Archaeological Discovery, 2025, 13(1), 26-47
https://www.scirp.org/journal/ad
ISSN Online: 2331-1967
ISSN Print: 2331-1959

Exploring Early Distillation Hypotheses: Investigating Unique Pottery from Tepe Sagzabad on the Central Iranian Plateau (Iron Age)

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How to cite this paper: Ghaleh, M. B., Eftekhari, N., Pahlavan, M. D., & Vaccaro, C. (2025). Exploring Early Distillation Hypotheses: Investigating Unique Pottery from Tepe Sagzabad on the Central Iranian Plateau (Iron Age). *Archaeological Discovery, 13,* 26-47.
https://doi.org/10.4236/ad.2025.131002

Received: October 4, 2024
Accepted: January 10, 2025
Published: January 13, 2025

Abstract

Tepe Sagzabad (2200 BC to 500 BC), located in the northwestern region of Iran's central plateau, lies along a key east-west trade route on the Iranian Plateau. This site faces numerous challenges, including seasonal floods, and seismic activity. In 2016, the excavation of Trench 6 unearthed a distinctive vessel in Context 6006, characterized by a closed head, knob-shaped top, and side handles. Its unusual form suggests similarities to traditional alembics used in distillation, sparking debate over its function. Chemical analysis revealed secondary crystallizations such as gypsum and calcite, likely a result of environmental weathering, but no dairy lipid residues were found, challenging the theory of their use in milk production. This study compares Tepe Sagzabad vessels with similar artifacts, offering insights into the development of early distillation technology in the region. These findings highlight the complexity of reconstructing ancient technological systems and emphasize the need for further research to understand early distillation practices on the Iranian Plateau. This study serves as a preliminary exploration of distillation-related artefacts in prehistoric Iran, offering a unique case for future comparative analyses.

Keywords

Tepe Sagzabad, Qazvin Plain, Early Distillation, SEM-EDS, Ancient Technology

1. Introduction

Tepe Sagzabad, a significant archaeological site located on the Qazvin Plain, plays a pivotal role in understanding the Central Iranian Plateau's ancient human settlements. Its continuous occupation from the Bronze Age to the Achaemenid period (c. 2200-500 BCE) offers invaluable insights into the region's sociocultural and technological development over millennia (Shahmirzadi, 1979). The site, which spans approximately 13 acres and rises 5 meters above the plain, contains around 9 meters of archaeological deposits, a testament to its long-term significance as a hub of human activity (Talai, 1983). (**Figure 1**)

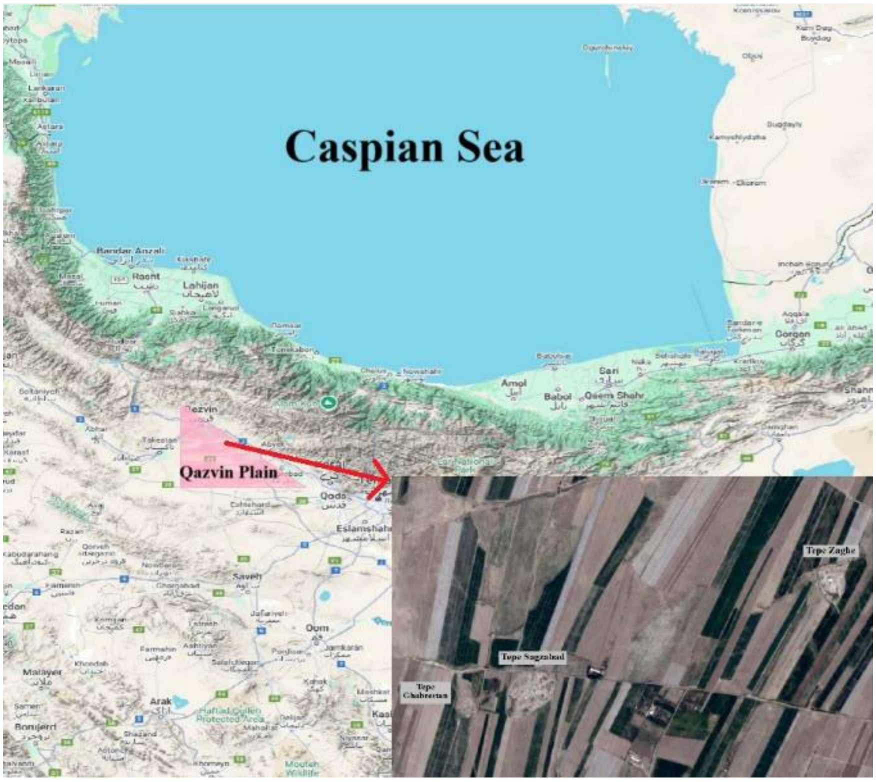

Figure 1. Location of Qazvin Plain and Tepe Sagzabad, Tepe Ghabrestan and Tepe Zaghe (authors).

The site benefited from fertile alluvial deposits and seasonal waters flowing from the surrounding mountains, which provided essential resources for early agricultural communities (Maghsoudi, 2012). Additionally, the Hajji'Arab River, located just south of the site, offered a consistent water supply, further supporting long-term habitation and agricultural development (Schmidt & Fazeli, 2007). Tepe Sagzabad functioned as a critical crossroads for prehistoric and historic interactions between the East and West (Fisher, 1968; Dehpahlavan, 2016). Despite the natural barriers of the Caspian Sea, Alborz Mountains, Dasht-i Kavir desert, and Zagros Mountains surrounding the region, the Qazvin Plain provided a favourable route for the movement of people, goods, and ideas. This strategic position made the plain, and consequently Tepe Sagzabad, an essential site for studying early trade and cultural exchanges across the Iranian Plateau (Alden, 1982). The plain's importance as a crossroads is underscored by the presence of several key archaeological sites, including Tepe Ghabrestan and Tepe Zaghe, located 300 meters west and 2 kilometers east-northeast of Tepe Sagzabad, respectively. These sites, with their distinct phases of habitation dating from the 6th to the 1st millennium BCE, offer valuable comparative data for understanding broader settlement and cultural developments in the region (Mashkour et al., 1999; Maghsoudi, 2012).

Tepe Sagzabad and its neighboring sites also reveal the economic and technological advancements of the region, particularly in the exploitation of metal ores. At Tepe Ghabrestan, evidence of metal ore use during the Chalcolithic period highlights the area's role in early metallurgical practices, reflecting its economic importance in prehistoric times (Mortazavi, 2011).

Despite difficulties arising from natural conditions, research at Tepe Sagzabad continues to offer important insights into the area's historical development. Recent excavations, particularly those concentrating on the Iron Age and Achaemenid periods, are noteworthy because numerous sites across the Qazvin Plain experienced reduced populations or were abandoned during the transition from the late Iron Age to the early historic era, possibly linked to the rise of Median dominance (Tahlan, 2016). In 2015, the University of Tehran conducted an educational excavation at Tepe Sagzabad to further investigate the Iron Age III and Achaemenid layers. A geophysical survey in the northeastern section of the site detected anomalies indicative of human-made structures, prompting the excavation of Trench 6. This trench revealed 25 distinct contexts, including Contexts 6004 and 6006, both associated with kiln structures but differing in dimensions and cultural materials. One of the most significant discoveries from this excavation was a unique pottery vessel found in Context 6006. This vessel, characterized by a closed head, knob-shaped top, and two side handles, bears morphological similarities to alembics used in distillation processes (Dehpahlavan, 2016). (**Figure 2**)

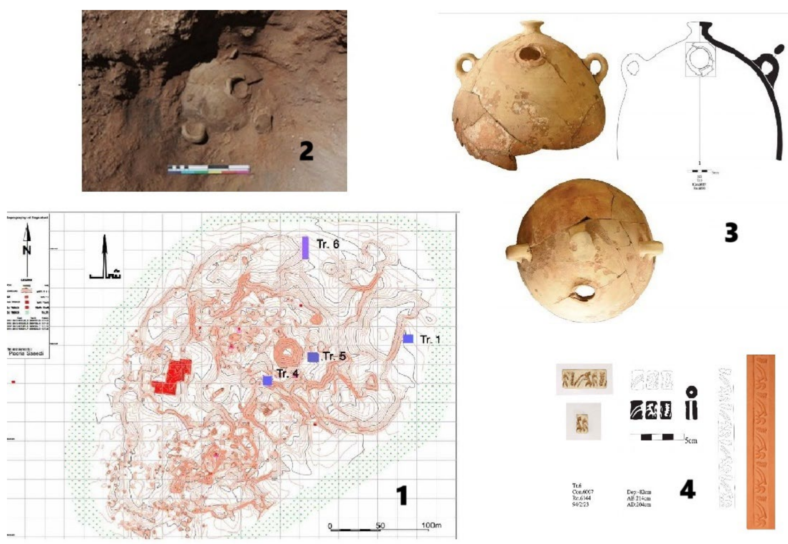

Figure 2. 1: Topographical map of Tepe Sagzabad showing the location of trench 6. 2: Image of vessel context 6006 inside the kiln. 3: Vessel context 6006. 4: Assyrian seal discovered in context 6006 (Dehpahlavan, 2016).

