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Research Article

Chlorite from the Southeast of Iran: A Stone of the Passage of Time and Culture

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Abstract: Chlorite is a metamorphic rock that can be found in ophiolites or areas with a high degree of regional metamorphism. The stone was mostly considered within a wide cultural context and for long-term usage due to its unique, fashioned characters and prestigious green-grey color tone. Due to its low hardness, chlorite is relatively easy to carve, and was a material of choice for small artefacts. Around the Persian Gulf, this stone was excavated in prehistory and antiquity, which was used to make vessels and small objects from the Neolithic to modern days. Between the third and second millennium before the Common Era, in the south and southeast of Iran, chlorite objects were prestige objects associated with funerary practices and were traded over long distances. Since the first discoveries, there have been debates about their provenance, but because the archaeological knowledge about the fashioned raw reservoirs in these regions is deeply complex, the nature, chronology, and modalities of this chlorite production and trade are still largely unknown. Therefore, the goal of this research is to synthesize the differences between the three main styles traded around the Persian Gulf - namely the Intercultural, Umm an-Nar, and Wadi Suq styles - and describe their particularities, distribution, and production areas. The basis of this part was the conception of some focal points, listing as exhaustively as possible the occurrences of chlorite artefacts, as well as the mapping of their distributions, and their formation in diverse geological contexts.

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1. Introduction

The trade and archaeological evidence of chlorite stone have long been a significant focus in archaeological research. Chlorite was not only processed and used as a common material but was also consistently regarded as a prestigious, ornamental stone. The existence of chlorite has been reported in a very large cultural corridor, and there have been many places in antiquity where it was enhanced. The trade, use, and demand of chlorites by different cultures through history have been reported by many scholars. This research will focus on some prominent localities for quarrying and the use of chlorite in the Persian Gulf region and the South Iranian Plateau (Perrot and Madjidzadeh, 2005). In literature, the most commonly used term to refer to chlorite artefacts is 'vessel'. The vast majority of the artefacts analysed are containers. In the case of the Intercultural style, there is evidence of some chlorite artefacts not being containers. The term artefact will be used to encompass both vessels and non-vessels. Historically, chlorite artefacts have mostly been called soft-stone, or steatite (Kohl, 1974; Madjidzadeh, 2003). Nearly all artefacts are largely composed of chlorite. The accepted term for the material is now chlorite for the stone (Emami et al., 2017).

Chlorite artefacts were first discovered in Mesopotamia at the beginning of the 20th century. In 1912, during excavations in Adab, Dr. E.J. Banks uncovered a vessel dump, in which chlorite vessels are present (Banks, 1912). The bank describes the motifs, identifies them as early Sumerian, and considers the origin of the material by which they have been made. He notes that chlorite, which he noted as softstone, is absent in the fertile crescent, and supposes that they come from the Zagros Mountains. He described in his report, “Where did the inhabitants of the stoneless, alluvial plain obtain the great variety of beautiful material for their vases?” He can note that from the earliest discoveries, chlorite artefacts have been associated with the outcrops in the southeast of Zagros orogeny and the ophiolitic subsequences of Faryab mountain (Emami et al., 2023). The recent studies singled out at least two major mineralogical groups, suggesting that different workshops, possibly in different times, exploited different local sources of chlorite. Results also indicate that the surroundings of Konar Sandal South, the main urban hub of the Halil valley, were involved, for several centuries, in the production of three major different classes of stone pots (cylindrical vessels with intricate geometric patterns, plain bell-shaped bowls, and incised *Série Recente* vessels) (Pitman, 2018; Shafee et al., 2023). Drawing on absolute dating results, the previously reported results show that the Jiroft style persisted into the early second millennium BCE (Shafee et al., 2023).

Until the 1960s, the Sumerian origin of the stones was the main interpretation among archaeologists. The first catalogue of chlorite vessels was made in 1964 by Farzand Durrani (Durrani, 1964). Based on the stylistic analysis of 41 artifacts, he poses the hypothesis of several origins. He distinguishes human and animal figures, as well as architectural scenes, from curvilinear and geometric designs. He supposes the first style originates from Mesopotamia, and the second from Baluchistan (South-East of Iran). The distribution of those vessels would then demonstrate long distance relationship between Mesopotamia and the Indus Valley, with the exchange of prestige goods.

The discovery of Tepe Yahya in 1967 changed this paradigm, showing that chlorite vessels were produced and distributed in the Iranian highlands. In 1973, Pierre de Miroschedji examined chlorite artefacts conserved in the Louvre’s collections and created a new stylistic classification, separating old series (*série ancienne)* from recent series (*série récente)* (Miroschedji, 1973). The old series would then be renamed to Intercultural Style in the following years by the works of C.C. Lamberg-Karlovski (Lamberg-Karlovsky, 1988) and Philip L. Kohl (Kohl, 1974), explaining the trade of chlorite with the World-System theory. International field research on Intercultural style vessels, then, probably because of the Iranian revolution of 1978. Since the beginning of the 21st century, studies of chlorite vessels are mostly centered around two poles: the Intercultural style in the Kerman region since 2002, and the Umm an-Nar (*série récente*) and Wadi Suq (*série tardive*) styles in the United Arab Emirates and Oman, countries that were rapidly developing their archaeology. In the following pages, we will examine the main elements of these styles and their distribution.

