Preference for Porphyry: Petrographic Insights into Lithic Raw Material Procurement from Palaeolithic Kazakhstan

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Abstract

Only a handful of stratified sites are known in loess, spring, and river contexts in the northern piedmonts of the Tian Shan, and the majority are dated to the Upper Palaeolithic. These sites have been studied from a geoarchaeological perspective, however, lithic procurement activities remain unknown. To address this deficiency, we present the results of the extensive field surveys aimed at locating prehistoric raw material sources in the Inner Asian Mountain Corridor of Kazakhstan. We also provide a detailed petrographic description of the lithologies exploited during the Palaeolithic of Kazakhstan. Based on the field survey results, combined with petrographic data, we conclude that the direct procurement strategy was the most common at the stratified sites. However, evidence of both direct and embedded procurement is found in the northern piedmonts of the Ili Alatau range at the site of Maibulaq. Additionally, we highlight the variation of chert lithologies within the larger Qaratau region, laying a foundation for future provenance studies.

Keywords: geoarchaeological survey; chert; PALAEOSILKROAD; petrography; Inner Asian Mountain Corridor
Introduction

In recent years, most of the research in central Asia, and particularly in Kazakhstan, has been focused on finding new Palaeolithic sites (Iovita et al. 2020; Namen et al. 2020; Cuthbertson et al. 2021; Leloch et al. 2021; Kot et al. 2022). The majority of the finds are surface scatters of lithics discovered in the piedmont and foothill zones of the Inner Asian Mountain Corridor (henceforth, IAMC) of Kazakhstan, which includes the Qaratau, Ili Alatau, Dzhungarian Alatau, and the Tarbagatai ranges (Frachetti 2012). Known stratified Palaeolithic sites are located in the piedmont and foothill zones of these ranges, and the majority are chronologically attributed to the Upper Palaeolithic. Currently, all known Palaeolithic localities in Kazakhstan are found in karst/pseudokarst, loess, spring, and river settings, which constitute an important setting for the preservation of archaeological horizons (Iovita et al. 2020; Varis et al. 2022; Namen et al. 2022a). Most stratified Palaeolithic sites (e.g., Maibulaq, Rahat, Valikhanova, and Ushbulaq) are found by water bodies such as rivers and springs. The water sources are certainly of great importance for settling in the landscape and for the subsistence of humans. However, this could possibly be a research bias in the archaeological record, since archaeologists look for evidence of human occupation in the aforementioned settings.

Since 2018, field campaigns within the framework of the bigger PALAEOSILKROAD project have been attempting to determine the adaptation strategies of prehistoric human populations in regard to the local raw materials in the IAMC of Kazakhstan. The major aim has been to locate and study lithic raw materials and their variability in the techno-complexes of the Palaeolithic sites of the region. The first preliminary field observations show that hominins predominantly exploited local raw materials, and due to the diverse formation history of the mountain ranges within the IAMC, raw materials of the lithic assemblages differed depending on the geographic location of the sites (Namen et al. 2022b). Despite the utilization of predominantly locally available raw
materials in the form of pebbles or from outcrops at most of the sites, the use of exogenous types of raw materials was previously described at the Upper Palaeolithic sites of Maibulaq, Rahat, and Ushbulaq (Taimagambetov 2009; Fitzsimmons et al. 2017; Anoikin et al. 2019; Ozherelyev, Dzhasybaev, and Mamirov 2019). Chert and microcrystalline varieties of metasedimentary pelitic rocks (e.g., shale, claystone, siltstone, etc.) are typically considered to be higher quality because they are fine-grained and flake easily and are found as exogenous raw materials at the aforementioned sites. However, in the piedmont of the Ili Alatau range, the number of tools knapped on these rocks is small compared to the local porphyritic rocks. Recent experiments conducted to determine the mechanical properties of these rocks demonstrate that some mechanical properties of porphyry can be compared to chert (Namen et al. 2022c), making the latter an unexpectedly high-quality raw material.