In 2019, a later excavation at Tepe Sagzabad uncovered pottery vessels like those found in Context 6006, and these vessels were situated within burial contexts (Dehpahlavan, 2019). The distinctive shapes of these containers raise intriguing questions about their intended purpose, suggesting the possibility of further experimentation with early technologies or unique cultural practices in the region. Pottery found in a pit or on a living floor does not represent a random or accurate sample of all pottery used at a site, as its composition can differ based on functional variations in different areas (Hodder, 1974). To accurately determine the function of an artifact, it is important to examine its typology and the role it plays in archaeological analysis. Form-based research is crucial in this context, as studying the physical characteristics of the pottery through comparative methods helps to identify its intended use (Trusty & Hruby, 2017).

The functional history of pottery vessels often leaves behind physical and chemical evidence, offering clues about their original use. These uses are typically classified into three main categories: storage, processing, and transfer (Gregg, 2009). To identify the purpose of vessels of Tepe Sagzabad, an analysis of the form is essential. With its closed head and hole in the body, the vessel resembles an alembic used for distillation. However, comparisons with traditional nomadic containers suggest it might have served as a barrel vessel, possibly used for milk storage. Such vessels have been used since the Early Bronze Age in the Aegean and Eastern Mediterranean (Morris, 2013). The detection of dairy lipid residues supports this idea, though further confirmation can be obtained by analysing carbon stable isotope (δ13C) values within the lipid mixture. Although archaeometric analysis could potentially reveal residues within the vessel, the absence of the lower portion of Context 6006 reduces the likelihood of finding such evidence. As a result, this situation necessitates a greater emphasis on the study of the vessel's form and a comparative analysis with similar vessels from other sites.

The primary objective of this study is to analyse the typology, function, and significance of the pottery vessels uncovered at Tepe Sagzabad, focusing on the notable artifact from Context 6006. The research seeks to reconstruct the technological capabilities of ancient Iran, particularly regarding distillation or processing practices. Additionally, it aims to compare the pottery from Sagzabad with similar artifacts found at other sites in Iran and Central Asia, enhancing the understanding of regional technological developments and cultural exchanges. By examining these vessels, the study provides insights into ancient practices and innovations in the region.

2. Typochronolgy Pottery in Tepe Sagzabad

Tepe Zaghe, Tepe Ghabrestan, and Tepe Sagzabad complete a significant archaeological cluster in the Qazvin Plain (Negahban, 1973: p. 32). Ghabrestan, excavated in the 1970s, comprises layers IV-I, revealing three phases of the Chalcolithic period (Majidzadeh, 1977; Nashli et al., 2013). Initially dominated by red pottery, buff ware became common by the middle Chalcolithic. The Early Bronze Age introduced Kura-Araxes Grey Ware, linking Ghabrestan and Sagzabad, with increased interregional influences by the end of this period (Nashli, 2005; Piller, 2003).

Tepe Sagzabad pottery consists of excavated artifacts (Dehpahlavan, 2016, 2019; Nashli et al., 2011) and smuggled items from 1948 onward, documented by various researchers (Akkermans, 1991; Dyson, 1973; Vanmoerkerke, 1991). In general, Tepe Sagzabad reveals 15 distinct cultural layers (Shahmirzadi, 1977). Based on the analysis of the associated pottery, the site's cultural sequence can be divided into four horizons.

Horizon I at Tepe Sagzabad, identified by Shahmirzadi as belonging to the Early Bronze Age, is dated to approximately 2400 BCE. This dating is based on the close similarities between its pottery assemblages and those from Godin III and Hasanlu VI-V (Shahmirzadi, 1977: p. 76). Distinct ceramic forms from this horizon include closed bowls and pedestaled vessels (Hamlin 1974, 133).

Horizon II at Tepe Sagzabad is characterized by a decline in polychrome pottery, an increase in greyware, and connections to regional sites such as Tepe Sialk IV and Khurvin. This horizon reflects a blend of local and regional influences, with parallels to the assemblages from Giyan III, Dinkha Tepe III, and Hasanlu VI-V (Shahmirzadi, 1977; Ghirshman, 1939; Piller, 2003; Vanden Berghe, 1964).

Horizon III at Tepe Sagzabad, dated to after 1500 BCE, is marked by the continued dominance of grey ware, typically featuring minimal decoration such as gloss bands and grooves (Shahmirzadi, 1977: p. 78; Piller, 2003: pp. 158-160; Danti, 2013: pp. 348-355). Similar pottery styles have been found at sites like Gehtariyeh in northwestern Iran.

Horizon IV at Tepe Sagzabad, dating from 850 to 500 BC, featured buff and red pottery with gloss bands and geometric decorations, reflecting Median and Achaemenid styles (Shahmirzadi, 1977: pp. 78-79). Roman Ghirshmann introduced the pottery culture of Sialk VI during the archaeological excavations of Sialk ("la Grande Construction" and the Cemetery B), which was related to the beginning of the first millennium BCE

(Ghirshman 1939: p. 94). Comparisons with Nush-i Jan support this classification (Kohl et al., 1989: p. 64; Stronach et al., 1978: pp. 1-3), while the pottery also indicates dynamic Scythian, Median, and Cimmerian tribal movements (Haywood et al., 2001). (**Table 1** & **Figure 3**)

Table 1. Comparative chronology of pottery horizons at Tepe Sagzabad.

Horizon	Period	Comparison	Reference
I	Early Bronze Age	Godin III, Hasanlu VI-V Tepe Dinkha	(Hamlin, 1974: p. 133) (Shahmirzadi, 1977: p. 76)
II	Middle Bronze Age	Khurvin Tepe Sialk IV	(Ghirshman, 1939: pp. 7-9; Piller, 2003: pp. 158-160)
III	Late Bronze Age- Early Iron Age (1250-800 BC)	Gehtariyeh, Northwestern Iran Tepe Sialk V	(Danti, 2013: pp. 348-349, 354-355) (Piller, 2003: pp. 158-160) (Shahmirzadi, 1977: p. 78)
IV	Late Iron Age (850-500 BC)	Nush-i Jan	(Shahmirzadi, 1977: p. 79) (Haywood et al., 2001) (Kohl, 1989: p. 64; Stronach, 1978: pp. 1-3)

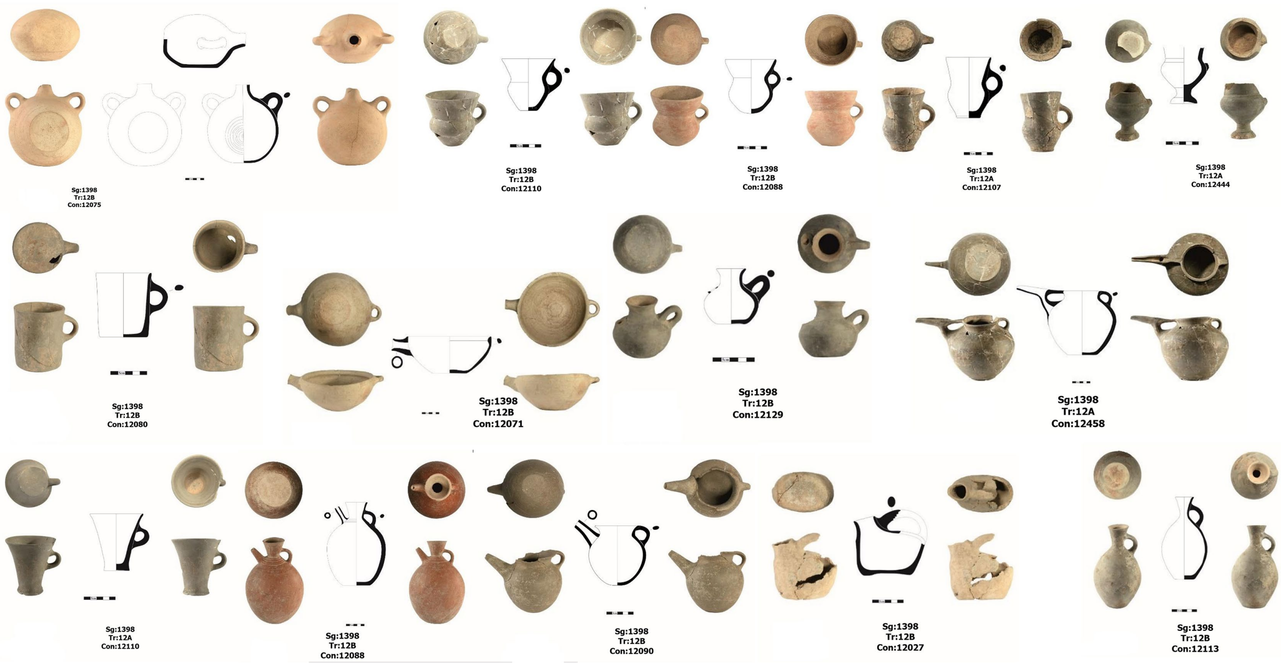

Figure 3. A variety of pottery types related to beverage consumption were found in trenches 12 and 13 (Dehpahlavan, 2019).

