a curved base could emit a purer sound with fewer, less strong partials beside the fundamental pitch; this was especially true of stones from the Eastern Zhou dynasty (770-256 BCE). Many partials were found close to the fundamental in the Shang dynasty (ca. 1600-1046 BCE) stones, so that their sound quality was distinctly different from the stones in the Western Han dynasty (202 BCE-8 CE). Contrasting theory and practice, the vertex angle of the stones does not seem to have a tight connection with fundamental frequency.

As a further experiment, sampled sound from chime stones, chime bells, clay ocarinas and *guzheng* zither as well as *di* flute, were used to recreate a traditional Chinese tune. After examining the musical tuning systems that were present in three different sample groups, it was found that even after being buried underground for 2000 or more years, these stones are still accurately tuned using the *twelve-lü* system. A tentative suggestion of a standard reference tuning of 429-430 Hz bears further investigation.

Chime stones in ancient China were used in ritual orchestras and played in ensemble performances. The make-up of ensembles was explored in different eras in a chronological sequence. The single chime stone of the Neolithic was played together with crocodile skin drums and pottery drums. During the Shang dynasty (ca. 1600-1046 BCE), chime stones, together with the newly emerging bronze *yong*-bells, drums and clay ocarinas, constituted a ritual orchestra and became the earliest combinational form of “metal and stone music”. However, in southern China, the bronze bell was the main instrument in the Shang, while the chime stone was very rare, suggesting that the “metal and stone music” in the south appeared later than in the north. From the Eastern Zhou to the Western Han dynasty, chime stones and chime bells became important symbolic instruments in ritual orchestras, and were combined with other percussion, wind and string instruments. Some of the chime stones and chime bells are in tune with each other (have the same *gong* note), which means they could certainly be played together in an ensemble performance.

In ancient China, sacrificial events, especially those related to ancestral cults, were prevalent in the whole country and played a very important role in social life. Some chime stones are buried in the ruins of ancestral temples, some are from ritual and burial pits; their ritual functions are linked to death and to ancestors. According to ancient Chinese literature, musical instruments and dance performances are crucial parts of ritual activities. In the process of ritual practice, the participants expected music, sound and dance to be the intermediary for communicating with living and dead human beings, gods and spirits, and instrumental performance became an important component of rites of passage. Musical iconographic sources show that chime stones and bronze bells were also used customarily in entertainment performances during court feasts.

Late Neolithic tombs which contained chime stones and a large number of funerary objects suggest a higher status of the tomb owners. Chime stones at this period were not only a musical instrument, but also a symbol of the status of the tomb owner in the tombs of the Shang (ca. 1600-1046 BCE) through the Western Han dynasty (202 BCE-8 CE). The ancient Chinese system of ritual and music (*Li Yue* Zhidu) consists of two parts: Li (rite) and Yue (music). The Li helped establish the political; the Yue contained music and dance performance that existed in conjunction with the ritual. The configuration of the instruments was based on the status of the tomb occupant, which decided the numbers of chime bells and chime stones, and the number of ritual dancers. The system of ritual and music (*Li Yue* Zhidu) marked by the "metal and stone music" of chime bells and stones, is thought to have formed in northern China in the late Shang dynasty (ca. 1260-1050 BCE), and was adopted by the culture of the vassal states in southern China during the Western Zhou dynasty (1046-771 BCE). This system was reformed and updated in the early Western Zhou dynasty (1046-977 BCE), to be more strictly standardized. However, in the tombs of Marquises of the vassal states during the Warring States period (475-221 BCE), the configuration of the instruments showed that it had already exceeded the specifications defined by the Zhou court. Thus, as a part of the "metal and stone music", bronze bells and chime stones were not only musical instruments for playing ritual music, but also as ritual objects that have symbolic meaning and function for representing the power, standing and wealth of the upper class in ancient Chinese society. Ancient Chinese ritual music culture combined a reinforcement of the political hierarchy with music and dance in the royal court. As a means to govern the country, ritual music culture consolidated and strengthened the socially dominant position of the royal court.

11.2 Limitations

What is regrettable in my research is that some of the chime stones are in poor condition. First-hand musical sources are also hard to obtain. These are objective deficiencies that cannot be overcome. As ancient artefacts, burial beneath the earth has led to many defects and deficits. However, as Edgar Allan Poe said: "There is no exquisite beauty… without some strangeness in the proportion" (Goodreads, 2019). It is these imperfections that inspire me to conceive further research.

11.3 Directions for Future Research

Future research on chime stones could concentrate further on their sound properties. It would be useful to study the tuning systems and scales of the chime stones in conjunction with a study of chime bells. Types of software such as Odeon, a modelling system for simulating acoustics, could be used to study normalised recordings of chime stones, using impulse response (T60) to evaluate the duration of individual partials. The vibrational modes of chime stones could be researched by 3D modelling chime stones to explore their mode vibration. It would be useful also to apply some of the methods explored in this study to a significantly larger comprehensive data set of recordings of chime stones, for example to see if many sets fit the *twelve-lü* tuning system; to explore whether stones are tuned similarly in particular regions or times; and to look for developments over time. As a correlation between the dimensions of chime stones and their partials was found, it would be useful to try to identify a precise formula for how both fundamental pitches and other partials can be adjusted by the variation of specific dimensions. Finally, I would make a comparison between ancient Chinese chime stones and the lithophones in other countries, and explore the wider cultural significance and associations of these stone-made percussive musical instruments.

In general, the research on chime stones is complex work. The innovations and findings of this study have considerable implications for future research. It is also likely that more archaeological finds will be made which would be extremely valuable for future chime stone research.

11.4 Strengths of the Research

This research contributes to a comprehensive understanding of the chime stones in ancient China on both a technical and cultural level, showing that chime stones are significant musical instruments for a long period of Chinese culture. The completion of this thesis has involved extensive research on chime stones, and included a number of samples from the late Neolithic period to the Western Han dynasty (ca. 2400 BCE-8 CE).

One of the strengths of this thesis lies in its approach. It is the first comprehensive extensive research study that focuses exclusively on chime stones from this lengthy time period. It adopts a novel use of SPSS and RX software, to explore pitch series, scales and modes, as well as the relationships between partials and fundamentals, and how they relate to chime stone dimensions. The thesis is the first significant study of

Chinese chime stones published in English, and creates a new taxonomy, as well as collecting together previous research published largely in Chinese. Exploring the ratio of the dimensions of chime stones through comparison to the *Kaogongji*, and researching the manufacture, performance as well as assemblage and ensemble conditions of chime stones has also been significant. Based on the analytical frameworks employed, this research made evaluations of timbre not only by comparing the straight and curved base of chime stones, but also comparing the numbers of partials in different eras against each other. All materials used in this thesis are supported by reliable archaeological evidence, unless stated otherwise.

This thesis quotes a number of Chinese ancient literature sources as given examples to explain and confirm the experiments. Ancient literature relating to the discipline of epigraphy which depicted chime stones in early periods are, for example, *Kaogu tu* (Illustrations for inquiring into antiquity), *Bogu tu* (Bronzewares with pictures) and *Lidai zhongding yiqi kuanzhi fatie* (Assessment of bells, tripods, and other ritual objects from historical times). A number of historical poems have also been reviewed and a range of ancient textual sources revealed more about musical performance in antiquity, this includes works such as *Zhou Li*, *Shi Jing*, *Shang Shu*, the *Record of music in The book of rites*, *Zhanguoce*, *Lun Yu* and *Lüshi Chunqiu*.

My fieldwork produced a large amount of data which provides direct evidence for my findings and which can also be used for future research. This includes materials from Chinese museums and original sound recordings for analysis. Aside from fieldwork data, a comprehensive and exhaustive analysis of hundreds of specimens of chime stones, including their archaeological sites, periods and multiple categories of co-existent discoveries are presented in this thesis.

As a core symbol for social rank and authority, chime stones are one representative component of “metal and stone music”. They have important cultural and ritual significance and were significant enough to be buried with ruling people. Developing from the late Neolithic period through to the far later period of the Western Han dynasty, they continued to be treated as items of the highest value. Past studies on chime stones were limited, and very little was published in English. To create a better understanding of the chime stones, this thesis explored not just their pitch but also identified different scales and modes of various chime stones. The research is not just focused on the fundamental pitch, but includes partials analysis; it has put this together with an understanding of culture, significance and origins. All of this illustrates the complexity of chime stones. They are remarkable musical instruments that exemplify the sophistication of early Chinese music.

Bibliographies

Classical texts

Allegedly compiled by Confucius. (475-221 BCE) [1980]. *Shang Shu* [Venerable documents from antiquity] 尚書, also known as *Shu Jing* 書經. In Y. Ruan (Ed.), *Shisanjing Zhushu* [Annotations and commentaries on the thirteen classics, vol.20] 十三經注疏. Beijing: Zhonghua Shuju.

Anonymous. (Probably 3rd century BCE) [1980]. *Zhou Li* [The ritual system of the Zhou] 周禮. Beijing: Zhonghua Shuju.

Anonymous. (900-700 BCE) [1937]. *Shi Jing* [The book of songs: the ancient Chinese classic of poetry] 詩經. (A. Waley, Trans.). New York: Grove Press.

Anonymous. (Probably 3rd century BCE) [2014]. *Er Ya* [The oldest surviving Chinese encyclopedia containing commentaries on classics, names, etc] 爾雅. (X. Guan, Trans.). Beijing: Zhonghua Shuju.

Ban, Gu. (32-92 CE) [1962]. *Han Shu* [Book of Han] 漢書. Beijing: Zhonghua Shuju.

Chen, Qiyou. (1984). *Lüshi Chunqiu jiaoshi* [An interpretation of the annals of Lü Buwei] 吕氏春秋校釋. Shanghai: Xuelin Chubanshe.

Dai, Sheng. (Ed.). (Western Han dynasty) [2013]. *Li Ji* [The book of rites] 禮記. (J. Legge, Trans.). Intercultural Press.

Dai, Sheng. (Ed.). (Western Han dynasty) [2017]. *Yue Ji* [Record of music, in the book of rites] 禮記樂記. (P. S. Hu & M. Zhang, Trans.). Beijing: Zhonghua Shuju.

Disciples of Confucius. (475-221 BCE) [1910]. *Lun Yu* [The analects of Confucius] 論語. (W. E. Soothill, Trans.). Shanxi: Principal of the Imperial University.

Fan, Ye. (420-479 CE) [2007]. *Hou Hanshu* [Official history of Western Han dynasty] 後漢書. Beijing: Zhonghua Shuju.

Guan, Zi. (475 BCE-220 CE) [1968]. *Guan Zi* [Master Guan] 管子. Guoxue Jiben Congshu edition, Shanghai/Taipei: Shangwu Yinshuguan.

Knoblock, J. (Trans.) (1999). *Xunzi: A Translation and Study of the Complete Works* 荀子. Stanford, CA: Stanford University Press.

Liu, An. & hanger-on of Liu An. (around Western Han dynasty) [1927]. *Huainan Zi* [Lord of Huainan] 淮南子. Sibu Congkan edition, Shanghai: Shangwu Yinshuguan.

Liu, Xiang. (77-6 BCE) [1996]. *Chan-kuo Ts'e* [Episodes from the Warring States] 戰國策. (J. I. Crump, Trans.). Centre for Chinese Studies, the University of Michigan.

Lü, Buwei. (475-221 BCE) [2000]. *Lüshi Chunqiu* [The annals of Lü Buwei] 呂氏春秋. (J. Knoblock & J. Riegel, Trans.). Stanford University Press.

Lü, Dalin. (1092) [2016]. *Kaogu tu* [Illustrations for inquiring into antiquity] 考古圖. Shanghai: Shudian Chubanshe.

Ruan, Yuan. (Ed.). (1764-1849 CE) [1980]. *Shisanjing zhushu* [Annotations and commentaries on the thirteen classics] 十三經注疏. Beijing: Zhonghua Shuju.

Sima, Qian. (145 or 135 -90 BCE) [1993]. *Shi Ji* [The records of the grand historian] 史記. (B. Watson, Trans.) (3rd ed.). New York: Columbia University Press.

Wang, Fu. (1123) [2017]. *Bogu tu* [Bronze objects with pictures] 博古圖. Shanghai Shudian Chubanshe.

Xu, Shen. (58- 147 CE) [1981]. *Shuowen jiezi* [Explaining the graphs and analysing the characters] 說文解字. Shanghai: Shanghai Guji Chubanshe.

Xu, Yuangao. (2002). *Guoyu jijie xiudingben* [The explanation of guoyu revised version] 國語集解修訂本. Beijing: Zhonghua Shuju Chubanshe.

Xue, Shanggong. (1144) [1986]. *Lidai zhongding yiqi kuanzhi fatie* [Assessment of bells, tripods, and other ritual vessels from historical times] 歷代鐘鼎彝器款識法帖. Beijing: Zhonghua Shuju.

Yu, Xingwu. (1976). *Shuangjianyi guqiwu tulu* [The philological studies on ancient texts and findings] 雙劍誃古器物圖錄. Taiwan: Tailian Guofeng Chubanshe.

Zuo, Qiuming. (probably fourth century BCE) [2013]. *Guo Yu* [Discourses of the states] 國語. (T. Chen, Trans.). Beijing: Zhonghua Shuju.

Zuo, Qiuming. (probably fourth century BCE) [1980]. *Zuo Zhuan* [The commentary of Zuo] 左傳. In Y. Ruan (Ed.), *Shisanjing Zhushu* [Annotations and commentaries on the thirteen classics, vol.60] 十三經注疏. Beijing: Zhonghua Shuju.

Articles and Books

Adams, W., & Adams, E. (1991). *Archaeological typology and practical reality: A dialectical approach to artifact classification and sorting.* Cambridge: Cambridge University Press.

Allan, S. (2007). Erlitou and the formation of Chinese civilization: toward a new paradigm. *The Journal of Asian Studies,66*(2), 461-496.

An, Zhimin. (1955). Shiqi lueshuo [A brief explanation of stone-made artefacts]. *Kaogu Tongxun,* (5), 62-71.

An, Zhimin. (1986). Kaoguxue wenhua [The archaeological cultures]. In Ding. Xia & Zhongshu. Wang (Eds.), *Chinese Encyclopedia, Volume archaeology* (pp. 253-254). Beijing: China Encyclopedia Publishing House.

Andrefsky, W. (1994). The geological occurrence of lithic material and stone tool production strategies. *Geoarchaeology*, *9*(5), 375-391.

Anhui Provincial Institute of Cultural Relics and Archaeology & Bengbu City Museum. (2010). Anhui Bengbu Shuangdun yihao Chunqiu mu fajue jianbao [A brief report on the Spring and Autumn period tomb M1 in Anhui Bengbu Shuangdun]. *Wenwu (Cultural Relics)*, (3), 4-18.

