



University of Zabol



ISMEO

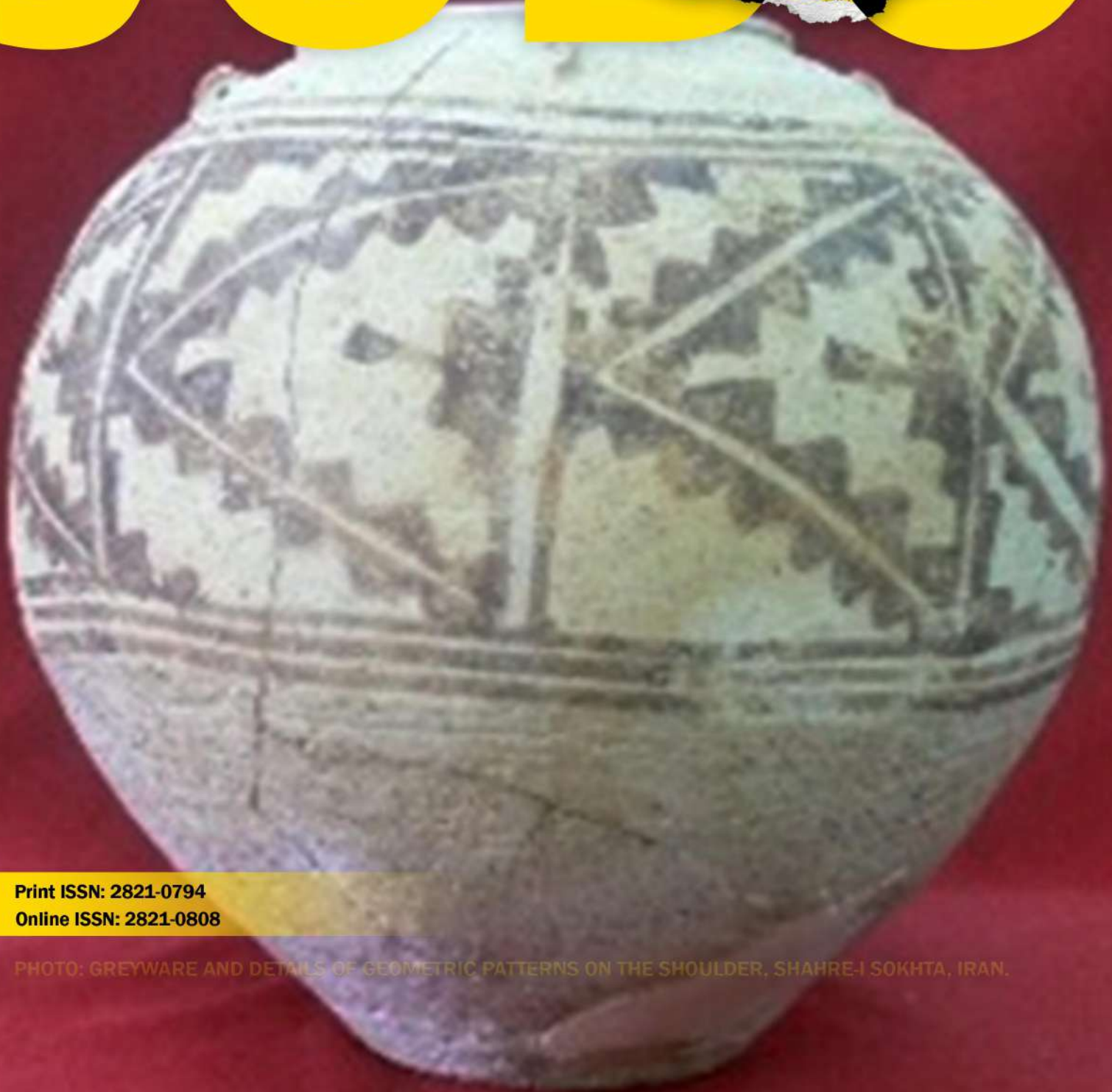


Society of Iranian Archaeology

Semiannual, Volume 2, Issue 1, 2022

JCS

Journal of Sistan and Baluchistan Studies



Print ISSN: 2821-0794

Online ISSN: 2821-0808

PHOTO: GREYWARE AND DETAILS OF GEOMETRIC PATTERNS ON THE SHOULDER, SHAHRE-I SOKHTA, IRAN.

University of Zabol, Iran

Journal of Sistan and Baluchistan Studies

Year 2022, Volume 2, Issue 1

Publication Ethics



Journal of Sistan and Baluchistan Studies It is rigorously following the **Committee on Publication Ethics COPE**. This enforces a rigorous peer-review together with strict ethical policies and standards to ensure adding high-quality scientific works to the field of scholarly publication. Unfortunately, cases of plagiarism, data falsification,

inappropriate authorship credit, and the like, do arise. **JSBS** takes such publishing ethics issues very seriously and our editors are trained to proceed in such cases with a zero-tolerance policy. To verify the originality of content submitted to our journals, we use [iThenticate](#) to check submissions against previous publications. Authors are responsible for obtaining permission to reproduce materials subjected to copyright.

About the Journal

Publisher: University of Zabol, Iran

Director-in-Charge: Reza Naseri *Associate Professor, Department of Archaeology, Faculty of Art and Architecture, University of Zabol, Zabol, Iran.*

Editor-in-Chief: Hossein Sarhaddi-Dadian *Associate professor, Department of Archaeology, Faculty of Art and Architecture, University of Zabol, Zabol, Iran*

Managing Editor: Babak Shaikh Baikloo Islam

Address: Department of Archaeology, Faculty of Art and Architecture, University of Zabol, Zabol, Sistan and Baluchestan, Iran, Post Code: 9861335856

E-mails: JSBS@uoz.ac.ir; Hossein.Sarhaddi@gmail.com

Review Time: 6-12 Weeks

Frequency: Semiannual

Publication Type: Paperback & Electronic

Open Access: Yes

Licensed by: CC BY-NC 4.0

Policy: Double Blind Peer Review

Language: English

Abstracts Available in: English

Article Processing Charges: No

DOI: 10.22034/JSBS

Print ISSN: 2821-0794

Online ISSN: 2821-0808

Manager: Dr. Babak Shaikh Baikloo Islam *Department of History & Archaeology, Science and Research Branch, Islamic Azad University, Tehran, Iran.*

Editorial Board:

Dr. Hasan Fazeli Nashli *Professor, Department of Archaeology, Faculty of Literature and Humanities, University of Tehran, Tehran, Iran.*

Dr. Seyed Mehdi Mousavi Kouhpar *Professor, Department of Archaeology, Faculty of Humanities, Tarbiat Modares University, Tehran, Iran.*

Dr. Bruno Genito *Department of Asian, African and Mediterranean Studies, University of Naples "L'Orientale", Naples, Italy.*

Dr. Marjan Mashkour *Institut écologie et environnement (INEE), French National Centre for Scientific Research, Paris, France.*

Dr. Enrico Ascalone *Department of Humanities, University of Roma Tre, Rom, Italy.*

Dr. Cameron A. Petrie *Professor, Department of Archaeology and Anthropology, University of Cambridge, Cambridge, United Kingdom.*

Dr. Mohammad Esmail Esmaili Jelodar *Associate Professor, Department of Archaeology, Faculty of Literature and Humanities, University of Tehran, Tehran, Iran.*