The pottery discovered during the excavations in 2016 and 2019 is associated with various sites on the Central Plateau of Iran, including Sialk, Ozbaki, Khurvin, and Qeytarieh, as well as regions in northwestern and western Iran, particularly Hasanlu, Haftavan, Ziwiye, and Nush-i Jan. The cultural materials retrieved indicate that the relative chronology of the layers spans Iron Age II and III (1100-550 BCE). This dating is further supported by two radiocarbon dates that corroborate the chronological framework (Dehpahlavan & Alinezhad, 2024).

3. Archaeological Context (Vessel 6006, 12176, and 12148)

Excavation of Trench 6, measuring 10 by 3 meters in the northeastern sector of the site, revealed two kiln structures of varying dimensions at a depth of 80 cm. Context 6006, identified as the larger structure, primarily consisted of a densely packed mass of heated soil displaying distinct color variations (yellow-reddish 6/6 5YR, white 1/8 5YR.7, brown-reddish light 3/7 5YR.2) and relatively consistent dimensions (thickness: 30 cm; length: 370 cm; width: 390 cm). The lower part of context 6006 exhibited a layer of dark ash containing charcoal fragments and substantial amounts of very soft, blackened wood residues (5.2/1 Gley). (**Figure 4**)

The cultural materials recovered from this context include pottery sherds, mudbrick, faunal remains, clay objects, stone tools, a rare welding furnace, heel stone and samples of seeds such as wheat. With respect to the kiln superstructure, the discovery of mudbricks in the collapsed layer—some of which display fragments of heated mudbrick and traces of tree branches—suggests that these may have been part of either the kiln roof or wall. (**Figure 5**)

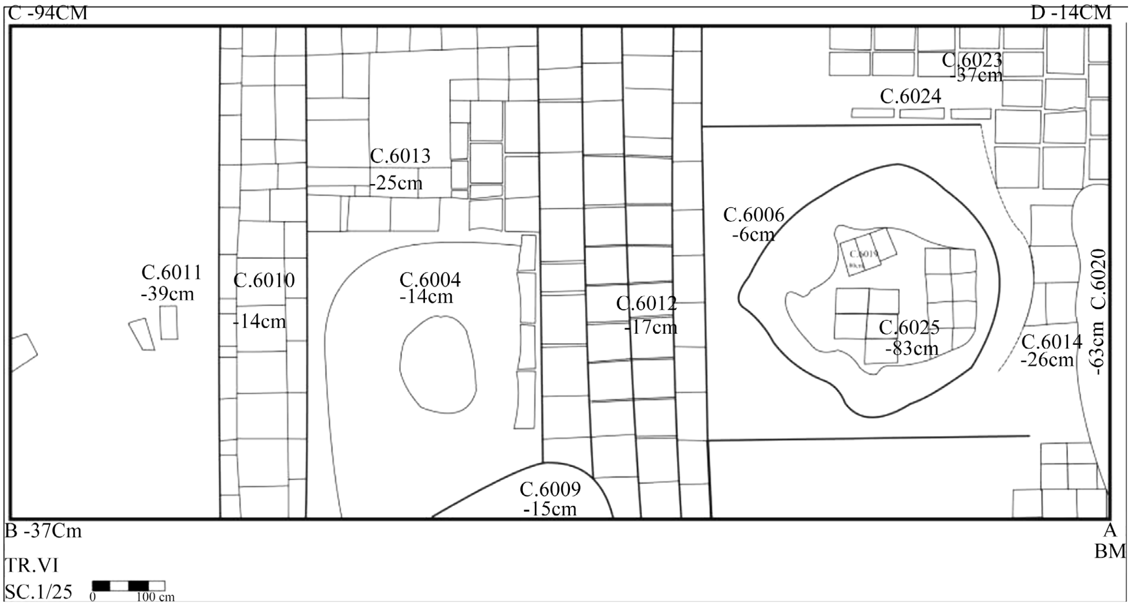

Figure 4. The final plan of trench 6 (Dehpahlavan, 2016).

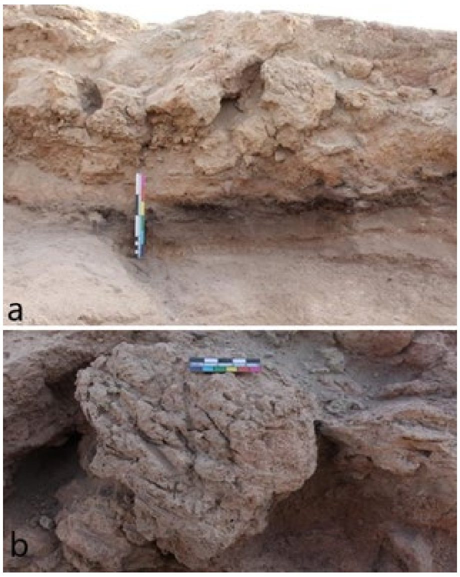

Figure 5. (a) Layers of context 6006 (kiln); (b) fragments of heated mudbrick and traces of tree branches (Dehpahlavan, 2016).

This implies that the firing chamber superstructure could have consisted of a temporary dome or vault built atop the firebox wall (Majidzadeh, 1975). The floor was intentionally covered with mud as a protective layer. An analysis of the micro debris of trench 6 revealed that these kilns contained the highest concentration of micro debris, including heated or burnt mudbricks, and fragments of chalk and lime. The relatively high density of chalk and lime is most likely indicative of their use as floor coatings (Dehpahlavan, 2016). Additionally, the effect of the direct fire flames was evident in this kiln, causing three mudbricks to become heavily smoked.

The lack of sufficient evidence in this context, such as slag, welding residues, storage pottery, or tools and implements, complicates the precise determination of the kiln's function, leaving it open to various potential uses. A total of 46 special finds were recovered from Trench 6, including a gypsum cylindrical seal, featuring a goat and tree motif, measuring 15 mm in length and 10 mm in width. Other notable artifacts include animal-shaped tokens. However, the most significant finding from this trench is an unusual vessel, identified as context 6006. The discovery of this oval-shaped vessel within the kiln (context 6006) is particularly noteworthy because of its distinctive and unconventional form. The vessel surface shows significant discoloration and erosion, likely due to prolonged exposure to environmental factors or burial conditions. Closed Head: Unlike typical open-topped pottery, this vessel features a closed head, which enhances its distinctiveness. The vessel is topped with a knob-shaped cap, adding to its uniqueness and potentially serving a functional purpose.

Handles: Two handles are situated on the sides of the upper part of the body, resembling those found on a pot lid, potentially aiding in handling or transportation. Upon closer examination, the handles appear relatively small compared with the overall dimensions of the container.

Central Hole: Positioned at the center of the upper part of the vessel, a 5 cm hole serves a strategic function as a spout, indicating a specialized purpose. The presence of this central hole suggests that a reed could have been inserted to act as a tube, enabling the pouring or transfer of liquids. Around this hole, there are signs of cracking, indicating that a fragment was previously joined to it under pressure.

Lower Part: Despite damage to the lower section of the vessel, it is estimated that the entire vessel originally measured approximately 75 cm in height with a diameter of 36 cm. It is inferred that the lower part of the vessel had also been closed, ensuring secure containment of liquids. Given its dimensions, the vessel could have accommodated approximately 7 litre of liquid.

In 2019, similar vessels were discovered in burial contexts. (**Figure 6**)

Vessel 12176 (Trench 12C): a relatively intact vessel measuring 11.4 cm in height with a rim diameter of 12 cm and a bottom diameter of 4.5 cm. The thickness of the tube is 2.2 cm. It is equipped with two vertical handles, one measuring 3.3 cm in length, and 0.7 cm in thickness; however, one of them is damaged. Decorative buttons with diameters of 1.4 cm and heights of 0.7 cm are positioned between the handles. The container has a capacity of approximately 1 litre of liquid.

Vessel 12148 (Trench 12B): A fully intact vessel, likely used as a distillation pot, was discovered with dimensions of 35 cm in diameter, 0.5 cm in thickness, and a height of 24 cm. It features a closed head, a knob-shaped top without handles, and a 5 cm diameter hole installed in the upper part, potentially used as a spout. The noticeable cracks around the hole suggest that it may have been associated with tubing connected to another pottery vessel, possibly a receiver container. This vessel has a capacity of approximately 2 liters of liquid. A common feature among the mentioned samples is that they all have a closed head with a central hole in the containers, suggesting that they were used to hold liquids (Table 2).

