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SHERDS OF SOCIETIES: QUANTITATIVE AND PETROGRAPHIC ANALYSIS OF NEOLITHIC CERAMICS IN NORTHEAST CHINA

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Abstract

In China, Neolithic sites are routinely attributed to "archaeological cultures" through typological comparisons of complete pottery vessels. However, ceramic datasets have the potential to reveal more than a chrono-cultural attribution. Taking into account not only all the complete vessels but also all the sherds excavated from a site makes it possible to use quantitative analysis as well as morpho-stylistic and petrographic approaches to measure the heterogeneity of the ensemble and ask why and how it was formed. The Wutaishan site in Nong'an, Jilin province, located at the centre of Northeast China, was chosen to implement this methodology. The ceramology research on the complete pottery dataset excavated at this site sheds light on the long- and short-distance exchanges networks in Northeast China at the turn of the 4th millennium BCE, provides a new understanding of inter-site relations in the Yitong River valley, and opens perspectives on the interpretation of the functional spatial layout within the site itself.

Keywords

Ceramic analysis Petrography Neolithic China Settlement Craft production

1. Introduction

In recent years, new research questions and methods are deeply transforming Chinese archaeology (Berger et al., 2021). The discipline traditionally aimed to identify archaeological cultures – fundamentally understood as pottery assemblages - through their preeminent traits and spatiotemporal delimitations, the most important methodological approach to do so being typological analysis of complete ceramic vessels (Hein, 2016). Routinely, after the excavation of a new site, the refitted vessels are compared to previously published objects to attribute the site to an archaeological culture, date it and place it in its regional sequence. In other words, the excavated artefacts from a "level" or occupation period of one excavation sector of a site are used to attribute the entire site to an "archaeological culture". The concept of archaeological culture, in this context, is often – more or less unconsciously - understood as a closed and homogeneous material culture corresponding to a specific human group (e. g. Zhao, 2012). However, a multiscale study of the entirety of the pottery remains unearthed at one site, taking into account quantitative data about types of fabrics and decoration on all the sherds, manufacturing macro-traces, morphology and decoration of complete vessels, as well as petrographic fabric compositions on thin-sections, shows a more nuanced reality: this type of assemblage, far from being homogeneous, reflects exchanges of products, objects, techniques and ideas between communities, which were anything but closed groups.

The Wutaishan site was chosen to test this approach. It is located in the Yitong River valley in central Jilin province, in Northeast China, and has been identified as belonging to the local "Culture of the Lower Level of Zuojiashan" (hereafter called LLZ culture, ca. 5500-3500 BCE). Well-known contemporary Middle Neolithic archaeological cultures in neighbouring areas are: to the north, the culture of the II[nd] Level of Houtaomuga (or Huangjiaweizi type, ca. 6000-5300 BCE) and the culture of the III[rd] Level of Houtaomuga (ca. 4300-3500 BCE) in the Lower Nen River valley (Wang et al., 2017; Wang, 2018); to the southwest, the Xinglongwa culture (ca. 6000-4500 BCE) with the Xinglongwa (Zhongguo, 1985; Zhongguo, 1997b), Xinglonggou (Zhongguo, 2004), Baiyinchanghan (Neimenggu, 2004), and Chahai (Liaoning, 2012) sites and the Zhaobaogou culture (ca. 5000-4700 BCE) (Zhongguo, 1997a) in the Liaoxi region (Jia et al., 2016); and to the south, the culture of the Lower Level of Xinle (ca. 5500-4500 BCE) (Shenyang and Xinle, 2018) in the Liao River valley (Fig. 1).

In Northeast China, the earliest potteries appear around 10,000 BCE in a context of hunter-gatherer seasonal occupations in the Lower Nen River valley (Kunikita et al., 2017; Wang and Sebillaud, 2019). Following a trajectory somewhat similar to that of North China, defined as the region of the Yellow River basin and areas to its north (Shelach- Lavi and Tu, 2017), during the Neolithic, pottery production progressively intensified, which can be seen through an increase in the number of vessels produced and through the diversification of their functions. The Wutaishan site belongs to this context (Neolithic Northeast China), and its excavations have revealed a group of well-preserved aligned semi-subterranean buildings, along with pits and ditches, which yielded over a ton of sherds.

After presenting the Wutaishan site and its ceramic assemblage, as well as the methods and goals of this research, the present article will show how morpho-stylistic and petrography analyses reveal various groups among the Wutaishan sherds and will discuss the socio-regional significance of this heterogeneity, providing new insights on artefact exchange networks in Northeast China, on the nature of the relations between the sites of the Yitong River valley, and on the functional layout of the Wutaishan settlement itself.

2. The Wutaishan site and its pottery dataset

2.1. Geographical context

Northeast China is the region of the rivers flowing into the Bohai Bay, delimited to the west by the Da Xing'an (Greater Khingan) Mountains, to the north by the Xiao Xing'an (Lesser Khingan) Mountains and the Amour River, and to the east by the Changbai Mountains, the Yalu and the Tumen Rivers. Between Mongolia, Russia and Korea, it includes Heilongjiang, Jilin and Liaoning provinces and the eastern part of Inner Mongolia. The Northeast China Plain – the sedimentary basin of the Songhua and Liao Rivers – is covered with alluvial, lacustrine and eolian deposits (unconsolidated sediments, such as sand, gravel and clay).

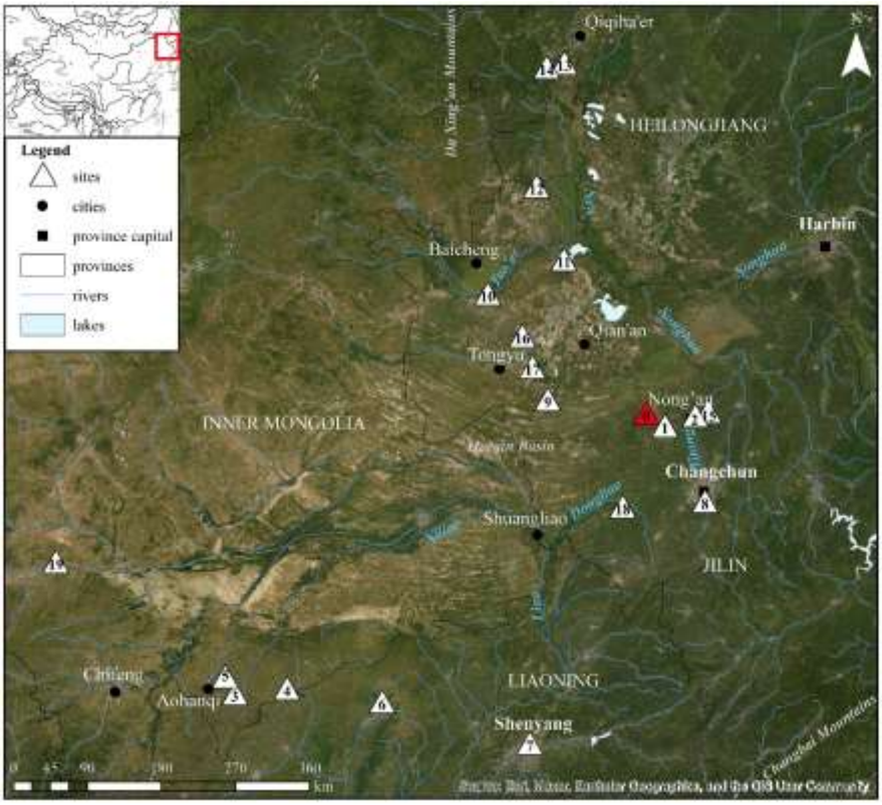

Fig. 1. The Northeast China Plain. 0. Wutaishan, 1. Yuanbaogou, 2. Zuojiashan, 3. Zhaobaogou, 4. Xinglongwa, 5. Xinglonggou, 6. Chahai, 7. Xinle, 8. Yaohongzuizi, 9. Yaojingzi, 10. Shuangta, 11. Houtaomuga, 12. Huangjiaweizi, 13. Angangxi, 14. Honghe, 15. Liangjiazi, 16. Zhourongtun beigang, 17. Chuanzijing, 18. Changshan, 19. Baiyinchanghan

The Wutaishan site is located on five terraces dominating the northwestern shore of Boluo Lake, in the western part of the Yitong River valley. Located west of the Ke'erqin Basin (Sebillaud et al., 2019) and east of the Yitong, this area is a landscape of flat lands full of marshes and lakes - today in process of desertification (Fig. 2), and somewhat less dominated by water and less affected by the erosion processes than the Lower Nen River valley (Sebillaud et al., 2021).

2.2. History of related research: From a site to an archaeological culture

The Zuojiashan site, after which the material assemblage at Wutaishan is named, is located north-northwest of Nong'an, on the northeast shore of a currently dried-up lake, about 35 km east of Wutaishan, and has been excavated twice, in 1985 (Jilin, 1989a) and 2015 (Jilin et al., 2018a). The excavation covered a total of 885 m_2, and yielded 25 Neolithic features.

In 1985, the 400 m_2 excavation zone yielded remains which were divided into three periods and four phases by the excavators, who established the first sequence with two C14 dates and comparisons with contemporary data from Northeast China available at the time (Jilin, 1989a) (Table 1). Later, Chen Quanjia and Zhao Binfu consolidated this chronological frame (Chen and Binfu, 1990). This chronological sequence of Zuojiashan was then further discussed and slightly amended by other authors (Xu, 1989; Chen, 1992). Based on these data, in 2003, in his large synthesis of Northeast China Paleolithic and Neolithic periods (Zhao, 2003), Zhao Binfu names three archaeological cultures corresponding to the three levels of occupation of the Zuojiashan site, attributing other surrounding discoveries to each one. But in 2012, he merges the first two into one (Zhao, 2012), creating the structure with a three-phased "Culture of the Lower Level of Zuojiashan" (ca. 5500–4000 BCE) and a two-phased "Culture of the Upper Level of Zuojiashan" (ca. 4000–2500 BCE), which became the standard and was used for the report on the 2015 excavation (Jilin et al., 2018a; Duan, 2018).