Dr. Zuliskandar Ramli *Associate Professor, Institute of the Malay World and Civilisation (ATMA), Universiti Kebangsaan Malaysia (UKM), Bangi 43600, Selangor.*

Dr. Ahmad Reza Sheikhi *Assistant Professor, Member of the Sustainable Kazakhstan Research Institute, Narxoz University, Almaty, Kazakhstan.*

Guide for Authors

Preface

The *Journal of Sistan and Baluchistan Studies (JSBS)* is devoted to South-Eastern Iran and welcomes articles in various areas of the world with a Sistan and Baluchistan legacy, especially adjacent areas such as Afghanistan, Pakistan, India, Oman, the Persian Gulf, and Central Asia with a chronological span from Paleolithic to Modern times. Contributions must be original and have not previously been published elsewhere. Please be ensure that there are no conflicts between the authors before submitting. Before being published, manuscripts submitted to the *Journal of Sistan and Baluchistan Studies (JSBS)* are critically reviewed. The purpose of the review is to reassure readers that the papers have been approved by competent and unbiased professionals. Manuscripts should be written in English, with the use of one spelling style throughout the entire manuscript. Both British and American spelling will be accepted. The manuscript should be submitted only via the *Journal of Sistan and Baluchistan Studies (JSBS)* the Editorial System (<http://www.jsbs.uoz.ac.ir/>). All papers are available free of charge at the Journal's webpage.

Types of article

The following types of contribution are published in the *Journal of Sistan and Baluchistan Studies (JSBS)*:

Original research article: Papers in all disciplines dealing with the mentioned geographical scope are the most welcome, with a specific focus on cultural heritage studies with new and innovative data based on archaeology, natural science applied to archaeology, history and art history, ancient technology, linguistics, ethnoarchaeological perspective, traditional architecture, and conservation as well as digital heritage and critical reviews. It should describe novel and well validated findings, and experimental techniques should be described in sufficient detail to allow the study to be verified. Research papers of 6000-8000 words in length, with tables, illustrations, and references, in which hypotheses are tested and results reported.

Review article: Review and perspective on current issues are accepted and encouraged. The format and length of review papers are more flexible than for a full paper. Typical reviews are less than 12000 words including references.

Short Communications: It is appropriate for recording the results of small-scale research including new projects, significant fieldwork discoveries, and innovative applications of technology. Research papers of 1500-2500 words in length and 6 figures maximum, with tables, illustrations, and references.

Structure of Articles

The structure of the articles can be modified based on their subject. The text should be written in a succinct and cohesive manner, with an emphasis on significant points, conclusions, breakthroughs, or discoveries, as well as their broader relevance. All running text should be saved as a Word document with Times New Roman 12, 1.5 spacing. Figures and tables can be put within the text or at the bottom. Figures should have a high enough resolution to allow for refereeing.

Short communication consists of title page, text, acknowledgments, and references with figure and table captions.

The original research articles should contain the following sections:

Title page

The title page must contain the title that should be clear, intelligible to experts in different disciplines, and represent the substance of the article. Moreover, full name(s) of the author(s),

affiliation(s) of the author(s) containing the full name of the institution. The postal address and email address of the corresponding author must be mentioned.

Abstract

The title's information does not need to be duplicated in the abstract. The abstract should not be more than 350 words long. It must include the study's goal, methods, findings, and conclusions.

Keywords

Provide three – seven keywords, covering the most precise phrases in the article. They should explain the subject and results and should not be the same as the terms used in the title.

Introduction

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

Material and methods

Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized and indicated by a reference. If quoting directly from a previously published method, use quotation marks and also cite the source. Any modifications to existing methods should also be described.

Results

Results should be clear and concise.

Discussion

This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusions

The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

Appendices

If there is more than one appendix, they should be identified as A, B, etc.

Acknowledgments

Acknowledgments of persons, grants, money, and so forth should be included before the reference list in a distinct section.

References

References are in “Harvard style” and all the sources in the final bibliography should be placed alphabetically. The authors are listed with comma separation up to three ones. When four or more authors are listed, please use first author + *et al.* The full list of authors is required in the final bibliography.

In-Text Citation:

Citing one author: (Curtis, 2012)

Citing two: (Piperno and Salvatori, 2007)

Citing three or more authors: (Kavosh *et al.*, 2019)

Reference list:

Book

Curtis, J. (2012). *The Oxus Treasure*. London: British Museum Press.

Piperno, M. and Salvatori, S. (2007). *The Shahr-I Sokhtya graveyard (Sistan, Iran): excavation campaigns, 1972-1978*. Roma: ISIAO.

Chapter in an edited book

Vidale, M. (2020). Chlorite Containers from the Oxus civilization between technical choices and iconographic codes. In: B. Lyonnet, and N. A. Dubova, (eds.), *The World of the Oxus Civilization*. London: Routledge, pp.293-332.

Journal paper (electronic)

Perrot, J. (2008). Jiroft iv. Iconography of Chlorite Artefacts. *Encyclopædia Iranica*, 14, pp.656–664. [Online]. Available at: <https://www.iranicaonline.org/articles/jiroft-iv-iconography-of-chlorite-artifacts> [Accessed 25 August 2021].

Journal paper (printed copy)

Sajjadi, S. M. S. (2007). Wall painting from Dahaneh-ye Gholaman (Sistan). *Ancient Civilizations from Scythia to Siberia*, 13(1-2), 129–154.

Jarrige, J. F., Didier, A. and Quivron, G. (2011). Shahr-i Sokhta and the chronology of the Indo-Iranian regions. *Paléorient*, 37 (2), 7–34.

Website

Shahr-i Sokhta - UNESCO World Heritage Centre. [Online]. Available at: <http://whc.unesco.org/en/list/1456/> [Accessed 25 August 2021].

Thesis

Shirazi, R. (2008). *Etudes typologiques et comparatives des représentations humaines en terre crue, en terre cuite et en pierre de l'Asie centrale et de l'Iran oriental du Chalcolithique à l'âge du Bronze (4000-1800 av. J.-C.)*. Ph.D. Thesis. Panthéon-Sorbonne University.

Tables and Figures

Please submit tables as editable text and not as images, each table should be numbered consecutively (1, 2, etc.). Please avoid using vertical lines in tables. All tables should be embedded while correctly positioned and be referred to in the text. Please use "Table" in both text and captions in bold.

Figures should be used only if they clarify or reduce the text. All photographs, graphs, and diagrams should be referred to as a 'Figure' and they should be numbered consecutively (1, 2, etc.). Data should be presented only once in a graph or a table, not in both. Figures should be submitted in separate files. The required resolution is 300 DPI for greyscale images and at least 600 DPI for black-and-white drawings. All figures must be referred to in the text and the references should be typed in bold. Use (Fig.) at the end of the sentence and captions and use (Figure) in text.

Abbreviations

dates: 1980-1985, not 1980-85

pages: 250-275, not 250-75

following/s: f./ff.

centimeter/s: cm

meter/s: m

etcetera: etc.

circa: c.

videlicet: viz.

exempli gratia: e.g.

volume/s: Vol./Vols.

chapter: Chapt.

column: Col.

folio/s: Fol./Fols.

translator: transl.

second [II] century: 2nd century, etc.

century and millennium: never abbreviated

before Christ: BCE

after Christ: CE

plate/s: only when referring to author's plates within one's own text: Pl./Pls.

figure/s: only when referring to author's figures within one's own text: Fig./Figs.

fig./figs., pl./pls. in all other cases

note/s: fn./fns.

number/s: n./nn.

editor/s: ed./eds.

no place: n.p.

no date: n.d.

doctor: Dr

Mister: Mr

Suggest Reviewers

With the manuscript, the author should include a list of three qualified, independent, prospective reviewers who could perform quality peer reviews of your document. Be sure to include their complete names, affiliations, and current e-mail addresses.