2. Styles and distribution

2.1. Intercultural style chlorite artifacts

Philip L. Kohl describes the Intercultural style and identifies twelve constituting motifs. They can be separated into figurative and geometric motifs (Fig. 1). These motifs are often combined together or with secondary motifs. All primary motifs are considered evenly distributed, with some slight variations (Laursen, 2016). In *Seeds of Upheaval,* Kohl has described the production of chlorite at Tepe Yahya and an analysis of commodity production and trade in Southwest Asia in the mid-third millennium (Kohl, 1974).

Statistical analysis of combinations of primary and secondary motifs could therefore hold the key to some provenance insights in combination with geochemical analysis. Combination analysis was conducted on the artefacts from Tepe Yahya by Geoffrey Emberling (Lamberg-Karlovsky, 1988), who identified two main clusters of motifs, one cluster of geometric motifs associated mainly with Architectural motifs (Hotpot and beveled square) and another around the Combatant snakes. Those combinations could vary geographically. However, a large-scale statistical analysis would require defining motifs clearly and reclassifying all existing artefacts. If we consider the shapes in which chlorite artifacts are shaped, the Intercultural style is the most diverse. Most are, of course, vessels: open bowls, tall vessels, cups, and jars. In the Kerman region, chlorite decorative plaques, as well as the "hand-bag" shape stones whose function is still uncertain, have been found (Perrot & Madjidzadeh, 2005; Pittman, 2018; Madjidzadeh & Pittman, 2008). The distributions of Figurative and geometric intercultural styles are comparable. Although we remark that figurative motifs spread over a larger area, this is probably just caused by the larger number of artefacts. Indeed, there are more artefacts with figurative patterns than artefacts with geometric patterns.

Name	Description	Notes	Illustration
Combattant Snakes	Snakes have feline like features (ears and large mouth), and are pictured fighting either other snakes, eagles or felines.		
Date Palm trees	Patterns of rows of identical palm trees	May be linked with Dilmund Royal House (Laursen, 2016)	
Scorpions	Patterns of rows of identical scorpions. Execution of this motif is very consistent over the corpus		
Human Figures	Most varied motif, it includes all human representations, often associated other figurative motifs, linking them together	This motif is overrepresented in Diyala Valley, and in the Jiroft Corpus	
Imdugud	Anthropomorphic Eagle	Personification of thunder god in Sumerian mythology	

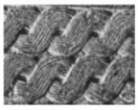
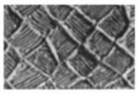
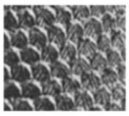
Name	Description	Notes	Illustration
Guillochine	Intertwined coil design	May be a simplified representation of snakes motifs	
Hutpot	Architectural motif	The exact architectural element represented is unknown, it is supposed to be a temple, a palace or a gate	
Mat / Basket-Weave	Stylized geometric design of parallel lines		
Imbricate	Overlapping semi-circles	Could represent fish/reptile scales, or a mountain range	
Whirl	Twisting whirl		
Beveled Square	Superposed squares/rectangles	Sometimes linked to brickwork	

Figure 1. Summary of main figurative motifs and geometric motifs found in the Intercultural style. (Simplified after Hakemi, 1997; Madjidzadeh, 2003; Kohl, 1976).

Geographically, we can identify four main areas concentrating on chlorite artefacts (the numbers of excavated artefacts are in brackets). Areas concentrating artefacts could provide insights into the patterns of trade of chlorite artefacts (Fig. 2A, B). The data was treated with R software (R Core Team, 2016) and visualized in QGIS (QGIS Development Team, 2025), an open-source geographic information system. Maps represent the distribution of vessels, the black dots locating the site, and the colored circles the number of artefacts. On the maps, the sites are referred to by a number and a full name (Aitchison, 2008). The Kerman region in Iran, with Tepe Yahya (79), Shahdad (63), and Hali Rud Valley sites (38, 43, 26); Sumerian cities along the Tigris and Euphrates; Susa (70), Failaka Island (19), and Tarut Island (73) in the Persian Gulf. However, a large portion completely lacks archaeological context, especially in Tarut, where artefacts were retrieved on the surface, and the Jiroft corpus, which originates from plundering. The sites in Mesopotamia also have incomplete context, having been excavated hastily at the beginning of the 20th century. This leaves two major sites with clear stratigraphy: Tepe Yahya and Failaka (Fig. 2). The data used in this research is, for the most part, from the database compiled by Helen David-Cuny (2001), who has listed all the occurrences of soft stone vessels before 1996. This data set was updated with artefacts known as "Jiroft Corpus" (Perrot & Madjidzadeh, 2005), the report of the excavations on the island of Failaka (Hilton, 2016), and with articles on the excavations in the Hali Rud Valley, Konar Sandal (Madjidzadeh & Pittman, 2008) and Mahtoutabad (Vidale & Desset, 2013), and in Gonur Depe (Potts, 2008). The style of chlorite artefacts is still debated; however, based on recent archaeological arguments, the 'Jiroft style' name has been replaced by the 'Intercultural Style' name, and the word chlorite is used for both 'chlorite-schist' or 'chloritite' (Emami et al., 2017; Eskandari & Vidale, 2023).