The surrounding sites which have been attributed to the LLZ culture after excavation, and which have enough published data to allow comparisons, are Yuanbaogou, Yaohongzuizi and Yaojingzi. Other sites, which have not been excavated or have less published materials, attributed to the LLZ culture include Xiduanliangshan and over 40 other sites with LLZ culture sherds discovered during the Second National Survey (Zhao and Huaishi, 2016a).

The Yuanbaogou site is located on the southeast shore of Boluo Lake, about 20 km away from Wutaishan. A total of 373 m_2 at the site were excavated in 1985 (Jilin, 1989b), yielding five pits filled with sherds and animal bones. It is dated between ca 4500 and 3500 BCE.

The Yaohongzuizi site, south of the modern city of Changchun and about 100 km south-southeast of Wutaishan, was excavated in 1994 (Jilin and Changchun, 2003), on 1107 m_2.

The Yaojingzi site, located in Changling District, about 120 km west of Wutaishan, was excavated in 1986 (550 m_2) and yielded seven house foundations, one pit and two burials (Jilin et al., 1992).

For a region covering thousands of square kilometres and a period spanning over two millennia, these quite scarce data give a misleading impression of cultural unity, hiding local nuances.

The Wutaishan site was discovered in 2016 during the Third National Survey and excavated in 2017 and 2018 (Cui, 2020). It stands out by its extent: coring shows remains on a 4 km long stretch of the terraces on the shore of Boluo Lake, further divided into five sectors, two of which (A and D, sector D being given the new name of "Xingshushan" site in a recent publication [Jilin et al., 2023]) were excavated, totaling 1568 m_2. It yielded the greatest number of features and the largest quantity of artefacts among the known LLZ culture sites. Radiocarbon dates place the Neolithic occupation around 4000 BCE (between 4300 and 3800 BCE) (Table 2).

2.3. The Wutaishan pottery dataset

The excavated material is mostly ceramic: 116,699 sherds (Total Number of Sherds, TNS) weighing 1209.88 kg, with a Minimum Number of Individuals (MNI) of 3186. Here, the MNI has been calculated using the sherds of rims (15,733 rim fragments, 13.5% of the TNS), which corresponds to the number of rims showing distinct morphological features in each Stratigraphic Unit (SU), thus providing a rough estimate of the actual number of vessels (Husi, 2001). 58.3% of the TNS shows decoration, with over 40 variations. In addition, over 80 complete vessels have been reconstructed so far (Fig. 3).

3. Methods and goals

This article aims to raise the following questions: was the pottery unearthed at Wutaishan, attributed to the LLZ culture, really a homogeneous production? What caused the variability within this collection? Can it be explained by aesthetic, chronological, functional or socio-cultural choices? What role did these ceramics play in the community? What do they reveal about human interactions in Neolithic Northeast China?

The totality of the reconstructed artefacts and excavated sherds unearthed at Wutaishan have been analyzed, along with 20 thin sections, allowing us to use quantitative morpho-stylistic analysis, as well as spatial and petrographic analyses.

3.1. Quantitative analysis

Previous research on similar (LLZ) datasets were only cultural typochronologies based on morpho-stylistic criteria. In order to set this project in the continuity of previous research, ceramic groups have first been delineated by stylistic attributes and then, tested and refined according to petrographic criteria.

In addition to the traditional typological analysis applicable only to reconstructed vessels, a quantitative analysis of the entirety of the TNS has been carried out. To our knowledge, this is a first in China, where, even if they are often counted, the sherds are rarely taken into account in the interpretation of the data (Duval et al., 2019).

In order to classify them into morpho-stylistic groups, the sherds of each SU were sorted according to temper type, vessel part, decoration and shape, when possible. Due to firing hazards and variability of taphonomic context, several colours were often present on the same object, so this criterion is not relevant for the analysis of the sherds.

In the database, the choices of categories and terminology revolve around the key concepts of fabric, morphology and decoration. The decoration shows complex variations, and has been was described according to techniques (incision, impression, or addition) and themes (Shepard, 1956; Balfet et al., 1989; Cauliez et al., 2002; Roux and Courty, 2019). Decoration themes are divided into three description levels: the pattern (smallest measurable morphological unit), the figure (organization of the patterns) and the theme (composition) (Fig. 4). The term 'decoration' designates all the decorative levels of a particular artefact, which can be composed of one or more themes; it refers to the final rendering on the object.

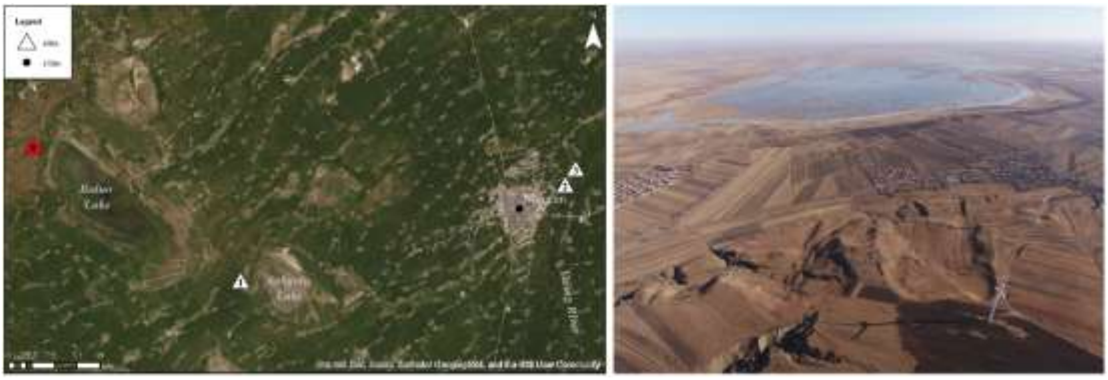

Fig. 2. Landscape around the Wutaishan site. Left: Map of the Wutaishan site area. 0. Wutaishan, 1. Yuanbaogou, 2, Zuojiashan, 3. Liangjiazi. Right: aerial photograph of the Wutaishan site on the shore of the Boluo Lake.

Table 1 From "site" to "culture": the Zuojiashan site typochronology.

<table>
<tr><th colspan="2">Zuojiashan site occupation phases
Bibliographical references</th><th>Period I Early phase</th><th>Period I Late phase</th><th colspan="2">Period II</th><th>Period III</th></tr>
<tr><td rowspan="2">Jilin 1989a, Chen and Zhao 1990</td><td>comparison</td><td>contemporary to Xinle Lower Level F2 group (7245±BP, 5295 BC), Xinglongwa (5290±BC)</td><td>contemporary to Xinle Lower Level F1 group (6145±120BP, 4195±120BC, cal. 6800±145BP)</td><td colspan="2">contemporary to Houwa, Dagang, Xiaozhushan period I</td><td>contemporary to Xiaozhushan period II (5810±100 BP, 3860 BC; 5455±110 BP, 3505 BC; 5720±150 BP, 3770 BC; 5270±100 BP, 3320BC)</td></tr>
<tr><td>Zuojiashan</td><td>6th millennium BC</td><td>5th millennium BC, C14: 6100±80 BP, cal. 6755±115BP, ca. 4700 BC</td><td colspan="2">Early 4th millennium</td><td>3800-2800 BC, C14: 4375±80 BP, cal. 4870±180 BP, ca. 2800 BC</td></tr>
<tr><td colspan="2">Xu 1989</td><td colspan="2">contemporary to Xiaozhushan Lower Level, Houwa, Dagang, Xinglongwa, Gaotaishan period I</td><td colspan="3">contemporary to Xiaozhushan Middle Level, Guojiacun Lower Level, Wujiacun</td></tr>
<tr><td colspan="2">Chen 1992</td><td>Phase I contemporary to Xiaozhushan Lower Level, Gaotaishan,</td><td>Phase II contemporary to Xinle Lower Level F2 group</td><td>Phase III contemporary to Xiaozhushan Middle</td><td>Phase IV</td><td>Phase V contemporary to Xiaozhushan Upper Level, Guojiacun Upper Level</td></tr>
</table>

	Xinglongwa		Level, Guojiacun Lower Level, Shangmashi F1 group			
Zhao 2003: 329-339	“Early stage of the Culture of the Lower Level of Zuojiashan”, 5500-5000 BC	“Late stage of the Culture of the Lower Level of Zuojiashan”, including Yaojingzi, Yuanbaogou, Daqingzui, Erqingzui, Chuanzijing, Yongfeng, Erdaolingzi, Hutoulizi, C14: 6100±80 BP, cal. 4936-4773 BC; rounded to 5000-4500 BC	“Culture of the Middle Level of Zuojiashan”, including Period I of Xiduanliangshan; 4500-4000 BC		“Culture of the Upper Level of Zuojiashan”, including the Upper Level of Xiduanliangshan, C14: 4375±80 BP, cal. 2921-2703 BC; rounded to 3500-2500 BC	
Zhao 2012, Zhao and Yu 2016a	“Culture of the Lower Level of Zuojiashan” early phase 5500-5000 BC	“Culture of the Lower Level of Zuojiashan” middle phase 5000-4500 BC	“Culture of the Lower Level of Zuojiashan” late phase 4500-4000 BC		“Culture of the Upper Level of Zuojiashan” early phase 4000-3500 BC	“Culture of the Upper Level of Zuojiashan” late phase 3500-3000 BC
Jilin et al. 2018a, Duan 2018	“Culture of the Lower Level of Zuojiashan”, C14: 4800±30 BC, cal. 3635 BC; 4740±30 BC, cal. 3625-3525 BC				“Culture of the Upper Level of Zuojiashan”, 3500-3000 BC	

Table 2 Radiocarbon dates on animal bones from Wutaishan.