Nevertheless, the question of the characterization, provenance, and transport distance of the exogenous raw materials from these sites remains open and requires a comprehensive multidisciplinary approach employing a variety of analytical tools. Examples of long-distance transport of higher quality raw materials such as micro- and cryptocrystalline varieties of silica rocks are known in the Palaeolithic industries of Europe, Africa, and across the Asian continent (Binford 1980; Feblot-Augustins 1993, 2009; Bar-Yosef 2002; Sano 2010; Arrizabalaga et al. 2014; Tomasso and Porraz 2016; Ekshtain et al. 2017; Frahm and Hauck 2017; Caruana, Tasker, and Stratford 2019; Khatsenovich et al. 2020; Koch and Schmidt 2022). This led to the growth of raw material provenance studies (Brandl 2016), which, in turn, became an interpretive tool to investigate hominin raw material selection behaviors (McBrearty and Brooks 2000; Wadley 2013), population movements (Feblot-Augustins 2009), and human-environment interactions (Bar-Yosef 2002; Blinkhorn and Petraglia 2017; Ghasidian and Heydari-Guran 2018; Heydari-Guran and Ghasidian 2020). Many of the models applied to archaeological sites are derived from ethnoarchaeological research examining the procurement strategies of indigenous people in the Arctic (Binford 1979, 1980).
and Australia (Gould and Sagger 1985). In central Asia, Ghasidian and Heydari-Guran (2018) addressed raw material acquisition in the Iranian Palaeolithic, suggesting an opportunistic use of local raw materials among highly mobile hunter-gatherer groups. The authors explain that the opportunistic use of raw materials is driven by decreased time and energy costs and eventually the adaptation of knapping techniques with available resources (Ghasidian and Heydari-Guran 2018).

In this study, we characterize a variety of lithologies (from both archaeological and geological contexts) that were available to the hominins in the IAMC of Kazakhstan employing a traditional petrographic microscope. The primary objectives are to characterize the mineralogical composition of geological samples of rocks and archaeological lithics and to attempt to describe specific mineralogical components that could aid future provenance analysis. Previous investigations demonstrated the feasibility of petrographic analysis to discriminate characteristic mineral components for the sourcing of stone tools (Soto, Gómez de Soler, and Vallverdú 2018; Soto et al. 2020; Favreau et al. 2020; Prieto, Yusta, and Arrizabalaga 2020). Our results contribute to the in-depth study of raw material variability in the IAMC of Kazakhstan and will serve as a referential framework for research on both raw material provenance and on ancient hominin economic strategies.
Archaeological Setting of the Inner Asian Mountain Corridor of Kazakhstan

The IAMC is a chain of different mountain ranges (the Qaratau, Ili Alatau, Dzhungarian Alatau, Tarbagatai, and Altai) that are affected by fault systems separating them into different ranges, and the study areas are separated by major geological boundaries. However, they share a common geological formation with modern topographic expressions originating from tectonic activity, erosion, and other surface processes. The foothill and piedmont zones of the IAMC were probably some of the regions that provided shelter during the climatic instabilities in the Late Pleistocene (Beeton et al. 2014; Iovita et al. 2020) and perhaps played
an important role in human dispersals across the Eurasian continent (Khatsenovich et al. 2019; Li et al. 2019).

The Palaeolithic record of this vast region is largely represented by well-dated Lower (Qoshqorgan-Shoqtas site complex, 500–430 kya; Derevianko 2006) and Upper Palaeolithic sites (i.e., Ushbulaq [45–39 kya Cal. B.P.], Maibulaq [40–25 kya], and Valikhanova [43.5–9 kya]), but surface finds at localities such as Qyzyltau, Boriqazgan, Tanirqazgan, and Semizbugu contain lithics that can be attributed to all periods of the Palaeolithic, based on techno-typological characteristics (Alpysbaev 1979; Artyukhova 1990; Artyukhova and Mamirov 2014; Osipova and Artyukhova 2019). Our work concentrates on identifying and characterizing lithic raw materials from the Upper Palaeolithic sites of Ushbulaq, Maibulaq, Rahat, Buirekbastaubulaq, and Valikhanova, as well as the Lower Palaeolithic Qoshqorgan-Shoqtas site complex (Figure 1). The stratigraphic setting and archaeology of the sites are well-documented and described (see Alpysbaev 1979; Taimagambetov 1990, 2009; Derevianko 2006; Fitzsimmons et al. 2017; Shunkov et al. 2017; Anoikin et al. 2019; Ozherelyev, Dzhasybaev, and Mamirov 2019; Kunitake and Taimagambetov 2021). Below, we provide a brief background to each site studied, organized by region.

**The Qaratau sites**

So far, the majority of the known Palaeolithic sites are located within the Qaratau range. They cover the periods spanning from the Lower Palaeolithic to the Neolithic. The Lower Palaeolithic is represented by the travertine sites of Qoshqorgan-Shoqtas. The complex of sites is located on a piedmont plain on the southwestern slopes of the Greater Qaratau. Due to the high salinity of the water, the springs are encircled by travertine rings. Subsequent excavations revealed several stages of travertine formation and distinct archaeological horizons attesting to human presence (Derevianko 2006). The assemblage is mainly represented by small flake tools and dated by electron paramagnetic resonance (EPR) to 500 ±
430 kya (Derevianko et al. 1998; Derevianko 2006). This is the only stratified Lower Palaeolithic complex discovered in Kazakhstan, the rest being surface finds that are typologically ascribed to the Lower Palaeolithic.