TRACE OF THE MIDDLE PERSIAN /W/ IN IRANIAN SISTANI DIALECT

Farideh OKATI

Assistant Professor, English Department, University of Zabol, Zabol, Iran, (farideh.okati@uoz.ac.ir).

Received: 09 April 2022

Accepted: 01 June 2022

Available online: 20 June 2022

Abstract: The Old and Middle Persian *w*, although shifted to *v* in New Persian (NP), is still found in some Iranian languages and some Persian dialects, such as Sistani, Bakhtiari, Roodbari, etc. This study traces the ancient sound *w* of Middle Persian (MP) in the Sistani dialect (SD). SD is spoken in southeastern Iran in Sistan, where its name comes from the Old Persian Sakastana, and its original name Zarangiana comes from the Old Persian Zranka, 'Waterland'. The words of Sakzi, the language of Sistan since ancient times, were found in the translation of the old Qorān-e Qods into Persian, the translation in which *w* can be traced. Sistani has preserved some characteristics of MP, such as initial consonant clusters and long /e:/ and /o:/. The finding of this study is the existence of MP *w* in Sistani that can be interpreted in different ways: 1- *w* as an allophone of the phoneme *v*, which mostly occurs between [o] and the syllable break, 2- *w* as the phoneme descending from MP and still existing in Sistani, and *v* as its allophone in some environments, 3- *w* analyzed as a vowel in the sequence of [ow] forming diphthong [oʊ], 4- *w* is in the halfway of transition: shift of *w* to *v* in some words and still preserved in some other words. However, the shifting process of MP *w* to *v* seems not to be yet completed in this dialect, and it is possible to assume Sistani is a stage between MP and NP. The data for the study was gathered from all districts of Sistan, from non-literate and graduate consultants. The pure Sistani words were used as much as possible. Auditory pretest, articulatory/acoustic phonetics examinations, and Wavesurfer/Praat software were used. The method of analysis was adapted from Burquest (2006). The data were transcribed in IPA, and phonemes/allophonic variations were determined by the contrastive method of minimal pairs, analogous, and complementary distribution patterns. This study can be useful for documentation, and reconstruction of the older Iranian languages, and help show the manner of a shift in ancient sounds.

Keywords: Middle Persian, sound *w*, Sistani dialect, New Persian.

چکیده: صدای فارسی باستان و میانه‌ی *w* اگرچه در فارسی نو (NP) به *v* تغییر یافته‌است، هنوز در برخی از زبان‌های ایرانی و برخی از گویش‌های فارسی مانند سیستانی، بختیاری، رودباری و غیره دیده می‌شود. این پژوهش به ردیابی صدای باستانی *w* فارسی میانه (MP) در گویش سیستانی (SD) می‌پردازد. SD در جنوب شرقی ایران در سیستان صحبت می‌شود، جایی که نام آن از واژه‌ی Sakastana و نام اصلی آن Zarangiana از فارسی باستان، از واژه‌ی Zranka، به معنای "سرزمین آب"، گرفته شده‌است. واژه‌های گونه‌ی زبانی سکزی، که از زمان‌های قدیم زبان مردم سیستان بوده‌است، در ترجمه‌ی "قرآن قدس" به فارسی یافت می‌شود. در ترجمه‌ی این قرآن، که از جمله قرآن‌های قدیمی و کهن محسوب می‌شود، صدای *w* را می‌توان ردیابی کرد. گویش سیستانی برخی از خصوصیات MP مانند خوشه‌های همخوان اولیه و واکه‌های بلند /e:/ و /o:/ را حفظ کرده‌است. یافته‌های این پژوهش وجود صدای *w*، به جا مانده از MP در گویش سیستانی است که می‌توان آن را به چند روش تفسیر کرد: ۱- *w* به عنوان واجگونه‌ای از واج *v* که بیشتر بین [o] و وقفه‌ی هجایی (پایان هجا) رخ می‌دهد، ۲- *w* به عنوان واجی که از MP به‌جامانده و همچنان در سیستانی وجود دارد و *v* واجگونه‌ی از آن است که در برخی محیط‌ها دیده می‌شود، ۳- *w* به عنوان یک واکه در ترتیب [ow] که می‌تواند واکه‌ی مرکب [oʊ] را تشکیل دهد، ۴- *w* در نیمه‌راه مرحله‌ی تغییر: تغییر *w* به *v* فقط در برخی کلمات اتفاق افتاده‌است و همچنان در دیگر کلمات باقی مانده‌است. به هر حال، به نظر می‌رسد روند تغییر و تبدیل صدای *w*، از صداهای MP، به *v* در گویش سیستانی هنوز کامل نشده‌است، و می‌توان سیستانی را مرحله‌ای بین MP و NP فرض کرد. داده‌های پژوهش از تمامی نواحی سیستان، از گوشوان بدون سواد تا فارغ‌التحصیلان دانشگاهی جمع‌آوری گردیده، و تا حد امکان سعی شده‌است از کلمات اصیل سیستانی استفاده شود. پیش‌آزمون شنوایی، آزمون‌های آوایی بیانی/آکوستیک، و نرم افزارهای Wavesurfer/Praat جهت تحلیل استفاده شده‌است. روش تجزیه و تحلیل از Burquest (۲۰۰۶) اقتباس گردیده‌است. داده‌ها در IPA آوانگاری شده‌اند و صورت‌های واج/واجگونه‌ای به کمک الگوهای تمایز، جفت‌های کمینه، قیاس پذیری، و توزیع تکمیلی تعیین گردیده‌اند. این مطالعه می‌تواند برای مستندسازی و بازسازی زبان‌های قدیمی ایرانی مفید باشد و به نشان دادن نحوه تغییر آواهای باستانی کمک کند.

کلمات کلیدی: فارسی میانه، صدای *w*، گویش سیستانی، فارسی نو.

I. Introduction

Sistan is a border region in southeastern Iran and southwestern Afghanistan. One portion of Sistan is part of the Iranian province of Sistan and Baluchestan, and the other portion is part of the Nimrooz Province in Afghanistan. The original name of Sistan, Drangiana or Zarangiana, comes from the Old Persian *Zranka*, 'waterland' (Schmitt, 1995), and the Old Persian 'Sakastana', 'land of the Sakas', as a source for the name, became later known as Sijistan and then as Sistan (Bosworth, 1997).