Sample number	Feature	Radiocarbon age	Calibrated dates (95.4%)
2017NWAIF2：6	House foundation	5460 +/- 30 BP	(50%) 4304 - 4251 cal BC (6253 - 6200 cal BP) (45.4%) 4356 - 4312 cal BC (6305 - 6261 cal BP)
2018NWAIIF2②：74	House foundation	5360 +/- 30 BP	(28.2%) 4136 - 4054 cal BC (6085 - 6003 cal BP) (24.5%) 4268 - 4216 cal BC (6217 - 6165 cal BP) (24.1%) 4206 - 4159 cal BC (6155 - 6108 cal BP) (18.6%) 4328 - 4286 cal BC (6277 - 6235 cal BP)
2017NWAIF6：15	House foundation	5260 +/- 30 BP	(45.8%) 4082 - 3984 cal BC (6031 - 5933 cal BP) (34.5%) 4169 - 4092 cal BC (6118 - 6041 cal BP) (15.1%) 4230 - 4195 cal BC (6179 - 6144 cal BP)
2017NWAIH8：z17	Pit	5140 +/- 30 BP	(60.8%) 3994 - 3928 cal BC (5943 - 5877 cal BP) (27.9%) 3876 - 3804 cal BC (5825 - 5753 cal BP (6.3%) 4041 - 4017 cal BC (5990 - 5966 cal BP) (0.5%) 3921 - 3916 cal BC (5870 - 5865 cal BP)

3.2. Spatial analysis

The results obtained through quantitative analysis can be further interpreted by looking at them in their archaeological context. Spatial analysis is used to compare the results between excavation sectors and zones inside the site to reveal discrepancies in the distribution and offer hypotheses to explain these patterns.

The Wutaishan site was excavated using the Wheeler method (standard procedure in China), and the sherds were recorded according to their SU and square. This method allows us to study their distribution on the excavation grid. The spatial analysis aims to shed light on differences or similarities between the excavation sectors at Wutaishan

(Fig. 5).

3.3. Petrographic analysis

Petrographic analysis is used to further characterize the difference between the morphostylistic groups by examining the fabrics of the potteries. The choice of raw materials, their proportions, and the way they are processed are essential traits to further interpret the quantitative data. Revealing a link between pottery styles and raw materials, petrographic analysis is key to explain the causes of heterogeneity in this corpus.

Over the last few years, the use of petrographic analysis on ceramics is developing in China (Stoltman et al., 2009; Liu et al., 2017; Quinn et al., 2017; Druc et al., 2018; Stoltman et al., 2018; Lu et al., 2019; Hein et al., 2020; Li, 2020; Womack et al., 2021), but remains exceptional, especially in this region.

Using a petrographic microscope, this method is based on sedimentary petrology and soil micromorphology to describe ceramic material and interpret all the mechanical or thermal transformations that the materials undergo (Roux and Courty, 2019; Eramo, 2020; Quinn, 2022). The method used in the present research is the one recommended by Quinn (2022) where each thin section was systematically described. Three main components enter in this standardized description: the clay matrix (of groundmass fraction, size <10 μm), the porosity (voids) and the inclusions (non-plastic material). The homogeneity, colours and optical activity of the matrix, the shape, size and orientation of the porosity, and the abundance, distribution, size and type of inclusions are described. The inclusions are divided into two size classes: the “coarse fraction” and the “fine fraction” (above or below 0.2 mm). All of those attributes are related to the work and choice of the potters when producing pottery, for example, the size distribution of the inclusions (modal or bimodal) or their abundance is an indicator of raw material transformation such as tempering or fractioning.

These descriptions are of a qualitative nature and numbers have been estimated (identified impressionistically) and not verified through quantitative or semi-quantitative methods (such as point-counting). The abundance has been estimated using an abondance comparator chart and described according to frequency labels: predominant (>70%), dominant (70–50%), frequent (50–30%), common (30–15%), few (15–5%), rare (<5%), absent (0%) (Quinn, 2022: 98–113). The estimated average grain size of inclusions is characterized using the Udden- Wentworth scale, composed of grades of particles such as silt (0.004–0.0625 mm), fine sand (0.125–0.25 mm), medium sand (0.25–0.5 mm) and coarse sand (0.50–1 mm). Based on these data, the thin sections were sorted into petrofabrics (Quinn, 2022).

20 sherds have been chosen to manufacture 30 μm thin sections to be examined under a petrographic microscope (x4 to x40, with polarizing light), to characterize the nature of the raw materials and how they were processed. The sampling strategy is based on the results of the quantitative and spatial analysis and aims to include sherds from the three identified ceramic groups and from both excavation sectors. In total, 8 sherds from group 1 (4 from sector A and 4 from sector D; one was destroyed during preparation), 8 sherds from group 2 (this group is over-represented because it presents

the largest morpho-stylistic diversity), and 4 sherds from group 3 have been selected. The sherds have been chosen based on quantitative data and from random features. Once the stratigraphic unit was chosen, we selected sherds presenting undeniable characteristics attributing them to one of the three ceramic groups, favoring ones with decoration. We also purposely chose rims (9), body (6), and bottoms (4) sherds to look for variations in correlation with the placement of the sample in the complete vessel (Supplementary materials Table 1).

The painstaking process of counting sherds and all subsequent material analyses were undertaken across the entire dataset. Furthermore, this work is based on a methodological and lexical reflection essential to the construction of a database adapted to the Chinese academic context.

4. Results: a heterogeneous assemblage

4.1. Different morpho-stylistic groups

According to morpho-stylistic classification, Wutaishan sherds are divided into three groups (excepting 1.4% of intrusive later sherds). The first group largely dominates, with various vessels shapes (Fig. 3), while in the other two, only *guan* cylindrical jars have been identified. In Chinese archaeology, this term designates a general shape, not a function, being a large or medium size container, with a depth at least 1.5 times larger than its opening diameter.

The confidence interval has been calculated according to Drennan's *Statistics for Archaeologists: A Common Sense Approach* section on Standard deviation (2009: 139–142): on the basis of our samples, we estimate that the proportion of group 1 is 90.5% ±0.28%, group 2 is 5.7% ±0.22%, and group 3 is 2.4% ±0.15% at the 99.9% confidence level.

4.1.1. Group 1: 90.5% of the TNS

This group corresponds to a sandy fabric with very small inclusions and presents a variety of artefacts: *guan* cylindrical jars (Fig. 3A), *xiekouqi* asymmetric jars (specific to Northeast China, this type of container has a large slanted opening (Fig. 3B), shaped like a winnowing basket, and its specific function remains unknown [Xu, 2018: 342–356, Zhou, 1984]), bowls (Fig. 3C), and cups.

Stylistically, with few exceptions, only the jars and cups are decorated. The decoration is composed of wave-like lines and nail impressions organized in basketry, stairs or net themes (Fig. 6A). The wave-like lines pattern can be divided into two sub-classes: thick line and thin double line.

Morphologically, cylindrical jars have a large opening, slightly arched and flared tapered walls, and small flat bottoms. These are the largest containers at Wutaishan, sometimes reaching over 30 cm in height.

Fig. 3. Common types of potteries at Wutaishan. A. 2018NWAIF14①:48 – *Guan* jar; B. 2017NWAIT0202③a:13 – Asymmetric jar; C. 2017NWAIT0103③a:3 - Bowl.

These jars can be divided into two morpho-stylistic subgroups:

Subgroup 1–1 (Fig. 6A): jars with thick lines decorations have mainly straight rims (81% of the thick lines decorated rims) or bent rims (16.2%), and their main decoration theme is the basketry theme (33.5% of the thick lines decorated rims) and the stairs (8.6%).

Subgroup 1–2: jars decorated with double incised line (made with a two-pointed tool); 48% of double incised lines rims are bent. In this subgroup, the decoration is dominated by the stairs theme (38% of the double incised lines rims) followed by the basketry theme (7.9%).

The typical Group 1 artefact (the cylindrical jar with covering wave-like incised lines organized as a stairs or basketry theme) is considered characteristic of late phase I (ca. 5500–5000 BCE) at the Zuojiashan site (Chen, 1992) (Fig. 6B). The Yuanbaogou site (Jilin, 1989b) yielded the same cylindrical jars with large openings and small bottoms, as well as high concentrations of sherds, showing a hard and thin fabric with barely discernable sand inclusions, bearing wave-like thin double lines organized in stairs, basketry and net themes (Fig. 6C). Other figures are also present, such as chevrons, but in far smaller quantities. The same division into two morpho-stylistic subgroups (corresponding to our 1–1 and 1–2 subgroups) was also observed at Yuanbaogou, but no quantitative data have been published to further the comparison.

Similar sherds have been reported at other neighbouring sites, but only survey data are available, with few illustrations and unclear quantities in published sources. For instance, the Liangjiazi site (< 2 km northeast of Zuojiashan) yielded a large proportion of thin sand tempered-sherds with incised stairs theme decorations (Jilin, 1987: 30). Further away, within a 150 km radius around Wutaishan, a few sites have yielded some similar sherds, never in tantamount proportions, but anecdotally similar, such as Yaojingzi (Fig. 6D) (Jilin et al., 1992). Most of these sites are only documented by the Second National Survey, such as Zhourongtun Beigang in Tongyu District (about 180 km northwest of Wutaishan) (Jilin, 1985a: 40–42) and Chuanzijing Nangang in Qian'an

District (about 150 km northwest of Wutaishan) (Jilin, 1985b: 13–18).

Fig. 4. Wutaishan ceramic decoration description levels.

4.1.2. Group 2: 5.7% of the TNS

This group has a sandy fabric associated with very rich and varied patterns.

The decorations in this group show the most diversity: fluted, impressed dots, incised and impressed chevrons (Fig. 4). Various themes can be combined on the belly of the jars, creating complex compositions. The most common pattern is the fluted line and the three most frequent combinations are: 1. Fluted lines and dotted lines, 2. Fluted lines and straight incised lines, 3. Alternating registers of impressed and incised chevrons.

Few complete group 2 containers have been reconstructed. They are mostly middle-size jars with a large opening, a sometimes slightly arched and flared belly and a small flat bottom. Their rims are more clearly hemmed or flared (Fig. 7A).

Group 2's main morpho-stylistic trait is its rich decoration, particularly the fluted line sometimes associated with other patterns. This fluted line-based decoration is quite widespread in the region. It can be found on several sherds unearthed at Zuojiashan (Fig. 7B) and somewhat more rarely on sherds from Yuanbaogou (Fig. 7C). The Yaohongzuizi site revealed large quantities of sherds with chevrons and fluted line-based patterns (Fig. 7D) (Jilin and Changchun, 2003), which was the main type of decoration at this site. At the much further Zhaobaogou site (about 600 km southwest of Wutaishan) (Fig. 7E), two minor decoration classes referred to in the report as "type B fluted line" and "geometrical pattern 3.I" (fluted lines organized in basketry theme often association with chevrons) (Zhongguo, 1997a: 169, 161) are similar to the fluted line-base decoration seen at Wutaishan. By contrast, at both Yaohongzuizi and Zhaobaogou, there is no mention of anything similar to group 1's characteristic wave-like lines pattern. In the Neolithic levels of the Changshan site, at Shuangliao in the Dongliao River valley, there were many examples of fluted line patterns and a few sherds with alternating registers of impressed and incised chevrons (Jilin et al., 2018b).