The Upper Palaeolithic is represented by the site of Valikhanova, which was discovered by Khasan Alpysbaev (1979) in the 1960s. It is located on the left bank of the Arystandy river in the southern foothills of the Lesser Qaratau. The original Alpysbaev publications describe three archaeological horizons preserved in a loessic sedimentary context, with each horizon separated by sterile layers of varying thicknesses. He erroneously attributed the lowermost horizon to the late Mousterian period (Alpysbaev 1979). Archaeological excavations were resumed in the 1980s (Taimagambetov 1990). The main sequence was re-dated in 2013, attributing the age of the earliest archaeological horizon (CH6) to ca. 43.5–35.5 kya (see Fitzsimmons et al. 2017). New excavations in 2018 revealed three additional horizons under the previously recorded three (Z. Taimagambetov, personal communication 2020). Although these additional horizons have not yet been dated, currently the archaeological sequence of the Valikhanova site spans at least ca. 43.5–9 ka and so far represents the Early Upper Palaeolithic rather than the final Mousterian as suggested earlier by Alpysbaev (1979).

Buirekbastau-Bulaq was discovered in 2017. The site is located in the northeastern foothills of the Lesser Qaratau and is found in a spring geomorphological context. The archaeological assemblage is characterized by a blade industry and is chronologically attributed to the Early Upper Palaeolithic. However, the periodization of the site is based on a techno-typological analysis of the unearthed lithic artifacts, with absolute dates pending (Kunitake and Taimagambetov 2021).

Several surface lithics were collected from the large surface Palaeolithic complex of Qyzyltau. It is located in the northeastern foothills of the Lesser Qaratau, and lithic artifacts are scattered in a territory of over 40 km². The site was discovered by Khasan Alpysbaev
in the 1960s, and a Kazakh-Russian archaeological expedition continued the fieldwork in the 1990s (Derevianko 2017). The lithic collection is attributed to all periods of the Palaeolithic. This signifies intense human interaction with the environment for long periods of time. The authors explain the formation of the complex by the regression of the paleolake surface and landscape evolution (Derevianko et al. 2002).

The Ili Alatau sites

The piedmont zone of the Ili Alatau range has recently become a promising region to search for and locate new Palaeolithic sites. This is because thickly deposited loess accumulations preserve traces of human occupation (Li et al. 2020). Currently, Palaeolithic horizons are known at the sites of Maibulaq and Rahat (Taimagambetov 2009; Ozherelyev, Dzhasybaev, and Mamirov 2019). The Maibulaq site was discovered in 2004 and excavated in the following years, which revealed three cultural horizons divided by sterile loess sediments (Taimagambetov 2009; Fitzsimmons et al. 2017). All three cultural horizons have been dated, and, so far, the chronology of the site spans ca. 40–25 kya. Currently, new detailed chronology for Maibulaq is in preparation. Cultural horizon 1 is reported to be partially disturbed by Holocene activity, possibly an Early Iron Age burial (kurgan), whereas the lowermost cultural horizons 2 and 3 revealed an abundant number of lithic artifacts. The assemblages are characterized by prepared cores with two hierarchically-organized surfaces, their flake products, and bladelet and Levallois technologies (Figure 2) (Fitzsimmons et al. 2017). Thus, the chronology and technological features containing Levallois technology and bladelet production suggest an Early Upper Palaeolithic character for the site, although not enough is currently known about the cultural sequences in this region to make such characterizations. In particular, the total absence of dated Middle Palaeolithic sequences makes such discussions counterproductive.
Rahat is another Upper Palaeolithic site, located approximately 80 km east of Maibulaq. It has been excavated since 2018 (Dzhasybaev, Ozherelyev, and Mamirov 2018). The archaeological assemblage is techno-typologically analogous to the Maibulaq materials and knapped on local volcanic rock pebbles (Ozherelyev, Dzhasybaev, and Mamirov 2019). The chronology of Rahat is preliminarily attributed to the Upper Palaeolithic based on techno-typological features and site stratigraphy.

Figure 2. Illustration of the lithic artefacts from the occupational horizon 3, Maibulaq. A, F, G, L – bladelet; B, D – flake; C, E, H-K – blade.
The Tarbagatai sites

The Tarbagatai range is located in eastern Kazakhstan, south of the Kazakh Altai. It stretches in an east-west direction and spans over 200 km. We located several occurrences of surface lithics in the northern foothills of the range. These are described by Iovita and colleagues (2020). However, Ushbulaq is the only currently known stratified Upper Palaeolithic site in the region. It was discovered in 2016 by a Kazakh-Russian archaeological expedition (Derevianko et al. 2017). Excavations carried out in the following years revealed several horizons with lithics. However, the lowermost two horizons contained a high density of lithic artifacts. The assemblages are dominated by prismatic and double-platform bidirectional cores knapped to detach long blades. The radiocarbon dates were taken from Stratum 6 and date the site to 42,100–39,364 CAL B.P. (AA-111921) and 45,249–44,012 CAL B.P. (NSKA-01811) (Anoikin et al. 2019). Based on the presence of characteristic features of double-platform blade cores and blades exceeding 20 cm, the authors associate the lower horizons with the Initial Upper Palaeolithic (Shunkov et al. 2017; Anoikin et al. 2019).