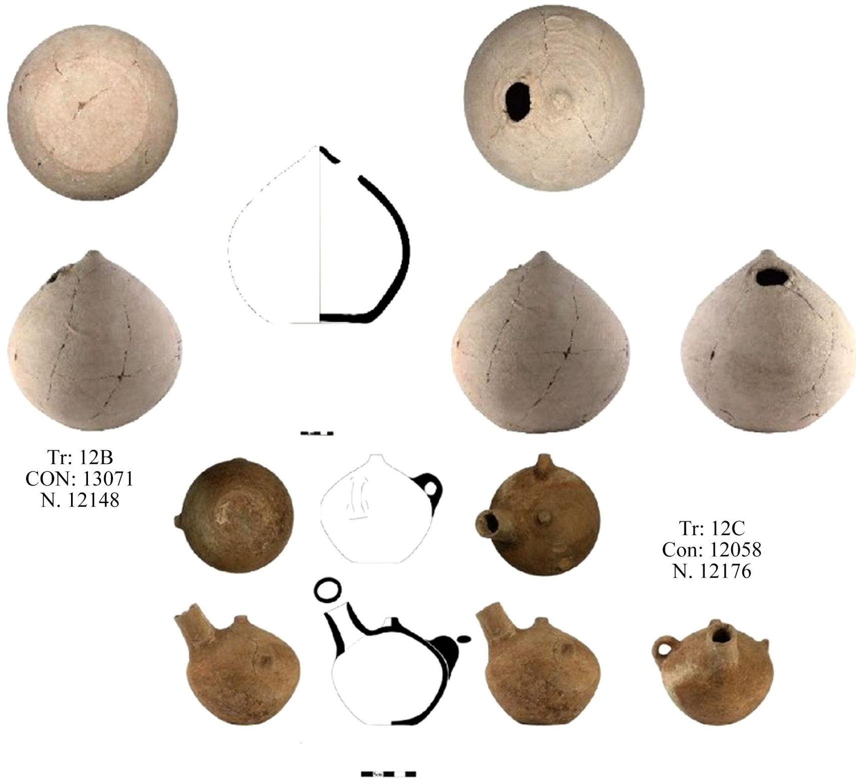

Figure 6. Two vessels that may be associated with distillation, found in burial contexts at Tepe Sagzabad in 2019.The vessel 12176 (Trench 12C). The vessel 12148 (Trench 12B) (Dehpahlavan, 2019).

Table 2. Summary of vessel characteristics.

Vessel	Dimensions	Handles	Hole/ Spout	Special features	Capacity
6006	Height: 75 cm Diameter: 36 cm	Two small handles on upper part	Central hole: 5 cm	Closed head, knob-shaped cap, significant discoloration and cracked around the hole	7 liters
12176	Height: 11.4 cm Rim Diameter: 12 cm Bottom Diameter: 4.5 cm	Two vertical handles (one damaged) in 3.3 cm length and 0.7 thickness	Spout: thickness 2.2 cm	Decorative buttons between handles (1.4 cm diameter, 0.7 cm height)	1 liter
12148	Height: 24 cm, Diameter: 35 cm	None	Central hole: 5 cm	closed head, knob-shaped top, cracks around hole	2 liters

4. Geological Context

The Tepe Sagzabad has been significantly influenced by the braided alluvial fan formed by the Khar Roud River and the Haji Arab River, which flows into the plain, passes through agricultural lands and the surrounding gardens and eventually reaches the salt marsh area. In the Qazvin plain, fluvial and coarse sediments 5.5 meters deep, indicate a high-energy fluvial system, and Quaternary alluvial deposits cover a wide range, spreading over a relatively flat surface with a low-angle slope, with most sediments linked to young alluvial deposits. Thus, fluvial environmental conditions likely forced the inhabitants to leave the area (Tahan & Naghshineh, 2016). The geochemistry of the Quaternary sediments from the Haji Arab River reveals that the major element oxides in these sediments are SiO_2 (57.17%), Al_2O_3 (11.24%), and CaO (9.12%). The results suggest that the sediments were derived from felsic igneous rocks with a low fraction of plagioclase during weathering. The siliciclastic sediments in the study area likely originated from the Eocene volcanic rocks of the Karaj Formation (granite) which are exposed in the northern and southern part of the Qazvin Plain. (Figure 7)

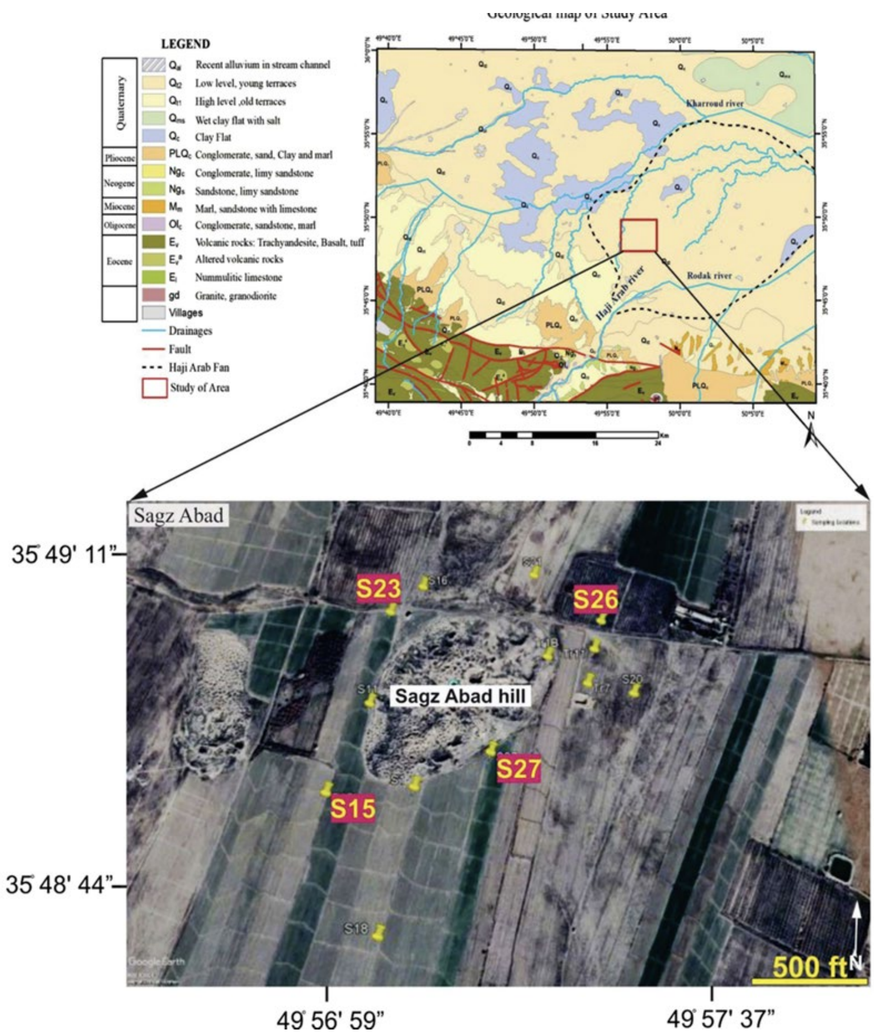

Figure 7. The geological map of Qazvin Province in the mountainous area just south of the Sagzabad site, gypsum-bearing rock formations are present (Khakestari et al., 2022).

Chemical analysis of Bronze Age pottery revealed notable concentrations of these elements, indicating a correlation with the local clay soil in the area (Khakestari et al., 2022). Furthermore, the petrographic analysis of the heated mudbrick from Tepe Sagzabad (context 6006) revealed the presence of carbonate clay, quartz, iron oxide, clasts of igneous rock, and chert. Additionally, fine-grained secondary calcite was observed in the paste of the mudbrick (Dehpahlavan, 2016).

5. Archaeological Evidence of Distillation Vessel

Historically, distillation has encompassed a range of extraction techniques, including methods for purification and separation such as filtration, crystallization, and sublimation. Early alchemical writings connect distillation to the concepts of essences, vapors, and material compositions (Sherwood Taylor, 1952; Holmyard, 1957; Moran, 2006). "A Short History of the Art of Distillation" (1948, expanded in 1970), Forbes provides a comprehensive overview of how distillation practices have evolved across various regions.

The beginnings of the earliest civilizations are often associated with "ancient Mesopotamia" as well as technological innovations in Southwest Asia and the Eastern Mediterranean (Levey, 1959). M. Levey made important contributions to the understanding of distillation in prehistoric Mesopotamia by studying distillation devices found at Tepe Gawra and correlating their functions with Akkadian cuneiform texts (**Figure 8**). His work examined known Sumero-Babylonian techniques and included an ancient Mesopotamian cooking pot with a distinctive double-rimmed design. Comparable vessels were subsequently discovered at Bronze Age sites in Türkiye, Cyprus, Sardinia, and Slovakia, further confirming evidence of distillation practices during the second millennium BCE (Belgiorno, 2020).