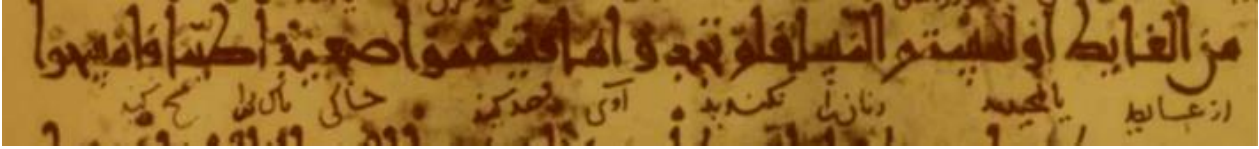
Sistani, regarded as a dialect of standard Persian, belongs to the southwestern group of Iranian languages (Windfuhr, 1989; Bearman *et al.* 2003). Iranian Sistani

Dialect (SD) is spoken in different towns of the Iranian Sistan: Zabol, Zahak, Bonjar, Nimrooz (Adimi), Hamoon (Mohammad Abad), and Hirmand (Dust Mohammad), and in about its 885 inhabited villages with slightly varied forms (Okati, 2018). It has its own specific features in different disciplines of phonology, morphology, and syntax, making it somehow different from Standard Persian (Okati *et al.*, 2009, 2010). This dialect is also spoken in some places outside the Sistan region (Dusti, 2001).

Since ancient times, Sakzi has been the name of the people and language of Sistan. The translation of the old *Qorān-e Qods* into Persian and *Tarix-e Sistan*, in which Sakzi words can be found, are of the most ancient

sources of the SD (Mohammadi Khamak, 2000). Comparing the present SD with Sakzi words shows that this dialect is likely to be the survivor of the ancient Sakzi language (*Ibid.*, VII). Some of these words in the translation of the *Qorān-e Qods* (Ravaqi, 1985) are as

follows: /ʃow/ ‘night’, /avi/ (ow+-i) ‘some water’, /kut/ ‘deaf’. The following is the figure 1 of the word /avi/ (ow+-i) ‘some water’ taken from *Qorān-e Qods* (Okati, 2018):



أولى [avi] (ow+-i)

Figure 1. *Qorān-e Qods*, Nesa/43, [avi] ‘some water’ (Ravaqi, 1985: 34).

Some characteristics of Middle Persian (MP) and Classical New Persian (NP), such as initial consonant clusters and the long vowels /e:/ and /o:/, are preserved in SD (Windfuhr, 2011, Okati, 2018). The sound *w*, descending from Old Persian into MP, has shifted to *v* in NP. But this shift has not been occurred in all Iranian languages, for example *w* is still found in Balochi words such as *gwask* ‘calf’ (Korn, 2005), and in Kurdish words such as *xwebr* ‘bent’ (Chyet, 2003). Also, the *w* sound is still found in some Persian dialects such as Bakhtiari, e.g., *rwah* ‘fox’, though it has changed to *b* in some words of this dialect, e.g., *wahīg* ‘kid’ changed to *big* (MacKenzie, 1990; Taheri, 2016). Roodbari dialect is another example of Persian dialects that maintained the *w*, e.g., *memwa* ‘fruit’, *dəw* ‘demon’ including the labialized forms such as *x^wah* ‘sister’ (Abolghasemi, 2013; Seddiqi Nezhad and Motallebi, 2018). The sound *w* of MP is even though disappeared in the Farsi variation of NP, it is however pronounced in Dari and Tajiki variations of NP and is dealt with as a phoneme (Lazard, 1963; Sadeghi, 1978; Zomorrodian, 1995).

The dynamic nature of language brings about continuous changes in languages occurring gradually over time. This study traces the ancient sound *w* of MP in Sistani, a Persian dialect, to investigate its existence and its status in this dialect and its connection to the *v* sound.

II. Literature review

There are several studies made on the SD spoken in different areas of Sistan. In none of them the sound *w* is explicitly studied. In some of these works, such as Weryho’s *Sistani-Persian Folklore* (1962), which is a general study of the pronunciation, grammar, and vocabulary of this dialect in the Sistan region of Iran, the phonemes are not specified, and they can only be derived from the transcriptions, where the status of *w* is not clear. The Russian linguist Gryunberg (1963), who studied phonology and morphology of the SD of Sarakhs in Turkmenistan, has not worked on the consonants and only distinguishes eight vowels /ü/, /i/, /e/, /ə/, /a/, /u/, /ū/, /ā/ in the vowel system of this dialect without referring to any diphthongs

containing *w*. He (*Ibid*) mentions that there are no considerable differences between consonants of this dialect and those of Persian. Lazard (1974) describes verb morphology in the SD in the town of Zabol and its suburbs. In his observation, he shows *w* as part of a diphthong, /öw/, in this dialect. Omrani, (1996), Barjasteh Delforooz (1996), Dusti (2001), and Ahangar (2003) described the phonological system of the SD spoken in Zabol, Posht-e Ab district, and the village of Sekuhe in Iranian Sistan. They present *w* in /ow/ as part of a diphthong. On the Iranian SD, some glossaries are also published, among which Mohammadi Khomak (2000) and Shahnazi (2020) are more comprehensive than the others. Likewise, in the other printed documents, *w* is just presented as part of a diphthong in these two works.

III. Methodology

The modern generative phonology was used as the framework, and the functional approach of Burquest (2006) was used for the phonological analysis in this study. The data was gathered by interviewing more than 50 male/female consultants from all different districts of Sistan with a range of literacy from non-literate to graduate degrees. The author herself is a native speaker of Sistani. It has been tried to use pure Sistani words, which are less affected by Persian, and not Persian/Arabic loan words. The speech sounds have been examined through articulatory and acoustic phonetics (Roach, 2010). The analysis of the data was started with an auditory pretest. Afterward, the Wavesurfer and Praat software were used to obtain more certain judgments by means of spectrograms (spectrograms are not presented in the study), which show acoustic characteristics of language segments (Sepanta, 1998). The phonemes under investigation were transcribed in the IPA symbols (International Phonetic Association, 1999) and have been determined by contrastive methods of minimal pairs and analogous environments. For allophonic variation, complementary distribution patterns have been

investigated¹. Phonemes are shown in slashes / /, and allophones and phonetic representations are presented in square brackets [].

IV. Analysis and Result

Out of the analysis, the finding of this study is the existence of MP *w* in Sistani that can be interpreted in four different ways as follow:

Table 1. Comparing [f] to [v]: Showing the phonemic status of *v*.

[ʔfa:l] ‘fortune’	[ʔva:l] ‘fine material’
[ʔkʰe:f] ‘enjoy’	[ʔde:v] ‘beast’
[ʔla:f] ‘blanket’	[ʔbda:v] ‘(you) run’
[kʰaʔfa:] ‘shroud’	[kʰaʔval] ‘watermelon’

[f] and [v] are in contrast in [ʔfa:l] and [ʔva:l] as the minimal pairs. Also, to confirm this, by considering an analogous environment, words [ʔde:v] and [ʔke:f] are near minimal pairs as they are both made of a plosive + a long vowel + a fricative, so [v] and [f] occur in the same environments and this can prove that they are two separate phonemes. To argue more about this analogous environment, say if the feature [-voicing] of [k] in [ʔke:f] or in [kʰaʔfa:] caused the occurrence of voiceless [f] in these words, we have the word [kʰaʔval]

IV.1. *w* as an allophone of the phoneme *v*, mostly occurs between [o] and the syllable break

To start with the analysis, first contrast *v* with another phoneme, e.g., /f/, via minimal pairs and analogous environment, shown in Table 1, to see if *v* has a phonemic status:

in which [k] is also cooccurred with voiced [v], so, the reasoning above for the separation of [f] and [v] can be confirmed. The distinctive feature of both sounds is [+anterior], i.e., they are produced at or in front of the alveolar ridge (Berquest, 2006). As a result:

[f] → /f/: voiceless, labiodental, fricative phoneme

[v] → /v/: voiced, labiodental, fricative phoneme

Then by contrasting *v* and *w*, shown in Table 2, the allophonic relationship between the two sounds is investigated:

Table 2. Comparing [v] to [w]: Showing *w* as the allophone of *v*.