Materials and Methods

Geoarchaeological survey

The geoarchaeological surveys were conducted in the 2019 and 2021 field seasons. The survey primarily concentrated around previously known stratified sites and unstratified surface lithic scatters located in the foothill zones of the Ili Alatau (Almaty region) and the Qaratau mountain ranges (southern Kazakhstan). Preliminary results of this work were previously reported by Namen and colleagues (2022b). We aimed to cover a 20 km radius from the sites to locate primary and/or secondary sources of knappable raw materials. The
exploratory raw material survey was conducted by car and on foot where necessary. Given that porphyry constitutes the majority of the local raw materials, we focused on locating sources of exogenous materials (e.g., shale and chert) exploited at the sites of Maibulaq and Rahat.

For this reason, we surveyed the piedmont zone stretching approximately 20 km west and 5 km east of the site of Maibulaq. The eastern part of the area is located on private land within the densely populated Almaty metropolitan area and could not be systematically surveyed. The southern part is constrained by the steep slopes of the Ili Alatau range (Tian Shan Mountain system), and the northern part is primarily represented by eroded debris of rocks outcropping from the mountain range and the accumulation of aeolian sediments. The Rahat site is situated in a similar geomorphological context, and therefore our survey focused on the piedmont zone along the mountain front. A similar survey strategy was also applied in the Qaratau range, where the uplifted carbonate beds create a precondition for the formation of specific types of silica rocks, such as cherts and siliceous shales.

In order to predict the location of potential raw material sources, we used georeferenced geological maps of Kazakhstan, as well as lithological data from the Mineral Deposits Database and Thematic Maps of Central Asia ArcGIS platform developed by the Centre for Russian and Central EurAsian Mineral studies (CERCAMS; Seltmann, Armstrong, and Dolgopolova 2004). We successfully used the CERCAMS database in previous raw material surveys to locate sources of individual types of raw materials (Namen et al. 2022b). Data on the occurrences of raw materials of interest were retrieved from the CERCAMS database as keyhole markup language (.kml) files and uploaded onto field tablets to structure the survey. Lithologies of interest, such as varieties of porphyritic rocks, that were not available on the CERCAMS database, were retrieved as shapefiles (.shp) from the geological maps created by the Institute of Geology of the Soviet Academy of Sciences using the open-access platform QGIS (Geological Map of Kazakhstan and Middle Asia). The GPS locations
of sources of interest were recorded and photographed, and samples for further laboratory processing were taken.

Figure 3. Secondary position of shale found in a dried riverbed at the Beriktas locality (Trans-Ili Alatau) (A), and a pebble showing a conchoidal fracturing pattern (B).

**Samples**

The types of samples collected during the fieldwork are summarized in Table 1. The archaeological samples of surface lithics were collected from the Upper Palaeolithic sites of Ushbulaq, Rahat, Maibulaq, Buirekbaaubulaq, and Valikhanova and the Lower Palaeolithic complex of Qoshqorgan-Shoqtas (see Table 1, Figure 1). So as not to disturb the integrity of assemblages found in stratified contexts, we only sampled lithics collected from the surface that could not be attributed to a specific cultural layer. The geological samples were collected from primary positions such as outcrops or secondary positions such as river pebbles located close to the sites (≤ 20 km). The sample collection criteria were based on macroscopic similarity to the archaeological assemblage and other macroscopic attributes such as color, texture, translucence, and surface roughness as identified by hand lenses and visual inspection. Such macroscopic analysis provides a fast, non-destructive, and inexpensive means of comparing large collections. Similar survey strategies have also been used to
investigate raw material distribution in other parts of the world (Spinapolic 2012; Suga et al. 2022; Ghasidian and Heydari-Guran 2018).

Sample preparation and petrographic analysis

Macroscopic and microscopic observations were used to identify different types of lithologies. Firstly, we classified each material by color and texture. A total of 64 thin sections, consisting of 23 geological reference samples and 41 surface lithics, were microscopically investigated. The thin sections were prepared at the Geological Laboratory of Satbayev University (Almaty, Kazakhstan). Traditional petrographic analysis was conducted at the Laboratory for Geoarchaeology of the Institute for Archaeological Sciences (INA), University of Tübingen (Germany). Thin sections were analyzed using a Zeiss petrographic microscope, and photomicrographs were obtained using an Axio camera coupled to the microscope.