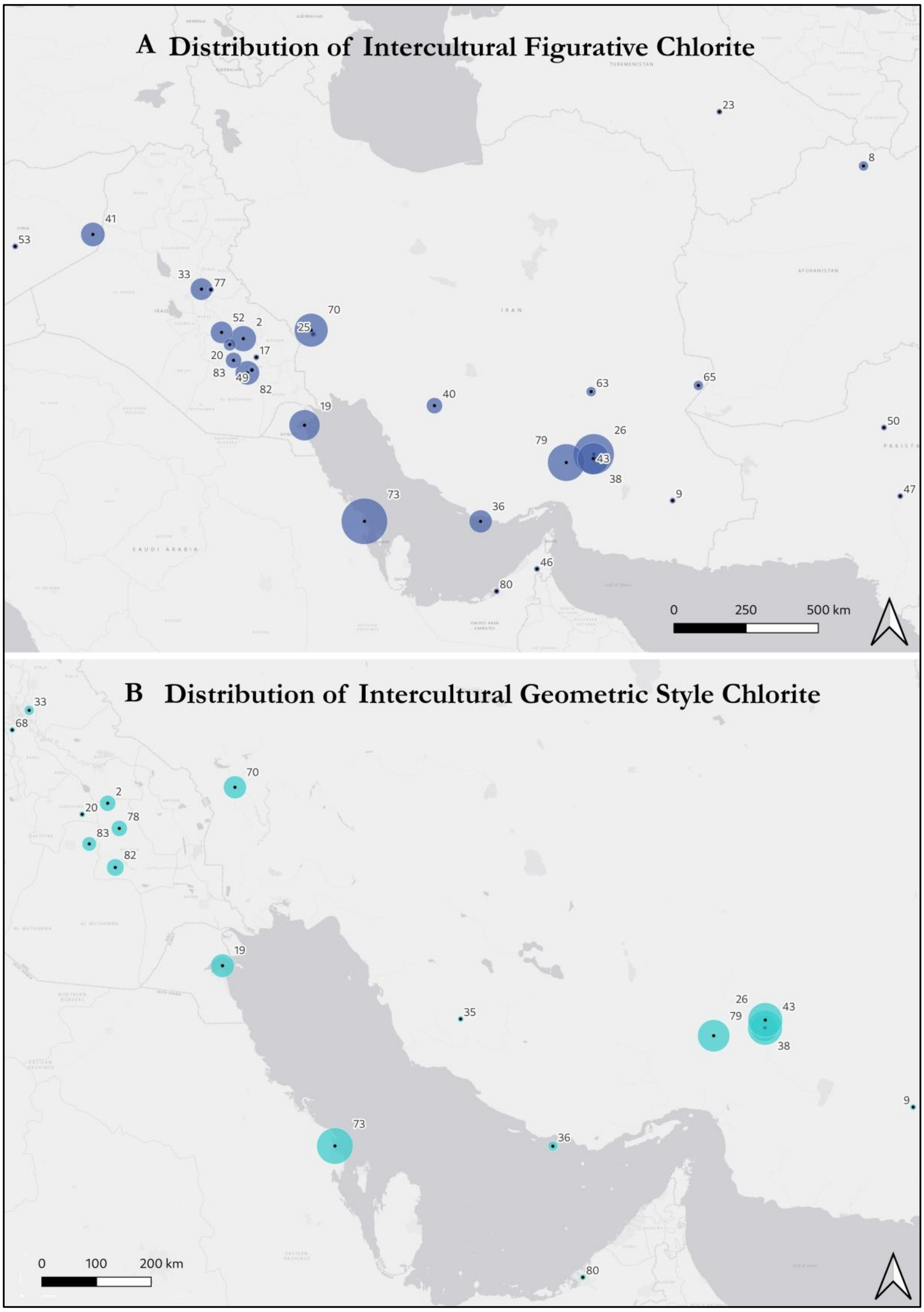


Figure 2. Distribution of chlorite artifacts of figurative (A) and geometric (B) styles, scaled logarithmically with the number of artifacts.

3. Modelling of the Trade

3.1. Tepe Yahya and the Kerman region

Tepe Yahya is a small mound (*tepe*), in Shogun Valley, Kerman, Iran. It is the site that provides the most information about Intercultural style vessels, and by far the most studied (Kohl, 1974; Kohl, 1976; Kohl et al., 1979; Lamberg-Karlovsky, 1988; Potts et al., 2001). The *tepe* is 20m high and occupies an area of 4 hectares. It was inhabited discontinuously from the Neolithic to the early Sassanian period. The chronology is defined through ceramic relative chronology and two radiocarbon dates: 3240 ± 120 BP and 3560 ± 110 BP. First discovered in 1967, the site was then excavated between 1968 and 1975 by Harvard archaeologists directed by C.C. Lamberg-Karlowsky. As a matter of fact, there is evidence of chlorite production from the early stages of occupation, but the production greatly increases during period IVB1 (2200-2000 BCE) (Pittman, 2018; Hilton, 2016). First Intercultural vessels appear in period IVB6, but 69.9 % of all Intercultural vessels found in Tepe Yahya are from levels IVB4-1, with 52 % from period IVB1 alone (Kohl, 1974). This increase in production is accompanied by the introduction of the Intercultural style (Shafee et al., 2023). The ceramics corresponding to period IVB are similar in style to those produced previously; we can therefore conclude that the stylistic change is not related to a new population occupying the site.