Thus, group 2's morpho-stylistic traits are distributed across a very large geographical area extending over 500 km south and southwest of Wutaishan.

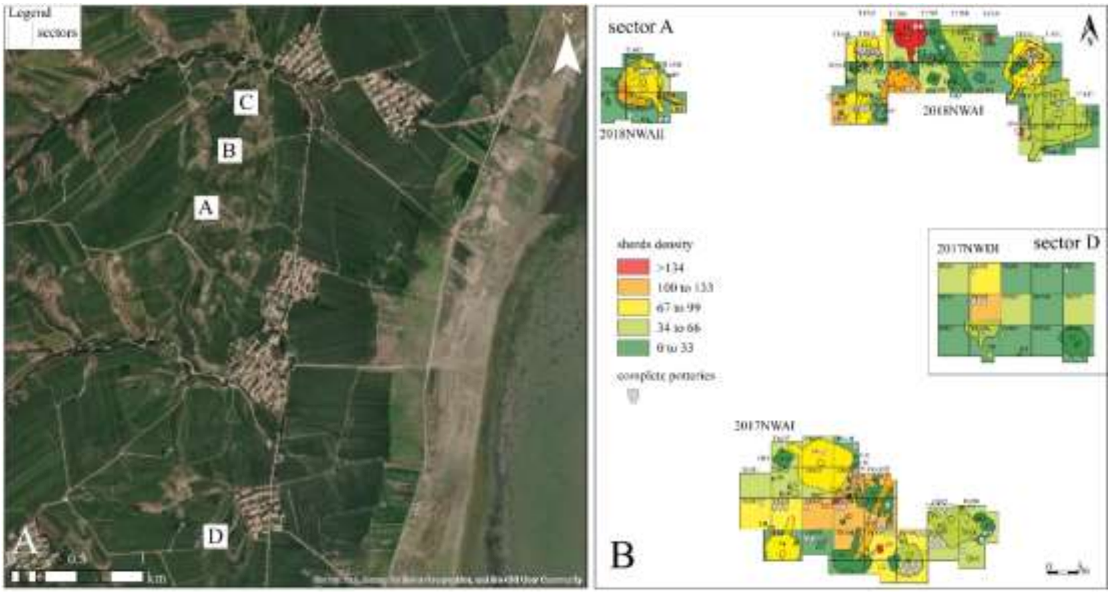

Fig. 5. Map of the Wutaishan site. A. Satellite view of the Wutaishan site with the location of the four excavation sectors (A to D). B. Map of the excavation zones with sherd densities of the squares and features.

Fig. 6. Morpho-stylistic traits of group 1 jars and comparisons. A. Wutaishan, B. Zuojiashan (Jilin, 1989a: Fig. 9–18 p. 195), C. Yuanbaogou (Jilin, 1989b: Fig. 7–6 p. 1071), D. Yaojingzi (Jilin et al., 1992: fig. 17–6 p. 684).

Fig. 7. Morpho-stylistic traits of group 2 jars and comparisons. A. Wutaishan, B. Zuojiashan (Jilin et al., 2018a: Fig. 11–14 p. 17), C. Yuanbaogou (Jilin, 1989b: Fig. 6–6 p. 1069), D. Yaohongzuizi (Jilin et al. 2003: Fig. 9-4 p. 688), E. Zhaobaogou (Zhongguo, 1997a: Fig. 49–2 p. 54).

4.1.3. Group 3: 2.4% of the TNS

This group is characterized by its shell-tempered fabric and added band decoration. However, unlike groups 1 and 2, in this group, the majority of the sherds bear no decoration (only 8% of these sherds show patterns). In addition, when they have one, the decoration is localized on the upper third of the jars, and not on the belly as was the case in groups 1 and 2. This group is also the only one to present added band and beaded lines impressions (Figs. 4, 8A), with rare occurrences of incised or impressed chevrons similar to the one from group 2.

Fig. 8. Morpho-stylistic traits of group 3 jars and comparisons. A. Wutaishan, B. Zuojiashan (Jilin, 1989a: fig. 14–6 p. 200), C. Honghe (Jiang et al., 2019: fig. 28 p. 58), D. Houtaomuga (Jilin and Jilin, 2016: fig. 17–5 p. 12).

In this group, the only identified shape is the cylindrical jar (Fig. 8A). The shaping of the rim is irregular, so it is impossible to distinguish between straight and flared rims. However, unlike in the two other groups, there were no folded rims in group 3. In this group, the cylindrical aspect of the jars is more pronounced, with a tapered belly with almost no arching or flaring, and the bottoms are also larger.

The Zuojiashan site yielded sherds that show group 3's characteristics (shell tempered fabric and added band decoration), and one complete jar even possesses all these traits (Fig. 8B). According to the Zuojiashan site's original typo-chronology, this type of added band decoration supposedly occurred subsequent to the wave-like pattern and is seen as typical of the second occupation phase of the site (Jilin, 1989a). However, these traits are all characteristic of Nen River valley pottery production: in phase I of the Shuangta site (ca 9000 to 7000 BCE) (Jilin and Jilin, 2013), Houtaomuga phases II (6000-5300 BCE) and III (4300-3500 BCE) (Wang et al., 2017; Wang, 2018), and the Angangxi archaeological culture (2500-2000BCE) (Jiang et al., 2019), across the millennia and changes in vessels shapes and fabric components, the Nen River valley ceramics share shell temper and added band decoration (Fig. 8C and D).

To sum up, the quantitative analysis shows that the Wutaishan pottery was composed of three distinct groups which have different fabrics (sand or shell tempered) and morpho-stylistic traits. Group 1 largely dominates (90.5% of the TNS) compared to sherds from group 2 (5.7% of the TNS) and 3 (2.4% of the TNS), which are very few. Therefore, groups 2 and 3 are not representative of the ceramic dataset of Wutaishan. Although group 1 sherds are in the majority at this site, this style does not seem to occur in the larger region, while traits of groups 2 and 3 are well known in neighbouring regions where they are considered distinguishing features of local archaeological cultures.

The fragmentary or absent state of quantitative data from surrounding archaeological sites renders comparisons particularly difficult. However, available information about the composition of the pottery dataset from the Yitong River valley raises some avenues for potential research:

First, the Yuanbaogou dataset is very close to the Wutaishan one, with a high presence of group 1 sherds and a lesser proportion of group 2, but without any mention of shell-tempered ceramic. Sherds from the Zuojiashan and the Yaojingzi sites seem far more heterogeneous. These datasets include specimens showing all the characteristics of the three groups present at Wutaishan, but at Zuojiashan and Yaojingzi, the shell-tempered sherds make up over 30% of the pottery dataset, and the decorations seem more diverse, with a majority being chevron patterns. Finally, at Yaohongzuizi, there is no mention of group 1 nor group 3 sherds, and the described artefacts seem to all belong to group 2.

4.2. Spatial disparities

The spatial analysis of sherds distribution according to morpho-stylistic groups revealed important disparities within the site.

4.2.1. Between sectors

Sectors A and D are located 1.7 km apart: sector A (excavated on a total of 1187 m_2, divided into three zones) yielded a lot of features (semi-subterranean houses, pits, and ditches), and sector D is less rich and smaller (excavated on 381 m_2) and only yielded two Neolithic houses (Fig. 5). These two sectors are considered to belong to the same site and the same archaeological culture. However, the size and composition of their pottery datasets differ greatly (Table 3).

The three excavation zones of sector A yielded a large quantity of pottery with an average density of between 76.3 and 97.4 sherds/m_2, with an average of 0.9 kg/m_2. The sherd density in sector D is two to three times lower, with an average of 36.2 sherds/m_2 and 0.29 kg/m_2 (Table 4). Since sector D is also smaller than sector A, it yielded 7.5

times fewer sherds than sector A, which means the sample from the site is biased in favour of sector A. However, the disparity of the proportional composition of both assemblages is distinct enough to be significant ($\chi_2 = 39{,}972{,}86$; $0{,}001 > p > 0{,}000$; V = 0,59) (Chi-test calculation method from Drennan, 2009: 187–194).

Almost all of the sherds in sector A belong to group 1, with a low quantity of group 2 sherds and very rare, maybe intrusive, group 3 specimens. On the other hand, the ceramic assemblage of sector D is characterized by a greater diversity: group 1 still dominates, but only makes up 49.1% of the sherds, while group 2 represents 30.6% and group 3 20% (Table 3, Fig. 9).

Table 3 Distribution of the sherds by sectors and by morpho-stylistic groups at Wutaishan.

Sector	Number of sherds	Group 1	Group 2	Group 3	Other
Sector A	102,893	96%	2.5%	0.02%	1.48%
Sector D	13,806	49.1%	30.6%	20%	0.3%
TNS	116,699	90.5%	5.7%	2.4%	1.4%

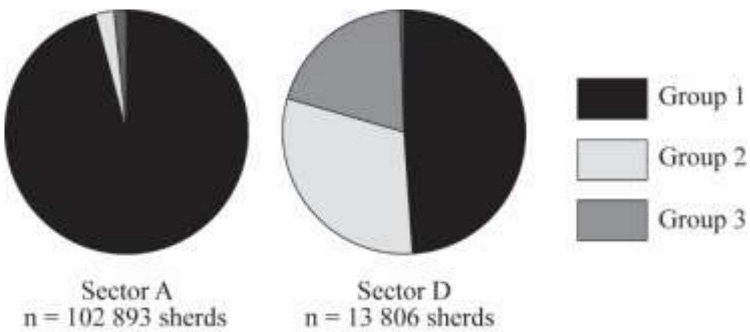

Fig. 9. Graph of the proportions of sherds from groups 1 to 3 in sectors A and D at Wutaishan.