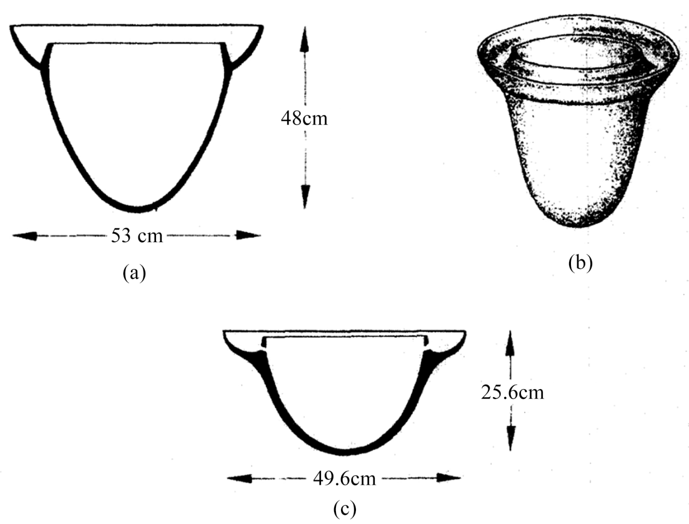

Figure 8. Tepe Gawara, suggested as primary extraction apparatus (Levey, 1959: pp. 33-35).

Several vessels associated with distillation apparatuses have been found in South-Central Asia, particularly at sites such as Taxila, Shaikhān Dherī, and Barikot. The typology of these pottery items suggests a mix of local, imported, and "Greek" vessels, dating from the 4th century BCE to the 4th century CE. Among these discoveries, a notable artifact identified as a receiver, receiver-condenser, or condenser was excavated in the ancient Gandhāra region (Marshall, 1951). While Marshall, after making this bold reconstruction, refrained from speculating on the specific function of the apparatus, others were less cautious. Ray (1956: p. 86) and Mahdihassan (1972: p. 164) quickly noted its clear potential for use in alcohol distillation. (**Figure 9**)

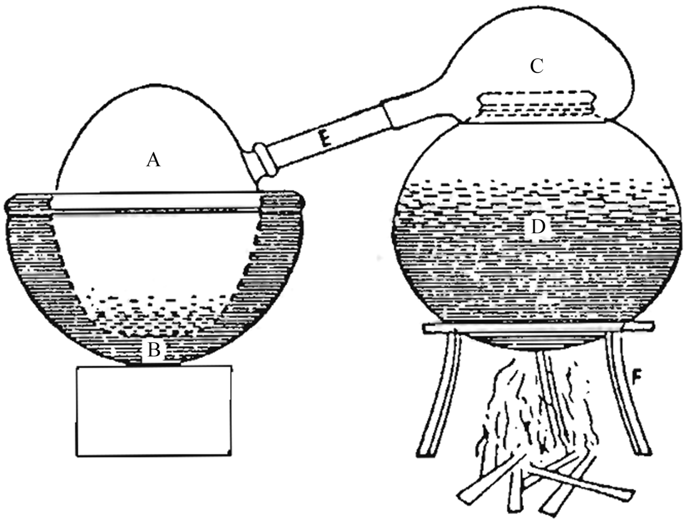

Figure 9. Still reconstructed from finds at Taxila, Punjab (after Marshall, 1951).

The study of distillation apparatus at Shaikhān Dherī has revealed significant findings across multiple excavation periods, categorizing different types of vessels and their respective attributes. The following summarizes the key developments and classifications of distillation apparatus components: Greek or Indo-Greek (big pot for condensing water), Scytho-Parthian (receivers/still head with different morphology and start of stamping tradition), Early Kushan (new rounder globular style of receiver), Middle Kushan (increase in number of squat receivers) and Late Kushan (several stamped receivers produced) (Husain, 1980; Dani, 1966: p. 145).

Early Evidence of Distillation Vessel in Iran

Hermann Schelenz reported that the process of distillation was invented by the Persians, who utilized it to produce rose water, rose oil, and various perfumes (Kockmann, 2014). Some historians, based on substantial textual evidence, argue that the art of distillation was discovered in Hellenistic Alexandria during the early centuries AD and subsequently developed by Arab scholars in the 8th and 9th centuries. These scholars refined the distillation techniques for extracting essential oils for perfumery and for producing alcohol from wine, although they largely refrained from exploiting alcohol distillation for religious reasons (Levey, 1959).

By the 9th century CE, the proto-chemist Muhammad ibn Zakariya al-Razi documented the distillation of alcohol for medicinal purposes, coinciding with the evolution of elaborate stills designed for rosewater and herbal compounds, as well as experiments with solvents for base metals (Forbes, 1970). This method continues to be practiced today, particularly in Iran, where it is officially used to produce Golab (rosewater). In the book "Mafatih al-Uloom," two types of vessels, Jam-ol-Jor and Jam-e-Adl, are described, sharing characteristics with the previously mentioned vessel (Dadkhah & Pourjavady, 2020). The sizes of these containers vary, likely depending on the amount and type of materials to be distilled (Hosseinian et al., 2020).

The only pottery vessel investigated for its potential function as a distillation apparatus is the "Unique Ceremonial Clay Vessel No. 9617" from Kaluraz, dated to the Iron Age. This vessel was analyzed in 1988 at the Iranian National Museum (Mohsenianrad, 2017; **Figure 10**). Although it is hypothesized that this vessel may be related to distillation apparatuses, this assertion has not been studied deeply and remains a preliminary hypothesis. Further research is needed to clarify its origins and functionality.

Figure 10. The "Unique Ceremonial Clay Vessel No. 9617" from Gilan Kaluraz, dating to the Iron Age (550-850 BC), has been proposed as a distillation apparatus (Mohsenianrad, 2017).

This vessel features an inverted funnel connected to its opening inside the pot, allowing for the pouring of liquid when turned upside down by 180 degrees. Once the liquid reaches the spout level, it begins to pour out. However, if the vessel is turned only 90 degrees clockwise while water is poured in, it can hold significantly more liquid, filling almost to the top. If turned another 90 degrees to an inverted position, the vessel remains upside down.

6. Sampling

Four white powder samples (SAG.01, SAG.02, SAG.03, and SAG.04) and a small fragment of pottery (SAG.05) were collected from the inner and lower sections of the pottery to perform a preliminary analysis. SAG.01 was collected from the interior part of the head of the pottery (knob-shaped); SAG.02 was collected from the inner wall of the pottery (left); SAG.03 was collected from the inner wall of the pottery (right); SAG.04 was collected from the outer part of the hole (spouts); and SAG.05 was collected from the lower part of the pottery as sherds. A comprehensive summary of the samples examined in the current study is provided in Table 3 and Figure 11.

Table 3. Summary of the samples examined.

Sample ID	Location collected	Sample type	Micro-Raman	SEM-EDS
SAG.01	The interior part of the head (knob-shaped)	Powdery	x	x
SAG.02	Inner wall	Powdery	x	x
SAG.03	Inner wall	Powdery	x	x
SAG.04	The outer part of the hole (spout)	Powdery	x	x
SAG.05	Lower part of the pottery	Sherds		x

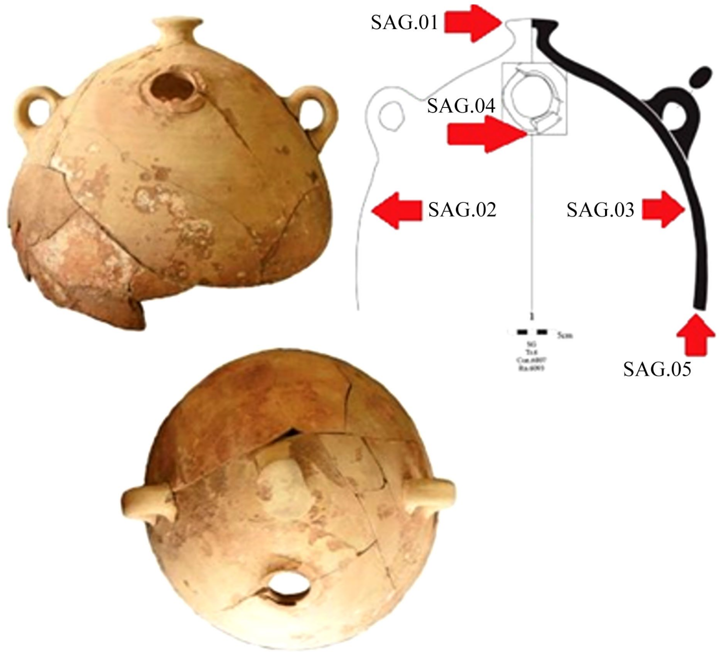

Figure 11. Details of the sampled areas (authors, 2023).