Many chlorite artefacts found for period IVB1 are unfinished. The fragments of decorated artefacts, however, present all the main themes of Intercultural style, and are executed with the same level of craftsmanship as those found in Susa and Mesopotamia. Philip L. Kohl concludes that Intensive production ceases after period IVB1 does not originate from Tepe Yahya, but that, due to the proximity of chlorite outcrops, it became a major production and exportation site in response to external demands (Kohl, 1974). He developed the previously mentioned World-System theory to explain the diffusion of chlorite vessels. In this theory, inspired by Immanuel Wallerstein, an imbalance between interregional exchanges would lead to the development of a core area (Mesopotamia) and a periphery area (Kerman region) (Lamberg-Karlovsky, 1988). Long-distance exchanges between Tepe Yahya and Mesopotamia are indeed attested by the presence of seals and seal impressions closely related to those found in Susa, Ur, and Fara (Potts, 2013). However, to understand if the primary focus of chlorite production is exportation to Mesopotamia, local, regional, and interregional trade has to be compared. Kohl argued that production greatly exceeded local needs, although this affirmation is hard to assess. On the local level, the tombs associated with Tepe Yahya, if they exist, have not been found, so we cannot compare usage to production. Local, Regional, and Inter-regional scales are always hard to assess; here, it will be considered by local, the immediate vicinity of the site, where people working on chlorite in Tepe Yahya could live and access chlorite outcrops. The term local is defined as everything in a 20km radius around the site, corresponding to the distance to Ashin, the probable source of the chlorite of Tepe Yahya (Fig. 3).

All studies of Intercultural vessels link them to funerary practices, and of the 580 Intercultural style artefacts with known archaeological context, 65.3% were found funerary context, and 82.98% if we exclude the artefacts found in a production context in Tepe Yahya (Lamberg-Karlovsky, 1988). First Intercultural vessels appear in period IVB6, but 69.9 % of all Intercultural vessels found in Tepe Yahya are from levels IVB4-1, with 52 % from period IVB1 alone. On the regional scale, the closest excavated site to Tepe Yahya at the time of Kohl's thesis was the cemeteries of Shahdad, 250 kilometres to the north-east. The cemeteries are contemporary from level IVB1, but the Intercultural Style is virtually absent from the tombs, the main style being the Oxus style, characteristic of the Bactria-Margiana Archaeological Complex (Hakemi, 1997). It would therefore seem that Intercultural vessels see no usage on a regional scale. Yet, it has since been demonstrated that the archaeological map of the Kerman region is largely incomplete. The number of Intercultural style vessels coming from the Kerman region is overwhelmingly underestimated. Indeed, many vessels found in private collections and acquired in dubious circumstances are supposed to have a Kerman origin (Hakemi, 1997). In addition, after a flood in the Halil Rud river basin, several hundred tombs were unearthed and then pillaged by the local population between 2001 and 2002. Some artefacts were seized by Iranian authorities and published under the 'Jiroft Corpus'. This corpus of 144 pieces of carved chlorite has been published and studied by Professor Madjidzadeh (Madjidzadeh, 2003), alongside several exclusive articles in Dossier d'Archéologie (Dossiers d'Archéologie, 2003). The corpus presents classical aspects of the intercultural style, as well as some unique features, such as pedestal goblets and the meadow motif. This motif consists of scenery combining palm trees and goats. Other motifs, such as human figures and scorpions, are relatively more present in the corpus. This discovery led to the definition of "Jiroft Culture", which was supposed to be the origin of the production of Intercultural style (Madjidzadeh, 2003). However, the absence of archaeological context, incoherences in the chronological and stylistic interpretation (Amiet, 2002), and the lack of documentation on the pillaging and the seizure of the artefacts lead to doubts on the authenticity of some pieces (Muscarella, 2001). The discovery of the Jiroft corpus nonetheless provoked the development of archaeological programs in the Halil Rud river basin. Excavations at Konar Sandal mounds (Pittman, 2008) and Mahtoutabad (Vidale & Desset, 2013; Vidale et al., 2021) cemetery led to the discovery of chloritite artefacts, but not as impressive as the ones found in the pillaged corpus. Overall, if the chronology is still unclear, Intercultural style vessels in the Kerman region fairly outnumber those found in Mesopotamia, invalidating Kohl's diffusion model.

3.2. Umm an-Nar style chlorite artefacts

The style classified by Miroschedi (1973) as serie récente is now named after the Umm an-Nar culture, a Bronze Age culture that existed from 2700 to 2000 BCE (Mery, 2000). However, the style only seems to appear around 2300 BCE according to the stratigraphy of Ra's al-Junayz (David-Cuny, 1996; Rodríguez & Zoilo, 2002). Interestingly, the eponymous site of Umm an-Nar does not present a single Umm an-Nar style chlorite artefact (Fig. 3). The style is characterized by a single motif: a double dotted circle. The motif is repeated in rows over the surface of vessels. The shapes are open bowls, tall vessels, and rectangular boxes. As we can see on the previous figure, most vessels are found in Oman and United-Arab-Emirates. The style is also quite present in Bahrain, the island of Failaka (19), and the cities of Susa (70), Tello (78), and Ur (82). A few artefacts can also be found further away, indicating long-distance interactions across Iran, such as the typical rectangular box found in Gonur Depe (23) (Potts, 2008).

3.3. Wadi-Suq style chlorite artefacts

The Wadi Suq culture replaced the Umm an-Nar culture at the end of the third millennium BCE in Oman and the United Arab Emirates. This sudden cultural evolution is attributed to a shift in climate that began around 2200 BCE, resulting in the aridification of soils and the collapse of the Umm an-Nar culture (Gregoricka, 2016; Shaikh Baikloo, 2021). The transition to the Wadi Suq culture impacts the style of chlorite vessels produced (Fig. 3). The double-dotted circle typical of the Umm an-Nar style remains but is used differently, covering the vessel and associated with straight lines forming geometric designs (Velde, 2003). The shapes are the same as Umm an-Ar style 1, but with more variability or a lack of standardization. Overall, the vessels are very coarse, presenting uneased tool marks and careless engravings (David-Cuny, 1996; Rodríguez & Zoilo, 2002). Similar to Umm an-Nar style vessels, the majority are in Oman and the UAE. However, if there is some presence on coastal sites in Bahrain and on the island of Failaka (19), long-distance trade is nonexistent. The style does not penetrate the Iranian highlands. It would be interesting to consider if this is linked to a potential disappearance of trade routes. The exact chronology is uncertain, but it seems that the Umm an-Nar / Wadi Suq transition is contemporary to the stop of the intensive production in Tepe Yahya.