The distribution of the sherds by excavating zones (Table 4) shows that, at Wutaishan, the larger the excavated area, the higher the number of sherds: all the opened zones show remains of Neolithic occupation. The coring carried out before the excavation to choose the best location to excavate was successful. Sector A was more densely occupied, either for a longer period or with more intense activities than sector C. The sherds from the zone AI excavated in 2017 (higher number, lighter weight) are more fragmented than zone AI excavated in 2018 (lower number, higher weight). This phenomenon can be explained by a better understanding of the remains during the second season, or a slight change in the excavation methods (e.g. keeping fewer small sherds), or possibly by better preservation of the 2018 zone AI due to slightly different post-depositional conditions (such as less deep ploughing in recent years).

Table 4 Densities of sherds by excavation zones at Wutaishan.

Zone	Excavated area (m^2)	TNS	% of the TNS	Sherds density by m^2	Weight (kg)	Densities (sherds and weight)
AI 2017	560	54,516	46.7%	97.4	464.73 kg	97.4 sherds/m^2 0.83kg/m^2
AI 2018	513	39,136	33.5%	76.3	541.41 kg	76.3 sherds/m^2 1.06 kg/m^2
AII 2018	114	9241	7.9%	81.1	91.96 kg	81.1 sherds/m^2 0.81 kg/m^2
D	381	13,806	11.8%	36.2	111.78 kg	36.2 sherds/m^2 0.29 kg/m^2
Total	1568	116,699	100%	average: 72.8	1209.88 kg	average: 74.4 sherds/m^2 average: 0.77 kg/m^2

4.2.2. Inside the excavation zones

The densities of sherds recorded in the squares and features range from 0 to 304 sherds/m_2 (0 to 128 for the squares' layers outside the features, up to 166 for the house foundations, up to 304 for the pits) (Supplementary materials Table 2). This configuration first shows the difficulty of recognizing the features during the excavation: most of the sherds within features have been attributed to levels in the squares, for example in the case of houses F3 and F5 in zone 2017NWAI (Fig. 5B). This phenomenon was more severe during the first season (2017) and disappeared with the experience of the team during the second year of excavation (2018). In some places, a feature was not recognized during excavation, like the northern part of house F1 in sector D square T0202.

The spatial orientation and distribution of the house foundations show that, except for F6 in zone AI from 2017, the buildings opened towards a central space (which could not be excavated due to the presence of a contemporary burial ground), indicating that they belonged to the same village community, which might have used this central space for various collective activities (Fig. 5B).

Some features were largely destroyed and emptied of their artefacts by the constant rebuilding of houses on the same location, for example, houses F1, F2 and F3 were rebuilt at the same location in the 2018 AII zone. This adds to the impression of a dense village community living in sector A.

The general distribution of the sherds shows that the highest concentrations of ceramics were located in the buildings' foundations, the potteries being everyday life implements associated with domestic activities. Some houses yielded considerably higher densities of sherds, such as house F11 in zone 2018NWAI with over 166 sherds/m_2. This could be explained by a variety of factors: some houses were used for a longer period, abandoned with more artefacts left inside, occupied by a richer household or a household counting more members, better delimitation during excavation, etc.

Groups of pits of the same size and same sherds density may be linked to activities performed in the buildings. In the 2018 zone AI, the high-density H46 pit might have functioned with house F10, as the high-density pits H38 and H37 were possibly linked to activities of house F8. The 10 small round low-density pits located at the back of house F6 in the 2017 zone AI, the similar ones surrounding the back of the rebuilt houses in the 2018 zone AII mentioned above, and the similar ones located between houses F12 and F13 in the 2018 zone AI might have had comparable functions. A line of larger oval pits with low sherd density also separates houses F14 and F11 from F12 in the 2018 zone AI, reinforcing the impression of buildings organized into rows.

Complete vessels were not necessarily found where the sherds density was highest. For example, in house F11 of the 2018 zone AI, where sherd density was high, only two complete vessels were reconstructed, showing that most of the sherds correspond to incomplete discarded objects, rather than in situ abandonment. The three complete vessels found in high-density square T0202 in sector D could have belonged to the northern part of house F1. In the 2017 AI zone, most of the complete vessels were found in the southeast, and in the 2018 AII zone, symmetrically, they were more numerous in the west. These spaces may correspond to a relatively dense domestic activity area, or were closer to pottery production areas or spaces where containers were used in other types of production.

4.3. Fabric variations

Microscopic observation of the 20 specimens chosen to produce thin sections shows that they can be divided into four classes of petrofabrics.

Fig. 10. Petrofabrics from Wutaishan. Thin sections microscope photographs with analyzed polarized light A to D Petrofabric 1: fine monocrystalline quartz fabric; E to H Petrofabric 2: polycrystalline quartz fabric; I to L Petrofabric 3: feldspar microcline fabric; M to P Petrofabric 4: shell fragments fabric. Q: Quartz, Pl: Plagioclase, Mc: Feldspar Microcline, Sh: Shell.

4.3.1. Petrofabric class 1: fine monocrystalline quartz fabric

The first petrofabric class is characterized by fine inclusions (fine sand, ⩽0.25 mm) mainly consisting of subangular monocrystalline quartz (Fig. 10 A to D). The angularity of the quartz grains in this very homogeneous class points to alluvial deposits. Also, no material was deliberately added as temper, so the clay materials were likely subject to particle size sorting, with the coarse elements extracted to obtain a fabric that was easier to work with. This petrofabric's thin sections are very homogeneous, without any differences between sectors A and D, so the materials most likely originated from the same source and the recipe was very stable. This class's samples are only from morpho-stylistic group 1.

4.3.2. Petrofabric class 2: polycrystalline quartz fabric

The second petrofabric class is composed of compact inclusions, which are coarse (ca. 0.5 mm, medium sand) and poorly sorted. They are polycrystalline quartz and granite fragments (Fig. 10 E to H). These coarse inclusions and the fine fraction are of the same type; therefore, these inclusions might have been naturally present in the clay or correspond to deliberately added sand which was extracted from the same place as the clay. The mineral inclusions are more diversified in petrofabric class 2 than in class 1, their clay did not come from the same source. Petrofabric class 2's samples all belong to morpho-stylstic group 2 sherds bearing chevron patterns, and one of them has fluted lines (sample n. NW12).

4.3.3. Petrofabric class 3: microcline feldspar fabric

The third petrofabric class is characterized by a majority of angular microcline feldspar inclusions and the absence of quartz in the coarse fraction (coarse sand, ⩾ 0.5 mm) (Fig. 10 I to L). The fine fraction differentiates itself from the coarse fraction by the presence of a few quartzes: here it seems that the ceramic material was tempered with sand originating from plutonic rock of the syenite type, although these inclusions could be naturally present. The raw materials of petrofabric class 3 were most likely extracted near the primary rock. Petrofabric class 3's samples all come from morpho-stylistic group 2 samples decorated with fluted line patterns.

Hence, morpho-stylistic group 2 contains at least two petrofabrics which are each correlated with a different decoration type (except sample NW12).

4.3.4. Petrofabric class 4: shell fragments fabric

The last petrofabric class is characterized by a very high concentration of fragments from freshwater bivalves (Fig. 10 M to P). These inclusions are angular and very poorly sorted (medium sand). Some sub-rounded inclusions of quartz and plagioclase are also present in the fine fraction. In addition, in the thin section of the sample NW19 (Fig. 10 O), there are some coarse inclusions of plutonic (intrusive) rock, specifically granite. It is possible that the clay materials used in this fabric were sorted to remove coarse elements, and that potters then added shells of freshwater bivalves that had been crushed into the fabric. The fine fraction probably originates from an alluvial deposit which is clearly different from the one used in the petrofabric classes 1 and 2, and the tempering material comes from a lake or a river rich in freshwater bivalves. All the samples from morpho-stylistic group 3 have this petrofabric.

To sum up, quantitative, spatial and petrographic analyses reveal a ceramic dataset composed of three groups. Based on morpho-stylistic criteria defined during the quantitative analysis, these groups were confirmed by the petrographic analysis, demonstrating the stability of the fabric recipe inside each group as well as the consistency of very distinct sources of raw materials.

Petrofabric class 1 and 4 are very homogeneous. On the other hand, petrofabric 2 and 3 are quite heterogeneous, variations can be observed between samples, however their characteristics are clear enough to distinguish them from other petrofabrics. We are confident that the four paste groups identified here do capture the full range of fabric types present in the wider population of pots.

5. Discussion: the socio-regional significance of ceramic heterogeneity

The three ceramic groups are based primarily on stylistic criteria and technological data. Our analyses show different mechanisms for the choice and the extraction of the raw materials with distinct sources, different processing methods (deliberately adding temper or not, type of tempers, removing of coarse inclusions, etc.), as well as distinct decoration techniques (gestures and tools). Therefore, the ceramic groups relate to distinct technical practices or *chaînes opératoires*, defined as “a sequence of technical movements through which raw materials are transformed into a usable product” (Cresswell, 1976).

However, the ceramic technique has a socio-cultural dimension, and this can be explained, from a theoretical point of view, by the transmission process, as “studies of transmission show that a technical practice necessarily results from a learning process based on the observation of actions in a social group” (Roux and Courty, 2019: 4). Thus, a *chaîne opératoire* is a way of doing things, transmitted from master to student over several generations within the same community, it is the product of a technical tradition. The social group (or community of practices) is defined here by the technical tradition; and the spatial distribution of these ways of doing things form social perimeters within which they were learned and transmitted (Roux and Courty, 2019: 4–6, Manem, 2020).

A *chaîne opératoire* corresponds to a social group, however a social group does not correspond to one *chaîne opératoire*. Variations from one tradition to another can be multifactorial (sociological, functional, environmental, etc.), so the same social group can master several technical traditions according to constraints and needs. For example, depending on the nature of the raw materials or the way in which they are processed, the final products will not have the same functional properties (e.g. the addition of a coarse temper improves resistance to repeated thermal shocks, a high porosity increases isothermal qualities, etc.), there are also multiple constraints such as access (not all sources are permanently available, there may be several extraction sites, etc.) (Eramo, 2020; Gualtieri, 2020). Furthermore, surface treatments (such as polishing or decorations) only modify the surface layer of the containers they are very conspicuous and generally require relatively little learning, which is why they can be easily imitated from one group to another without direct human contact.