[po.ʔve:me] ‘my feet’	[ʔpʰow] ‘foot’
[ʔfo.ʔva] ‘nights’	[ʔfow] ‘night’
[ʔgo.ve] ‘a cow’	[ʔgow] ‘cow’
[ga:.ʔlo.ve] ‘a melon’	[ga:ʔlow] ‘melon’
[o.ʔva.ra] ‘the waters’	[ʔow] ‘water’
[ʔtʰva:i] ‘axe’	
[va:ʔdi] ‘to find’	
[ʔde:v] ‘beast’	

The data in Table 2 shows that [w] only occurs between [o] and the syllable break ([o] — #), and [v] occurs elsewhere, so they are in complementary distribution. It seems, in the final position, [v] changes to [w], and whenever it is adjacent to an affix, it reoccurs, e.g., [ʔfow] ‘night’ + plural marker [-a] → [ʔfo.ʔva] ‘nights’. Since [v] has the wider distribution, it can be the phoneme and [w] is considered as its allophone, i.e., there is an allophonic relationship between them:

[v] → [w] [o] — # [v] → [v] elsewhere

As a result:
[v] → /v/: voiced, labiodental, fricative phoneme
[w] → [w]: voiced, labial-velar, approximant allophone of /v/

The distinctive feature of /v/ is [+anterior] and of [w] are [+anterior, +back].

¹ “A minimal pair is a pair of words which differ in meaning and which show the two units (two phonemes) to be contrasting in identical environments. Contrast in analogous environments is the difference between two phonetically similar segments that occur in two separate words and have similar adjacent sounds. If neither segment has been modified or affected by its environment, the segments are separate phonemes” (Okati, 2018: 28-29). If the two sounds are in complementary distribution, they are different variants

of the same phonological segment, and then an allophonic relationship exists between them. Complementary distribution is the mutually exclusive relationship between two phonetically similar segments. It exists when one segment occurs in an environment where the other segment never occurs. Complementary distribution is related to the phonemics principle which says that sounds tend to be modified by their environments (Burquest, 2006: 3).

IV.2. *w* as the phoneme descending from MP and still existing in Sistani, and *v* as its allophone in some environments

There are many data that contain *w* as one of their sounds, though limited in position. As the second

interpretation, *w* can probably be taken as a phoneme, and *v*, besides being a phoneme, plays the role of allophone of *w* in some environments too. Table 3 shows some examples:

Table 3. Comparing [w] to [v]: Showing *w* as a phoneme and *v* playing as its allophone in some environments.

[p ^h ow] 'foot'	[po've:me] 'my feet'
[fow] 'night'	[fo'va] 'nights'
[ga:'low] 'melon'	[ga:'love] 'a melon'
[ow] 'water'	[o'vara] 'the waters'
[gow] 'cow'	[gove] 'a cow'
[gow] 'cow'	[gova ba:r] 'take the cow'
[gow] 'cow'	[govo gos'la] 'cow and calf'
[drow] 'harvest'	[drovo das'ta] 'harvest and bundle'
[fow] 'wood, stick'	[fovo f'ov'ki] 'act of fighting with stick'
[dow] 'swear'	[dovo dov'ki / dovdown'ki] 'act of swearing each other'
[fow'go:ʃ] 'eavesdropping'	
[lowʃ] 'melon rinds'	
[em'fow] 'tonight'	
[owda:'ri] 'irrigation'	
[dow'ry] 'large tray'	
[row'ʃa] 'kind of red grape'	
[kowʃ] 'shoes'	
[kow] 'desire'	
[kowɪ] 'shout'	
[gow'daɪ] 'herdsman'	
[lowʃ] 'lip'	

Examples in Table 3 show the occurrence of [w] in many words, in medial and final positions. Those in word final position, change to [v] when adjacent to an affix, such as:

[o] 'and' in [gow + o + gosla] → [govo gos'la] 'cow and calf,

[-a] the plural marker in [fow + -a] → [fo'va] 'nights',

[-e] 'a, one' in [ga:'low + -e] [ga:'love] 'a melon',

[-a] the object marker in [gow + -a + ba:r] [gova ba:r] 'take the cow'.

As there is a wide distribution of [w] in many words, and it is displaced by [v] just in certain environments, the argumentation of [w] as a phoneme and [v] as the allophone seems not unlikely:

Table 4. Comparing [oo] to [o]/[o:]: Showing probable change of *w* to [o] forming diphthong [oo].

[o] 'that'	[oo] 'water' (or [ow]?)
[f ^h ol] 'cesspool'	[f ^h ool] 'wish' (or [f ^h owl]?)
[k ^h ol] 'all, entire, hug'	[k ^h ool] 'desire' (or [k ^h owl]?)
[loʃ] 'paralysed hand'	[looʃ] 'big lip' (or [lowʃ]?)
[t ^h o] 'you'	[moo] 'grapevine' (or [mow]?)
[a:r'mo:] 'wish'	[oo'ri] 'rabies, mad' (or [ow'ri]?)
[do:l] 'drum'	[dool] 'way, form' (or [dowl]?)
[ko:i] 'blind'	[kooɪ] 'shout, wail' (or [kowɪ]?)
[fo:i] 'salty'	[fooi] 'consult' (or [fowɪ]?)
[o:] 'yes'	[poo] 'foot' (or [pow]?)

[w] → [v] /— affix [w] → [w] / elsewhere
As a result:

[w] → /w/: voiced, labial-velar, approximant phoneme
[v] → [v]: voiced, labiodental, fricative allophone of /w/ (in certain environments)

The distinctive features of /w/ are [+anterior, +back] and [v] is [+anterior].

IV.3. *w* analyzed as a vowel in the sequence of [ow] forming diphthong [oo]

The following step is to analyze the sequence [ow] to see if it has gradually changed to diphthong [oo] and formed a phoneme. To show [oo] as a phoneme, it should be contrasted to other vowel sounds, e.g., /o/ and /o:/. The contrast is shown in Table 4:

Based on the data in Table 4, it can be argued that [ou] and [o]/[o:] are in contrast in the minimal pairs above, such as [k^hol] 'all' and [k^hool] 'desire', [ko:i] 'blind' and [kou] 'shout'. All three sounds occur in the same syllabic patterns: V, CV, CVC, and can be found in word-initial, medial, and final positions. So, each of them can be taken as a phoneme:

[o] → /o/: back, close-mid, rounded phoneme

[o:] → /o:/: back, close-mid, rounded long phoneme

[ou] → /ou/: diphthong phoneme

IV.4. *w* is halfway through transition: shift of *w* to *v* in some words and still preserved in some other words

By this interpretation, to show the gradual shift of *w* to *v*, the phonemic status for both sounds should be represented in some data. At the same time, their allophonic conditions resulting from certain environments should also be shown in some other data. Table 5 depicts examples of such data, the data that have also been represented in the above tables:

Table 5. Comparing [w] to [v]: Showing the gradual shift of *w* to *v*.