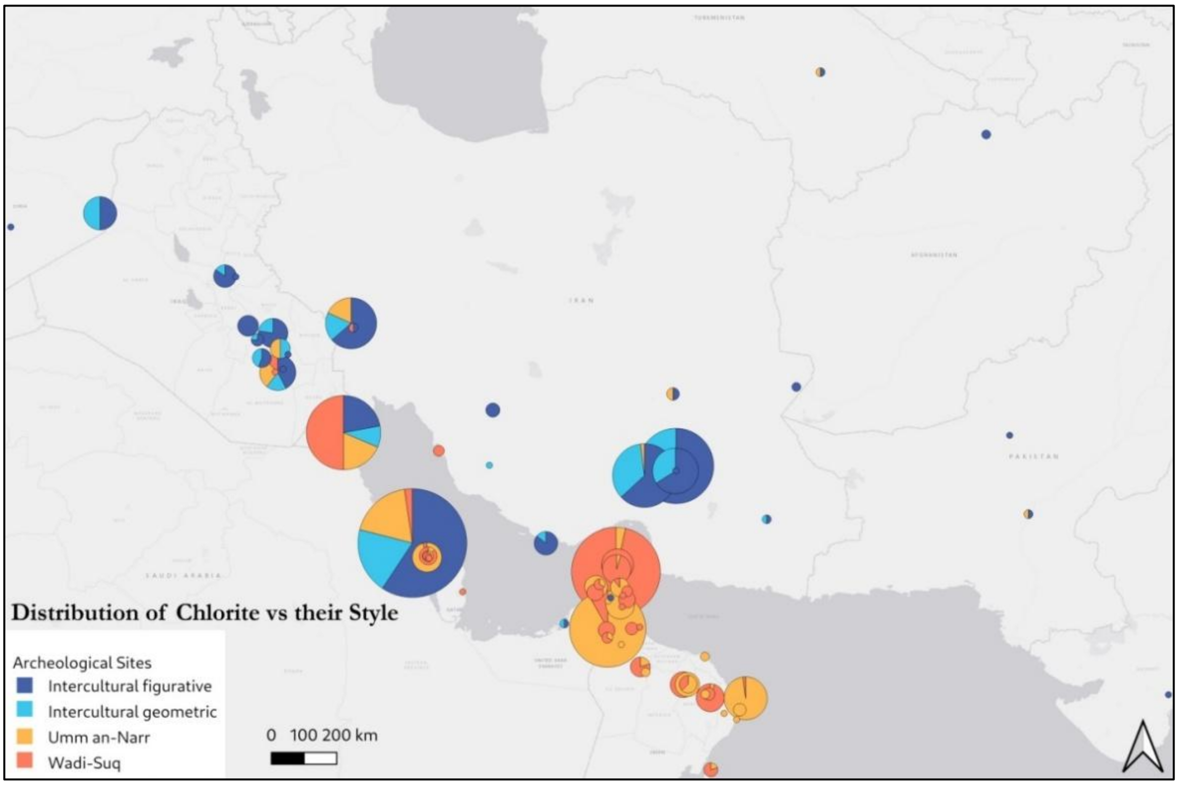


Figure 3. Distribution of Chlorite versus their stylistic features in Tepe Yahya, Wadi Suq, Umm an-Nar style, scaled linearly to the number of artifacts.

3.4. The georchaeological context of chlorite in the Persian Gulf and Iranian Plateau

Chlorite can be found directly in large surface veins, which can be several dozen meters long, embedded in between other igneous rocks. Such veins are attested in the Oman ophiolite and in regional metamorphic areas in Iran (Ilkhchi, 2010). They can also be found in other ophiolites, such as in the Apennine-Alpine ophiolite (Santi et al., 2009). Chlorites are metamorphic rocks altered from mafic and ultramafic rocks through a metasomatic process (Magee et al., 2005; Yoshitake et al., 2009). Metasomatism is a process in which “the chemical composition of a rock or rock portion is altered in a pervasive manner and which involves the introduction and/or removal of chemical components as a result of the interaction of the rock with aqueous fluids” (Harlov & Austrheim, 2012). During this process, there is a recrystallization of the original minerals to form phyllosilicate minerals such as talc, serpentine, chlorite, uscovite, etc. Petrographic studies of chlorites have shown that they are composed predominantly of chlorite and of talc, muscovite, serpentine i various proportions, as well as minerals of the clay group. I has four end-members, coaining either magnesium, iron, nickel or manganese: clinochlores $(Mg_5Al)(AlSi_3)O_{10}(OH)_8$, chamosites$(Fe_5Al)(AlSi_3)O_{10}(OH)_8$, nimites $(Ni_5Al)(AlSi_3)O_{10}(OH)_8$ and pennantites $(Mn_5Al)(AlSi_3)O_{10}(OH)_8$ (Bailey, 1988). Structurally, it is composed of 2:1 layer (tetrahedral-octahedral-tetrahedral) of composition with octahedral interlayers of composition (Wiewióra & Weiss, 1990). Because of these interlayers, chlorites do not have the plasticity of clay minerals such as Illites or Smectites. The composition of chlorites is mostly related to the original igneous mineral; for example, iron-rich chlorite is found in replacement of iron-rich minerals (Deer et al., 2013). Therefore, the extent of the metasomatic process that is one of the causes of variability observed in the chlorites may have a limited impact on the Fe, Ni, Al, Mg, and Mn concentrations. This could be the key to provenance studies of chlorite artefacts. For now, only two regions have been documented as a probable source of chlorite artefacts, the Al Hajar Mountains in Oman and the Jiroft region in Iran. If we superpose those two regions with the distribution maps presented previously, it is not unreasonable to conclude that the Jiroft region is a source of the chlorite for Intercultural style artifacts, while the Al Hajar mountains are the source of the chlorite for Wadi Suq and Umm an-Nar style.