7. Analytical Methods

The samples from Tepe Sagzabad were analyzed for chemical and mineralogical characterization by the Department of Environmental and Prevention Science, University of Ferrara, Italy, employing the following analytical techniques.

SEM-EDS

A ZEISS EVO MA 15 scanning electron microscope (SEM), coupled with an energy dispersive X-ray spectroscopy (EDS) system (Oxford Instruments) equipped with a silicon drift detector (SDD), a LaB6 filament as an electron source, and cobalt as a calibration standard, was employed for microstructural characterization and to determine the chemical compositions of the samples. Aztec 3.3 software was used to collect and process the SEM–EDS data. The white powder samples and a small piece of pottery were studied at 20 kV and an 8.5 mm working distance under variable pressure (VP) conditions. Images were captured using both the backscattered electron detector (BSD) and the secondary electron detector (SED).

To preserve samples for future analyses, they were not coated, and they were observed under variable pressure conditions.

MICRO-RAMAN SPECTROSCOPY

A LabRam HR800 micro-Raman from Horiba Scientific, equipped with an air-cooled CCD detector at −70˚C, an Olympus BXFM microscope (objective 10. and 50.), and a 600 groove/mm grating, was used to collect the Raman scattering signals of mineral phases present on the samples. The excitation source was a He–Ne laser (632.8 nm line) with a maximum laser power of 17 m W and the spectrometer was calibrated with silicon at 520 cm^{-1}. Spectra acquisition and treatment were performed using HORIBA Scientific's Lab Spec 6 Spectroscopy Suite Software. The identification of the mineral phases and peaks attribution is performed by referring to the BIO-RAD spectral database, using Know It All spectroscopy software.

8. Results

The areas were analyzed using EDS microprobe, to determine its semi-quantitative chemical composition, which resulted in a compound enriched in Ca and S, in addition to other elements such as Si and Fe. Gypsum (peaks at 415,494, 1008, and 1135 cm^{-1}) was also detected employing micro-Raman spectroscopy. Consistently, on all the samples and in different areas, SEM-EDS analyses revealed high percentages of Ca and S and the clear morphology of gypsum crystals. In addition, the EDS microprobe in SAG.01 and SAG.02 samples, also provides reasonably strong discrimination between elements. Analysis of this sample is characterized by the presence of Ca, Fe, Na, and Cl (Figure 12 & Table 4).

Table 4. Chemical composition of vessel context 6006.

Element	Symbol	Presence in Samples	Additional Information
Calcium	Ca	High	Enriched in all samples; major component of gypsum
Sulfur	S	High	Significant presence in gypsum
Silicon	Si	Moderate	Detected in various areas
Iron	Fe	Moderate	Present in SAG.01 and SAG.02 samples
Sodium	Na	Low	Identified in SAG.01 and SAG.02 samples
Chlorine	Cl	Low	Identified in SAG.01 and SAG.02 samples

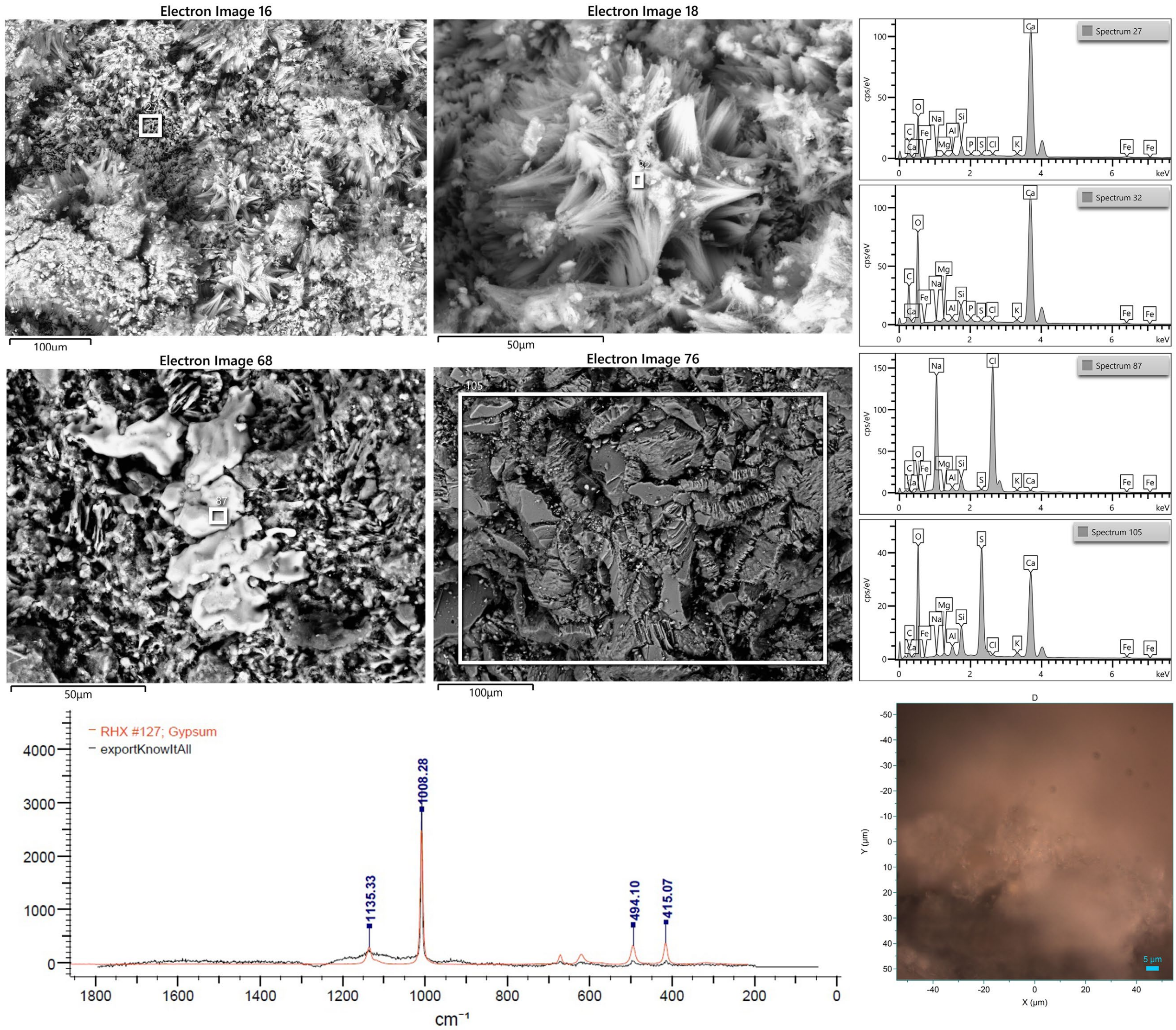

Figure 12. Summary of the SEM micrograph (BSE) of the area and related EDS spectra results obtained on samples. The presence of (a), (b) calcite (c) halite and (d) gypsum, are the most relevant phases detected in the samples. (e) mineralogical phases of gypsum detected by micro-Raman spectroscopy (authors, 2023).

9. Discussion

The presence of gypsum, calcite, and halite represents the most significant phases detected in the samples. Secondary crystallization on the pottery surface, resulting from various weathering processes during archaeological deposition, was identified in all samples. With respect to gypsum and halite, secondary evaporitic minerals are very common in ceramics found in arid and semi-arid environments of Central Asia. These processes involve significant changes in the chemical and mineralogical compositions of surfaces and ceramic bodies (Luneau et al., 2022). The presence of these phases is highly unlikely to be attributable to past uses of the pottery. Instead, the occurrence of gypsum may be linked to precipitation phenomena resulting from the infiltration of sulfate-rich waters. Geologically, in the mountainous area just south of the site, gypsum-bearing rock formations are present. It is conceivable that surface waters, which historically flowed through these rocks, became enriched with sulfates and subsequently reached the alluvial plain where Tepe Sagzabad site is situated (Khakestari et al., 2022). This may have contributed to the enrichment of the soils in the alluvial plain with sulfate phases. The infiltration of surface waters (rivers and rainfall) into the ground could have facilitated the precipitation of the gypsum found inside the vessel. Similarly, regarding calcite, there are also calcareous rock formations in the mountainous area that could have provided carbonate to the flowing waters. Furthermore, studies in literature have shown that the presence of gypsum promotes carbonate precipitation. The petrographic analysis of the heated brick-clay sample from Context 6006 reveals the presence of components such as quartz, iron oxide, pieces of igneous rock, and clay-carbonate soil. The calcite present is in the form of fine grains and is not observed as separate or coarse grains. Chemical analysis of pottery from the Bronze Age and Iron Age at Tepe Segzabad revealed a significant presence of calcium. The quantity of calcium is likely influenced by carbonate compounds in the soil, which are potentially added to the clay used for pottery production (Salehi & colleagues, 2020). These results explain the presence of clay-carbonate and calcite in the findings of this study. On the other hand, as the density of pottery sherds increases, the density of heated soil gradually decreases from the oldest phase to the newest phase. This issue may be related to the use of explored spaces and the change in thermal technology employed in these kilns.