The geological reference samples were studied for direct comparison with the archaeological lithic artifacts (see for example Rybin et al. 2018; Prieto, Yusta, and Arrizabalaga 2020; Favreau et al. 2020; Abrunhosa et al. 2020). Thin sections were investigated under plain parallel and cross-polarized light to characterize their mineralogical composition, matrix, crystal size, and shape. Due to the homogeneity of chert samples under the optical microscopy, a quartz lambda auxiliary plate was used to obtain additional information regarding chalcedony types (i.e., length-fast and length-slow) and the corresponding variety. The length-fast and the length-slow terms are defined as the relationship between the crystallographic axes and the magnitude of refractive indices. The sign of elongation is determined on the basis of whether the slow and fast component is vibrating in the longest direction of the crystal (Miehe, Graetsch, and Flörke 1984). A recent paper by Koch and Schmidt (2022) graphically represents the length-fast and length-slow chalcedony types. The identification of chalcedony types is an important parameter that helps
to provenance chert. This is because length-slow chalcedony fibers generally form under geological environments different from those for length-fast chalcedony (Hattori 1989). The identification of pelitic rocks followed the grain size classification by Wentworth (1922).

Table 1. Description of the archaeological sites and geological localities where the samples of raw materials were collected.

<table>
<thead>
<tr>
<th>Site ID</th>
<th>Period</th>
<th>Absolute Dates</th>
<th>Raw Material Source</th>
<th>Type of Raw Material</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rahat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Current work, Kunitake and Taimagambetov 2021</td>
</tr>
<tr>
<td>Berikta Buirekbastaubulaq</td>
<td>Riverbed Upper Palaeolithic</td>
<td>N/A, Pending</td>
<td>Secondary</td>
<td>Siltstone Chert, claystone</td>
<td></td>
</tr>
<tr>
<td>Qyzyltau</td>
<td>Middle–Upper Palaeolithic</td>
<td>N/A</td>
<td>-</td>
<td>Chert</td>
<td>Derevianko et al. 2002</td>
</tr>
<tr>
<td>Sorkol Valikhanova</td>
<td>Neolithic Upper Palaeolithic Outcrop</td>
<td>N/A, 43.5–9 kya, N/A</td>
<td>Primary</td>
<td>Chert, Chert</td>
<td>Iskakov 1998, Fitzsimmons et al. 2017</td>
</tr>
<tr>
<td>Valikhanova outcrop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Current work</td>
</tr>
<tr>
<td>Qoshqorgan-Shoqtas complex</td>
<td>Lower Palaeolithic</td>
<td></td>
<td>-</td>
<td>Chert, quartzite</td>
<td>Derevianko et al. 1998</td>
</tr>
</tbody>
</table>

**Results**

Here we provide petrographic characteristics for each geological and archaeological raw material sample collected during surveys, organized by the different mountain ranges within the IAMC. The piece counts of exogenous raw materials are shown in Table 2, and the detailed petrographic description is provided in Table 3.
Geoarchaeological survey

In the Ili Alatau range, the survey yielded secondary and primary sources of igneous lithologies which originate from the Devonian volcanic granitoid base rock. Even though cobbles and pebbles of different volcanic rocks are visible in fluvially eroded valleys, the thick accumulation of wind-blown aeolian loess sediments hinders locating the outcrops of various lithologies in the piedmont and foothill zones. There, we observed a variety of porphyritic rocks available in riverbeds and channels. The geological samples for further laboratory investigation were collected based on macroscopic similarities to the lithic assemblage from the mentioned sites. Our survey failed to locate chert or flint in primary or secondary contexts. According to geological map data retrieved from the CERCAMS database, the nearest sources of chert are located to the north in the Dzungarian Alatau and to the west in the Chu-Ili Alatau (previously reported by Namen and colleagues [2022b]). We mainly located sources of knappable porphyritic and felsitic rocks in the vicinity of Maibulaq. However, a secondary source of higher quality exogenous metasedimentary pelitic rocks was located in the piedmont zone of the Ili Alatau range some 20 km west of Maibulaq and 70 km west of Rahat at a locality named Beriktas (see Figures 1, 3). The Beriktas locality is thus far the only known location in the Ili Alatau foothills that has siltstone, a material that is macroscopically similar to the exogenous materials knapped at the aforementioned sites. Both geological and archaeological samples from Maibulaq and Rahat, and geological samples from Beriktas, were collected for the petrographic studies and are described below.