In the case of the Wutaishan dataset, the present research shows the existence of at least three distinct technical traditions. These differences in the *chaîne opératoire* are probably not environmental, because the choice of raw materials is also linked to the decoration techniques, and they are not functional either, since all three groups mainly produce cylindrical jars which could have had similar functions. However, decoration does have a functional impact: patterns covering the whole belly help with gripping and increase resistance to repeated firing by limiting the spread of micro-fissures (Skibo, 2013). Jars from morpho-stylistic groups 1 and 2 were thus perhaps handled in a different way than jars from group 3, whose added band at the rim can correspond to the use of a soft handle to take them on and off the hearth (Skibo, 1992: Fig. 4.9 p. 66). The straighter bellies and larger bottoms of jars in group 3 could also point to a slightly different use (cooking, hearth types, etc.). Group 1 jars are thin with deeply engraved patterns, often reaching over half the thickness of the wall, so although well fired, they often break along a decoration line and are not very resistant to shock, not ideal for transportation.

In any case, the variations between the three groups might very well be sociocultural: these containers could have been produced by different social groups and used together at the Wutaishan site.

The specific meaning of the decorations is harder to interpret. Some of the patterns, such as the wave-like lines are intrinsically linked to a ceramic group, so one could wonder about their meanings within social groups (e.g. functional, cultural identity). On the other hand, other themes, such as associated incised chevrons, clearly transcend the barriers of social groups identified by the technical traditions. This highlights larger but more tenuous networks of influences, or a broader and more diffuse form of cultural identities, but it remains difficult to understand the precise links between the actors (direct, indirect, close, distant?) based on a decorative theme.

5.1. Northeast China Neolithic ceramic exchange network

The combined presence of these artefacts originating from multiple sociocultural groups on the Wutaishan site raises the question of production centres and especially of their locations. If they are all local, it could mean that several groups of potters could have possibly lived together at the site, but if they are exogenous then it is evidence of exchange networks during the Middle Neolithic. Unfortunately, there are currently no studies on the provenance of raw materials in this region with which to further compare our results.

5.1.1. Provenance of group 1 pottery

The Wutaishan site is located in the sedimentary plain of the Songhua and the Liao Rivers, on the shore of Boluo Lake, near the Yitong River, which originates in the Changbai Mountains. Within a radius of 100 km, the surroundings' sedimentary context is composed of fluvial, lacustrine and eolian deposits, which are mostly unconsolidated sand, gravel and clay (Zhongguo, 2002: 82–83). Our petrographic analysis shows that morpho-stylistic group 1 is characterized by a relatively varied mineral assemblage where quartz dominates, and which probably comes from an alluvial deposit, consistent with the geological context around Wutaishan. Moreover, the wave-like patterns, which are characteristic of this group, were discovered only on relatively close sites (within a 100 km radius). Finally, group 1 largely dominates the Wutaishan dataset (90.5% of the TNS), with the largest variety of shapes suitable for multiple functions. All these elements point to the local production of group 1 vessels.

5.1.2. Provenance of group 2 pottery

The case of morpho-stylistic group 2 is more complex, as it includes petrofabric classes 2 and 3. Petrofabric class 2 is characterized by angular granite fragments, but granite is fairly common in Northeast China and it could have been carried by the Yitong River. Morpho-stylistically, its characteristic chevron patterns are also quite widespread during the Middle Neolithic in the Northeast China Plain. Thus, the raw materials and morpho-stylistic traits of petrofabric class 2 are not useful for determining their provenance.

By contrast, petrofabric class 3 is characterized by a majority of syenite inclusions, but according to geological maps, there are no deposits of this type of rock near Wutaishan. In addition, the angularity of the inclusions and the very low presence of quartz indicate that the site of extraction must have been close to the primary source (the outcropping of unweathered syenite) and that these quartz grains were not naturally transported very far. Therefore, these cannot be produced locally at Wutaishan.

The nearest syenite outcropping is located east of the city of Changchun, < 50 km east of the Yaohongzuizi site, the very same site which yielded a large number of sherds similar to morpho-stylistic group 2, but this outcropping is small and very localized. There are larger syenite outcroppings (porphyritic, quartziferous or granitic syenite) south of the Da Xing'an Mountains (between southeastern Inner Mongolia, northern Hebei and western Liaoning) in the western part of the Xiliao River. This is the westernmost portion of the Liaoxi region, within the sphere of cultural influence of the Zhaobaogou archaeological culture. Given the composition of the pottery assemblage from the Yaohongzuizi site and the presence of a syenite outcropping close by, petrofabric class 3 probably comes from this area. The Liaoxi hypothesis could be tested by comparing our samples to samples from the Zhaobaogou area.

5.1.3. Provenance of group 3 pottery

The fabric of morpho-stylistic group 3, i.e. petrofabric class 4, includes very few inclusions apart from the temper made of crushed freshwater bivalves. The fine fraction comes from alluvial or lacustrine deposits. Nevertheless, shell temper pottery was very abundant in the Nen River valley throughout the entire Neolithic. The scarcity of this ceramic group at the Wutaishan site and the similarity to fabric recipes and decorations discovered in large quantities in the Nen River valley show that the pottery from morpho-stylistic group 3 most probably comes from this region.

Therefore, this research shows that morpho-stylistic group 1 was a local production with low diffusion, and that the vessels of groups 2 and 3 were produced elsewhere and then used and discarded at Wutaishan (Fig. 11). These artefacts were imported goods, transmitted by gifting or exchange. The cause of these exchanges remains to be identified: artefacts exchanged for their prestige value? For their contents? For their technical qualities? Further study could deepen our understanding of these questions through the investigation of the relations between the various producers and their relations with the consumers at the Wutaishan site.

5.2. Spatial divisions between distinct social groups

While the exact relations between the three socio-cultural groups that produced the Wutaishan ceramics remain to be further explored, by focusing on the consumers, the spatial analysis of the present ceramic dataset did reveal two very distinct ways of life. In sector A, where the excavation revealed a dense web of building foundations and other features linked to domestic life, large quantities of pottery were used, but they were mainly locally produced pots (group 1, representing 96% of the TNS of sector A), and there were only very few exogenous containers (2.5% of the TNS of sector A). On the contrary, in sector D, where a low number of features is associated with a low density of sherds, the ceramic dataset is still more varied and the imported pots (groups 2 and 3) reach 50.6% of the TNS (Fig. 9, Table 3). We propose several hypotheses to explain these phenomena.

5.2.1. First hypothesis: chronological variability

Previous research traditionally attributes these distinctions to the effect of time: a heterogeneous ceramic assemblage is typically regarded as belonging to successive chronological phases, thus establishing a pure and stable ceramic assemblage during each phase (e.g., the case study of Yaojingzi: Zhao and Huaishi, 2016b). According to the initial typo-chronology of the Zuojiashan site, the shell tempered pottery group (morpho-stylistic group 3/petrofabric group 4 in the present article) is subsequent to group 1 (Jilin, 1989a), but no chronological attribution is proposed for group 2. Since then, shell-tempered pottery has always been seen as subsequent to the other groups in the region (Chen, 1992; Zhao, 2012). In an effort of abstract systematization of the LLZ culture, it was even proposed that chevron patterns ceramic cultures disappeared around 4000 BCE and were “replaced” by incised and added band ceramic cultures (Zhao and Huaishi, 2016a). In this model, the Wutaishan remains could be interpreted as belonging to a transitional period. Thus, it would seem reasonable to distinguish sectors A and D as belonging to two chronological periods at the site with changes in the material culture. Indeed, during the Middle Neolithic in this region, human groups or parts of groups did not necessarily occupy sites continuously, but rather seasonally (Jia, 2008; Sebillaud et al., 2021). Thus, sectors A and D could correspond to two distinct and successive periods of occupation, the settlement spatially shifting with time and changes in the human presence on the shores of Boluo Lake. The differences between the ceramic datasets could thus also be evidence of changes in consumption patterns.

However, sherds from morpho-stylistic group 3 were only discovered in sector D. From these data, one could deduce that sector A could have been occupied earlier than sector D. In this scenario, the Yuanbaogou site, located on the opposite shore of Boluo Lake, could have been another more or less seasonally occupied settlement belonging to the same group or to groups in some way related to the Wutaishan inhabitants. Further, several complete vessels unearthed at Yuanbaogou are nearly identical to the ones discovered at Wutaishan in morpho-stylistic group 1. This chronological hypothesis needs to be tested further through a direct examination of the artefacts unearthed at Yuanbaogou to verify the identification of the morpho-stylistic groups, the petrofabrics and their proportions.

Nevertheless, the chronological hypothesis only partly explains these discrepancies, because in both sectors A and D, the majority of the sherds belong to morpho-stylistic group 1, and this is very homogeneous. In both sectors, the clay is always extracted from the same source, the recipe is very stable, and the vessels are morphologically identical. The only notable difference within group 1 is the presence of thin double lines wave-like patterns, which are only found in sector A. Therefore, it seems unlikely that a significant chronological gap could have existed between the two sectors.

5.2.2. Second hypothesis: functional differences between sectors

These disparities could also be caused by differences in how the people used the space at Wutaishan. Several scenarios can explain the data.

One explanation for the differences in characteristics and quantities of ceramic artefacts between sectors A and D is that the Wutaishan site was densely populated, with a very active core-settlement zone (sector A) and at least one peripheral area (sector D) with less activity.

However, this does not explain the disproportions between the morpho-stylistic groups and the petrofabric classes: the relative abundance of the imported vessels in sector D and their near-absence in sector A. The nature of the activities that took place in these zones is therefore also a determining factor.

The ceramic dataset of sector A can be described as highly homogeneous, with only one pottery type (morpho-stylistic group 1), and a single *chaîne op΄ eratoire* without any variability. According to Valentine Roux: “Simple homogeneous assemblages characterize sites where producers belong to a homogeneous social group, that is, a group that uses and transmits the same way of doing ceramics to individuals in the group. This case occurs in habitats with a single social component (whether they are producers or producers/consumers)” (Roux and Courty, 2019: 245). In other words, this phenomenon is typical of a settlement site where the pottery producers are also among the consumers. Thus, sector A could have been dedicated to the everyday life activities of one group for an unknown period.