3.5. Al Hajar Mountain range

The Al Hajar mountain range is located along the northern coast of Oman, corresponding to the corner of the Arabian Plate (Fig. 4). The mountain range formed during the Maastrichtian (early Cretaceous, 72.1-66 Ma). The oceanic sediments, crust, and mantle from the Tethys Ocean were abducted onto the Arabian plate, forming the Semail ophiolite nappe (Stanger, 1985). This nappe consists of ultrabasic peridotite (harzburgite, lherzolite, dunite) from the upper mantle and gabbro, diorite, dolerite, and lavas from the crust David-Cuny, 2001). The Hawasina Nappes are part of the oceanic sediments of the Arabian plate, which were abducted with the Semail Nappe. Fractures due to tectonic activity led to hydrothermal fluids circulating in the nappe, provoking the metasomatism of the rocks. Outcrops of chlorite have been documented in all the ophiolite (David-Cuny, 2001). Figure 4 shows the geological setting in which the chlorite context of the Al Hajar Mountain range has been outcropped, and distinguishes the two nappes; Waby al-Zady, the only documented excavation site in the region, is located on a mountainous slope of tectonized harzburgite in which a large chlorite vein of 60 m long for several dozens of centimeters wide can be found (Sivitskis et al., 2018).

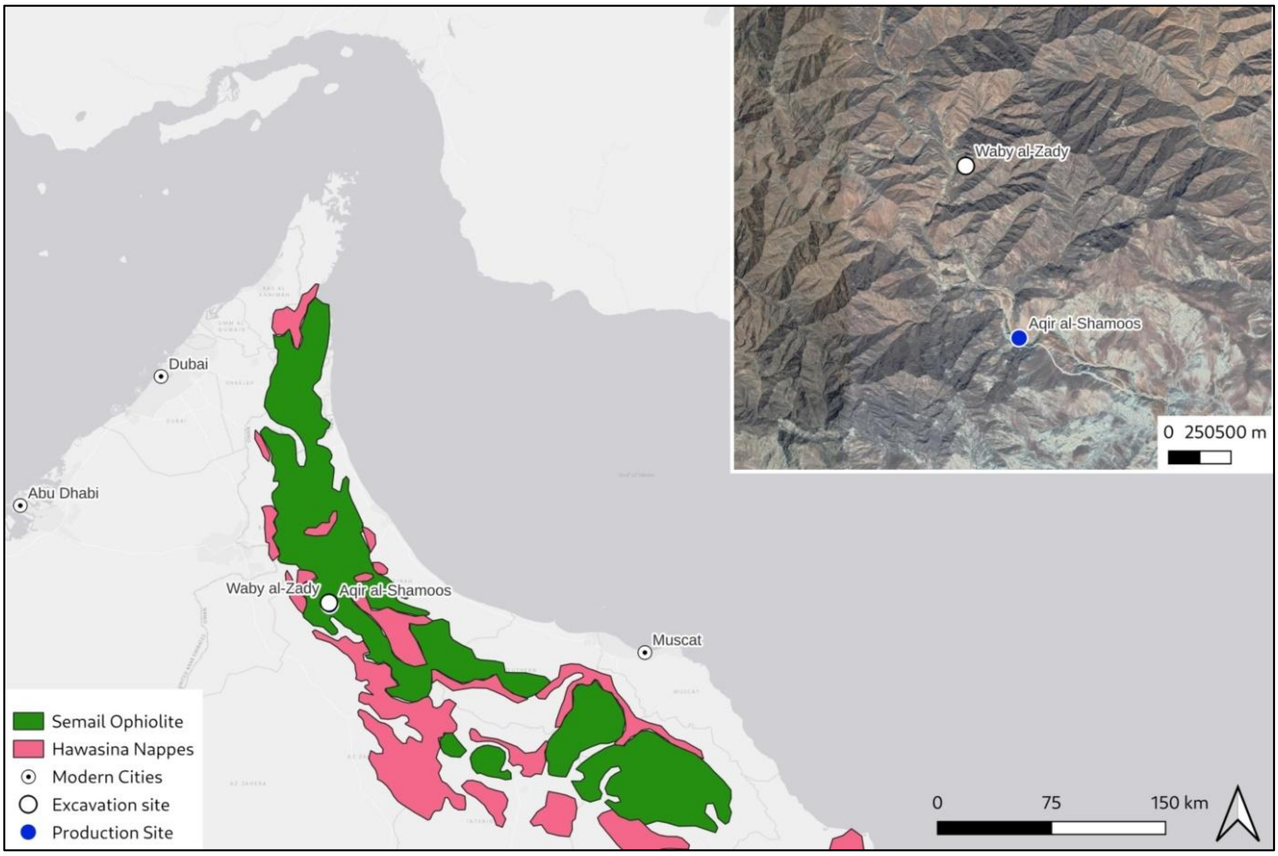


Figure 4. Geological context of the Al Hajar Mountain range.