Anhui Provincial Institute of Cultural Relics and Archaeology & Bengbu City Museum. (2013). Chunqiu Zhongli jun Bai mu fajue baogao [Excavation report on the king Bai's tomb at Zhongli state dated to the Spring and Autumn period]. *Kaogu Xuebao (Chinese Journal of Archaeology)*, (2), 239-282.

Anhui Provincial Institute of Cultural Relics and Archaeology & Heritage Management Office in Fengyang. (2009). Anhui Fengyang Bianzhuang yihao Chunqiu mu fajue jianbao [A brief excavation report on the tomb M1 dated to the Spring and Autumn period at Fengyang Bianzhuang in Anhui]. *Wenwu (Cultural Relics)*, (8), 21-29.

Anhui Provincial Institute of Cultural Relics and Archaeology & Heritage Management Office in Fengyang. (2010). *Fengyang Dadongguan yu Bianzhuang* [Fengyang Dadongguan and Bianzhuang]. Beijing: Kexue Chubanshe.

Arau-Puchades, H. (2012). Sound pressure levels in rooms: a study of steady state intensity, total sound level, reverberation distance, a new discussion of steady state intensity and other experimental formulae. *Building Acoustics*, *19*(3), 205-220.

Arnold, D. (1983). *The new oxford companion to music*, Vol.1. Oxford: Oxford University Press.

Archaeology Department of the School of History and Culture in Shandong University. (1998). Shandong Changqingxian Xianrentai Zhoudai mudi [The Zhou dynasty tombs at Changqingxian Xianrentai in Shandong]. *Kaogu (Archaeology)*, (9), 11-25.

Archaeology Department of the School of History and Culture in Shandong University & Shandong Provincial Institute of Cultural Relics and Archaeology. (2010). Jinan Daxinzhuang yizhi 139 hao Shangdai muzang [The Shang dynasty tomb M139 at the site of Jinan Daxinzhuang]. *Kaogu (Archaeology)*, (10), 3-6.

Archaeological Excavation Team of Anyang, Institute of Archaeology, Chinese Academy of Social Sciences. (1972). 1971 nian Anyang Hougang Fajue Jianbao [A brief excavation report on Hougang at Anyang in 1971]. *Kaogu (Archaeology)*, (3), 14-25.

Archaeological Excavation Team of Anyang, Institute of Archaeology, Chinese Academy of Social Sciences. (1976). Yinxu chutu de taoshuiguan he *shiqing* [The ceramic water pipe and the chime stone excavated at Yinxu]. *Kaogu (Archaeology)*, (1), 61, 16.

Archaeological Excavation Team of Fengxi, Institute of Archaeology, Chinese Academy of Social Sciences. (1987). 1984-1985 nian Fengxi Xizhou yizhi, muzang fajue baogao [The excavation report on sites and tombs of the Western Zhou dynasty at Fengxi from 1984 to 1985]. *Kaogu (Archaeology)*, (1), 15-32.

Archaeological Institution of Zhejiang & Changxing County Museum. (2007). Zhejiang Changxing Bizishan Yueguo guizu mu [The Changxing Bizishan Yue state aristocratic tombs in Zhejiang]. *Wenwu (Cultural relics)*, (1), 4-21.

Archaeological Institution of Zhejiang & Haiyan County Museum. (1985). Zhejiang Haiyan chutu yuanshi ci yueqi [The original porcelain-made musical instruments excavated at Haiyan in Zhejiang]. *Wenwu (Cultural relics)*, (8), 66-72.

Archaeological Team of Chifeng, Institute of Archaeology, Chinese Academy of Social Sciences, Inner Mongolia Institute of Cultural Heritage and Archaeology & The Archaeology Department in Jilin University (1998). Neimenggu Kalaqin qi Dashanqian yizhi 1996 nian fajue jianbao [A brief excavation report on the site at Kalaqin Dashanqian in Inner Mongolia in 1996]. *Kaogu (Archaeology),* (9), 43-49.

Archaeological Team of Dantu in Jiangsu. (1988). Jiangsu Dantu Beishanding Chunqiu mu fajue baogao [The excavation report on the Spring and Autumn tombs at Dantu Beishanding in Jiangsu]. *Dongnan Wenhua (Southeast Culture)*, (Z1), 13-50.

Archaeological Team of Dongxiafeng. (1980). Shanxi Xiaxian Dongxiafeng yizhi dongqu, zhongqu fajue jianbao [A brief excavation report on the eastern and middle areas at the site of Xiaxian Dongxiafeng in Shanxi]. *Kaogu (Archaeology)*, (2), 97-107.

Archaeological Team of Erlitou, Institute of Archaeology, Chinese Academy of Social Sciences. (1976). Yanshi Erlitou yizhi xinfaxian de tongqi he yuqi [The new finds of bronzes and jades at the site of Yanshi Erlitou]. *Kaogu (Archaeology)*, (4), 259-263.

Archaeological Team of Liaoning Provincial Museum & The Chaoyang Heritage Museum Group. (1983). Liaoning Jianpingxian Kalaqin Hedong yizhi shijue jianbao [A brief report on the site at Jianping Kalaqin Hedong at Jianpingxian in Liaoning]. *Kaogu (Archaeology),* (11), 973-1003.

Archaeological Working Team of Anhui. (1982). Anhui Shucheng Jiulidun Chunqiumu [The Spring and Autumn period tomb at Shucheng Jiulidun in Anhui]. *Kaogu Xuebao (Chinese Journal of Archaeology)*, (2), 229-242.

Archaeological Working Team of Anyang, Institute of Archaeology, Chinese Academy of Social Sciences. (1979). 1969-1977 Yinxu Xiqu muzang fajue baogao [The excavation report on tombs at Yinxu Xiqu in Anyang]. *Kaogu Xuebao (Chinese Journal of Archaeology)*, (1), 27-146.

Archaeological Working Team of Anyang, Institute of Archaeology, Chinese Academy of Social Sciences. (1982). Anyang Houjiazhuang Beidi yihaomu fajue jianbao [A brief excavation report on the no.1 tomb of Houjiazhuang Beidi in Anyang], in *Kaoguxue Jikan Dierji* (pp. 35-40). Beijing: Zhongguo Shehui Kexue Chubanshe.

Archaeological Working Team of Anyang, Institute of Archaeology, Chinese Academy of Social Sciences. (1988). Anyang Dasikong dongnan de yizuo yinmu [A Shang dynasty tomb located at the southeast of the Dasikong in Anyang]. *Kaogu (Archaeology),* (10), 865-874.

Archaeological Working Team of Anyang, Institute of Archaeology, Chinese Academy of Social Sciences. (1992). 1980 nian Henan Anyang Dasikongcun M539 fajue jianbao [A brief excavation report on Anyang Dasikongcun M539 in Henan during 1980]. *Kaogu (Archaeology),* (6), 509-517.

Archaeological Working Team of Anyang, Institute of Archaeology, Chinese Academy of Social Sciences. (2004). Henan Anyangshi Huayuanzhuang 54 hao Shangdai muzang [The no. 54 tomb of Anyang Huayuanzhuang during the Shang dynasty]. *Kaogu (Archaeology),* (1), 7-19.

Archaeological Working Team of Shandong, Institute of Archaeology, Chinese Academy of Social Sciences. (1992). Tengzhou Qianzhangda Shangdai muzang [Excavations on the Shang tombs of the Qianzhangda site, Tengzhou]. *Kaogu Xuebao (Chinese Journal of Archaeology)*, (3), 365-392.

Archaeological Working Team of Zhouyuan. (2002). Shaanxi Fufengxian Yuntang, Qizhen Xizhou jianzhu jizhi 1999-2000 niandu fajue jianbao [A brief report on the Western Zhou architectural site excavated from 1999 to 2000 at Fufeng Yuntang and Qizhen in Shaanxi]. *Kaogu (Archaeology)*, (9), 3-26.

Bagley, R. (2000). Percussion. In Jenny F. So (Ed.), *Music in the age of Confucius* (pp.35-63). Washington DC: Freer Gallery of Art and Arthur M. Sackler Gallery, Smithsonian Institution.

Bamforth, D. B., & Finlay, N. (2008). Introduction: archaeological approaches to lithic production skill and craft learning. *Journal of Archaeological Method and Theory,15*(1), 1-27.

Barrow, J. (2001). *Travels in China* (2nd ed.). Cambridge University Press.

Beament, J. (2005). *How we hear music*. Woodbridge: Boydell & Brewer.

Bellman, J. (2000). *A short guide to writing about music*. New York, N.Y.; Harlow: Longman.

Blades, R, J. (2001). Lithophone. In S. Sadie & J. Tyrrell (Eds.), *The new Grove dictionary of music and musicians* (2nd ed., pp. 886-887). London: Macmillan.

Blake, E. C., & Cross, I. (2008). Flint tools as portable sound-producing objects in the upper Palaeolithic context: an experimental study. In P. Cunningham, J. Heeb, & R. Paardekooper (Eds.), *Experiencing Archaeology by Experiment* (pp. 1-19). Oxbow Books.

Blake, E. C., & Cross, I. (2015). The acoustic and auditory contexts of human behavior. *Current Anthropology*, *56* (1), 81-103.

Bowman, S. (1990). *Interpreting the past*. London: British Museum Publications.

Brezina, P. (2013). Acoustics of historic spaces as a form of intangible cultural heritage. *Antiquity*, *87*(336), 574-580.

Buckley, A. (1998). Music Archaeology: its contribution to 'Cultural' Musicology and 'Historical' Ethnomusicology. *Archaeologia Musicalis, 3* (1), 109–113; In B. Joachim & S. Uri (Eds.), *Studies in Socio-Musical Sciences* (pp.109-115). Ramat Gan: Bar-Ilan University Press.

Cai, Ming. (2014). Taosi yizhi chutu shiqi de weihen yanjiu [The research on stone implements unearthed at the Taosi site]. *Huaxia Kaogu (Huaxia Archaeology)*, (1), 38-50.

Cai, Shuliang. (2011). Dui shiqi weihen fenxi de jidian sikao [Consideration of microwear analysis of stone implements]. *Sichuan Wenwu (Sichuan Cultural Relics)*, (5), 77-80.

Cannam, C., Landone, C., & Sandler, M. (2010, October). Sonic visualiser: an open source application for viewing, analysing, and annotating music audio files. In *proceedings of the 18th ACM International Conference on Multimedia* (pp. 1467-1468). ACM. Retrieved from https://www.sonicvisualiser.org/sv2010.pdf

Cao, Dingyun. (1993). *Yinxu Fu Hao mingwen yanjiu* [Research on the inscriptions of the Yinxu Fu Hao tomb]. Taipei: Wenjin Chubanshe.

Chang, Renxia. (1954). Yin-Zhou shiqing xiaoji [A brief note on Shang and Zhou musical stones]. In R. X. Chang (Ed.), *Zhongguo Gudian Yishu* (pp. 17-31). Shanghai: Shanghai Chuban Gongsi.

Changsha Cultural Bureau Heritage Group. (1979). Changsha Xianjiahu Xihan Caozhuan mu [The tomb of Caozhuan at Xianjiahu during the Western Han dynasty in Changsha]. *Wenwu (Cultural Relics)*, (3), 1-16.

Chen, Mengjia. (2004). *Xizhou tongqi duandai* [Research on the date of Western Zhou bronzewares]. Beijing: Zhonghua Shuju.

Chen, Qixiang, & Lu, Zhihua. (2000). Zhongguo gudai yuelü xitong de xingcheng he fazhan [The development of temperament in ancient China]. *Art of Music (Journal of the Shanghai Conservatory of Music)*, (4), 9-13.

Chen, Tong., & Wang, Zhongyan. (1989). Acoustical properties of *qing*. *Chinese Journal of Acoustics*, *8* (4), 289-294.

Chen, Yingshi. (2002). Zenghouyi zhongqing mingwen yinanzi shiyi pingshu [Comments on doubtful characters on the chime bells and chime stones of the Marquis Yi's tomb of the Zeng state]. *Art of Music (Journal of the Shanghai Conservatory of Music),* (3), 6-12.

Chen, Zhida. (1986). Yinxu yuqi de gongyi kaocha [Research on the manufactures of jade implements during the Shang dynasty at Yinxu ruins]. In Chinese archaeological research editorial board (Ed.), *Zhongguo Kaoguxue yanjiu-Xia Ding xiansheng kaogu wushinian jinian lunwenji (The Archaeological Research in China- collection of 50th Anniversary of Archaeology on Xia Ding's work).* Beijing: Wenwu Chubanshe.

Chen, Zhenyu. (1988). Woguo Xianqinshiqi shiqing chuxi [The preliminary research on chime stones in pre-Qin dynasty in China]. *Hunan Wenwu (Hunan Cultural Relics)*, (3), 17-36.

Cheng, Jianzheng., & Zhang, Dejun. (2000). Bianqing zhendong texing de shengquanxi yanjiu [Research on the vibration of chime stones by means of acoustical holography]. *Shengxue Xuebao (Acta Acustica)*, *25* (1), 87-92.

Cheng, Jianzheng., Zhang, Dejun., Lan, Congqing., & Ye, Chaohui. (2000). Research on vibration modes of the Chinese chime stone. *Chinese Physics*, *9* (12), 913-921.

Chong, Jianrong. (2019, January 3). Shaanxi Chengcheng Liujiawa yizhi faxian Zhoudai zhuhou damu, queding yizhi wei Ruiguo houqi de ducheng yizhi ji mudi [The report on the tombs excavated at Shaanxi Chengcheng Liujiawa, defining this site and tombs belonging to the late Rui state]. Retrieved from https://mp.weixin.qq.com/s/o6TO5U1U92AkJIbVXKrjXA

Collaborative Archaeological Research Group of the Early Qin Culture. (2007). Gansu Lixian Dapuzishan zaoqi Qin wenhua yizhi [Research on the site of the early Qin archaeological culture found in Gansu Lixian Dapuzishan, Gansu]. *Kaogu (Archaeology),* (7), 38-49.

Cooke, C. (1964). Rock gongs and grindstones: plumtree area, southern Rhodesia. *The South African Archaeological Bulletin*, *19*(75), 70.

Cui, Dayong., & Zou, Weiping. (2006). Luozhuang hanmu 14 hao peizangkeng bianqing keming chutan [Preliminary exploration into inscriptions of chime stones excavated at pit 14 near the Han dynasty tomb in Luozhuang]. In *Handai Kaogu yu Han Wenhua Guoji Xueshu Yantaohui Lunwenji* [Analects of the international symposium of archaeology and culture of the Han dynasty] (pp.146-156). Jinan: Qilu Shushe.

Cui, Tianxing., & Zhang, Jian. (2017). Mozhi shiqi dingkong gongyi de shiyankaogu yanjiu [Archaeological research on hole drilling in the manufacture of ground stone tools]. *Huaxia Kaogu (Huaxia Archaeology)*, (4), 127-130.