1) [p ^h ow] 'foot'	[po've:me] 'my feet'
2) [fow] 'night'	[fo'va] 'nights'
3) [ga:'low] 'melon'	[ga:'love] 'a melon'
4) [ow] 'water'	[o'vara] 'the waters'
5) [gow] 'cow'	[gove] 'a cow'
6) [gow] 'cow'	[gova ba:r] 'take the cow'
7) [gow] 'cow'	[govo gos'la] 'cow and calf'
8) [drow] 'harvest'	[drovo das'ta] 'harvest and bundle'
9) [fow] 'wood, stick'	[fovo f'ov'ki] 'act of fighting with stick'
10) [dow] 'swear'	[dovo dov'ki / dovdow'ki] 'act of swearing each other'
11) [lago 'low] 'stout'	[lago 'lovija] 'he/she is stout'
12) [ow'yo] 'Afghan'	~ [a:v'yo] ~ [a:f'yo] 'Afghan'
13) [ow'sa:i] 'bridle'	~ [a:v'sa:r] ~ [a:f'sa:r] 'bridle'
14) [dowte'la:b] 'volunteer'	~ [da:vte'la:b] 'volunteer'
15) [ow'za:i] 'tool' (also genital organ)	~ [a:vza:r] ~ [a:bza:r] 'tool'
16) [kowf] 'shoes'	~ [kavf] ~ [kabf] ~ [kaf] 'shoes'
17) [lowf] 'lip'	~ [labf] 'lip'
18) [owda:'ri] 'irrigation'	[va:'di] 'to find'
19) [kow] 'desire'	[va:l] 'fine material'
20) [row'fa] 'kind of red grape'	[ve:l] ~ [be:l] 'wandering'
21) [ow'ri] 'mad, insane'	[vo'zu] ~ [bo'zu] 'ablution'
22) [lowf] 'melon rinds'	[t ^h va:i] 'axe'
23) [dow'ry] 'large tray'	[de:'va:l] 'wall'
24) [kow] 'shout'	[k ^h a'va:l] 'water melon'
25) [gow'da] 'herdsman'	[bja:'vo] ~ [bja:'bo] 'desert'
26) [fow'go:] 'eavesdropping'	[dva] 'curse'
27) [tow] 'high temperature'	[de:v] ~ [de:b] 'beast'
28) [row] 'down'	[fe:v-a] ~ [fe:b] 'steep, slope'
29) [ow'ba:l] 'sin, punishment'	
30) [ow] 'water'	

The data in Table 5 above can analyze the gradual shift of *w* to *v* as follow:

-The first 11 examples can be used to show the phonemic status of *v* and the allophonic status of *w*, with the same result obtained for the same data and the same purpose represented in Table 2 above.

-The first 11 examples plus the ones from 18 to 30 can be analyzed as data representing the phonemic status of *w* and the allophonic status of *v* in certain

environments, as it is also indicated for the same data and purpose in Table 3.

-The examples from 12 to 17 show the free variations of words containing *w* or *v*, as well as the rest of the examples down to 30 can be used for the analysis of *w* and *v* to show them as both being phonemes as both have occurred in the same environments, e.g., medial and final positions. Some data such as [de:v] ~ [de:b] 'beast' show the free variation of *v* and *b*, the

word that was [dew] in MP and still exists in some Persian dialects (see Introduction section).

V. Discussion and Conclusion

The result of the analysis shows the existence of MP *w* in SD that can be interpreted in different ways:

Interpretation A: Based on the analysis in section 4.1, *v* in SD can be proved to possess a phonemic status as it contrasts with another sound such as /f/, and *w* as the allophone of *v*, which occurs in a certain environment. It can be argued that the phoneme /w/ of MP has changed to [w], an allophone of phoneme /v/ in Sistani. The existence of /w/ in Balochi and Kurdish, the Persian sisters, and the shift of /w/ in MP to v/b in NP as well as in some words in SD, such as walg/warg (MP) → barg (NP) ba:lg (SD), or āwāz/wāng (MP) → āvāz/bāng (NP) → āvāz/bāng (SD) (Mackenzie, 1990), as evidence, can support this interpretation.

The allophone [w] reappears as /v/ in the affixed forms, e.g. [gow] ‘cow’ → [govara] ‘the cows’, [grow] ‘pledge’ → [grove] ‘in pledge’, and [drow + o + dasta] → [drovo dasta] ‘harvest + and + bundle’. This can be a proof of the allophonic relationship between /v/ and [w]. However, there are words such as [dowri] ‘large tray’, [rowʃa] ‘kind of red grape’, and [kowʃ] ‘shoes’ that do not have any affixed or other forms to show the reappearance of the /v/ in these words. Through the analysis, these words have been treated and explained either as words having diphthong [oʊ], or as having a sequence of [ow]. The appearance of /v/ here may also be taken as an intervening consonant between two vowels for the sake of easier pronunciation. However, it seems more reasonable to not think of /v/ as an intervening element as there are many words (see Table 6) in which the /w/ in MP has evolved to /v/ in the NP. The sound *w* has also remained as an allophone in the Bakhtiari language in words such as (taken from Anonby and Asadi, 2014) [xow] → /xov/ ‘good’, [taw] → /tav/ ‘fever’ (it seems in Bakhtiari [w] stayed somewhere between [w] and [v], i.e., /v/). In addition, there are words in which [v] appears in their affixed forms not only before a vowel but also adjacent to a consonant that can support the [v] as not being a mediator: [dow] ‘swear’ → [dow + o + dow + ki] → [dovo dovki or dovdownki] ‘act of swearing each other’, [ʃow] ‘wood’ → [ʃow + o + ʃow + ki] → [ʃovo ʃovki] ‘act of fighting with a stick’. In these examples, in the affixed forms, [v] even is not always changed to [w] after [o] when occurring in the same syllable, [dow → dow.ki or dov.ki]; this may be allowed just in some certain forms; more related investigation is needed.

Interpretation B: The result of analysis in section 4.2 can indicate that *w* as the phoneme descending from MP still exists in Sistani, and *v* acts as its allophone in some environments. Table 3 above shows the occurrence of *w* in open and closed syllables and in the

medial and final positions in many words. As *w* has a wide distribution and is found in many words, and as it only changes to *v* when adjacent to an affix in the word’s final position, it can be taken as a phoneme and the *v* as its allophone. So far, this interpretation has never been investigated by other researchers in any related studies.

Interpretation C: The result in section 4.3 can also discuss *w*, in the sequence of [ow], as changing to [ʊ] and forming diphthong [oʊ] in this dialect (see Lazard, 1974; Ahangar, 2003). Based on minimal pairs, some words can be either treated as having diphthong [oʊ] restricted mainly in closed syllables or as the sequence [ow]. According to the data, because [w] appears after [o] in open syllables (usually at the end of the word), there is a possibility for words such as [kowʃ] ‘shoes’ to be treated as words having [ow] and not [oʊ]. As there is no lexical evidence in the speech of speakers to show the reappearance of [v] in such words (may be due to the historical reasons or the structure of the words), they can either be treated as words having diphthong [oʊ] or words having the sequence [ow]. Regarding the data and the minimal pairs, it is possible to argue that the diphthong mainly occurs in closed syllables and those in open syllables are a sequence of [ow].