We located primary and secondary sources of chert, mainly in the northern foothills of the Qaratau (see Figure 1). In the 2019 field season, we recorded a primary source of chert at the Yntaly locality (Namen et al. 2022b) in the northeastern foothills of the Lesser Qaratau range. Archaeological and geological samples of lithic raw materials were collected at the sites of Buirekbastau-Bulaq, Qyzyltau, Sorkol, Qoshqorgan-Shoqtas complex, and
Valikhanova. Hominins at all of the mentioned sites used locally occurring varieties of chert and other silica-rich rocks. The raw material survey was primarily concentrated near the stratified site of Valikhanova. A primary outcrop of chert was located approximately 200–300 m from the site on the right bank of the Arystandy River. The majority of the chert-bearing outcrop is currently almost completely covered by aeolian loess sediments; however, small parts of the outcrop remain exposed, allowing access for sampling purposes (Figure 4).

Figure 4. Panoramic view to the Valikhanova site (A) and the raw material outcrop located on the right bank of the Arystandy river (B). The outcrop is currently covered by thick loess sediments and illustrated on C) and D).

Petrographic analysis

The Qaratau sites

From the Qaratau range, raw materials from five Palaeolithic sites were sampled (Table 2). The Valikhanova assemblage is entirely knapped on a locally outcropping grey to dark grey chert with a varying degree of fossil inclusions. It is located on the right bank of the
Arystandy River, some 200 m away from the Valikhanova site. A total of eight geological and one archaeological surface lithic samples were thin sectioned and studied using the petrographic microscope. They are primarily composed of cryptocrystalline fibrous chalcedony grains and partly quartz veins. Some samples contain diagnostic microfossils of radiolarian filled with secondary quartz grains (Figure 5A–C). All of the studied samples are microscopically similar.

The Qyzyltau assemblage also contains lithic artifacts exclusively knapped on a locally outcropping dark grey to black variety of chert. A total of nine surface lithics were thin sectioned. The microstructural difference between Valikhanova and Qyzyltau chert is easily visible under the microscope (Figure 5D–F). The latter is entirely composed of length-fast fibrous chalcedony grains with minor inclusions of secondary mega quartz crystals. Similarly, the Sorkol samples were macroscopically identified as a grey and light pink variety of chert. The outcrop of the materials was not located in the nearby vicinity. However, a macroscopically similar light pink variety of chert outcrop is known some 3 km southwest of the site at a locality named Yntaly. As with the Qyzyltau chert, the Sorkol thin sections are composed of fibrous length-fast chalcedony.

Based on the petrographic characteristics of each chert, we can distinguish three types: Valikhanova, Qyzyltau, and Sorkol chert (shown in Figure 5). They possess characteristic inclusions such as microfossils, as well as mega quartz and quartz veins within the chalcedony fibers. These structural differences (microfacies) may assist future provenance analyses in distinguishing different sources of chert artifacts in the Qaratau region.

Despite the abundance of chert in the Qaratau region, the lithic assemblage from Buirekbastau-Bulaq is knapped on pelitic rocks such as siltstones and claystone (see Table 2, Figure 6 A–B). The preference for pelitic rocks over chert raises questions about hominin raw material selection choices in the region. The Qoshqorgan-Shoqtas complex assemblage was
also knapped on various types of available raw materials such as quartz, quartzite, limestone, chert, and sandstone (Derevianko et al. 2000).

Figure 5. Photomicrograph of the chert types found in the Qaratau range. The Valikhanova chert contains microfossils (A, B) within the cryptocrystalline quartz matrix, and secondary chalcedony inclusions (C). The Qyzyltau chert consists of quartz inclusions within the cryptocrystalline quartz matrix (E, F). The Sorkol chert consists of length-fast chalcedony (G, H), and inclusions of opaque minerals (I).
The Ili Alatau sites

The thin sections from Maibulaq porphyry can be petrographically characterized by phenocrysts of quartz and K-feldspars embedded in a siliceous matrix (Namen et al. 2022c).

The proportion of exogenous raw materials (e.g., chert and shale) from Maibulaq is illustrated in Table 2 and graphically shown in Figure 7. Whereas two geological samples and one surface lithic from Rahat were thin sectioned. They are also characterized by a siliceous matrix with randomly oriented subangular to angular crystals of quartz, cracks filled with quartz, and K-feldspars (Figure 8). Microscopically, all of the samples exhibit similar features. Additionally, the Beriktas samples contain clay minerals of varying sizes. The
microscopic investigation revealed predominantly psammitic sandstones, greywacke, and siltstones.

Table 2. The piece counts of local and exogenous raw materials in each horizon at Maibulaq excavated during the 2004 and 2005 excavation seasons.