Cultural Relics Excavation Team in Danjiangku Area in Henan. (1980). Henansheng Xichuanxiasi Chunqiu Chumu [An excavation report on Chunqiu Chu tomb at Xichuanxiasi in Henan]. *Wenwu (Cultural Relics),* (10), 13-19.

Cultural Relics Working Station in Luoyang. (2009). *Luoyang Wangcheng guangchang Dongzhoumu* [The cemeteries at Wangcheng square of the Eastern Zhou dynasty in Luoyang]. Beijing: Wenwu Chubanshe.

Dai, Nianzu. (1993). *Zhongguo shengxueshi* [A history of acoustics in China]. Hebei Jiaoyu Chubanshe.

Dai, Zunde., & Liu, Daiyu. (1980). Shanxi Lingshixian Jingjiecun Shangdai mu he qingtongqi [The Shang tombs and bronzewares at Lingshi Jingjiecun in Shanxi]. In Heritage editorial board (Eds.), *Wenwu Ziliao Congkan* (vol.3, pp. 46-49). Beijing: Wenwu Chubanshe.

Dams, L. (1985). Palaeolithic lithophones: descriptions and comparisons. *Oxford Journal of Archaeology, 4*(1), 31-46.

Davidson, B. (1959). Rock gongs and rock slides. *Man, 59*, 85.

Deng, Yi. (2009). *Shanxi chutu xianqin shiqi qinglei yueqi zhong de kexue jishu yanjiu* [Technological research on chime stones of the pre-Qin period excavated from Shanxi] (Masters thesis). University of Shanxi, Shanxi.

Department of Archaeology, Peking University & Shanxi Provincial Institute of Archaeology. (1993). 1992 nian chun Tianma Qucun yizhi muzang fajue baogao [The excavation report on the mausoleum precinct of the Marquis Jin at Tianma Qucun in Shanxi during the year of 1992]. *Wenwu (Cultural Relics),* (3), 11-30.

Department of Archaeology, Peking University & the Archaeological Research Institution of Shanxi. (1994a). Tianma Qucun yizhi Beizhao Jinhou mudi dierci fajue [The second season of excavation on the mausoleum precinct of the Marquis Jin at Tianma Qucun in Shanxi]. *Wenwu (Cultural Relics),* (1), 4-28.

Department of Archaeology, Peking University & the Archaeological Research Institution of Shanxi. (1994b). Tianma Qucun yizhi Beizhao Jinhou mudi disici fajue [The fourth season of excavation on the mausoleum precinct of the Marquis Jin at Tianma Qucun in Shanxi]. *Wenwu (Cultural Relics),* (8), 4-21.

Department of Archaeology, Peking University & the Archaeological Research Institution of Shanxi. (1995). Tianma Qucun Yizhi Beizhao Jinhou mudi diwuci fajue [The fifth season of excavation on the mausoleum precinct of the Marquis Jin at Tianma Qucun in Shanxi]. *Wenwu (Cultural Relics),* (7), 4-39.

Department of Archaeology, Peking University & the Archaeological Research Institution of Shanxi. (2001). Tianma Qucun Yizhi Beizhao Jinhou mudi diliuci fajue [The sixth season of excavation on the mausoleum precinct of the Marquis Jin at Tianma Qucun in Shanxi]. *Wenwu (Cultural Relics),* (8), 4-21.

Du, Zhengguo. (1965). *Kaogongji* zhong de lixue he shengxue zhishi [The mechanics and acoustics knowledge in the *Kaogongji*]. *Wuli Tongbao (Physics Bulletin)*, (6), 255-267.

Duckworth, W. (2014). *Creative approach to music fundamentals*. New York: Cengage learning.

Dudas, R., & Ahn, J. H. (2015). Physical modeling synthesis of the stone chime instrument “Pyeongyeong”. In *41st International Computer Music Conference (ICMC)*. Retrieved from http://www.richarddudas.com/documents/ahn_dudas_icmc2015.pdf. ICMA. 254-257

Dumbrill, R. (2000). *The musicology and organology of the ancient near east*. London: Tadema Press.

Early Qin Culture Archaeological Joint Team. (2008). 2006 nian Gansu Lixian Dapuzishan Jjisi yiji fajue jianbao [A brief excavation report on the sacrificial site at Lixian Dapuzishan in Gansu in 2006]. *Wenwu (Cultural Relics)*, (11), 14-29.

Excel Easy (Excel tutorial on the net). (2010-2017). *Correlation.* Retrieved from http://www.excel-easy.com/examples/correlation.html

Experts in the project of Xia, Shang and Zhou dynasties chronology. (2000). *Xiashangzhou duandai gongcheng 1996-2000 jieduan chengguo baogao (brief version)* [Report on the dating framework used in the Xiashangzhou duandai project from the year of 1996 to 2000]. Beijing: Shijie Tushu Chuban Gongsi Beijing Gongsi.

Fagg, B. (1956). The discovery of multiple rock gongs in Nigeria. *Man*, *56*, 17-18.

Fagg, M.C. (1994). What is a lithophone - and what is a rock gong?. *The Galpin Society Journal*, *47*, 154-155.

Fagg, M.C. (1997). *Rock Music*. Oxford: Pitt Rivers Museum, University of Oxford.

Falkenhausen, L.V. (1993). *Suspended music: Chime-bells in the culture of bronze age China*. Berkeley and Los Angeles: University of California Press.

Fan, Weiyue., & Wu, Zhenfeng. (1980). Shaanxi Lantianxian chutu Shangdai qingtongqi [The Shang bronzewares unearthed at Lantian in Shaanxi]. In Heritage editorial board (Eds.), *Wenwu Ziliao Congkan* (vol.3, pp. 25-27). Beijing: Wenwu Chubanshe.

Fan, Yuzhou. (1982). Guanyu Yinxu 1973 nian chutu shiqing de wenshi [The decoration of the chime stone excavated at Yinxu in 1973]. *Wenwu* (*Cultural Relics),* (7), 76-77.

Fang, Jianjun. (1988). Houjiazhuang 1217 hao damu de *qing* he *gu* [The chime stone and drum in the tomb M1217 at Houjiazhuang in Yinxu, Henan]. *Jiaoxiang (The Journal of Xi'an Conservatory of Music),* (2), 49-51.

Fang, Jianjun. (1989a). Luoyang Zhongzhou Daqu chutu bianqing shitan [Discussion on the chime stones uncovered at Zhongzhou da qu in Luoyang]. *Kaogu(Archaeology),* (9), 834–838.

Fang, Jianjun. (1989b). Shangdai *qing* he Xi–Zhou *qing* [The Shang dynasty chime stones versus the Western Zhou chime stones]. *Wenbo (Relics and Museology),* (3), 36-45.

Fang, Jianjun. (1989c). Xizhou *qing* yu *Kaogongji Qingshi* qingzhi [The chime stones in the Western Zhou dynasty and the manufacture of the chime stone in *Kaogongji*]. *Yueqi (Musical Instrument)*, (2), 2-4.

Fang, Jianjun. (1996). *Zhongguo gudai yueqi gailun* [The conspectus of ancient Chinese musical instruments]. Shaanxi: Shaanxi Renmin Chubanshe.

Fang, Jianjun. (2006). *Shang Zhou yueqi wenhua jiegou yu shehui gongneng yanjiu* [Research on the cultural structure and social functions of musical instruments during the Shang and the Zhou dynasty]. Shanghai: The Shanghai Conservatory of Music.

Fang, Jianjun., & Zheng, Zhong. (2007a). Luozhuang Hanmu 14 hao peizangkeng bianzhong bianqing shengpu fenxi [Spectrogram analysis on bronze bells and chime stones excavated at funeral pit 14 of the Han dynasty tomb in Luozhuang]. *Art of Music (Journal of the Shanghai Conservatory of Music),* (4), 35-38.

Fang, Jianjun., & Zheng, Zhong. (2007b). Luozhuang Hanmu 14 hao peizangkeng bianqing de zuhe bianci he yinjie [Assemblage order of arrangement and scale of chime stones excavated at funeral pit 14 of the Han dynasty tomb in Luozhuang]. *Zhongguo Yinyue* (*Musicology in China)*, (4), 18-28.

Fang, Jianjun. (2008). Xinchu Ruiguo yueqi jiqi yiyi [The newly excavated musical instruments of the Rui state and their significance]. *Yinyue Yanjiu (Music Research)*, (4), 34-39.

Fang, Jianjun. (2010a). Scale, tuning, and spectrum: the early Han dynasty chime stones and bronze bells excavated in Luozhuang, China. In R. Eich-mann, E. Hickmann, L.-C. Koch (Eds.), *Studien zur Musikarchäologie VII*, *Orient- Archäologie* (Vol.25, pp. 167-188). Berlin: DIA.

Fang, Jianjun. (2010b). Qinzibo ji tongchu zhongqing yanjiu [Study of simultaneously unearthed Qinzi *bo*-bells, *yongzhong*-bells and chime stones]. *Zhongguo Yinyuexue* (*Musicology in China)*, (4), 11-14.

Fang, Jianjun. (2011). *Yinyue kaogu yu yinyueshi* [Music archaeology and music history]. Beijing: Renmin Yinyue Chubanshe.

Fang, Jianjun. (2018). Lun yinyue kaoguxue wenhua [Discourse on music archaeological culture]. *Zhongguo Yinyuexue* (*Musicology in China)*, (2), 15-22.

Fang, Qin. (2015). Hubei Zaoyang Guojiamiao Zengguo mudi [The Zeng state tombs at Zaoyang Guojiamiao in Hubei]. *Dazhong Kaogu (Popular Archaeology)*, (1), 1-2.

Fang, Xueyang., & Till, R. (2019). A Study on nine chime stones found in an Eastern Zhou tomb in Hebi, China. In R. Eich-mann, E. Hickmann, L.-C. Koch (Eds.), *Studien zur Musikarchäologie XI*, *Orient- Archäologie* (Vol.40, pp. 69-87). Berlin: DIA.

Fang, Xiuzhen. (1993). Zenghouyi mu zhongqingju de zhuangshi zaoxing [The shape and decoration of chime bells and chime stones racks found in the tomb of Marquis Yi of the Zeng state]. *Sichuan Wenwu (Sichuan Cultural Relics)*, (3), 28-30.

Farnell, A. (2010). *Designing sound*. Cambridge, Mass; London;: MIT Press.

Feng, Yongqian., & Deng, Baoxue. (1983). Liaoning Jianchang pucha zhong faxian de zhongyao wenwu [Important cultural relics found in the investigation of Liaoning Jianchang]. *Wenwu (Cultural Relics)*, (9), 66-72.

Feng, Zengzhao. (1993). *Chenji yanshixue* [Sedimentary rock petrology]. Beijing: Shiyou Gongye Chubanshe.

Fletcher, N. H., & Rossing, T. D. (1993). *The physics of musical instruments* (2nd ed.). New York: Springer-Verlag.

Furniss, I. (2008). *Music in ancient China: An archaeological and art historical study of strings, winds, and drums during the Eastern Zhou and Han periods (770BCE-220CE)*. New York: Cambria Press.

Gao, Hongxiang. (1988). Zenghouyi zhongqing bianpei jishu yanjiu [Research on the techniques of arrangement of chime bells and chime stones from the Marquis Yi's tomb]. *Huangzhong (Journal of Wuhan Conservatory of Music)*, (4), 85-95.

Gao, Lei. (2004). Xizhou *qing* yanjiu zonglun [Comprehensive discussion on the Western Zhou chime stones]. *Journal of Nanjing Arts Institute*, (2), 48-54.

Goodreads. (2019). *Edgar Allan Poe- Quotes*. Retrieved from https://www.goodreads.com/quotes/66649-there-is-no-exquisite-beauty-without-some-strangeness-in-the.

Goodwin, A. (1957). Rock gongs, chutes, paintings and fertility. *The South African Archaeological Bulletin*, *12*(45), 37.

Guangzhou Municipal Cultural Relics Management Committee. (1991). *Xihan*

Nanyuewang mu [The tomb of Nanyue king in the Western Han dynasty]. Beijing: Wenwu Chubanshe.

Guo, Baojun. (1951). 1950 nian chun Yinxu fajue baogao [The excavation report on the ruins of Yin in the year of 1950]. *Kaogu Xuebao (Chinese Journal of Archaeology)*, (1), 1-61.

Guo, Baojun. (1959). *Shanbiaozhen yu Liulige* [Shanbiaozhen and Liulige]. Beijing: Kexue Chubanshe.

Guo, Baojun. (1964). *Xunxian Xincun* [The Xunxian Xincun]. Beijing: Kexue Chubanshe.

Hall, D. (2012). *How to calculate correlation coefficients in Excel 2010*. Retrieved from http://dedicatedexcel.com/how-to-calculate-correlation-coefficients-in-excel 2010/

Hao, Huifang., & Hao, Yunchang. (2007). Qingong damu shiqing wenzi yu shiguwen, Houman mengshu [The inscriptions of chime stones found in Qingong's Mausoleum and the inscriptions on drum-shaped stone blocks and Houma allied oath]. *Zhongguo Wenzi Yanjiu (The research on Chinese characters)*, (2), 165-170.

He, Shuangfei. (2009). *Kaogongji* de niandai zuozhe yu jiazhi [On the date, author and value of *Kaogongji*]. *Journal of Hunan City University, 30* (4), 68-69.

Hebei Provincial Institute of Cultural Relics. (1985). *Gaocheng Taixi Shangdai yizhi* [The site of the Shang dynasty at Gaocheng Taixi]. Beijing: Wenwu Chubanshe.

Hebei Provincial Institute of Cultural Relics. (1987). Hebei Pingshan Sanji gucheng diaocha yu muzang fajue [Excavation report on the ancient city at Pingshan Sanji in Hebei]. In *Kaoguxue Jikan* (vol.5). Beijing: Zhongguo Shehui Kexue Chubanshe.

Hebei Provincial Institute of Cultural Relics. (1996). *Cuo mu: Zhanguo*

Zhongshanguo guowang zhi mu [Cuo tomb: king Cuo'S tomb of Zhongshan kingdom in Warring States period]. Beijing: Wenwu Chubanshe.

Henan Provincial Institute of Cultural Relics and Archaeology. (1993). *Zhengzhou Shangcheng kaogu xinfaxian yu yanjiu 1985-1992* [The research of new archaeological findings in Zhengzhou Shangcheng excavated from 1985 to1992]. Zhengzhou: Zhongzhou Guji Chubanshe.

Henan Provincial Institute of Cultural Relics and Archaeology. (1999). *Sanmenxia Guoguo mu* [Sanmenxia Guo state tombs]. Beijing: Wenwu Chubanshe.

Henan Provincial Institute of Cultural Relics and Archaeology. (2000). *Luyi Taiqinggong Changzikou mu* [The Changzikou'S tomb at Luyi Taiqinggong]. Zhengzhou: Zhongzhou Guji Chubanshe.