On the contrary, sector D’s dataset, in which only half the sherds belong to morpho-stylistic group 1, is more diversified, with a significant proportion of exogenous sherds. This could be an indication of the presence of individuals from a different social class (possibly a form of social elite, if the imported artefacts were associated with prestige value), or of a place of worship. This last possibility is unlikely: the shapes of the containers are the same as in sector A (mostly jars), and they were used, then broken, and the sherds were discarded there. The excavation did not yield any traces of hoards, offerings or sacrifices, which could point to a religious use of space, nor marked differences in the other types of artefacts, in the nature of the features, or in the architectural forms and techniques of the buildings. Sector D could rather correspond to a gathering or meeting area: a space where exchanges took place, a zone of circulation, set apart from the residential site, for outsider populations to be temporarily hosted at Wutaishan.

5.3. Inter-site relations in the Yitong River valley

This research on the Wutaishan pottery also opens new perspectives on human interactions on a regional scale at the turn of the 4th millennium BCE.

The relations between the Yuanbaogou and the Wutaishan pottery datasets, especially for sector A, indicate that these two sites were occupied by very close groups who might have maintained regular contact. If the chronological hypothesis mentioned above (sector A being in use earlier than sector D) were correct, it follows that the Yuanbaogou settlement is earlier than Wutaishan sector D.

In addition, among the five sites located in the Yitong River valley that have been excavated so far, sector A at Wutaishan, Yuanbaogou and Yaohongzuizi each has a very homogeneous ceramic dataset. Yet, Yaohongzuizi is profoundly different from the two other sites, since it mainly yielded sherds from morpho-stylistic group 2, which are only found in very small quantities at Wutaishan. Conversely, the Zuojiashan and Yaojingzi site datasets are far more heterogeneous, with a high number of specimens of each of the ceramic groups observed at Wutaishan, and in this way, they resemble more closely Wutaishan sector D.

If we consider sector A as a place of daily activities and sector D as a place of meetings or exchanges, this reasoning could be extended to the other sites: sector A at Wutaishan and Yuanbaogou could be seen as two very close settlement sites used by neighbouring groups or groups who maintained frequent contact. Farther to the south, Yaohongzuizi was also a settlement site but occupied by a group producing a ceramic assemblage quite distinct from that of the sites on the shores of Boluo Lake. By contrast, sector D at Wutaishan, Zuojiashan and Yaojingzi could have been places where different groups met, and may reveal active exchange networks between neighbouring populations.

All in all, although during the Middle Neolithic the populations living in the Yitong River valley had a ceramic tradition that was distinct from that of other regions of Northeast China, ceramology research reveals that, within this region and sites, several socio-cultural groups coexisted and intensely exchanged, with their own specific customs and techniques. One of these groups certainly lived on the shores of Boluo Lake and produced the fine ceramics of morpho-stylistic group 1 of Wutaishan. A second group was active in the south, in the Upper Yitong River valley around the

Yaohongzuizi site, and manufactured the richly decorated pottery of morpho-stylistic group 2. Finally, a third group produced shell tempered added band decorated pottery in the Nen River valley.

Future research on complete assemblages of sherds from other sites and functional analyses will further test these hypotheses and deepen our understanding of the production, use and exchange processes at play.

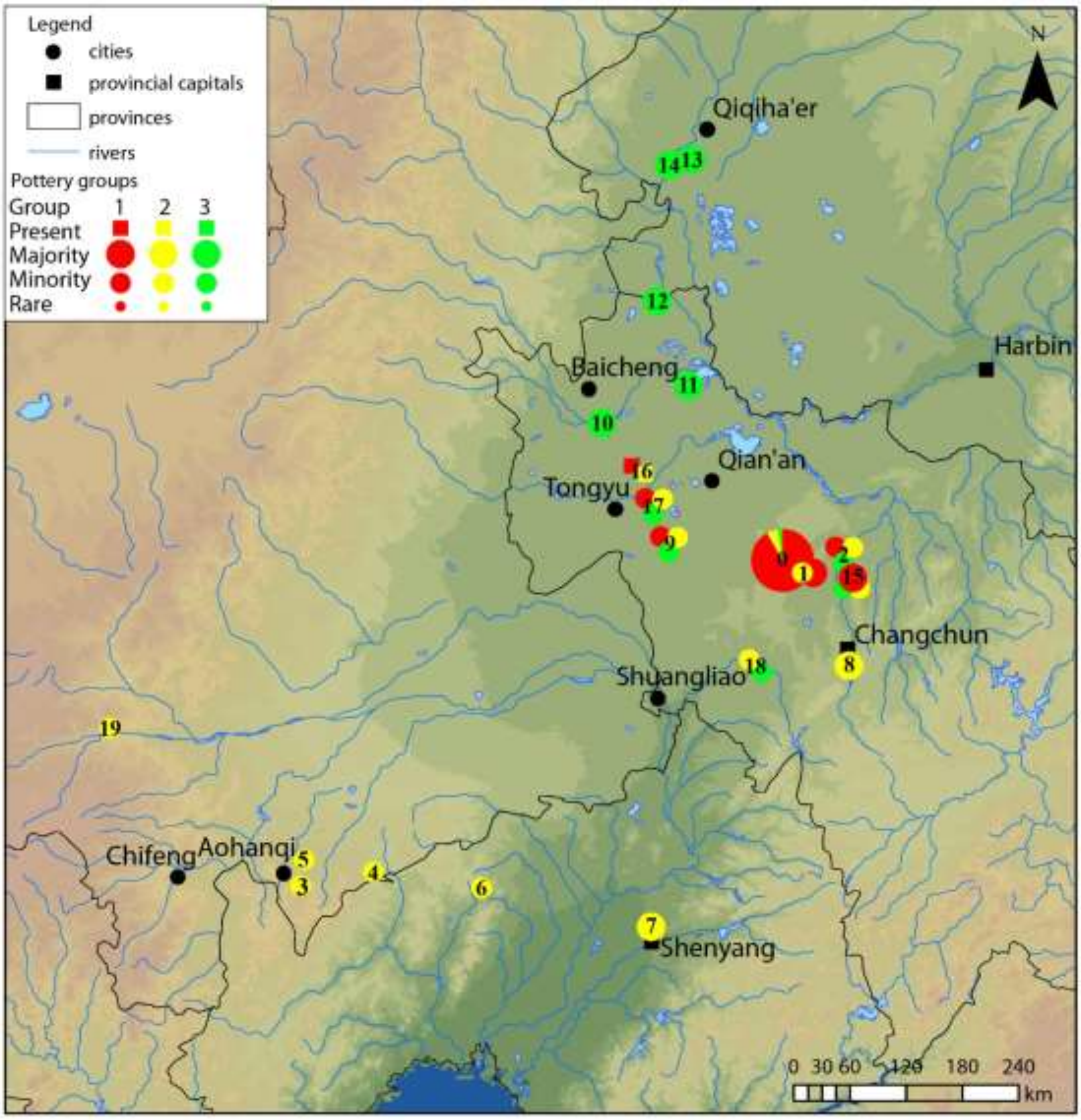

Fig. 11. Distribution of the three pottery groups in the Northeast China Plain. 0. Wutaishan, 1. Yuanbaogou, 2. Zuojiashan, 3. Zhaobaogou, 4. Xinglongwa, 5. Xinglonggou, 6. Chahai, 7. Xinle, 8. Yaohongzuizi, 9. Yaojingzi, 10. Shuangta, 11. Houtaomuga, 12. Huangjiaweizi, 13. Angangxi, 14. Honghe, 15. Liangjiazi, 16. Zhourongtun beigang, 17. Chuanzijing, 18. Changshan, 19. Baiyinchanghan (Accurate data are only available for the Wutaishan site, for the other sites: Majority ⩾50%; Minority ⩽50%; rare ⩽10%; none = 0%)

6. Conclusion

The pottery assemblage in the Wutaishan site is not homogeneous, but composed of three groups. Group 1 dominates with jars decorated with wave-like lines made out of fine monocrystalline quartz fabric, locally produced, while there are some Group 2 middle-size jars with large opening decorated with fluted lines, impressed dots, incised and impressed chevrons using a polycrystalline quartz fabric or a microcline felspar fabric which were produced in other subregions, to the south or the southwest of Wutaishan. The rare objects from Group 3 are jars with irregular rims, added band decoration and a shell-tempered fabric, most probably produced in the Lower Nen River valley. Through quantitative and qualitative analysis of a large quantity of materials, this paper also demonstrates that exchanges happened not only between archaeological cultures but within one, providing new insights on inter-site relations in Northeast China.

This quantitative approach reinforced by spatial analysis and petrography differs from the traditional typology commonly used by Chinese archaeologists to identify archaeological cultures across regions. The quantitative method was used to find heterogeneities of material cultural expressions across different sites that are labeled under the same archaeological culture. It provides useful clues to explore the behavioral implications behind these variations.

This article shows how relatively basic –low-tech and easy to implement - ceramic analyses can offer profound insights into the shape of social networks, mobility, and exchange dynamics in the past. We hope that this work could inspire Chinese archaeologists to renovate their methods for pottery analysis, rethink the division of archaeological cultural zones, and identify new patterns of pottery distribution that convey important behavioral information.

This research lays the foundations for future systematic analyses of complete ceramic datasets, mixing quantitative, petrographic and spatial data in Northeast China. With further field research, more production centres will be identified, and with more complete pottery dataset analysis followed by petrography sampling and sediment sampling, it will become possible to identify extraction locations, and look for firing structures (kilns, on heaps, depressions, pits, etc.) (Roux and Courty, 2019: 112) around the settlement sites. In other words, technological analysis focusing on the whole *chaîne op´ eratoire* deepens our understanding of the groups of potters and their relations to each other, and by narrowing down possible locations for production centres, more will be learned about interactions and exchanges between social groups at a regional scale.

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Credit authorship contribution statement

Pauline A. Duval: Conceptualization, Data curation, Formal analysis, Writing – original draft. **Pauline Sebillaud:** Formal analysis, Methodology, Writing – review & editing. **Yixue Wang:** Funding acquisition, Project administration, Resources.