As for the [ow], two interpretations have led to two findings. First, because the [w] sound found in the data has been interpreted as the allophone of /v/ (which occurs in a certain environment), [ow] can be treated as a sequence of a vowel plus a consonant, V + C (o + w). Also, [ow] as V + C can be fitted into the syllable patterns of this dialect. So, with this interpretation, [ow] cannot act as diphthong because, according to the permitted syllable patterns in SD, if [ow] was a diphthong, a CC cluster could occur after it. However, it never allows a following CC cluster in the same syllable, for the [w] itself as a consonant occupies one of the C positions of the allowed cluster CC (and not CCC) in the coda. Besides, it is not economical to create a new phoneme while this sound can be interpreted via the existing sounds in the inventory; see examples (Okati, 2018):

[ʃow] ‘night’	[ow] ‘water’	[khowʃ] ‘shoes’	[ow.da:ri] ‘irrigation’
CVC	VC	CVCC	VC.CV.CV

The second interpretation is taking [ow] as diphthong [oʊ]. In words such as [dowri] ‘large tray’, [rowʃa] ‘kind of red grape’, [lowʃ] ‘melon rind’, [kowʃ] ‘desire’, and [kowʃ] ‘shout’ that do not have any affixed or other forms in the lexicon to show the reappearance of /v/ (such as [gow] ‘cow’ → [gove] ‘a cow’), the sequence [ow] can be taken as a diphthong, [oʊ], occurring mainly in closed syllables but with the restriction of not allowing consonant clusters after it. With this interpretation, these types of words have been listed as

the words containing diphthong to be compared with other words in the analysis section; some of them made minimal pairs with other words, which means the diphthong is in contrast and so it can be a phoneme. If [ow] is taken as diphthong [ou] in all words containing it, then the [v] could be thought of as a mediator occurring between two vowels, such as in [(gow) gov + -e] ‘cow’ → [(gove) goʊve] ‘a cow’; in this case, the evolution of [w] to [v] or the existing of [w] as an allophone in the genetically related varieties to SD is ignored. Besides, the form [goʊve] is odd in Sistani, so in this case, [v] cannot be a mediator, and the correct form will be [gove (go.ve) ← gov. + -e]. As a result, it is possible to suggest two different interpretations: first to say that in SD there is no positions and open and closed syllables. It changes to *v* only when it is adjacent to an affix. Moreover, the examples 12 to 17 in Table 5, which show the free variations of *v* and *w* in different words, can also be interpreted as showing the orientation of *w* towards gradual shifting to *v/b*. These examples, together with the rest of the examples down to 30, can also argue both *w* and *v* as phonemes, for both sounds are occurring in the same environments, but with the gradual shift of *w* to *v* observed in the free variations, e.g., [ow'yo] ~ [a:v'yo] ‘Afghan’. Some data such as [de:v] ~ [de:b] ‘beast’ show the free variation of *v* and *b*, the word that was [dew] in MP and still exists in some Persian dialects (see Introduction section). Looking at the existing /w/ sound in the system of MP (MacKenzie, 1990) and changing it to /v/ or /b/, and in some cases to /g/, in NP and consequently in SD as a Persian dialect, could be taken as the evidence to show the existence of *w* and its connection and the gradual shift to *v*. However, *w* can still be found as a phoneme in the system of some genetically related languages to Persian such as Balochi and Kurdish, or as an allophone in other Iranian language varieties such as Bakhtiari language (Anonby and Asadi, 2014).

There are many words of MP in which [w] is located in different positions, and many of them reached NP, having [v] or [b] instead. Based on the changes, SD seems to be in some stages between MP and NP; there are some examples shown in Table 6: diphthong at all and that [w] is the allophone of /v/ after [o] in the syllable break like [gow] and [kowʃ], and wherever [w] is not tautosyllabic with [o], i.e., not being in the same syllable, it turns to the phoneme [v] such as in [ˈgow] ‘cow’ → [ˈgo.ve] ‘a cow’. Or vice versa, that it means there is no allophone [w], and instead, all the sequences of [ow]s are diphthongs. The second suggestion is that both [ou] and [ow] exist in Sistani: a) as a diphthong, [ou], but mostly in the closed syllables, e.g. [kowɪ →

kouɪ] ‘shout’ that is in contrast with [ko:ɪ] ‘blind’, and b) as a sequence of V + C, [ow], with the [w] as the allophone of /v/ occurring after [o] at the syllable break, e.g. [ʃow] ‘night’, [gow.dar] ‘herdsman’. The second suggestion shows both the existence of [w] as an allophone and the probability of changing of [ow], in some cases, to a diphthong but with the restriction of not allowing a CC cluster after it. However, some data can be listed both under the words having allophone [w], or having diphthong [ou]; this can also support Interpretation D below.

Interpretation D: The analysis in section 4.4 can result in the argumentation of taking *w* as in the halfway of transition: shift of *w* to *v* in some words and still preserved in some other words. The first 11 examples of the data in Table 5, although can support the interpretation A, in which *w* is taken as an allophone of *v*, they can also, along with examples 18 to 30, show the phonemic status of *w*, and *v* as its allophone in certain environments, because, as mentioned above, *w* appears in different environments that is in medial and final positions and open and closed syllables. It changes to *v* only when it is adjacent to an affix. Moreover, the examples 12 to 17 in Table 5, which show the free variations of *v* and *w* in different words, can also be interpreted as showing the orientation of *w* towards gradual shifting to *v/b*. These examples, together with the rest of the examples down to 30, can also argue both *w* and *v* as phonemes, for both sounds are occurring in the same environments, but with the gradual shift of *w* to *v* observed in the free variations, e.g., [ow'yo] ~ [a:v'yo] ‘Afghan’. Some data such as [de:v] ~ [de:b] ‘beast’ show the free variation of *v* and *b*, the word that was [dew] in MP and still exists in some Persian dialects (see Introduction section). Looking at the existing /w/ sound in the system of MP (MacKenzie, 1990) and changing it to /v/ or /b/, and in some cases to /g/, in NP and consequently in SD as a Persian dialect, could be taken as the evidence to show the existence of *w* and its connection and the gradual shift to *v*. However, *w* can still be found as a phoneme in the system of some genetically related languages to Persian such as Balochi and Kurdish, or as an allophone in other Iranian language varieties such as Bakhtiari language (Anonby and Asadi, 2014).

There are many words of MP in which [w] is located in different positions, and many of them reached NP, having [v] or [b] instead. Based on the changes, SD seems to be in some stages between MP and NP; there are some examples shown in Table 6:

Table 6. Gradual shift of *w* to *v* and SD in a stage between.

MP	SD	NP	English
gaw	gow	gav	‘cow’
aswar	sva:r	savar	‘rider’
dwazdah	dva:zda	davazdah	‘twelve’
rawadʒ	rava:dʒ	ravadʒ	‘current’
awaz	a:va:z	avaz	‘song’
we:wag	gi:va ~ be:va	bive	‘widow’
de:war	de:va:l ~ deva:l	divar	‘wall’
walg/warg	ba:lg	barg	‘leaf’
graw	grow	gero(v)	‘pledge’
tawan	ta:vo	tavan	‘obligation’
dʒawe:d	dʒa:ve:d	dʒavid	‘eternal’
ʃawgan	---	ʃo:gan	‘polo’
warf	barf	barf	‘snow’
wad	ba:d	bad	‘wind’
wattar	bata:r	battar	‘worse’
go:fwar	gofva:ra	gufvare	‘ear-ring’
awe:ran	ve:ro:	viran	‘ruined’

To sum up, as there has been *w*, and not a *v*, in the sound inventory of MP, it can be concluded that the *v* in NP and its dialects is descended from *w* in MP. Regarding this, it can be argued that the shift of *w* to *v* is not yet accomplished in Sistani as one of the Persian dialects. That is why there are still many words containing *w*, taken as a phoneme, in Sistani that in the time of affixation will change to *v* (as an allophone) for the case of easier pronunciation. Of course, as another possible interpretation, *v* can be taken as a phoneme (and *w* as an allophone, see Table 2) in some words, e.g., [ve:rona] ‘ruined’, in which the shift of MP *w* to *v* is accomplished; this word was written by *w* in MP: [awe:ran].