Henan Provincial Institute of Cultural Relics and Archaeology & The Cultural Relics Excavation Team in Danjiangku Area in Henan. (1991). *Xichuan Xiasi Chunqiu Chu mu* [The chu tombs of the Spring and Autumn period in Xichuanxiasi]. Beijing: Wenwu Chubanshe.

Henan Provincial Institute of Cultural Relics and Archaeology & The Cultural Relics Excavation Team in Danjiangku Area in Henan. (1992). Pingdingshan Yingguo mudi 95 hao mu de fajue [The excavation of the no. 95 tomb of the Ying state at Pingdingshan]. *Huaxia Kaogu* (*Huaxia Archaeology*), (3), 92-103.

Henan Provincial Institue of Cultural Relics and Archaeology. (2015). Henan Qixian Songzhuang Dongzhou mudi M4 fajue jianbao [A brief excavation report on the tomb M4 of Qixian Songzhuang dating from the Eastern Zhou dynasty in Henan province]. *Huaxia Kaogu (Huaxia Archaeology)*, (4), 3–11.

Heritage Bureau of Zibo Linzi. (2015). Shandong Linzi Fanjiacun mudi 2012 nian fajue jianbao [A brief excavation report on the tomb of Shandong Linzi Fanjiacun]. *Wenwu (Cultural Relics)*, (4), 9-27.

Heritage Management Bureau in Pingdingshan & Culture Bureau of Henan Yexian. (2007). Henan Yexian Jiuxian sihao Chunqiumu fajue jianbao [A brief excavation report on Yexian Jiuxian tomb M4 of the Spring and Autumn period in Henan]. *Wenwu (Cultural Relics)*, (9), 4-37.

Heritage Management Office in Anhui. (1995). Anhui Liu'anxian Chengxi Yaochang erhao Chu mu [The tomb M2 of the Chu state at Liu'anxian Chengxi Yaochang in Anhui]. *Kaogu (Archaeology)*, (2), 124-140.

Heritage Working Station in Anhui & the Museum of Fuyang. (1978). Fuyang Shuanggudui Xihan Ruyinhou mu fajue jianbao [A brief excavation report on the tomb of Ruyinhou during the Western Han dynasty at Shuanggudui in Fuyang]. *Wenwu (Cultural Relics)*, (8), 12-33.

Heritage Working Team and Cultural Bureau of Hebei. (1965). Hebei Yixian Yanxiadu di shiliuhao mu de fajue [An excavation report on the No.16 tomb of Yixian Yanxiadu, Hebei]. *Kaogu Xuebao (Chinese Journal of Archaeology)*, (2), 79-102, 166-175.

Heritage Working Team and Cultural Bureau of Henan. (1960). Luoyang xingxiu Zhongzhou Daqu gongcheng zhong faxian zhengui wenwu [The precious cultural relics discovered in the process of building the Zhongzhou Daqu in Luoyang]. *Wenwu (Cultural Relics),* (4).

Heritage Working Team of Anyang. (1991). Yinxu Qijiazhuang dong 269 hao mu [The tomb M269 at the east part of the Qijiazhuang in Yinxu]. *Kaogu Xuebao (Chinese Journal of Archaeology)*, (3), 325-352.

Heritage Working Team of Luoyang. (2002). Luoyang Jiefanglu Zhanguo Peizangkeng fajue baogao [The excavation report on the Warring States funeral pit at Jiefanglu in Luoyang]. *Kaogu Xuebao (Chinese Journal of Archaeology),* (3), 359-380.

Hester, J. (1982). *Introduction to archaeology* (2nd ed.). New York; London: Holt, Rinehart and Winston.

Hickmann, E. (2001). Archaeomusicology. In S. Sadie & J. Tyrrell (Eds.) *The new Grove dictionary of music and musicians* (2nd ed., pp. 848–854). London: Macmillan.

Hindley, G. (1971). *Larousse encyclopedia of music*. London: Hamlyn.
Hinkle, D. E., Wiersma, W., & Jurs, S.G. (2003). *Applied statistics for the behavioral sciences* (5th ed.). Boston: Houghton Mifflin.

Hood, M. (1969). Ethnomusicology. In W. Apel (Ed.), *Harvard dictionary of music* (2nd ed., pp. 298). Cambridge, Mass.: Harvard University Press.

Hood, M. (1971). *The ethnomusicologist* [Mc Graw-Hill music series]. New York: McGraw-Hill Books.

Hornbostel, E. (1933). The ethnology of African sound-instruments. Comments on *Geist und Werden der Musikinstrumente* by C. Sachs. *Africa*, *6*(2), 129-157.

Hornbostel, E. & Sachs, C. (1992) [1914]. Classification of musical instruments. In H. Meyers (Ed.), *Ethnomusicology: An Introduction* (pp. 444–461. Anthony Baines & K. P. Wachsmann, Trans.). New York /London: W.W. Norton & Company.

Huang, Xiangpeng. (1978, 1980) Xinshiqi he Qingtongshidai de yizhi yinxiang ziliao yu woguo yinjie fazhanshi wenti [The presently known sonic materials from Neolithic and Bronze Age China and issues of the developmental history of scales]. *Yinyue Luncong,* (1), 184-206; (3), 127-161.

Huang, Xiangpeng. (1981). Zenghouyi zhongqing mingwen yuexue tixi chutan [The preliminary research on the inscriptions of the chime stones and chime bells of the Marquis Yi's tomb of the Zeng state]. *Yinyue Yanjiu (Music Research)*, (1), 22-53.

Hubei Provincial Institute of Cultural Relics and Archaeology & Suizhou City

Musuem. (2014). Suizhou Wenfengta M1, M2 fajue jianbao [A brief excavation report on the tombs of M1 and M2 at Suizhou Wenfengta]. *Jianghan Kaogu (Jianghan Archaeology)*, (4), 3-51.

Hubei Provincial Institute of Cultural Relics and Archaeology & Xiangyang City Institute of Archaeology and Cultural Relics. (2018). Hubei Zaoyang Jiuliandun M2 yueqi qingli jianbao [A brief report on musical instruments excavated from tomb M2 in Hubei Zaoyang Jiuliandun]. *Zhongyuan Wenwu (Cultural Relics of Central China)*, (2), 17-76.

Hubei Provincial Museum. (1972). Hubei Jiangling faxian de Chuguo caihui shibianqing jiqi xiangguan wenti [A study of Chu state chime stones with painted patterns found in Jiangling, Hubei]. *Kaogu (Archaeology)*, (3), 41-48.

Hubei Provincial Museum. (1981). Suixian Zenghouyi mu zhongqing mingwen shiwen [The explanations of inscriptions on the chime stones and chime bells of tomb Marquis Yi of the Zeng State]. *Yinyue Yanjiu (Music Research)*, (1), 3-16.

Hubei Provincial Museum. (1989). *Zeng Hou Yi mu* [The tomb of Marquis Yi of the Zeng state]. Beijing: Wenwu Chubanshe.

Hubei Provincial Museum & Suizhou Museum. (1985). Hubei Suizhou Leigudun erhaomu fajue jianbao [A brief excavation report on the tomb M2 at Suizhou Leigudun in Hubei]. *Wenwu (Cultural Relics)*, (1), 16-36.

Hubei Provincial Museum & Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences. (1984). Zhanguo Zenghouyi bianqing de fuyuan ji xiangguan wenti yanjiu [Research on replication and other related issues of Warring States chime stones from the Marquis Yi's tomb of the Zeng state]. *Wenwu (Cultural Relics)*, (5), 60-65.

Huimin Area Cultural Heritage Census Team & Shandong Yangxin Cultural Centre. (1990). Shandong Yangxin Chengguanzhen xibeicun Zhanguomu qiwu peizangkeng qingli jianbao [A brief excavation report on the funeral pit in a Warring States tomb at Yangxin Chengguanzhen Xibeicun in Shandong]. *Kaogu (Archaeology)*, (3), 218-222.

Hunan Provincial Institute of Cultural Relics and Archaeology. (1992). Hunan Shimenzaoshi Shangdai yicun [The Shang dynasty remains at Shimencao in Hunan]. *Kaogu Xuebao (Chinese Journal of Archaeology)*, (2), 185-219.

Hunan Provincial Museum & Hunan Provincial Institute of Cultural Relics and Archaeology. (2004). *Changsha Mawangdui er, san hao Han mu* [The Han dynasty tombs M2 and M3 in Changsha Mawangdui]. Beijing: Wenwu Chubanshe.

Ing, M. (2016). Philosophy in Western Han dynasty China (206 BCE-9 CE). *Philosophy Compass*, *11*(6), 289-304.

Institute of Archaeology, Chinese Academy of Social Sciences. (1956). *Huixian fajue baogao* [The excavation report on Huixian]. Beijing: Kexue Chubanshe.

Institute of Archaeology, Chinese Academy of Social Sciences. (1980). *Yinxu Fu Hao mu* [The Fu Hao'S tomb in Yinxu]. Beijing: Wenwu Chubanshe.

Institute of Archaeology, Chinese Academy of Social Sciences. (1983). 1978-1980 nian Shanxi Xiangfen Taosi mudi fajue jianbao [A brief excavation report on the tomb of Xiangfen Taosi in Shanxi during the excavation years of 1978-1980]. *Kaogu (Archaeology),* (1), 30-42.

Institute of Archaeology, Chinese Academy of Social Sciences. (1987*). Yinxu fajue baogao: 1958-1961* [The excavation report on Yinxu: 1958-1961]. Beijing: Wenwu Chubanshe.

Institute of Archaeology, Chinese Academy of Social Sciences. (1994). *Shanxian Dongzhou Qinhan mu* [The tombs of the Eastern Zhou, Qin and Han dynasties in Shanxian]. Beijing: Kexue Chubanshe.

Institute of Archaeology, Chinese Academy of Social Sciences. (1998). *Anyang Yinxu Guojiazhuang Shangdai muzang* [Guojiazhuang cemetery of the Shang dynasty within the Yin ruins, Anyang]. The Encyclopedia of China Publishing House.

Institute of Archaeology, Chinese Academy of Social Sciences. (1999). *Zhangjiapo Xizhou mudi* (The tomb of Zhangjiapo during the Western Zhou dynasty). Encyclopedia of China Publishing House.

Institute of Archaeology, Chinese Academy of Social Sciences. (2001). *Yinzhou jinwen jicheng shiwen* [The explanation of Chinese bronze inscriptions during the Shang and the Zhou dynasties]. The Chinese University of Hongkong: Institute of Chinese studies.

Institute of Archaeology, Chinese Academy of Social Sciences, Shanxi Provincial Institute of Archaeology, Shanxi Yuncheng Culture Relics Bureau & Linyi City Museum. (2003). *Linyi Chengcun mudi* [The tomb of Linyi Chengcun in Shanxi]. Beijing: Zhongguo Dabaikequanshu Chubanshe.

Institute of Archaeology, Chinese Academy of Social Sciences. (2016). *Huixian fajue baogao* [The excavation report on Huixian]. Beijing: Kexue Chubanshe.

Institute of Archaeology, Chinese Academy of Social Sciences and Linfen Municipal Cultural Relics Bureau, Shanxi province. (2015). *Xiangfen Taosi* [Taosi site in Xiangfen-report on archaeological excavations in 1978-1985]. Beijing: Cultural Relics Press.

Institute of Music in Chinese National Academy of Arts. (1984). *Zhongguo Yinyue Cidian* [The encyclopedia of Chinese music]. Beijing: Renmin Yinyue Chubanshe.

Institute of Music in Chinese National Academy of Arts. (2007). *Huang Xiangpeng Wencun* [The corpus of Huang Xiangpeng]. Jinan: Shandong Wenyi Chubanshe.
Izotope. (2010-2017). *Understanding the spectrogram/waveform display.* Retrieved from https://www.izotope.com/en/learning/rx/understanding-the-spectrogram-

waveform-display.htm

Jeffreys, M. (1959). Rock gongs or sounding stones. *The South African Archaeological Bulletin*, *14*(55), 111.

Ji, Liankang. (1980). *Chunqiu Zhanguo yinyue shiliao* [Music historical materials in the Spring and Autumn and Warring States periods]. Shanghai: Shanghai Wenyi Chubanshe.

Jiang, Linchang. (2001). *Xia Shang Zhou wenming xintan* [A new exploration on the culture of the Xia, Shang and Zhou Dynasties]. Hangzhou: Zhejiang Renmin Chubanshe.

Jiangxi Provincial Institute of Cultural Relics and Archaeology. (2016). Nanchangshi Xihan Haihunhou mu [The tomb of Marquis Haihun of the Western Han dynasty in Nanchang]. *Kaogu (Archaeology),* (7),45-62.

Jinan Municipal Institute of Archaeology, The Archaeology Department of the School of History and Culture in Shandong University, Shandong Provincial Institute of Cultural Relics and Archaeology & Zhangqiu City Museum. (2004). Shandong Zhangqiu shi Luozhuang Hanmu peizangkeng de qingli [The excavation of funeral pits around the Han period Luozhuang tomb in Zhangqiu city, Shandong]. *Kaogu (Archaeology),* (8), 3-16.

Jingzhou City Museum in Hubei. (1982). Jiangling Tianxingguan 1hao Chumu [The no.1 tomb of the Chu state at Tianxingguan in Jiangling, Hubei]. *Kaogu Xuebao (Chinese Journal of Archaeology),* (1), 71-116.

Kern, M. (2008). *Text and ritual in early China*. Seattle: University of Washington Press.

Kleinitz, C., Till, R., & Baker, B.J. (2015). The Qatar-Sudan archaeological project – archaeology and acoustics of rock gongs in the ASU BONE concession above the fourth Nile cataract, Sudan: a preliminary report. *SUDAN & NUBIA (The Sudan Archaeological Research Society), 19*, 106-114.

Kong, Lingyuan., & Chen, Yongqing. (2002). Jiangsu Pizhoushi Jiunüdun sanhaodun de fajue [The excavation of tomb no.3 at Pizhou Jiunüdun in Jiangsu]. *Kaogu (Archaeology)*, (5), 19-30.

Kovar, A. (1966). Problems in radiocarbon dating at Teotihuacan. *American Antiquity*, *31*(3), 427-430.

Kuang, Jun. (2015). Minzu yueqi gexing yinse de shengxue yuanli [The acoustic theory of timber in folk music instruments in China]. *Renmin Yinyue (People's Music)*, (5), 44-47.

Kuang, Yu., & Jiang, Tao. (1984). Yuxian Yanzhai Longshan wenhua yizhi [The site of Longshan culture in Yuxian Yanzhai]. In Archaeological Society of China (Eds.). *Zhongguo Kaoguxue Nianjian* [Yearbook of Archaeology in China, pp.126]. Beijing: Wenwu Chubanshe.

Kuttner, F. A. (1953). The Musical significance of archaic Chinese jades of the *pi* disk type. *Artibus Asiae*, *16* (1/2), 25-50.