3.6. Tepe Yahya and the Jiroft region

The Jiroft region is located along the alluvial plain formed by the Hali Rud River. The alluvial plain is bordered on the North and West by the Zagros orogeny range, in which the Hali Rud takes its source. This mountain range stretches over 1800 kilometers from Turkey to the southwest of the Iranian plateau (Fig. 5). The geological formation west of the valley is the Sanandaj-Sirjan zone, a metamorphic area characterized by a blueschist belt mixed with ultramafic rocks and schists (Ilkhchi, 2010). The Sanandaj-Sirjan zone, formed by the collision between the Iranian Plate and the Eurasian Plate, is anterior to the Zagros fold and thrust belt, which dates from the Miocene (collision of the Arabian and Eurasian plates). Tepe Yahya and the probable chlorite mines are located in the Shoghun valley, west of the Hali Rud alluvial plain (Fig. 5). Those mines are, in fact, large veins of chlorite embedded in serpentinized shists. The larger veins, as well as smaller deposits, often present pick and saw marks (Kohl et al., 1979). QXRD was used to cluster artefacts with a similar geochemical signature (Emami et al., 2017). Dendrograms were obtained from the diffractograms using the Rietveld refinement method, which enables the identification of samples that are geochemically the closest to each other. However, the cluster only determines chemical similarities and does not correspond to a specific source. Additionally, the entire diffractogram is utilised; there is no selection criterion for aspects of the composition that would be less influenced by the metasomatic process. Indeed, the results are not very conclusive.

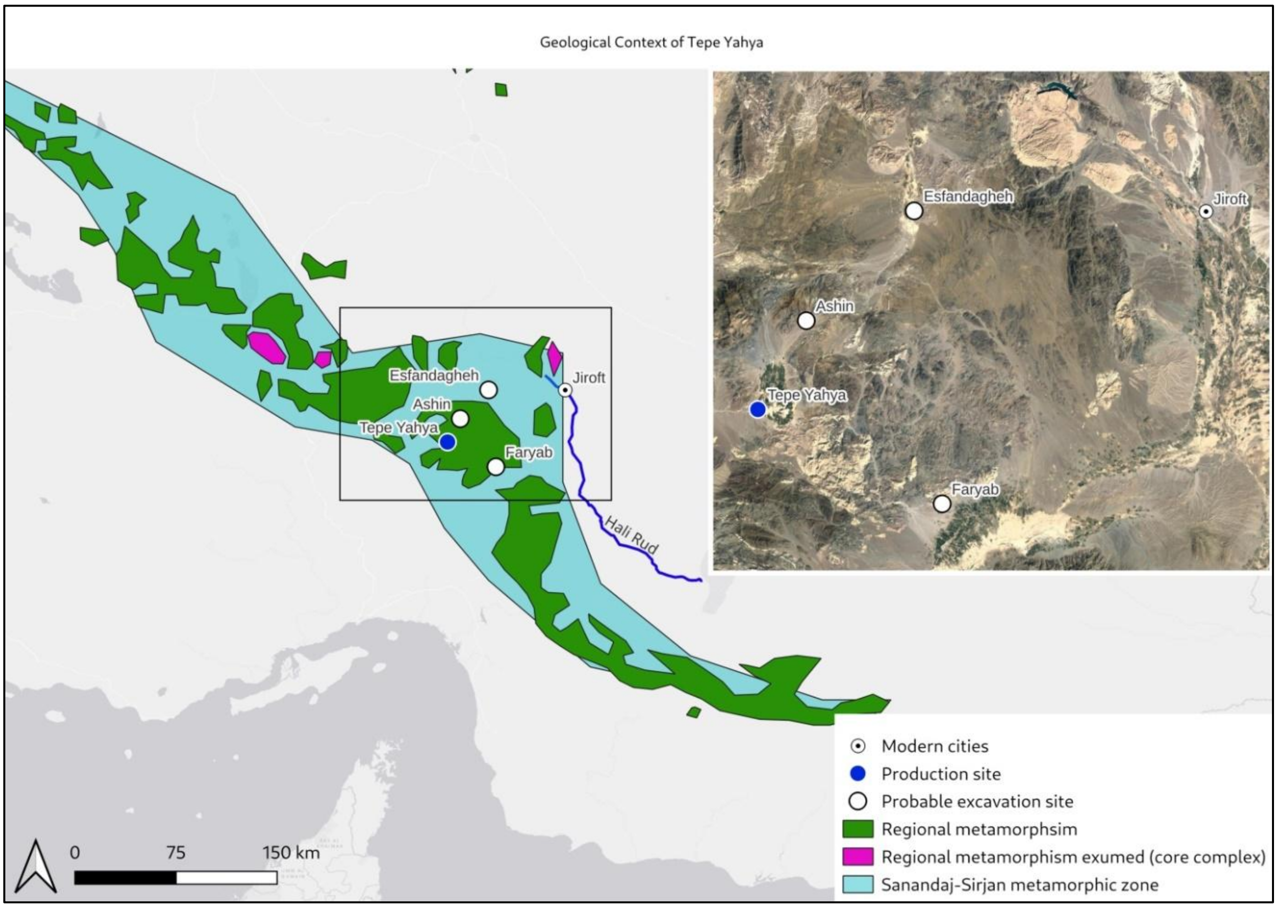


Figure 5. Geological context of Tepe Yahya and the Jiroft Region.