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>2004 and 2005 Excavation Horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mixed</td>
</tr>
<tr>
<td>Porphyry</td>
<td>90</td>
</tr>
<tr>
<td>Shale</td>
<td>8</td>
</tr>
<tr>
<td>Chert</td>
<td>1</td>
</tr>
<tr>
<td>Quartzite</td>
<td></td>
</tr>
<tr>
<td>Sandstone</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 7. Bar chart of the Maibulaq raw materials. The 2004 and 2005 excavations were combined.
Figure 8. Photomicrograph of porphyry from Maibulaq (A and B), Rahat (C and D), and Beriktas localities (E and F) taken in different magnifications under cross-polarised light (XPL).

*The Ushbulaq site*

Previously, the exploitation of the sedimentary rocks and petrographic features of the assemblage were investigated and described in detail by Rybin and colleagues (2018). They report the predominance of aleurolithic, fine, and microcrystalline varieties of silicites.
(силицит), as well as a few siltstones and tuffs (Rybin et al. 2018). The terminology of silicite in Russian is used to describe a sedimentary rock enriched by silica content (Krishtofovich 1978). For the current work, we examined a total of seven surface lithics from the Upper Palaeolithic site of Ushbulaq. The macroscopic investigation of the Ushbulaq assemblage and further petrographic analysis show a predominant utilization of fine-grained rocks from the pelitic group, mainly mudstones, claystone, and siltstone enriched by silica content, as shown in the microphotographs (Figure 9).

![Ushulaq](image)

Figure 9. Photomicrograph of claystone from Ushbulaq (A and B) taken in different magnifications under cross-polarised light (XPL).

Table 3. Detailed petrographic description of the studied thin sections. Legend: qz = quartz, fs = feldspar, ca = calcite, Kfs = potassium feldspar, MS = matrix supported, and CS = clast supported.

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Discussions and Conclusions

The petrographic analysis revealed the types of sedimentary and volcanic rocks exploited during the Palaeolithic in the IAMC of Kazakhstan. Based on these results, we observe differences between the types of chert utilized in the Palaeolithic assemblages of the Qaratau range. The photomicrographs of the chert thin sections demonstrate microscopic variations between the Valikhanova, Qyzyltau, and Sorkol cherts with varying degrees of quartz, chalcedony, and other opaque mineral inclusions (see Figure 5). It is especially important to point out the presence of different microfossils (mainly radiolarian) within the Valikhanova chert that makes it distinguishable from other types of chert available in the Qaratau region. Such microscopic features will help in the future to provenience chert artifacts in Kazakhstan. It is also necessary to investigate the influence of different inclusions on the knapping quality and the mechanical properties of these lithologies. Such investigations will inform discussions on knappability and technological variations between different types of silica rocks (Manninen 2016; Loendorf et al. 2018; Schmidt et al. 2019; Namen et al. 2022c).

The geoarchaeological survey results around the stratified and surface sites suggest that prehistoric hominins preferred to set their camps by water bodies and in close vicinity to raw material sources. This is a pattern that is characteristic of all of the sites mentioned in the current study. However, this observation could be the result of research bias (because archaeologists typically look for sites near water sources). Nevertheless, earlier investigations of the lithic assemblages report the acquisition of only local (e.g., Valikhanova) or predominantly local raw materials (e.g., Maibulaq, Rahat, and Ushbulaq; Taimagambetov 1990; Taimagambetov and Ozherelyev 2008; Anoikin et al. 2019; Ozherelyev, Dzhasybaev, and Mamirov 2019). In this context, the case of the Maibulaq site is rather interesting in terms of discussing the raw material availability and variation around the site. The eponymous valley where the site is located offers various types of knappable raw materials, including
porphyritic rocks and very fine-grained felsitic rocks that are found up the stream from the Maibulaq. In addition to the locally available rocks, a systematic survey along the Ili Alatau foothills revealed a source of higher quality siltstone that is located some 20 km west of the site. Despite the better knappability of felsitic rocks and siltstone, porphyritic rocks were the main raw material choice in the organization of tool manufacturing. This allows us to conclude that the toolmakers were highly selective in their choice of local raw materials and that they perhaps optimized something other than the ease of flaking. Moreover, the analysis of lithic raw material variation of the Maibulaq assemblage that is available in the collections of Al Farabi Kazakh National University (n = 437) shows that a small fraction of tools was knapped on materials transported from elsewhere (see Table 2, Figure 7). The small number of tools knapped on exogenous materials (siltstones and chert) could be an indicator of an embedded procurement strategy (Binford 1979). We suggest that these materials were collected while carrying out other tasks (embedded procurement) and subsequently carried to the site. However, we should note that our assumption is solely based on the presence of tools knapped on exogenous raw materials. Additionally, the preference for porphyritic rocks by human groups at Maibulaq calls for supplementary investigations into its quality for knapping and fracture mechanics (e.g., indentation fracture toughness, fracture strength, elasticity, etc.) (Mardon et al. 1990; Domanski, Webb, and Boland 1994; Doelman, Webb, and Domanski 2001; Schmidt et al. 2019; Namen et al. 2022c).