Kuttner, F.A. (1965). A musicological interpretation of the *twelve-lü* in China's traditional tone system. *Ethnomusicology*, *9* (1), 22-38.

Kuttner, F.A. (1990). *The archaeology of music in ancient China: 2000 Years of Acoustical Experimentation 1400 B.C.——A.D. 750.* New York: Paragon House.

Lee, Yuanyuan., & Shen, Sinyan. (1999). *Chinese musical instruments*. Chicago: Chinese Music Society of North America.

Lerch, A. (2012). *An introduction to audio content analysis: applications in signal processing and music informatics*. Piscataway, NJ: IEEE.

Li, Boqian. (1997). Cong Jinhou mudi kan Xizhou gongmu mudi zhidu de jige wenti [A study of the Western Zhou cemetery system through examining the Jinhou tombs]. *Kaogu (Archaeology)*, (11), 51-60.

Li, Chunyi. (1983). Zenghouyi mu bianqing mingwen chuyan [Preliminary research on inscriptions of chime stones from the tomb of Marquis Yi of the Zeng state]. *Art of Music (Journal of the Shanghai conservatory of Music)*, (1), 8-24.

Li, Chunyi. (1986). Guanyu zhengque fenxi yinyue kaogu cailiao de yixie wenti [The correct way to analyse music archaeological sources]. *Yinyue Yanjiu (Music Research)*, (1), 8-10.

Li, Chunyi. (1987). Tantan yinyueshi yanjiu de cailiao he fangfa [The materials and methods of researching music history]. *Jiaoxiang (Journal of Xi'an Conservatory of Music),* (2), 11-19.

Li, Chunyi. (1994). Xianqin yinyueshi yanjiu de liangzhong jiben ziliao [The two primary sources of researching the music history of pre-Qin periods]. *Yinyue Yanjiu (Music Research),* (3), 34-36.

Li, Chunyi. (1996). *Zhongguo shanggu chutu yueqi zonglun* [A comprehensive discussion of unearthed musical instruments of ancient China]. Beijing: Wenwu Chubanshe.

Li, Chunyi. (2005). *Xianqin yinyueshi* [pre-Qin music history]. Beijing: Renmin Yinyue Chubanshe.

Li, Qing. (2014). Bengbu Shuangdun yihao Chunqiumu chutu yueqi de yinyuexue yanjiu [The musicological study of musical instruments found in the no.1 tomb of the Spring and Autumn period at Shuangdun in Bengbu]. *Yinyue Tansuo (Explorations in music),* (3), 14-20.

Li, Qinghui., Li, Zebin., & Gu, Donghong. (2016). Archaeological and technical study of Western Han dynasty lead barium glass chimes (*bianqing*) unearthed from the

Jiangdu king's mausoleum. In Fuxi. Gan, Qinghui. Li &, J. Henderson (Eds.), *Recent advances in the scientific research on ancient glass and glaze* (vol. 2, pp.113-127). World Scientific.

Li, Xueqin. (1997). Xihan wanqi zongmiao *bianqing* kaoshi [The interpretation of the chime stones from late Western Han temples]. *Wenwu (Cultural Relics)*, (5), 24-26.

Li, Xueqin. (2000). Qin Huaihouqing yanjiu [Research on a Huaihou chime stone of the Qin dynasty]. *Wenwu* (*Cultural Relics)*, (1), 53-101.

Li, Yunqun., & Han, Mengru. (1986). Shanxi Wenxixian faxian Longshan shiqi shiqing [The chime stones dating to the Longshan period found at Shanxi Wenxi]. *Kaogu yu Wenwu (Archaeology and Cultural Relics)*, (2), n.p.

Li, Yuexun. (1993). Shandong Zhangqiu Nǚlangshan Zhanguomu chutu yuewu taoyong ji youguan wenti [Excavated pottery figurines of musicians and dancers from the tomb of the Zhangqiu Nǚlangshan during the Warring States period in Shandong]. *Wenwu (Cultural Relics)*, (3), 1-6.

Liang, Baoling., & Mei, Pengyun. (2012). Tianjinshi Zhangjiayuan yizhi faxian qingxing shiqi ji xiangguan wenti [A study of the chime stone shaped stoneware found at Zhangjiayuan site in Tianjin]. *Caoyuan Wenwu (Steppe Cultural Relics)*, (2), 51-54.

Liang, Guangcheng. (1986). *Yuesheng de aomi* [The arcanum of sound]. Beijing: Renmin Yinyue Chubanshe.

Liang, Siyuan., & Gao, Qucun. (1962). *Houjiazhuang—M1001*, Taiwan: Zhongyang Yanjiuyuan Lishiyuyan Yanjiusuo (Institute of History and Philology, Academia Sinica).

Liang, Siyuan., & Gao, Qucun. (1968). *Houjiazhuang—M1217*, Taiwan: Zhongyang Yanjiuyuan Lishiyuyan Yanjiusuo (Institute of History and Philology, Academia

Sinica).

Liang, Siyuan., & Gao, Qucun. (1970). *Houjiazhuang—M1004*, Taiwan: Zhongyang Yanjiuyuan Lishiyuyan Yanjiusuo (Institute of History and Philology, Academia Sinica).

Liang, Yun. (2008). Gansu Lixian Dapuzishan qingtong yueqikeng tantao [The discussion of musical instrument pit K5 at Lixian Dapuzishan in Gansu]. *Zhongguo Lishi Wenwu (Journal of National Museum of China),* (4), 25-38.

Lin, Huixiang. (1934). *Wenhua renleixue* [Cultural anthropology]. Shanghai: Shangwu Yinshuguan (The Commercial Press).

Liu, Wei. (2014). Shilun Zenghouyi bianqing de diaoshi yinjie [The discussion of the scales and modes of the chime stones from the Marquis Yi's tomb]. *Journal of Hubei University of Education*, *31* (9), 63-65.

Liu, Xinhong. (2006). Dui Huayuanzhuang M54 chutu biannao, shiqing de kaocha baogao [Investigation report on sets of *nao-bell* and stone chime unearthed at Huayuanzhuang M54]. *Huangzhong (Journal of Wuhan Conservatory of Music)*, (2), 91-98.

Liu, Yang. (2011). Homage to the Ancestors. *Apollo*, (3), 122–27.

Liu, Yongli. (2016). *Zhongguo xiandangdai xinshi wenben xidu* [Close reading of Chinese modern and contemporary new poetry texts]. Beijing: China Social Sciences Press.

Liu, Yongfu. (2015). Chongshi Shanggu tanyin shilü- Li Chunyi xiansheng Zenghouyi zhongqing mingwen kaosuo xueshu chengjiu shulue [The literature review of Li Chunyi's works relating to inscriptions of chime stones and chime bells from the Marquis Yi's tomb]. *Zhongguo Yinyuexue (Musicology in China)*, (2), 140-144.

Liu, Yijun., & Feng, Yi. (1996). Shandong Tanchengxian Erzhong Zhanguomu de qingli [The excavation of the Warring States tomb at Tanchengxian Erzhong in Shandong]. *Kaogu (Archaeology)*, (3), 8-13.

Liu, Zaisheng. (2006). *Zhongguo gudai yinyueshi jianshu* [A compendium on ancient Chinese music history]. Beijing: Renmin Yinyue Chubanshe.

Lu, Guoquan. (2017). Lishi yu pingshu: wenxian shixue guanyu Chunqiushi de fenqi he duandai yanjiu [History and commentary: a study of the stages and periods of the Spring and Autumn period from historical literature]. *Xibu Kaogu (Archaeology in Western China)*, (2), 70-105.

Lu, Liancheng., & Hu, Zhisheng. (1988). *Baoji Yuguo mudi* [The Yu state tombs in Baoji]. Beijing: Wenwu Chubanshe.

Lu, Liancheng., & Yi, Shengping. (1982). Gu Ceguo yizhi, mudi diaochaji [The investigation of the tombs and sites of the Ce state]. *Wenwu (Cultural Relics)*, (2), 48-57.

Lund, C. (2009). Early ringing stones in Scandinavia: finds and traditions, questions and problems. *Studia Instrumentorum Musicae Popularis, 1*(1), 173-194.

Luo, Xizhang. (1987). Zhouyuan Chutu de Xizhou shiqing [The Western Zhou chime stones from Zhouyuan in Shaanxi]. *Kaogu yu Wenwu (Archaeology and Cultural Relics)*, (6).

Luoyang City Museum. (1981). Luoyang Beiyaocun Xizhou yizhi 1974 niandu fajue jianbao [A brief excavation report on relics of the Western Zhou dynasty during the year of 1974 at Beiyaocun in Luoyang]. *Wenwu (Cultural Relics)*, (7), 52-64.

Ma, Dayou. (1995). Zhongguo shengxueshi [The history of acoustics in China]. *Shengxue Xuebao (Acta Acustica), 20*(4), 1.

Ma, Yanping., He, Zhenyu., & Chen, Song. (2011). Wanbei Lingbi Qingyunshi de yanshixue he diqiuhuaxue yanjiu [Petrography and geochemistry of Lingbi Qingyun stone in northern Anhui Province]. *Zhongguo Dizhi (Geology in China)*, *38*(3), 657-663.

Merriam, Alan P. (1960). Ethnomusicology: discussion and definition of the field. *Ethnomusicology*, *4*(3), 107-114.

Merriam, Alan P. (1964). *The anthropology of music*. Evanston: Northwestern University Press.

Miao, Tianrui. (1996). *Lüxue* [The Musical Temperament]. Beijing: Renmin Yinyue Chubanshe.

Miao, Tianrui. (1998). *Yiyue baike cidian* [Music encyclopaedia]. Beijing: Renmin Yinyue Chubanshe.

Mithen, S. (2006). *The singing neanderthals: the origin of music, language, mind and body.* Weidenfeld &Nicolson.

Montagu, J. (1965). What is a gong?. *Man*, *65*(5), 18-21.

Mook, W., & van der Plicht, J. (1999). Reporting ^{14}C activities and concentrations. *Radiocarbon*, *41*(3), 227-239.

Morley, I. (2013). *The prehistory of music: human evolution, archaeology, and the origins of musicality*. Oxford: Oxford University Press.

Mu, Haiting., & Zhu, Jieyuan. (1983). Xin faxian de Xizhou wangshi zhongqi Wusi *huzhong* [The new finding of the Wusi Hu-bell]. *Renwen Zazhi (The Journal of Humanities),* (2), 118-121.

Nanjing Museum & Xuyi Cultural Relics Bureau. (2013a). Jiangsu Xuyi Dayunshan Jiangdu wangling erhaomu fajue jianbao [The excavation of the royal mausoleum no.2 of the vassal king of Jiangdu State in the Western Han dynasty]. *Wenwu (Cultural Relics)*, (1), 25-66.

Nanjing Museum & Xuyi Cultural Relics Bureau. (2013b). Jiangsu Xuyixian Dayunshan Xihan Jiangdu wangling yihao mu [An excavation report on the no.1 tomb of the mausoleum precinct of the Jiangdu Feudatory Kingdom at Dayunshan in Jiangsu Xuyi]. *Kaogu (Archaeology),* (10), 3-68.

Nanjing Museum & Zhengyi Museum office. (1992). Yizheng Zhangji Tuanshan Xihan mu [The Western Han tomb in Yizheng Zhangji Tuanshan]. *Kaogu Xuebao (Chinese Journal of Archaeology)*, (4), 477-509.

Nanjing Museum, Xuzhou Culture Bureau & Pizhou City Museum. (1999). Jiangsu Pizhou Jiunüdun erhaodun fajue jianbao [A brief excavation report on the tomb DIIM at Pizhou Jiunüdun in Jiangsu]. *Kaogu (Archaeology)*, (11), 28-34.

Nanjing Museum, the Archaeological Institution of Jiangsu & Wuxi Heritage Management Committee (2007). *Hongshan Yuemu fajue baogao* [Excavation report on the burials of the Yue state at Hongshan]. Beijing: Wenwu Chubanshe.

Needham, J., & Wang, Ling. (1962). *Science and civilization in China. Part1, Vol.4, Physics and physical technology.* Cambridge: Cambridge University Press.

Nettl, B. (2005). *The study of ethnomusicology: thirty-one issues and concepts* (2nd ed.). Urbana: University of Illinois Press.

Nunes, T. (2004). Adobe Audition version 1.5 PC-based DAW. *Mix,28*, 88.

Pan, Jie., Li, Xiaodong., Tian, Jing., & Lin, Tanran. (2002). Short sound decay of ancient Chinese music bells. *The Journal of the Acoustical Society of America*, *112*(6), 3042-3045.

Picken, L. (1957). The music of far Eastern Asia. In E. Wellesz (Ed.) *The New Oxford*

History of Music: vol.1 Ancient and Oriental Music (pp. 83-134). London: Oxford University Press.

Qinghai Provincial Cultural Relics Management Office Archaeological Team & Institute of Archaeology, Chinese Academy of Social Sciences. (1984). *Qinghai Liuwan— Ledu Liuwan yuanshi shehui mudi* [The tomb of Qinghai Liuwan]. Beijing: Wenwu Chubanshe.

Qiu, Shihua., & Cai, Lianzhen. (2001). Xiashangzhou Duandai Gongcheng zhongde Tanshisi niandai kuangjia [The carbon 14 dating framework used in the Xiashangzhou Duandai project]. *Kaogu (Archaeology)*, (1), 90-100.

Qiu, Shihua., & Zhang, Changshou. (1999). Jinhou mudi M8 de Tanshisi niandai ceding he Jinhou Suzhong [The carbon 14 dating framework of the Marquis Jin's tomb M8 and the chime bells of Marquis Su of the Jin state]. *Kaogu (Archaeology)*, (5), 90-92.

Qiu, Xigui., & Li, Jiahao. (1981). Zenghouyi mu zhongqing mingwen shiwen shuoming [Explanations of inscriptions on the chime bells and chime stones from the Marquis Yi's tomb of the Zeng state]. *Yinyue Yanjiu* (*Music Research)*, (1), 17-21.

Ren, Hong. (2008). *Jinhou mudi chutu yueqi de yinyue kaoguxue yanjiu* [The music archaeological research on unearthed musical instruments from Marquis Jin's tomb] (Published postgraduate thesis). Chinese National Academy of Arts.

Renfrew, C., & Bahn, P. (2004). *Archaeology: theories, methods, and practice*. London: Thames and Hudson.

Research Institution of Cultural Relics in Henan. (1986). *Xinyang Chumu* [An excavation report on the tomb of Chu state in Henan Xinyang]. Beijng: Wenwu Chubanshe.

Rossing, T. D. (1986). Acoustics of oriental gongs and bells. *The Journal of the*

Acoustical Society of America, *80*(S1), S101.

Rossing, T. D. (2000). *Science of percussion instruments*. London; Singapore: World Scientific.

Rumsey, D. J. (2010). *Statistics essentials for dummies*. Wiley Publishing, Inc.