Trusty and Hruby (2017) argue that form-led research is essential for understanding the function of ancient vessels, emphasizing that the physical features of pottery can provide insight into its original use. The examination of the vessels from Tepe Sagzabad uncovers fascinating similarities when compared to the Gandhāra receivers/still. The notable characteristics of the vessels from contexts 6006, 12058, and 12071—including a closed head, two handles, and a central spout-like opening—closely resemble the design of the Gandhāra receiver-condenser, indicating their potential role in distillation. Additionally, the designs of vessels 6006, 12176, and 12148 suggest that they were likely components of a distillation apparatus, with a distilling flask positioned over a fire linked to the receiver via a condenser tube. This arrangement reflects the distillation methods observed in Gandhāra.

The vessels from Tepe Sagzabad differ from Gandhāra receivers in four key ways. First, vessel 6006 has a head button, which is absent in Gandhāra types. Second, the Tepe Sagzabad vessels have handles, a feature missing in Gandhāra receivers. Third, Gandhāra vessels date to the 5th century BCE–4th century CE, while Tepe Sagzabad vessels belong to Iron Age III, representing distinct cultural timelines. Fourth, surface stamps appear on some Gandhāra vessels but are absent on those from Tepe Sagzabad. However, an Assyrian seal in context 6006 hints at possible trade or cultural exchange, with influences from Mesopotamia and the Caucasus evident in luxury items and ceramics (Haywood et al., 2001; Nashli et al., 2013).

It is difficult to determine whether these vessels were used for distilling alcoholic or non-alcoholic beverages, as beer residue, specifically calcium oxalate (beerstone), is harder to identify compared to wine's chemical markers. Thus, fewer beer-related artifacts are found in the archaeological record, with its importance documented mainly in historical texts (Homan, 2004). Archaeological evidence for beer production and consumption is typically scarce, with exceptions like the Tell Hadidi brewery (Gates, 1988). Over the past three decades, scholars have highlighted the significance of alcohol in the development of complex Near Eastern societies, comparable to food (Dietler, 1990, 2006), influencing health, nutrition, rituals, and social identity (Joffe, 1998).

A key challenge in Iranian archaeology has been the over-reliance on typological comparisons between distant regions. Early research often drew parallels between pottery sequences from geographically separated sites, leading to unverified cultural connections. For example, Hasanlu pottery was frequently compared to Sagzabad artifacts, despite notable regional and chronological differences (Mousavi, 2005).

10. Conclusion

Chemical analysis revealed the presence of secondary crystallizations, including gypsum, calcite, and halite, which likely formed due to weathering processes in the arid environment of Central Asia. Although these minerals may not be directly related to the vessel function, they provide insights into the local geological influences. Additionally, the absence of dairy lipid residues suggests that the vessel was not associated with milk production. However, one of the limitations of this study is the missing lower part of the vessel, which reduced the chance of reaching any residual remains.

The unique shape of Tepe Sagzabad vessels, with their oval body, closed-head form, and spout, suggests they were likely used as alembics for distillation. Comparisons with modern distillation tools and Iran's tradition of producing rosewater and essential oils support this theory. Classifying these vessels as distillation apparatuses depends on modern models of distillation techniques (Butler & Needham, 1980).

The early history of distillation in the "Gandhāra tradition" was shaped by preconceived notions and embellished narratives. Initially termed "water condensers," spouted vessels are now recognized as alcohol distillation tools across South-Central Asia, linking Gandhāra to scientific progress. Indo-Scythian still receivers, with varied sizes and stamped surfaces, highlight the complexity of distillation technology's evolution (Groat, 2023).

The typological evolution of pottery from the Bronze Age to the Iron Age reflects technological advancements, marking a clear progression beyond domestic production (Babazadeh et al., 2024). Sociocultural, economic, and political shifts in the 1st millennium BCE are deeply tied to innovation and mobility, influencing metallurgy, ceramics, and glass production (White, 1984). The Tepe Sagzabad vessels, particularly from context 6006, represent a breakthrough in understanding ancient distillation techniques due to their distinct design, possibly linked to traditional alembics. Their unique features, unlike typical pottery, highlight broader technological and cultural developments from the Bronze to the Iron Age. Studying these vessels is essential for exploring early distillation and understanding innovation and cultural exchange in ancient societies.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Akkermans, M. M. G. (1991). *Archeologie van het Nabije Oosten*. De Bataafse Leeuw.

Alden, D. (1982). Trade and Interaction in Ancient Iran: The Role of Tepe Sagzabad. *Journal of Iranian Studies, 15,* 153-168.

Babazadeh, S., Dehpahlavan, M., & Malekzadeh, M. (2024). New Evidence of Increasing Social Complexities in the Qazvin Plain at the Beginning of the First Millennium BC. *Pazhoheshha-ye Bastan Shenasi Iran, 14,* 59-92.

Belgiorno, M. R. (2020). Ancient Distillation and Experimental Archaeology about the Prehistoric Apparatuses of Tepe Gawra. *EXARC Journal, No. 2*.

Butler, A. R., & Needham, J. (1980). An Experimental Comparison of the East Asian, Hellenistic, and Indian (Gandhāran) Stills in Relation to the Distillation of Ethanol and Acetic Acid. *Ambix, 27,* 69-76. https://doi.org/10.1179/amb.1980.27.2.69

Dadkhah, G., & Pourjavady, R. (2020). *Keys to the Sciences: (Maqālīd al-ʿulūm) a Gift for the Muzaffarid Shāh Shujāʾ on the Definitions of Technical Terms* (Vol. 112). Brill.

Dani, A. H. (1965-1966). Shaikhan Dheri Excavations, 1963 and 1964. *Ancient Pakistan, 2,* 1-407.

Danti, M. I. (2013). The Late Bronze and Early Iron Age in Northwestern Iran. In *The Oxford Handbook of Ancient Iran* (pp. 327-376). Oxford University Press.

Dehpahlavan, M. (2016). *Report of the Archaeological Excavations of Tepe Sagzabad*. Unpublished Report, Institute of Archaeology, University of Tehran.

Dehpahlavan, M. (2019). *Report of the Archaeological Excavations of Tepe Sagzabad*. Unpublished Report, Institute of Archaeology, University of Tehran.

Dehpahlavan, M., & Alinezhad, Z. (2024). The Cylinder Seals of Qareh Tepe in Sagzabad, Iron Age II and III. *Iran, 62,* 194-208. https://doi.org/10.1080/05786967.2022.2058409

Dietler, M. (1990). Driven by Drink: The Role of Alcohol in the Socialization of the Iron Age Mediterranean. In M. Dietler, & B. Hayden (Eds.), *Feasting in Prehistoric and Ancient Societies* (pp. 77-103). University of New Mexico Press.

Dietler, M. (2006). Alcohol: Anthropological/Archaeological Perspectives. In *Handbook of World Archaeology* (pp. 43-61). Springer.

Dyson Jr., R. H. (1973). The Archaeological Evidence of the Second Millennium B.C. on the Persian Plateau. In I. E. S. Edwards, C. J. Gadd, N. G. L. Hammond, & E. Sollberger (Eds.), *The Cambridge Ancient History* (3rd ed., pp. 686-715). Cambridge University Press. https://doi.org/10.1017/chol9780521082303.019

Fisher, W. (1968). The Role of Tepe Sagzabad in Early Cultural Exchanges in the Iranian

Plateau. *Bulletin of the American Schools of Oriental Research, 172,* 57-68.

Forbes, R. J. (1970). *A Short History of the Art of Distillation from the Beginnings up to the Death of Cellier Blumenthal*. Brill. https://doi.org/10.1163/9789004674073

Gates, T. (1988). Beer in the Ancient near East: A Study of Tell Hadidi. *Journal of Near Eastern Studies, 47,* 173-182.

Ghirshman, R. (1939). *Fouilles de Sialk, près de Kashan 1933, 1934, 1937 Volume II, Série Archéologique Tome V*. Musée du Louvre—Département des Antiquités Orientales.

Gregg, M. W. (2009). *Organic Residue Analysis and the First Uses of Pottery in the Ancient Middle East*. Doctoral Dissertation, University of Michigan Press. https://doi.org/10.30861/9781407304731

Groat, N. P. (2023). *Extracting Innovation: An Integrated Material and Experimental Analysis of Early Distillation Technology and Its Characterization in South-Central Asia*. Doctoral Dissertation, University of Sheffield.