Based on the above results, we conclude that hominin groups at Maibulaq had both direct and embedded raw material procurement strategies. However, the choice of mainly porphyritic rocks for the organization of knapping activities suggests that direct procurement was predominant. The human groups at Maibulaq were highly selective while acquiring local materials, as evidenced by selection of porphyritic rocks over other locally available materials. Moreover, the cobbles currently available in the Maibulaq stream bed today tend to have a higher incidence of large phenocrysts than those encountered in the archaeological
collection. We may, therefore, hypothesize that the quality of available lithologies was deemed suitable for the production of desired end products or that the hominins had to adapt their knapping technology to the quality of available rocks. Similar conclusions have been made before, but the major emphasis has been on the opportunistic use of the local raw material as a function of decreasing time and energy costs, which led to the adaptation of knapping techniques to the available resources (Ghasidian and Heydari-Guran 2018). However, the opportunistic use of local raw materials should not be considered in the Maibulaq case. The preference of porphyry over felsitic rocks available at the site or siltstones available within a 20 km distance should be viewed as the result of deliberate selection. The evidence of raw material selection patterns has already been discussed for the Palaeolithic of Africa (Goldman-Neuman and Hovers 2012; Harmand 2009; Harmand et al. 2015). Braun and colleagues (2009) argue that the selectivity of lithic raw material in Oldowan technology was driven by raw material quality. The use of so-called lower-quality porphyritic rocks is common in Palaeolithic assemblages of neighboring regions in central Asia (e.g., Kattasai 1 and 2 in Uzbekistan [Kot et al. 2022]), Siberia (Derbina V [Kharevich, Akimova, and Stasyuk 2010]), and the Russian Far East (Ezhantsy I and II [Mochanov 1977]). The exploitation of volcanic porphyritic rocks at these sites could possibly be interpreted as the ability of prehistoric human groups to knap these raw materials. We also believe the criteria guiding the selection of explicitly porphyritic rocks were driven by a number of factors, including the raw material quality, technological skills, and familiarity with working these materials. Despite the presence of exogenous rocks, and considering the inter-site variability of raw materials at Maibulaq, we suggest that a direct selective procurement strategy formed the basis for the technological and territorial organization.
Acknowledgments

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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Figure Captions

Figure 1. Topographic map of the Kazakh portion of the IAMC that is comprised of the A) Qaratau, B) Ili Alatau, and C) Tarbagatai mountain ranges (highlighted in squares). Numbered red marks are the sites mentioned in the text: 1) Valikhanova, 2) Yntaly, 3) Sorkol, 4) Qyzyltau complex, 5) Buirekbastau-Bulaq, 6) Beriktas, 7) Maibulaq, 8) Rahat, and 9) Ushbulaq. Data sources: Global Administrative areas (GADM) (Hijmans 2012); vector and raster data from Natural Earth (www.naturalearthdata.com) and Shuttle Radar Topography Mission (SRTM) Version 4 (Jarvis et al. 2008).

Figure 2. Illustration of the lithic artifacts from occupational horizon 3, Maibulaq. A, F, G, L) bladelets; B, D) flakes; C, E, H–K) blades.

Figure 3. A) Secondary position of shale found in a dried riverbed at the Beriktas locality (Trans-Ili Alatau) and B) a pebble showing a conchoidal fracturing pattern.

Figure 4. A) Panoramic view of the Valikhanova site and B) the raw material outcrop located on the right bank of the Arystandy river. C–D) The outcrop is currently covered by thick loess sediments.

Figure 5. Photomicrograph of the chert types found in the Qaratau range. A–B) The Valikhanova chert contains microfossils within the cryptocrystalline quartz matrix and C) secondary chalcedony inclusions. D–F) The Qyzyltau chert consists of quartz inclusions within the cryptocrystalline quartz matrix. G–H) The Sorkol chert consists of length-fast chalcedony and I) inclusions of opaque minerals.
Figure 6. Photomicrograph of the raw materials from Buirekbastau-Bulaq site illustrating A) parallel sedimentary bedding lines and B) deformed quartz crystals, possibly indicating a process of metamorphism. The Qoshqorgan-Shoqtas complex demonstrates C) quartzite and D) chert with quartz veins running through the rock.

Figure 7. Bar chart of the Maibulaq raw materials. The 2004 and 2005 excavations were combined. X-axis refer to the overall number of artifacts.

Figure 8. Photomicrograph of A–B) porphyry from Maibulaq, C–D) Rahat, and E–F) Beriktas localities taken in different magnifications under cross-polarized light (XPL).

Figure 9. Photomicrographs of claystone from Ushbulaq taken in different magnifications under cross-polarized light (XPL).