Rumsey, F., & Mc Cormick, T. (2009). *Sound and recording* (6th ed.). Amsterdam; London: Elsevier/Focal.

Rycroft, D., Baines, A., & Wraight, D. (1995). Rock gongs. *The Galpin Society Journal, 48*, 269-270.

Scarre, C., & Lawson, G. (2006). *Archaeoacoustics*. Cambridge: McDonald Institute for Archaeological Research.

Sembos, Evangelos C. (2006). *Principles of music theory: a practical guide*. Morrisville, NC: Lulu Press.

Shaanxi Provincial Institute of Archaeology, Institude of Archaeology and Relic Protection in Weinan City. Tourism and Relics Administration of Hancheng City. (2007). Shaanxi Hancheng Liangdaicun yizhi M27 fajue jianbao M27 [A brief excavation report on M27 at Liangdaicun site in Hancheng, Shaanxi]. *Kaogu yu Wenwu (Archaeology and Cultural Relics),* (6), 3–22.

Shaanxi Provincial Academy of Archaeology, Institude of Archaeology and Relic Protection in Weinan City. Tourism and Relics Administration of Hancheng City. (2010). *Liangdaicun Ruiguo mudi 2007 niandu fajue baogao* [The excavation report on the Rui state tombs of Liangdaicun during 2007]. Beijing: Wenwu Chubanshe.

Shaanxi Provincial Commission for Administration of Cultural Relics. (1957). Chang'an Puducun Xizhou mu de fajue [The excavation of the Western Zhou tomb in Chang'an Puducun]. *Kaogu Xuebao (Chinese Journal of Archaeology)*, (1), 75-85.

Shaanxi Provincial Museum & Shaanxi Cultural Relics Management Committee. (1976). Shaanxi Qishan Hejiacun Xizhou muzang [The tombs of the Western Zhou dynasty at Qishan Hejiacun in Shaanxi]. *Kaogu (Archaeology)*, (1), 31-38.

Shandong Provincial Institute of Cultural Relics and Archaeology. (1989). Qingzhoushi Subutun Shangdaimu fajue baogao [The excavation report on the Shang dynasty tomb of Qingzhou Subutun]. *Haidai Kaogu (Haidai area's Archaeology)*, (1), 257-274.

Shandong Provincial Institute of Cultural Relics and Archaeology. (2000). Shandong Ziboshi Linziqu Zihedian erhao Zhanguo mu [The tomb M2 at Linziqu Zihedian in Shandong]. *Kaogu (Archaeology)* (10), 46-65.

Shandong Provincial Institute of Cultural Relics and Archaeology, the Archaeological Working Team of Linyi & Yishui Museum. (2013). Shandong Yishuixian Jiwanggu Chunqiu mu [The tomb of the Spring and Autumn period at Yishui Jiwanggu in Shandong]. *Kaogu (Archaeology)*, (7), 33-48.

Shandong Provincial Museum. (1972). Qufu Jiulongshan Han mu fajue Jianbao [A brief excavation report on Han tomb at Qufu Jiulongshan]. *Wenwu (Cultural Relics)*, (5), 39-44.

Shandong Zhucheng Museum. (1987). Shandong Zhucheng Zangjiazhuang yu Gebukoucun Zhanguo mu [The Shandong Zhucheng Zangjiazhuang and Gebukoucun Warring States tomb]. *Wenwu (Cultural Relics)*, (12), 47-56.

Shanxi Changzhi City Museum & Shanxi Provincial Culture Relics Working Committee, Jindongnan working group. (1974). Changzhi Fenshuiling 269, 270 hao Dongzhou mu [The Eastern Zhou tombs of M269 and M270 in Changzhi Fenshuiling]. *Kaogu Xuebao (Chinese Journal of Archaeology)*, (2), 63-85.

Shanxi Provincial Cultural Relics committee, Houma working station. (1963). Shanxi Houma Shangmacun Dongzhou muzang [The tombs of the Eastern Zhou dynasty at

Houma Shangmacun in Shanxi]. *Kaogu (Archaeology)*, (5), 229-245.

Shanxi Provincial Cultural Relics Management Committee. (1957). Shanxi Changzhishi Fenshuiling gumu de qingli [The excavation of the tomb of Changzhishi Feishuiling in Shanxi]. *Kaogu Xuebao (Chinese Journal of Archaeology)*, (1), 103-118.

Shanxi Provincial Institute of Archaeology & Shanxi Provincial Culture Relics Management Committee. (1964). Shanxi Changzhi Fenshuiling Zhanguo mu dierci fajue [The second excavation on the Warring States tombs in Shanxi Changzhi Fenshuiling]. *Kaogu* (*Archaeology)*, (3), 111-137.

Shanxi Provincial Institute of Archaeology & Lingshi Culture Bureau. (1986). Shanxi Lingshi Jingjiecun Shangmu [The Shang dynasty tombs at Lingshi Jingjiecun in Shanxi]. *Wenwu (Cultural Relics)*, (1), 1-18.

Shanxi Provincial Institute of Archaeology. (1994). *Shangma mudi* [The Tombs in Houma Shangma]. Beijing: Wenwu Chubanshe.

Shanxi Provincial Institute of Archaeology, Shanxi Provincial Museum & Changzhi City Musuem. (2010). *Changzhi Fenshuiling Dongzhou mudi* [The Eastern Zhou tombs of Changzhi Fenshuiling in Shanxi]. Beijing: Wenwu Chubanshe.

Shanxi Provincial Institute of Archaeology & Shanxi Provincial Jindongnan Cultural Bureau. (1986). Shanxisheng Luchengxian Luhe Zhanguo mu [The Warring States tombs of the Lucheng Luhe in Shanxi]. *Wenwu (Cultural Relics)*, (6), 1-19.

Shanxi Provincial Institute of Archaeology & Taiyuan Municipal Cultural Relics Management Committee. (1989). Taiyuan Jinshengcun 251 hao Chunqiu damu ji chemakeng fajue jianbao [A brief excavation report on the Spring and Autumn tomb no.251 and chariot pit in Taiyuan Jinshengcun]. *Wenwu (Cultural Relics)*, (9), 59-86.

Sichuan Provincial Museum. (1976). Chengdu Baihuatan Zhongxue shihaomu fajueji

[Excavation records on tomb no.10 at Chengdu Baihuatan Zhongxue]. *Wenwu (Cultural Relics)*, (3), 40-46.

Steggerda, M. (1944). "Stone gongs" or "ringing stones". *American Anthropologist*. *46* (3), New series, 421.

Stock, Jonathan P. J. (2010). Recordings as research tools in ethnomusicology. In *Recorded music: performance, culture and technology*. Cambridge: Cambridge University Press.

Stock, Jonathan P. J. (2008). New disciplinary directions in ethnomusicology: seven themes toward disciplinary renewal. In *The new (ethno) musicologies*. Kanham, MA: Scarecrow.

Stoudt, H. (1973). Arm lengths and arm reaches: some interrelationships of structural and functional body dimensions. *American Journal of Physical Anthropology*, *38*(1), 151-161.

Suizhou City Museum. (1998). Hubei Suizhou chutu Xizhou qingtong *bo* [The bronze *bo*-bell from the Western Zhou dynasty unearthed in Hubei Suizhou]. *Wenwu (Cultural Relics)*, (10), 76-77.

Sun, Chen. (2009). Cong Liangzhou *shiqing* de *bo* tan *Kaogongji* de guobie he niandai [Studying the Zhou dynasty chime stones' *bo* to discuss both state and date of the *Kaogongji*]. *The New Voice of Yue—fu (The Academic Periodical of Shenyang Conservatory of Music)*, (4), 85-91.

Suo, Quanxing. (2009). Fangkong shiqi shi gudai yueqi ["The square holed stone implement" is an ancient musical instrument]. *Zhongyuan Wenwu (Cultural Relics of Central China),* (5), 35-37.

Tao, Fuhai. (1988). Shanxi Xiangfen Daguduishan faxian Xinshiqishidai shiqingpi [The finding of a semi-finished chime stone at Daguduishan in Shanxi Xiangfen].

Kaogu (Archaeology), (12), 1137.

Tao, Fuhai. (1991). Shanxi Xiangfenxian Daguduishan Shiqianshiqi zhizaochang xincailiao jiqi zaiyanjiu [The restudy of a prehistoric stone manufacturing site at Daguduishan in Shanxi Xiangfen]. *Kaogu (Archaeology)*, (1), 1-7.

The No.1 Excavation Team on the Tomb of Leigudun in Suixian. (1979). Hubei Suixian Zenghouyi mu fajue jianbao [A brief excavation report on the tomb of Marquis Yi of the Zeng state]. *Wenwu (Cultural Relics),* (7), 1-24, 98-105.

Tian, Kewen., & Lu, Yun. (1990). Dui "Baihuatan Tonghu" qiancuo tuxiangzhong yuewuwenhua de zairenshi [The re-study of the inscribed performance pictures on the "Baihuatan bronze pot"]. *Yinyue Tansuo* (*Explorations in Music)*, (2), 18-22.

Till, R. (2010). Songs of the stones: an investigation into the acoustic culture of stonehenge. *IASPM*: *Journal of the International Association for the Study of Popular Music,1*(2), 1-18.

Till, R. (2013). The return of ritual: sacred popular music cultures and cults. In R. Jiménez, R. Till, & M. Howell (Eds.) *Music & Ritual: Bridging Material & Living Cultures* (pp. 359-387). Berlin: ICTM Study Group on Music Archaeology.

Till, R. (2014). Sound archaeology: terminology, Palaeolithic cave art and the soundscape. *World Archaeology*, *46* (3), 292-304.

Till, R. (2017). An archaeoacoustic study of the Ħal Saflieni hypogeum on Malta. *Antiquity, 91* (355), 74-89.

Tong, Shibu. (1981). Zenghouyi mu *bianqing* fuzhi chenggong [The successful reproduction of the chime stones of the Marquis Yi's tomb of the Zeng state]. *Yueqi (Musical Instrument Magazine)*, (6), 8.

Sadie, S., & Tyrrell, J. (2001). *The new Grove dictionary of music and musicians* (2nd ed. XXII). London: Macmillan.

Wang, Anchao. (2005a). Shiqing de xingtai yanjiu [Typological research on Chinese chime stones]. *Zhongguo Yinyuexue (Musicology in China),* (1),70-79.

Wang, Anchao. (2005b). Dui Zenghouyi *bianqing* "Xian (Jian) yin" de zairenshi [The recognition on the "Xian (Jian) tone" of the chime stones from the Marquis Yi's tomb]. *Journal of Nanjing Arts Institute*, (2), 41-44.

Wang, Anchao. (2006a). Cong zaoqide *shiqing* xingzhi kan *shiqing* de qiyuan [On the origin of the chime stone from the shape of early chime stones]. *Zhongguo Yinyue (Chinese music)*, (1), 105-107.

Wang, Anchao. (2006b). Zenghouyi *bianqing* mingwen jiaoshi ji chubu yanjiu [The explanation and preliminary research on the inscriptions of the chime stones from the Marquis Yi's tomb]. *Journal of Zhejiang Vocational Academy of Art*, *4*(4), 19-25.

Wang, Anchao. (2007). Yetan Zenghouyi *bianqing* yuelü mingwen zhong de yinjie wenti [A discussion on issues relevant to the musical scales in the chime stones' inscriptions of musical temperaments of the Marquis Yi's tomb]. *Journal of Nanjing Arts Institute,* (2), 40-43.

Wang, Bin., & Jia, Zhiqiang. (1991). Wutaixian Yangbaiyizhi Longshan *Teqing* jiqi xiangguanwenti [The Longshan culture single stone found in Wutai Yangbai and some related issues]. *Zhongguo Yinyuexue (Musicology in China)*, (4), 44-60.

Wang, Entian. (2000). Shandong Shangdai kaogu yu shangshi zhuwenti [Archaeology and history of the Shang dynasty in Shandong]. *Zhongyuan Wenwu (Cultural Relics of Central China)*, (4), 10-14.

Wang, Hui. (1989). Lun Qin Jinggong [Discussion on the Jinggong of the Qin state]. *Shixue Yuekan (Journal of historical science)*, (3), 19-25.

Wang, Hui., Jiao, Nanfeng., & Ma, Zhenzhi. (1996). Qingong damu *shiqing* canming kaoshi [A study of the inscriptions on the chime stones from the tomb of a duke of Qin]. *Zhongyang Yanjiuyuan Lishiyuyan Yanjiusuo (Institute of History and Philology, Academia Sinica)*, *67*(2), 263-310.

Wang, Renxiang. (2001). Huanghe qingwang faxianji [Field notes on a discovered chime stone in the Yellow River area]. *Wenwu Tiandi (Cultural Relics World),* (1), 35-39.

Wang, Shimin. (1959). Shanxian Houchuan 2040 hao mu de niandai wenti [The issues of the date of the tomb M2040 in Shanxian Houchuan]. *Kaogu (Archaeology)*, (5), 262-263.

Wang, Shanyou., Zhu, Guangyao., Tang, Hong., Kan, Xuhang., & Zhou, Qun. (2013). Zhongli guojun "Bai" zhi mu chutu *shiqing* yanjiu [A study of the chime stones excavated from the tomb of Bai, the King of Zhongli]. *Dongnan Wenhua (Dongnan Culture),* (3), 71-78.

Wang, Xiangqian., Li, Zhanyang., & Tao, Fuhai. (1987). Shanxi Xiangfen Daguduishan Shiqianshiqi zhizaochang chubu yanjiu [A preliminary study of a prehistoric stone tool workshop in Shanxi Xiangfen Daguduishan]. *Renleixue Xuebao (Acta Anthropologica Sinica),6* (2), 87-95.

Wang, Yuzhu., An, Zhixin., Tan, Weisi., & Hua, Jueming. (1988). Qingtong bianzhong shengpu yu shuangyin [The spectrum of bronze chime bells and two tones]. *Kaogu (Archaeology)*, (7), 757-765.

Wang, Zichu. (1997). Zhuhai Guoshi cang Xihan Zongmiao *bianqing* yanjiu [The research on the Western Han dynasty temple chime stones housed by Guo in Zhuhai]. *Wenwu (Cultural Relics)*, (5), 27-33.

Wang, Zichu. (2004). Shiqing de yinyue kaoguxue duandai [The music archaeological chronology of chime stones]. *Zhongguo Yinyuexue (Musicology in China)*, (2), 5-18.

Watson, A. (2006). (Un) intentional sound? acoustics and Neolithic monuments. In C. Scarre & G. Lawson (Eds.), *Archaeoacoustics* (pp.11-22). Cambridge: McDonald Institute for Archaeological Research.

Webb, J., Ford, A., & Gorton, J. (2007). Influences on selection of lithic raw material sources at Huizui, a Neolithic/early Bronze Age site in Northern China. *Bulletin of the Indo-Pacific Prehistory Association*, *27*, 76-86.