Hamlin, C. (1974). The Early Second Millennium Ceramic Assemblage of Dinkha Tepe. *Iran, 12,* 125-153. https://doi.org/10.2307/4300507

Haywood, J., Catchpole, B., Hall, S., & Barratt, E. (2001). *Atlas van de Wereldgeschiedenis*. Uniepers Abcoude-Davidsfonds, Leuven, 1.11-1.13.

Hodder, I. (1974). *Reading the Past: Current Approaches to Interpretation in Archaeology*. Cambridge University Press.

Holmyard, E. J. (1957). *Alchemy*. Penguin Books.

Homan, M. (2004). Beer in the Ancient World: The Archaeological Record. *Historical Archaeology, 38,* 107-120.

Hosseinian Yeganeh, N., Shishegar, A., Emami, M., & Nejad Ebrahimi, S. (2020). Study of the Traces of Nature in Herbal Deposits of a Thousand-Year-Old Alembic Glass Analyzed and Processed by the Gas Chromatography-Mass Spectrometer (GC-MS). *Journal of Research on Archaeometry, 6,* 119-135. https://doi.org/10.29252/jra.6.1.119

Husain, J. (1980). *Shaikhan Dheri Pottery: A Methodological and Interpretative Approach*. Doctoral Dissertation, University of Cambridge.

Joffe, A. H. (1998). Disembedded Capitals in Western Asian Perspective. *Comparative Studies in Society and History, 40,* 549-580. https://doi.org/10.1017/s0010417598001406

Khakestari, M., Feiznia, S., Aleali, M., & Dehpahlavan, M. (2022). Geochemistry of Quaternary Sediments of Haji-Arab River Catchment, Qazvin Plain, Northwestern Iran: Provenance and Source Rock Weathering. *International Journal of Environmental Science and Technology, 19,* 2425-2442. https://doi.org/10.1007/s13762-021-03342-x

Kockmann, N. (2014). History of Distillation. In A. Górak, & E. Sorensen (Eds.), *Distillation: Fundamentals and Principles* (pp. 1-43). Elsevier. https://doi.org/10.1016/b978-0-12-386547-2.00001-6

Kohl, P. H., Dandamaev, M. A., & Lukonin, V. G. (1989). *The Culture and Social Institutions of Ancient Iran* (pp. 6-33). Cambridge University Press.

Levey, M. (1959). *Chemistry and Chemical Technology in Ancient Mesopotamia* (p. 36). Elsevier. https://doi.org/10.1111/j.1600-0498.1959.tb00244.x

Luneau, E., Ferreras, V. M., Boroffka, N., & Sverchkov, L. (2022). Archaeometric Investigations of the Molali Pottery Complex (Bronze Age, Uzbekistan): New Data on Technology and Exchanges at the End of the Oxus Civilization. *Archaeological Research in Asia, 31,* Article ID: 100392. https://doi.org/10.1016/j.ara.2022.100392

Maghsoudi, A. (2012). The Environmental Context of Tepe Sagzabad: Fertility and Resources. *Iranian Journal of Archaeological Research, 8,* 37-49.

Mahdihassan, S. (1972). The Earliest Distillation Units of Pottery in Indo-Pakistan. *Pakistan Archaeology, 8,* 159-168.

Majidzadeh, R. (1975). The Kiln Structures of Ancient Iran: Evidence from the Excavation of Tepe Sagzabad. *Iranian Journal of Archaeology, 8,* 45-57.

Majidzadeh, R. (1977). Excavations at Ghabrestan: Preliminary Report. *Iranica Antiqua, 12,* 75-89.

Marshall, J. (1951). *Taxila: An Illustrated Account of Archaeological Excavations Carried out at Taxila under the Orders of the Government of India between the Years 1913 and 1934*.

Mashkour, M., Fontugne, M., & Hatte, C. (1999). Investigations on the Evolution of Subsistence Economy in the Qazvin Plain (Iran) from the Neolithic to the Iron Age. *Antiquity, 73,* 65-76. https://doi.org/10.1017/s0003598x00087846

Mohsenianrad, M. (2017). *Within Three Thousand Distillation Vessels in the National Museum of Iran*. ATU. http://atu.ac.ir

Moran, B. T. (2006). *The Interaction of Ceramic and Metal Artifacts in Ancient near Eastern Society*. The British Institute of Persian Studies.

Morris, I. (2013). Mediterraneanization. *Mediterranean Historical Review, 18,* 30-55. https://doi.org/10.1080/0951896032000230471

Mortazavi, M. (2011). Metallurgical Practices in Prehistoric Iran: A Case Study from Tepe Ghabrestan. *Iranian Journal of Historical Studies, 19,* 11-30.

Mousavi, A. (2005). Comments on the Early Bronze Age in Iran. *Iranica Antiqua, 40,* 87-99. https://doi.org/10.2143/ia.40.0.583201

Nashli, H. F. (2005). Pottery of the Chalcolithic period in the Qazvin Plain. *Journal of Archaeological Research, 12,* 46.

Nashli, H. F., Darabi, H., Naseri, R., & Fallahian, Y. (2011). Relative and Absolute Dating of Tepe Sagzabad, Qazvin Plain. *Journal of Archaeological Research, 3,* 133-158.

Nashli, H. F., Valipour, H. R., & Kharanaghi, M. H. A. (2013). The Late Chalcolithic and Early Bronze Age in the Qazvin and Tehran Plains: A Chronological Perspective. In C. A. Petrie et al. (Eds.), *Ancient Iran and Its Neighbours* (pp. 107-130). Oxbow Books. https://doi.org/10.2307/j.ctvh1dn46.11

Negahban, E. O. (1973). Preliminary Report on the Excavation of Sagzabad 1970 Season. *Marlik: Journal of the Institute and Department of Archaeology, Faculty of Letters and Humanities, 1,* 1-37.

Piller, C. K. (2003-2004). Zur Mittelbronzezeit im nördlichen Zentraliran—Die Zentrairanische Graue Ware (Central Grey Ware) als mögliche Verbindung zwischen Eastern und Western Grey Ware. *Archäologische Mitteilungen aus Iran und Turan—AMIT, 35-36,* 143-173.

Ray, P. (1956). *History of Chemistry in Ancient and Medieval India*. Indian Chemical Society.

Salehi Nezami, R., Fazeli Nashli, H., & Oudbashi, O. (2020). Chemical Study of Bronze Age and Iron Age Potteries of Sagzabad Tepe. *Journal of Archaeological Studies, 12,* 147-164.

Schmidt, A., & Fazeli, H. (2007). Tepe Ghabristan: A Chalcolithic Tell Buried in Alluvium. *Archaeological Prospection, 14,* 38-46. https://doi.org/10.1002/arp.291

Shahmirzadi, S. M. (1977). The Excavation at Sagzabad Mound, Qazvin Plain, Iran, 1970-71. *Marlik: Journal of the Institute and Department of Archaeology, Faculty of Humanities, 2,* 67-80.

Shahmirzadi, S. M. (1979). Copper, Bronze, and Their Implementation by Metalsmiths of

Sagzabad, Qazvin Plain, Iran. *Archäologische Mitteilungen aus Iran Berlin, 12,* 49-66.

Sherwood Taylor, F. (1952). *The Alchemists*. Paladin.

Stronach, D., Roaf, M., Stronach, R., & Bökönyi, S. (1978). Excavations at Tepe Nush-I Jan. *Iran, 16,* 1-28. https://doi.org/10.2307/4299646

Tahan, H., & Naghshineh, A. S. (2016). Exploring the Prehistoric and Historic Sites in Joharin Village and Its Significance in Demonstrating the Settlement Patterns in the Southern District of the Qazvin Plain. *International Journal of the Society of Iranian Archaeologists, 2,* 37-44.

Tahlan, A. (2016). Settlement Patterns in the Qazvin Plain during the Late Iron Age: An Analysis of Regional Changes. *Journal of Iranian Archaeology, 22,* 102-115.

Talai, H. (1983). Late Bronze Age and Iron Age I architecture in Sagzabad, Qazvin Plain, the Central Plateau of Iran. *Iranica Antiqua, 18,* 51-57.

Trusty, D., & Hruby, J. (2017). *From Cooking Vessels to Cultural Practices in the Late Bronze Age Aegean*.

Vanden Berghe, L. (1964). *La nécropole de Khūrvīn*. Nederlands Histor-isch-Archeologisch Instituut in het Nabije Oosten te Istanbul, XVII.

Vanmoerkerke, A. (1991). *Oud-Iraanse culturen: Archaeologische navorsing van Prof. Dr. L. Vanden Berghe* (pp. 29-32). Stedelijk Museum A. Blomme.

White, K. D. (1984). *Greek and Roman Technology (Aspects of Greek and Roman Life)*. Cornell University Press.