4. Discussion

The geological context of the formation of chlorite vessels leads to a limited number of sources on the interregional scale. We can consider that the al-Hajjar mountain is the main source for Wadi Suq and Umm an-Nar style chlorite artefacts, and the Zagros Mountains for Intercultural style artefacts. However, analytical strategies have to be developed in order to understand on a regional level, the mechanisms of chlorite production and trade, and to identify epiphenomena. Analytical strategies based on elemental composition or crystallographic phases are common in other materials such as obsidian or ceramic. For chlorite or other similar soft stones, the provenance postulate still has to be validated to develop analytical strategies. Indeed, the provenance postulate, "namely, that there exist differences in chemical composition between natural sources that exceed in some recognizable way, the differences observed within a given source" (Weigand et al., 1977), is the condition sine qua non to any sourcing study. Only one study attempted to test the provenance postulate on chlorite artefacts. Peter Magee from Bryn Mawr College in Australia led a pilot program on the provenance of Iron Age chlorite vessels (Magee et al., 2005). Knowing that the heterogeneity of chlorite is mainly due to the process of metasomatism, they supposed that Rare Earth Elements (REE), as well as transition metals, are less affected by the metamorphic process, and could successfully discriminate sources. Indeed, REE and transition metal abundance have proven to be a reliable discriminatory factor on steatite sources from Scotland and the United States. The pilot program, therefore, measured those elements with ICP-MS/OES on samples from two archaeological sites (Muweilah and Jebel Buhais) from the Emirate of Sharjah, United Arab Emirates. Muweilah and Jebel Buhais are late Wadi Suq sites from the first millennium B.C. They are outside the chronological scope and are therefore not represented on the maps. Five samples from each site were analyzed, some of which were doubled to check for intra-sample variability. On all results, intra-sample measurements cluster together, indicating that their variability is negligible compared to inter-sample variability. Fe_2O_3/MgO concentrations and MgO/Al_2O_3 normalized by SiO_2 concentrations, represented in bivariate plots, successfully discriminate samples from Muweilah and Jebel Buhais, except for two samples from Muweilah, which present higher Fe and lower Mg concentrations. These outliers can be explained by the fact that Muweilah is further away from production areas and is supposed to be a trade site, chlorite (Emami et al., 2017). The same clustering is observed for REE, with Chromium / Scandium / Vanadium ternary diagrams. These results are promising for future provenance studies, but should be coupled with geological samples and archaeological reasoning on the meaning of the sources. For example, in Susa, Intercultural style vessels contained magnesian chlorites, while Umm an-Nar style vessels contained ferriferous chlorites. This shows that different sources are used for different styles, but it does not help to identify those sources.

The new excavations in prehistoric sites of Jiroft, located in the middle of the cultural zone between Oman and the Zagros Mountains, have provided a well-archaeological contextualization for research and investigation after three decades of activities in the South Eastern cultures of Iran. Indeed, one of the essential objects for representing the cultures in motion was the carved soft stones, chlorites. Due to the symbolic decorative pattern, many specialists are enthusiastic about researching its development. The main central peripheries for the usage of chlorite were Konar Sandal, Esfandaghe, Mahtoutabad Cemetery, and Tappe Yahya (Emami et al., 2017; Eskandari & Vidale, 2023). Despite indeterminate resources of chlorite, the strategic location of Jiroft between Susa and Hindu Valley suggests that the provenance of chlorite had to be scattered along the metamorphism zone from the northwestern part of Jiroft into the southeast in a wide geological outcrop located in Goodmorti, Ashin, and Faryab (Emami, 2023). Chlorites have locally been affected by metasomatic processes, which were focused on geochemical indicators through MnO, Fe_2O_3, and Al_2O_3 concentrations (Magee et al., 2005; Yoshitake et al., 2009).

5. Conclusion

On the basis of stylistic examination of chlorite vessels, we can establish global trade areas and identify site clusters. Traces of production or rework of the vessels can also give us some insight into the patterns of trade. However, the archaeological map is quite incomplete, and the lack of a definitive chronology prevents us from understanding precisely the modalities of the stylistic diffusion. We have seen that the interpretation of the vessels' origin has shifted several times in the light of newer discoveries. In the case of Intercultural style artefacts, different diffusion models still compete. Until newer sites with a better chronology are documented, existing archaeological data is insufficient to establish precisely the origin and the trade of chlorite vessels from stylistic information alone. However, physico-chemical characterization of existing artefacts combined with source mapping could give new information on the provenance of chlorite artefacts and trade around the Persian Gulf during the III and II millennium BCE. We have seen that chlorites are formed by hydrothermal alterations and regional metamorphism, which leads to a great variability in color, texture and crystallography. But because the ratio between chlorite end-members seems to be closely related to the composition of the original igneous rock, comparing the composition in transition metals of chlorite artifacts could permit provenance studies. Compositional analyses targeting rare earth elements (REE) or transition metals (primarily Fe, Mg, Mn, Al, and Ni), performed using techniques such as LA-ICP-MS, LIBS, or X-ray fluorescence, represent promising candidate methods for provenance studies.

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Author Contributions

The first author was responsible for conceptualization, methodology, and writing the original draft. The second author contributed to data curation, validation, and writing—review and editing. The third author was responsible for critical revision of the manuscript and final approval of the version to be published.

Conflict of Interest

The authors report no conflicts of interest.

Data Availability

Raw data are available from the authors upon request.

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