Wenren, Jun. (1982). *Kaogongji* zhong shengxue zhishi de shuli quanshi [Mathematical interpretations of the acoustics in the *Kaogongji*]. *Journal of Hangzhou University, 9* (4), 428-436.

Wenren, Jun. (2013). *Ancient Chinese encyclopedia of technology: translation and annotation of the Kaogongji*. New York: Routledge.

Winterson, J., & Harris, P. (2014). *Music theory: the essential guide*. London: Faber Music.

Wu, Hung. (2010). *The art of the Yellow Springs*. UK: London.

Wu, Shuoxian. (1994). Zhongguo gudai shengxue de fazhan [The development of ancient Chinese acoustics]. *Yishu Keji* (*Art Science and Technology)*, (4), 50-52.

Wu, Zhao. (1999). *Zhuixun shiqu de yinyue zongji: Tushuo Zhongguo Yinyueshi* [Searching for the lost music trail: an illustrated descriptive Chinese music history]. Beijing: Dongfang Chubanshe.

Xia, Ye. (1989). *Zhongguo gudai yinyueshi jianbian* [A compendium of ancient Chinese music]. Shanghai: Shanghai Yinyue Chubanshe.

Xiangfen County Museum. (2007). Shanxi Xiangfenxian Zhanghuai yizhi chutu daxing *shiqing* [The large sized chime stone excavated from the site of Xiangfenxian Zhanghuai in Shanxi]. *Kaogu (Archaeology)*, (12), 85-87.

Xing, Xiaofeng. (1992). Guanghan *shiqing* he Gubashu qingyue [The chime stones found in Guanghan and the music of chime stones in ancient Ba and Shu state]. *Sichuan Wenwu (Sichuan Cultural Relics)*, (6), 27-31.

Xing, Xiaofeng. (2002). Wushan chutu *taoxiangqi*, *shixun*, *shiqing* kaolue [Research on the unearthed clay rattles, stone ocarinas and chime stones at Wushan]. *Sichuan Wenwu (Sichuan Cultural Relics)*, (5), 15-17.

Xing, Xiaofeng., Liu, Zhihua., Sun, Wei., Shen, Bo., Wang, Qishu., & Liao, Ren. (2008). Gansu Wuwei Huangniangniangtai yizhi chutu yushibi yinyue shengxue xingneng chubu yanjiu [Preliminary research on the acoustical properties of the *pi* disk from Wuwei Huangniangniangtai in Gansu]. *Zhongguo Lishi Wenwu (Journal of National Museum of China)*, (4), 39-48.

Xing, Xiaofeng., & Wang, Fang. (2012). Jinsha yizhi chutu *shiqing* chubu yanjiu [Preliminary research on the excavated chime stones from Jinsha]. *Wenwu (Cultural Relics)*, (5), 63-73.

Xiu, Hailin., & Wang, Zichu. (2001). *Kandejian de yinyue- yueqi* [The musical instruments as a visual art]. Shanghai: Shanghai Wenyi Chubanshe.

Xu, Tianjin. (2006). Zhougongmiao yizhi de suohuo ji suosi [The acquisition and study of the relics at Zhougongmiao]. *Wenwu (Cultural Relics)*, (8), 55-62.

Xu, Weihong., Zhang, Yanglizheng., & Geng, Qinggang. (2016). Qin Xianyangcheng yizhi *shiqing* canjian fenxi [The analysis of broken chime stones found in Xianyangcheng of the Qin state]. *Wenbo (Relics and Museology)*, (2), 35-41.

Xu, Xuexian., Zhang, Baocheng., & Feng, Guangsheng. (1988). Zenghouyi mu biansheng fuyuan yanjiu [The reproduction of the sound of chime stones from the Marquis Yi's tomb of the Zeng state]. *Shengxue Jishu (Technical Acoustics)*, (2), 33-37.

Xu, Yanna. (2012). Lunshu Guozhuang Chumu de fajue yu tansuo [Research on the excavation and exploration of the Chu tombs in Guozhuang]. *Dazhong Wenyi (Popular Literature and Art)*, (1), 217-218.

Xuan, Zhaoqi. (1993). *Kaogongji* de guobie he chengshu niandai [The state affiliation and publication date of the *Kaogongji*]. *Ziran Kexueshi Yanjiu (Studies in the History of Natural Sciences)*, *12* (4), 297-303.

Xuzhou City Museum & The School of History at Nanjing University. (1988).Xuzhou Beidongshan Xihan mu fajue jianbao [A brief excavation report on the tombs of Beidongshan during the Western Han dynasty in Xuzhou]. *Wenwu (Cultural Relics)*, (2), 2-68.

Yang, Baocheng. (2002). Yinxu qingtongqi zuhe yanjiu [The research on combinations of the bronze vessels at Yinxu]. *Kaogu yu Wenwu (Archaeology and Cultural Relics)*, (3), 71-76.

Yang, Chaoming. (2007). *Chutu wenxian yu rujia xueshu yanjiu* [The unearthed texts and Confucian academic research]. Taiwan: Wunan Tushu.

Yang, Xuezheng. (2002). Zhongguo yuanshi zongjiao (Chinese primitive religion). In Compilation Committee (Eds.), *Zhongguo yuanshi zongjiao baike quanshu* [Chinese Original Religious Encyclopedia] (pp.7-29). Chengdu: Sichuan Cishu Chubanshe.

Yang, Yinliu. (1980). *Zhongguo gudai yinyue shigao* [The manuscript of the Chinese ancient music history]. Beijing: Renmin Yinyue Chubanshe.

Ye, Xiaoyan. (1983). Dongzhou kewen tongqi [Pictorial bronzewares in the Eastern Zhou period]. *Kaogu (Archaeology)*, (2), 158-164.

Ye, Zhengbo., & Wang, Xiuli. (2005). Zaoqing mingwen yanjiu [Research on the inscriptions of the Zao-chime stones]. *Zhongguo Wenzi Yanjiu (The Study of Chinese Characters)*, (6), 23-25.

Ying, Youqin. (1998). Zenghouyi *bianqing* de xuanfa yu xuangong [The suspension methods, transition and modulation of chime stones of the Marquis Yi's tomb of the Zeng state]. *Huangzhong (Journal of Wuhan Conservatory of Music),* (3), 20-29.

Yoo, J., & Rossing, T. (2006). Geometrical effects on the tuning of Chinese and Korean stone chimes. *The Journal of the Acoustical Society of America*, *120*(6), 78-83.

Yu, Yanjiao. (2013). *Huxiang chutu yuqi yanjiu* [Research on jade implements unearthed in Hunan]. Hunan: Yuelu Shushe.

Zhai, Shaodong. (2014). Shanxi Xiangfen Daguduishan yizhi shiliao ziyuan liyong moshi chutan [The exploration of using lithic products at Daguduishan site in Xiangfen, Shanxi]. *Kaogu (Archaeology),* (3), 58-67.

Zhai, Shaodong. (2015). Taosi Yizhi shizhipin fuzhi shiyan yu mozhi gongyi [Replication experiments on lithic products from the Taosi site including analysis of production techniques for ground stone tools]. *Renleixue Xuebao (Acta Anthropologica Sinica), 34*(2), 192-201.

Zhang, Baocheng., Xu, Xuexian., Chu, Meijuan., & Han, Liusheng. (1983). Wei jisuanji yongyu *qing* yin de fenxi [A mathematical analysis based on chime stones' pitches by using computer]. *Yueqi (Musical Instrument),* (6), 1-3.

Zhang, Dejun., Cheng, Jianzheng., & Zhu, Nianqiu. (1997). *Bianqing* zhenmo ji shengchang de jinchang shengquanxi moni yanjiu [A simulation research on vibration modes and radiation fields of chime stones using Nearfield Acoustic Holography]. *Wusun Jiance (NDT)*, *19*(11), 308-310.

Zhang, Guangzhi. (1976). *Zhongguo gudai wenming* [Early Chinese civilization: an anthropological perspective]. Cambridge: Harvard University Press.

Zhang, Lihua. (2006). *Zenghouyi yuegong de fuyuan yanjiu yu xuni chongjian*

[Research and virtual reconstruction on musical palace of Marquis Yi of the Zeng] (Masters dissertation). Zhejiang University.

Zhang, Qingli., & Zhang, Jie. (2017, August 25). Xinshiqishidai kaogu shenhua zhonghua wenming qiyuan renshi [Neolithic archaeology deepens the understanding of the origin of Chinese civilization]. *Chinese Journal of Social Science.* Retrieved from http://www.kaogu.cn/cn/kaoguyuandi/kaogusuibi/2017/0825/59366.html

Zheng, Ruifeng., & Zhang, Yicheng. (1983). Kalaqin qi faxian Xiajiadian xiaceng wenhua *shiqing* [The Lower Xiajiadian culture chime stone found in Kaliqin qi]. *Wenwu (Cultural Relics)*, (8), 54.

Zhang, Wei., & Ke, Li. (2019). Cong Haihunhou mu chutu yinyue ziliao tantao Haihunhou guo de yongyue zhidu [Discussion on the regularity of music usage in Haihun state from a perspective of musical materials unearthed in the tomb of Haihunhou]. *Xinghai Yinyue Xueyuan Xuebao (Journal of Xinghai Conservatory of Music)*, (3), 19-32.

Zheng, Zuxiang. (2005). Chutu *qing* he *bianqing* de kaogu leixingxue fenxi [The typological analysis of unearthed single chime stones and chime stone sets]. *Huangzhong* (*Journal of Wuhan Conservatory of Music*), (3), 61-68.

Zhongguo Yinyue Wenwu Daxi Editorial Department. (1996a). *Zhongguo yinyue wenwu daxi Henan juan* [The collected works on music and ancient findings in China, the volume of Henan]. Zhengzhou: Daxiang Chubanshe.

Zhongguo Yinyue Wenwu Daxi Editorial Department. (1996b). *Zhongguo yinyue wenwu daxi Shaanxi juan* [The collected works on music and ancient findings in China, the volume of Shaanxi]. Zhengzhou: Daxiang Chubanshe.

Zhongguo Yinyue Wenwu Daxi Editorial Department. (1996c). *Zhongguo yinyue wenwu daxi Hubei juan* [The collected works on music and ancient findings in China, the volume of Hubei]. Zhengzhou: Daxiang Chubanshe.

Zhongguo Yinyue Wenwu Daxi Editorial Department. (1996d). *Zhongguo yinyue wenwu daxi Sichuan juan* [The collected works on music and ancient findings in China, the volume of Sichuan]. Zhengzhou: Daxiang Chubanshe.

Zhongguo Yinyue Wenwu Daxi Editorial Department. (1996e). *Zhongguo yinyue wenwu daxi Beijing juan* [The collected works on music and ancient findings in China, the volume of Beijing]. Zhengzhou: Daxiang Chubanshe.

Zhongguo Yinyue Wenwu Daxi Editorial Department. (1998). *Zhongguo yinyue wenwu daxi Gansu juan* [The collected works on music and ancient findings in China, the volume of Gansu]. Zhengzhou: Daxiang Chubanshe.

Zhongguo Yinyue Wenwu Daxi Editorial Department. (2000). *Zhongguo yinyue wenwu daxi Shanxi juan* [The collected works on music and ancient findings in China, the volume of Shanxi]. Zhengzhou: Daxiang Chubanshe.

Zhongguo Yinyue Wenwu Daxi Editorial Department. (2001). *Zhongguo yinyue wenwu daxi Shandong juan* [The collected works on music and ancient findings in China, the volume of Shandong]. Zhengzhou: Daxiang Chubanshe.

Zhongguo Yinyue Wenwu Daxi Editorial Department. (2006). *Zhongguo yinyue wenwu daxi Hunan juan* [The collected works on music and ancient findings in China, the volume of Hunan]. Henan: Daxiang Chubanshe.

Zhongguo Yinyue Wenwu Daxi Editorial Department. (2008). *Zhongguo yinyue wenwu daxi Hebei juan* [The collected works on music and ancient findings in China, the volume of Hebei]. Henan: Daxiang Chubanshe.

Zhongguo Yinyue Wenwu Daxi Editorial Department. (2010). *Zhongguo yinyue wenwu daxi Guangdong juan* [The collected works on music and ancient findings in China, the volume of Guangdong]. Henan: Daxiang Chubanshe.

Zhu, Guowei. (2010). *Wuxi Hongshan Yuemu de yinyue kaogu faxian yu yanjiu* [The research on music archaeological findings of Hongshan Yue tomb in Wuxi] (Masters dissertation). Chinese National Academy of Arts.

Zhuang, Benli. (1966). Guqing yanjiu zhi yi [Studies on ancient musical stones, part one]. *Zhongyang Yanjiuyuan Minzuxue Yanjiusuo Jikan (Bulletin of the Institute of Ethnology Academia Sinica)*, (22), 97-137.

Appendix 1 Glossary of Chinese Terms

***Ba Yin* 八音**: Eight tones, a classification system of musical instruments which divided all musical instruments into eight groups based upon their manufacturing materials.

***biangong* 變宮**: In traditional Chinese music, the seventh degree has a proper term *biangong* (si).

***bianzhi* 變徵**: In traditional Chinese music, the fourth degree often appears as *bianzhi* (sharp fa or $^{\sharp}$fa) instead of using the original note fa.

***bo* or *bo*-bell 鎛鐘**: A large bell, one of the major classes of Chinese musical bells of the Zhou dynasty.

***chi* 篪**: A bamboo transverse flute with stopped pipe.

***chongdu* 舂牘**: A kind of bamboo-made percussion instrument.

***chunyu* 錞於**: A class of mallet-struck bronze bells with oval cross-sections and bulging manufactured in ancient China.

***Da Wu* 大武**: Great *Wu*, a distinguished composition of ritual music and dance for eulogizing King Wu, who defeated the Shang dynasty and built a new Western Zhou dynasty.

***ding* 鼎**: A bronze cooking vessel with three tripods.

***dou* 豆**: A bronze vessel for containing food.

***duo* 鐸**: A bronze signal-sounding handbell with clapper.

***fangkong chanxingqi* 方孔鏟形器**: A spade-shaped tool with a square hole.

***gong* 宮, *shang* 商, *jue* 角, *zhi* 徵, *yu* 羽**: Ancient Chinese music theory showed the nomenclature of five notes as *gong* 宮, *shang* 商, *jue* 角, *zhi* 徵 and *yu* 羽, which approximately corresponds to do, re, mi, sol, and la, respectively, in the modern tonic *sol-fa* system.

***gongfan* 宮反**: An octave note of *gong* (do) that appears on bells and chime stones inscriptions of Marquis Yi's tomb of the Zeng state.

***gongjue* 宮角**: A major third above *gong* (i.e. the mi), which appears on bells and chime stones inscriptions of Marquis Yi's tomb of the Zeng state.