Declaration of competing interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Table 1 Thin-section samples of Wutaishan, morpho-stylistic and petrographic classification

Sample n.	Profile	Patterns	Sector	Feature num. (H= pit, F= house, T= square)	Morpho-stylistic Group	Petrofabric
NW01	Rim	Wave-like lines	A	2017NWAIH6	1	Fine quartz fabric
NW02	Base	None	D	2017NWDIF1	1	Fine quartz fabric
NW03	Body	Net	A	2018NWAIF13	1	Fine quartz fabric
NW04	Base	Wave-like lines	A	2018NWAIT1507	1	Fine quartz fabric
NW05	Rim	Wave-like lines	D	2017NWDIT0303	2	Feldspar microcline fabric
NW07	Rim	Chevrons	A	2017NWAIT0204	2	Polycrystalline quartz fabric
NW08	Rim	Chevrons	D	2017NWDIF1	2	Polycrystalline quartz fabric
NW09	Rim	Fluted lines	D	2017NWDIF1	2	Feldspar microcline fabric
NW10	Body	Fluted lines	D	2017NWDIH2	2	Feldspar microcline fabric
NW11	Body	Chevrons	D	2017NWDIT0202	2	Polycrystalline quartz fabric
NW12	Base	Fluted lines	D	2017NWDIT0202	2	Polycrystalline quartz fabric
NW13	Body	Chevrons	D	2017NWDIT0304	2	Polycrystalline quartz fabric
NW18	Base	None	D	2017NWDIT0302	3	Shell fragments fabric
NW19	Body	None	D	2017NWDIT0303	3	Shell fragments fabric
NW20	Rim	None	D	2017NWDIT0202	3	Shell fragments fabric
NW21	Body	Wave-like lines	D	2017NWDIT0301	1	Fine quartz fabric
NW22	Rim	Dots	D	2017NWDIT0302	3	Shell fragments fabric
NW23	Rim	Wave-like lines	D	2017NWDIT0302	1	Fine quartz fabric
NW24	Rim	Wave-like lines	A	2018NWAIF8	1	Fine quartz fabric

Table 2 Quantities and densities of Neolithic sherds at Wutaishan by squares and features

squares and features num.	area (m²)	number of sherds	density (/m²)	Complete vessels
sector D				
2017NWDIT0301	25	1602	64.08	
2017NWDIT0302	25	1975	79	1
2017NWDIT0303	25	800	32	
2017NWDIT0304	25	451	18.04	
2017NWDIT0305	25	794	31.76	1
2017NWDIT0201	25	783	31.32	
2017NWDIT0202	25	2995	119.8	3
2017NWDIT0203	25	972	38.88	
2017NWDIT0204	25	364	14.56	
2017NWDIT0205	25	1008	40.32	

2017NWDIT0101	25	161	6.44	
2017NWDIT0102	27	485	17.96	
2017NWDIT0103	25	87	3.48	
2017NWDIT0104	25	85	3.4	
2017NWDIT0105	29	776	26.76	
2017NWDIF1	10.6	375	35.38	1
2017NWDIF2	17.8	0	0	
2017NWDIH1	0.4	0	0	
2017NWDIH2	1	40	40	
sector AI 2017				
2017NWAIT0402	20	773	38.65	
2017NWAIT0403	25	877	35.08	
2017NWAIT0404	17	527	31	1
2017NWAIT0301	20	1163	58.15	
2017NWAIT0302	25	1046	41.84	
2017NWAIT0303	25	1614	64.56	
2017NWAIT0304	24	2835	118.13	2
2017NWAIT0305	19	2441	128.47	1
2017NWAIT0201	25	2414	96.56	1
2017NWAIT0202	25	1987	79.48	3
2017NWAIT0203	25	2511	100.44	1
2017NWAIT0204	25	2651	106.04	2
2017NWAIT0205	25	2957	118.28	2
2017NWAIT0207	17	1564	92	4
2017NWAIT0208	22.4	1102	49.2	
2017NWAIT0102	30	871	29.03	
2017NWAIT0103	23	468	20.35	2
2017NWAIT0104	35	3664	104.69	
2017NWAIT0105	39.7	2837	71.46	2
2017NWAIT0106	43	3626	84.33	2
2017NWAIT0107	25	1339	53.56	5
2017NWAIT0108	31	1418	45.74	1
2017NWAIF1	37	1983	53.59	2
2017NWAIF2	20.8	1341	64.47	7
2017NWAIF3	23.5	768	32.68	
2017NWAIF4	23.2	1902	81.98	
2017NWAIF5	19	541	28.47	1
2017NWAIF6	59.6	4309	72.3	1
2017NWAIF7	17.2	71	4.13	3
2017NWAIG1	18.3	1981	108.25	1
2017NWAIH1	1.2	22	18.33	
2017NWAIH2	0.6	8	13.33	
2017NWAIH3	0.3	3	10	

2017NWAIH4	0.7	5	7.14	
2017NWAIH5	0.3	13	43.33	
2017NWAIH6	0.5	29	58	
2017NWAIH7	0.3	12	40	
2017NWAIH8	0.8	96	120	
2017NWAIH9	0.6	26	43.33	
2017NWAIH10	3.2	42	13.13	
2017NWAIH11	0.4	19	47.5	
2017NWAIH12	0.6	104	173.33	
2017NWAIH13	0.4	0	0	
2017NWAIH14	0.3	4	13.33	
2017NWAIH15	0.4	30	75	
2017NWAIH16	0.3	0	0	
2017NWAIH17	6.4	182	28.44	
2017NWAIH18	1.3	55	42.31	
2017NWAIH19	0.2	8	40	
2017NWAIH20	1	225	225	
2017NWAIH21	3.7	25	6.76	
2017NWAIH22	0.3	0	0	
2017NWAIH23	0.2	0	0	
2017NWAIH24	0.2	0	0	
2017NWAIH25	0.2	2	10	
2017NWAIH26	0.2	7	35	
2017NWAIH27	0.3	0	0	
2017NWAIH28	0.3	0	0	
2017NWAIH29	0.3	18	60	
2017NWAIH30	0.3	0	0	
2017NWAIH31	0.4	0	0	
2017NWAIH32	0.2	0	0	
sector AI 2018				
2018NWAIT1705	1.5	115	76.67	
2018NWAIT1706	9	133	14.78	
2018NWAIT1707	7.5	0	0	
2018NWAIT1708	4.5	0	0	
2018NWAIT1709	2.3	0	0	
2018NWAIT1604	7	509	72.71	1
2018NWAIT1605	21	1960	93.33	
2018NWAIT1606	25	1420	56.8	
2018NWAIT1607	25	772	30.88	
2018NWAIT1608	25	856	34.24	
2018NWAIT1609	23	326	14.17	
2018NWAIT1610	20	736	36.8	
2018NWAIT1611	9	147	16.33	

2018NWAIT1504	11	92	8.36	
2018NWAIT1505	25	1560	62.4	
2018NWAIT1506	25	809	32.36	
2018NWAIT1507	25	917	36.68	
2018NWAIT1508	25	686	27.44	
2018NWAIT1509	25	692	27.68	
2018NWAIT1510	25	669	26.76	
2018NWAIT1511	17	159	9.35	
2018NWAIT1404	20	2174	108.7	1
2018NWAIT1405	25	465	18.6	
2018NWAIT1410	20	512	25.6	
2018NWAIT1411	24	341	14.21	
2018NWAIT1412	12	195	16.25	
2018NWAIT1310	22	947	43.05	
2018NWAIT1311	25	376	15.04	
2018NWAIT1312	15	295	19.67	
2018NWAIF8	87.6	4170	47.6	2
2018NWAIF9	46.5	3315	71.29	2
2018NWAIF10	44.3	2633	59.44	1
2018NWAIF11	16.3	2710	166.26	2
2018NWAIF12	21.8	2625	120.41	2
2018NWAIF13	21.7	1490	68.66	4
2018NWAIF14	16.1	1414	87.83	9
2018NWAIH33	4.2	124	29.5	
2018NWAIH34	7.9	1029	130.25	4
2018NWAIH35	0.9	0	0	
2018NWAIH36	0.4	21	52.5	
2018NWAIH37	0.5	145	290	
2018NWAIH38	0.9	274	304.44	1
2018NWAIH39	2.4	0	0	
2018NWAIH40	2.6	0	0	
2018NWAIH41	3.2	67	20.94	
2018NWAIH42	1.4	38	27.14	
2018NWAIH43	2.5	62	24.8	
2018NWAIH44	2.1	10	4.76	
2018NWAIH45	0.8	0	0	
2018NWAIH46	1	229	229	
2018NWAIH47	1.2	19	15.83	
2018NWAIH48	1	32	32	
2018NWAIH49	0.7	18	25.71	
2018NWAIH50	0.3	46	153.33	
2018NWAIH51	0.4	39	97.5	
2018NWAIH52	1.7	84	49.41	

2018NWAIH53	1.2	0	0	
2018NWAIH54	0.8	0	0	
2018NWAIH55	1.8	18	10	
2018NWAIH56	0.3	0	0	
2018NWAIH57	0.1	0	0	
2018NWAIH58	0.3	0	0	
2018NWAIH59	0.1	0	0	
2018NWAIH60	0.2	0	0	
2018NWAIH61	0.5	16	32	
2018NWAIH62	0.5	56	112	
2018NWAIH63	1.4	9	6.43	
2018NWAIH64	0.7	3	4.28	
2018NWAIH65	1	20	20	
2018NWAIG2	20.2	557	27.57	1
sector AII 2018				
2018NWAIIT1603	6	22	3.67	
2018NWAIIT1502	16	0	0	
2018NWAIIT1503	25	303	12.12	
2018NWAIIT1504	8	297	37.13	
2018NWAIIT1402	19	0	0	
2018NWAIIT1403	24.5	656	26.78	1
2018NWAIIT1404	18	605	33.61	2
2018NWAIIF1	31.6	2474	78.29	3
2018NWAIIF2	33.6	4313	128.36	
2018NWAIIF3	42.2	0	0	
2018NWAIIH1	0.7	0	0	
2018NWAIIH2	0.2	5	25	
2018NWAIIH5	3.2	148	46.25	
2018NWAIIH6	0.5	0	0	
2018NWAIIH7	0.5	0	0	
2018NWAIIH8	0.4	14	0	
2018NWAIIH9	0.4	0	0	
Total		116646		86