***goudiao* 句鑃**: A kind of mallet-struck bronze bell, which is mounted mouth-up; its distribution is limited to the south-eastern region of China, belonging to the remains of Wu and Yue culture.

gui **簋**: A round-mouthed bronze vessel for containing food.

gushangbian **鼓上邊**: The long top edge of the chime stone; when the chime stone is hung up on the wooden or bronze rack, this side drops naturally.

guushangbian **股上邊**: The short top edge of the chime stone.

gushangjiao **鼓上角**: An angle connecting both sides of the *gushangbian* and *gubo* of chime stone.

guushangjiao **股上角**: An angle connecting both sides of the *guushangbian* and *guubo* of chime stone.

guxiajiao **鼓下角**: An angle connecting both sides of the *gubo* and *guxiabian* of chime stone.

guuxiajiao **股下角**: An angle connecting both sides of the *guubo and guuxiabian* of chime stone.

gubo **鼓博**: The short and straight side on the *gu* part of the chime stone.

guubo **股博**: The short and straight side on the *guu* part of the chime stone.

he **龢**: A term expressing the fourth degree note (fa) in Marquis Yi's bell-inscriptions, which appears in classical texts as *qingjue* 清角.

hu **壺**: A bronze wine vessel.

jian **鑒**: A bronze vessel for containing water.

jiangu **建鼓**: A pole drum.

jue **角**: A three-legged wine cup; a note of third degree in pentatonic scale.

jugou **倨句**: The vertex angle of a chime stone.

Kui **pattern 夔紋**: An imaginary animal pattern resembling bird, snake or dragon.

ling **clapper-bell 鈴**: A clapper bell suspended from loops, typologically ancestral to all types of Chinese chime bells.

Meihua Sannong **梅花三弄**: *Plum-blossom in three movements*. An ancient Chinese tune which appeared approximately in the Jin dynasty (265-420 CE).

mingqi **明器**: The imitational version of the real musical instrument chime stones, which are an unplayable pseudo-instrument.

mingqiu 鳴球: A sounding ball or ringing ball.

mu 穆: A tone-naming which appears in the Zeng inscriptions; equivalent to traditional note *run* 閏, the flat note of seventh degree (♭si).

***niuzhong*-bell** 鈕鐘: A bell with a suspension loop. One of the major classes of Eastern Zhou musical bells.

paixiao 排簫: A panpipe.

***pi* disk** 玉璧 (*bi* in *Pinyin* system): A Chinese jade disk.

pianyin 偏音: A remote or incidental note, which were "coloured tones" (tones that are bright and become a splash of colour in a scale) in ancient music. The *pianyin* usually include *qingjue* (fa), *bianzhi* (♯fa) and *biangong* (si).

se rui 瑟枘: A bronze anchor for fixing strings of the *se* zither, it usually appeared with four post on one end of the wooden front-panel.

sheng 笙: A mouth organ.

shijue 石钁: A kind of polished stone tool.

taogu 鞀鼓: A pellet drum.

tongchang 通長: The whole length of the chime stone.

tonggao 通高: The whole height of the chime stone.

twelve-lü 十二律: Twelve-pitch standards within one octave.

two-tone 雙音: The ancient Chinese musical bell can produce *two-tone* 雙音. The first tone is heard when the bell is struck in the centre above the mouth and the second tone produces when it is struck to the right (sometimes the left) of this area, producing one bell with *two-tone* phenomenon.

xiao 簫: A vertical bamboo flute.

xuankong 懸孔: The suspension hole of the chime stone.

xun 塤: An ocarina, a wind instrument often made of clay.

ya 雅: A kind of wooden percussion instrument resembling an ox horn in shape.

yayue 雅樂: Elegant music, a ritual music performed in the ancient court.

***yongzhong*-bell 甬鐘**: A bronze bell with a shank and its mouth facing downward when suspending from a rack; the principal class of chime bells during the Western and Eastern Zhou times.

***yong*-bell 庸**: Li Chunyi explains that the late Shang small chime bells found in Anyang were likely named *yong* 庸 according to information from oracle bone inscriptions and the classic poem *Shi Jing*, while their large counterpart found in southern China such as Hunan, Jiangxi and Anhui was called *yong* 鏞, both are the same pronunciation in *Pinyin* system but have different Chinese characters.

***yu* 竽**: A larger mouth organ.

***yue* 鉞**: A large-sized bronze weapon in the shape of an axe profile.

***yue* 籥**: A wind instrument.

Yuefu 樂府: The word Yuefu has two meanings, it can be understood to mean Chinese poetry composed in a folk song style but here it refers to an important music institution in the royal court which appeared as early as the Qin dynasty.

***zheng* 鉦**: A mallet-struck bell with a long shank, usually used as a signaling instrument.

***zhu* 柷**: A kind of wooden percussion instrument in the shape of a box, sounded by pounding with a pestle.

Note: Chinese musical instruments, Chinese musical terms (except the names of the *twelve-lü* tuning system) and the titles of books are written in italics in this thesis.

Appendix 2 The Abbreviation of Institutions in China

AHGZD: Anhui Sheng Wenwu Gongzuodui (Archaeological Working Team of Anhui)

AHSGZD & FY Museum: Anhui Sheng Wenwu Gongzuodui and Fuyang Diqu Bowuguan (Heritage Working Station in Anhui, the Museum of Fuyang)

AHWGS: Anhui Sheng Liu'anxian Wenwu Guanlisuo (Heritage Management Office in Anhui)

AHWYS, FYWGS: Anhui Sheng Wenwu Kaogu Yanjiusuo, Fengyang Xian Wenwu Guanlisuo (Anhui Provincial Institute of Cultural Relics and Archaeology, Heritage Management Office in Fengyang)

AYWGD: Anyang Wenwu Gongzuodui (Heritage Working Team of Anyang)

BDKGXX: Beijing Daxue Kaogu Xuexi (Department of Archaeology, Peking University**)**

CSWHJWWZ: Changsha Shi Wenhuaju Wenwuzu (Changsha Cultural Bureau Heritage Group)

DJWFD: Henan Sheng Danjiangkuqu Wenwu Fajuedui (Cultural Relics Excavation Team in Danjiangku Area in Henan)

DXFKGD: Dongxiafeng Kaogudui (Archaeological Team of Dongxiafeng)

EQARG: Zaoqi Qinwenhua Kaogu Lianhe Ketizu (Collaborative Archaeological Research Group of the Early Qin Culture)

EQJT: Zaoqi Qinwenhua Lianhe Kaogudui (Early Qin Culture Archaeological Joint Team)

GZWGW: Guangzhou Shi Wenwu Guanli Weiyuanhui (Guangzhou Municipal Cultural Relics Management Committee)

HBWYS: Hebei Sheng Wenwu Yanjiusuo (Hebei Provincial Institute of Cultural Relics)

HBWHJWGD: Hebei Sheng Wenhuaju Wenwu Gongzuodui (Heritage Working Team and Cultural Bureau of Hebei)

HMWPD & YXWHG: Huimin Diqu Wenwu Puchadui, Yangxinxian Wenhuaguan (Huimin Area Cultural Heritage Census Team and Yangxin Cultural Centre)

HNWHJWGD: Henan Sheng Wenhuaju Wenwu Gongzuodui (Heritage Working Team and Cultural Bureau of Henan)

HNWYS: Henan Sheng Wenwu Kaogu Yanjiusuo (Henan Provincial Institute of

Cultural Relics and Archaeology)

HUBWYS: Hubei Sheng Wenwu Kaogu Yanjiusuo (Hubei Provincial Institute of Cultural Relics and Archaeology)

HUNWYS: Hunan Sheng Wenwu Kaogu Yanjiusuo (Hunan Provincial Institute of Cultural Relics and Archaeology)

JNKGS: Jinan Shi Kaogu Yanjiusuo (Jinan Municipal Institute of Archaeology)

JSKGS: Jiangsu Sheng Kaogu Yanjiusuo (Archaeological Institution of Jiangsu)

JSDTKGD: Jiangsu Dantu Kaogudui (Archaeological Team of Dantu in Jiangsu)

JXWYS: Jiangxi Sheng Wenwu Kaogu Yanjiusuo (Jiangxi Provincial Institute of Cultural Relics and Archaeology)

JZ Museum: Hubei Sheng Jingzhou Diqu Bowuguan (Jingzhou City Museum in Hubei)

LNSBGZD & CYBWGWWZ: Liaoning Sheng Bowuguan Wenwu Gongzuodui & Chaoyang Diqu Bowuguan Wenwuzu (Archaeological Team of Liaoning Provincial Museum, The Chaoyang Heritage Museum Group)

LYWGD: Luoyang Shi Wenwu Gongzuodui (Heritage Working Team of Luoyang)

LZWWJ: Zibo Shi Linziqu Wenwuju (Heritage Bureau of Zibo Linzi)

NDLSX: Nanjing Daxue Lishixi Kaogu Zhuanye (School of History at Nanjing University)

NJBWY&XYWGJ: Nanjing Bowuyuan, Xuyi Xian Wenguang Xinju (Nanjing Museum and Xuyi Cultural Relics Bureau)

PDSWGJ&YXWHJ: Pingdingshan Shi Wenwu Guanliju and Yexian Wenhuaju (Heritage Management Bureau in Pingdingshan and Culture Bureau of Henan Yexian)

QHWGKGD: Qinghai Sheng Wenwu Guanlichu Kaogudui (Qinghai Provincial Cultural Relics Management Office Archaeological Team)

SCWYS: Sichuan Sheng Wenwu Kaogu Yanjiusuo (Sichuan Provincial Institute of Cultural Relics and Archaeology)

SDKGX & SDWYS: Shandong Daxue Lishi Wenhua Xueyuan Kaoguxi & Shandong Sheng Wenwu Kaogu Yanjiusuo (Archaeology Department of the School of History and Culture in Shandong University and Shandong Provincial Institute of Cultural Relics and Archaeology)

SDKGX: Shandong Daxue Lishi Wenhua Xueyuan Kaoguxi (Archaeology Department of the School of History and Culture in Shandong University)

SDWYS: Shandong Sheng Wenwu Kaogu Yanjiusuo (Shandong Provincial Institute of

Cultural Relics and Archaeology)

SDYXWHG: Shandong Yangxin Xian Wenhuaguan (Shandong Yangxin Cultural Centre)

SSWGHHMZ: Shanxi Sheng Wenwu Guanli Weiyuanhui Houma Gongzuozhan (Shanxi Provincial Cultural Relics Committee, Houma Working Station)

SXJDNWHJ: Shanxi Sheng Jindongnan Diqu Wenhuaju (Shanxi Provincial Jindongnan Cultural Bureau)

SXKGYJY: Shaanxi Sheng Kaogu Yanjiuyuan (Shaanxi Provincial Institute of Archaeology)

SXKGS: Shanxi Sheng Kaogu Yanjiusuo (Shanxi Provincial Institute of Archaeology)

SXLFWWJ: Shanxi Sheng Linfen Shi Wenwuju (Shanxi Linfen Municipal Cultural Relics Bureau)

SXWGW: Shaanxi Sheng Wenwu Guanli Weiyuanhui (Shaanxi Provincial Commission for Administration of Cultural Relics)

SXWGH: Shanxi Sheng Wenwu Guanli Weiyuanhui (Shanxi Provincial Cultural Relics Management Committee)

TYWGH: Taiyuanshi Wenwu Guanli Weiyuanhui (Taiyuan Municipal Cultural Relics Management Committee)

WNKGBHS: Weinan Shi Wenwu Baohu Kaogu Yanjiusuo (Institute of Archaeology and Relic Protection in Weinan City)

WWDXBJB: *Zhongguo Yinyue Wenwu Daxi* Bianjibu (*Zhongguo Yinyue Wenwu Daxi* Editorial Department)

XYWYS: Xiangyang Shi Wenwu Kaogu Yanjiusuo (Xiangyang City Institute of Archaeology and Cultural Relics)

ZJKGS & CX Museum: Zhengjiang Sheng Wenwu Kaogu Yanjiusuo, Changxing Xian Bowuguan (Archaeological Institution of Zhejiang and Changxing County Museum)

ZJKGS & HY Museum: Zhengjiang Sheng Wenwu Kaogu Yanjiusuo, Haiyan Xian Bowuguan (Archaeological Institution of Zhejiang and Haiyan County Museum)

ZKYWWYS: Zhongguo Kexueyuan Wuhan Wuli Yanjiusuo (Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences)

ZSKKGS & LFWWJ: Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo, Shanxi Sheng Linfen Shi Wenwuju (Institute of Archaeology, Chinese Academy of Social Sciences and Linfen Municipal Cultural Relics Bureau, Shanxi province)

ZSKKGS: Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo (Institute of Archaeology, Chinese Academy of Social Sciences)

ZSKKGSAYFJD: Zhongguo Kexueyuan Kaogu Yanjiusuo Anyang Fajuedui (Archaeological Excavation Team of Anyang, Institute of Archaeology, Chinese Academy of Social Sciences)

ZSKKGSFXFJD: Zhongguo Kexueyuan Kaogu Yanjiusuo Fengxi Fajuedui (Archaeological Excavation Team of Fengxi, Institute of Archaeology, Chinese Academy of Social Sciences)

ZSKKGS, CFD, NMWYS & JDKGX: Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo, Chifeng Kaogudui, Neimenggu Zizhiqu Wenwu Kaogu Yanjiusuo & Jilin Daxue Kaoguxi (Archaeological Team of Chifeng, Institute of Archaeology, Chinese Academy of Social Sciences, Inner Mongolia Institute of Cultural Heritage and Archaeology & The Archaeology Department in Jilin University)

ZSKKGSELTGZD: Zhongguo Kexueyuan Kaogu Yanjiusuo Erlitou Gongzuodui (Archaeological Team of Erlitou, Institute of Archaeology, Chinese Academy of Social Sciences)

ZSKKGSAYGZD: Zhongguo Kexueyuan Kaogu Yanjiusuo Anyang Gongzuodui (Archaeological Working Team of Anyang, Institute of Archaeology, Chinese Academy of Social Sciences)

ZSKKGSSDGZD: Zhongguo Kexueyuan Kaogu Yanjiusuo Shandong Gongzuodui (Archaeological Working Team of Shandong, Institute of Archaeology, Chinese Academy of Social Sciences)

ZYKGD: Zhouyuan Kaogudui (Archaeological Working Team of Zhouyuan)

ZYYJYYYS: Zhongguo Yishu Yanjiuyuan Yinyue Yanjiusuo (Institute of Music in Chinese National Academy of Arts)

Note: The abbreviations above are arranged by using capital letters of the Chinese *Pinyin* system for short. Although using English letters was considered, this thesis prefers to use the *Pinyin* pronunciation of the Chinese institutions. The brackets are English translations of the institutions.

Appendix 3 Spreadsheet

Spreadsheet 1 A statistical form of 65 chime stones from my fieldwork

This spreadsheet, which constitutes a number of database of my fieldwork, is unavailable to attach here. Please see U Disk for details.