The final interpretation can be the occurrence of the gradual shift of *w* to *v* in Sistani words that is not yet

completed. By providing evidence for the existence of *w* in SD, it can somehow certify the SD as an intervallic stage between Middle and Modern Persian. It has preserved the *w* and some other features such as initial consonant clusters from the MP². In the Modern Persian, it seems that [w] in the combination [ow], which still exists in Sistani, has been disappearing mainly in the colloquial dialect, leaving a long [o:] behind, e.g. [nowruz] > [no:ruz] ‘No:ruz’, [dowlat] > [do:lat] ‘government’.

This study can be useful in reconstructing the phonological system of older Iranian languages. Etymological research can also take advantage of this kind of study and help show a shift in ancient sounds.

References

- Abolghasemi, M. (2013). *Dasture tarixiye zabane farsi*. Tehran, Samt, (in Persian).
- Ahangar, A. A. (2003). To:sif-e Dastgāh-e Vādʒi-ye Guyesh-e Sistāni, *Guyesh Shenāsi, Farbangestān-e Zabān va Adab-e Fārsi, dore-ye avval sbomāre avval*, Tehran, 4-31 (in Persian).
- Anonby, E., and Asadi, A. (2014). *Bakhtiari studies: Phonology, text, lexicon*. Acta Universitatis Upsaliensis.
- Barjasteh Delforooz, B. (1996). Dastgāh-e Vādʒi-ye Guyesh-e Sistāni, *Majalle-ye Olum-e Ensāni Dāneshgāh-e Sistān va Baluchestān, sāl-e dov-vom sbomāre 1*, Daneshgāh-e Sistan and Baluchestan, Zahedan, Iran, 112-132, (in Persian).
- Bearman, P. J., Bianquis, Th., Bosworth, C. E., Donzel, E. Van, Heinrichs, W. P. (2003). ‘Iran, iii. Languages’. *The Encyclopaedia of Islam*, 425-448. Leiden: Brill.
- Bosworth, C. E. (1997). “Sistān”. *The Encyclopedia of Islam, New Edition, Vol. IX: San–Sze*, 681–685. Leiden, and New York: BRILL.
- Burquest, D. A. (2006). *Phonological analysis: A functional approach*. Dallas: SIL International.
- Chyet, M. L. 2003. *Kurdish-English Dictionary*. Ferhenga Kurmancî-Inglîzî, New Haven: Yale University.
- Dusti, M. (2001). *Barrasi-ye To:sifi-ye Sakht Vādʒi, Tasrifî va Eshteqāqi-ye Vāzhe dar Guyesh-e Sistāni Adimi* (MA Thesis). Shiraz University (in Persian).
- Grunberg, A. L. (1963). Serstanskiy Dialekt v Serakhse. *KSINA* 67, 76-86.

² For [w] in the alphabet of MP see http://www.iranchamber.com/scripts/pahlavi_script.php, and <http://www.omniglot.com/scripts/mp/>. “MP (Pahlavi) script developed from the Aramaic script and became the official script of the Sassanian empire (224-651 AD). It changed little during the time

it was in use, but around the 5th century AD, it spawned a number of new scripts, including the Psalter and Avestan scripts”.

- International Phonetic Association. (1999). *Handbook of the International Phonetic Association*. Cambridge: Cambridge University Press.
- Korn, A. (2005). *Toward a Historical Grammar of Balochi, Wiesbaden*. Ludwig Reichert Verlag.
- Lazard, G. (1963). *Langue des plus anciens monuments de la prose Persane*. Paris. Klincksieck.
- Lazard, G. (1974). Morphology du Verbe dans le Parler Persan du Sistan, *Studia Iranica Journal*, 13, 65-85.
- MacKenzie, D.N. (1990). *A Concise Pahlavi Dictionary*. Reissue, with corrections. London: Curzon Press.
- Mohammadi Khomak, J. (2000). *Vāzhe Name-ye Sakzi (Farhang-e Loḡat-e Sistāni)*. Tehran: Soroush (in Persian).
- Okati, F. (2018). *Iranian Sistani Dialect: Practical Phonology and Comparative Analysis with Persian*. University of Zabol.
- Okati, F., Ahangar, A. A., and Jahani, C. (2009). Fronting of /u/ in Iranian Sistani. *Orientalia Suecana*, 58, 120-131.
- Okati, F., Ahangar, A. A., Anonby, E., Jahani, C. (2010). Natural Phonological Processes in Sistani Persian of Iran, *Iranian Journal of Applied Language Studies*, 2, No. 1, 93-120.
- Omranī, Gh. (1996). To:sif-e Vādži-ye Guyesh-e Sistān (ho:ze-ye markazi-ye shahr-e Zābol) I – II, *Majalle-ye Zabān shenāsi sāl-e sizdabom shomāre-ye avval va dovom*, 70-91, and 106-14, (in Persian).
- Ravaqi, A. (1985). Qor'an-e Qods, Kohantarin Bargardane Qor'an be Far-si. *Mo'assese-ye Farhangi-ye Shabid Mohammad-e Ravaqi*. Mashhad: Astane Qods (in Persian).
- Roach, P. (2010). *English Phonetics and Phonology, A Practical Course*. Cambridge: Cambridge University Press.
- Sadeghi, A. (1978). *Takvin zaban Farsi*. Tehran, University of Azad Iran, (in Persian).
- Schmitt, R. (1995). *Drangiana or Zarangiana: Territory around Lake Hamun and the Helmand River in modern Sistan*. *Encyclopadia Iranica*, 534-537.
- Seddiqi Nezhad, S. and Motallebi, M. (2018). Motale'e-ye tarikhi-ye se joft ava-ye khas dar gun-e Roudbari Ghale Ganj Kerman. *Zaban-e Farsi va guyesh-ha-ye Irani*. 3 (1), No. 5, (in Persian).
- Sepanta, S. (1998). *Āvāshenāsi-ye Fiziki-ye Zabān-e Fārsi*. Esfahan: Golha, (in Persian).
- Shahnazi, J. (2020). *Khanj, a dictionary of Sistani dialect*. Tehran: Institute for Humanities and Cultural Studies.
- Taheri, E. (2016). Rishe shenasi-ye chand vazhe-ye kohan az guyesh-ha-ye Irani. *Zaban-e Farsi va guyesh-ha-ye Irani*. 1 (1) No. 1, (in Persian).
- Weryho, J. W. (1962). Sistani-Persian Folklore. *Indo-Iranian Journal* 5, Montreal, 276-307.
- Windfuhr, G. L. (1989). New Iranian Languages. *Compendium Linguarum Iranicarum*, 246-250.
- Windfuhr, G. L. (2011). *Persian grammar*. De Gruyter Mouton.
- Zomorrodian, R. (1995). Nezam-e ava-i-ye zaban-e Farsi az kohan-tarin rozegar-an ta konon. *Majmu'e maghalat-e daneshgab-e Allame Tabatabaei*. Tehran, 83, pp. 21-26, (in Persian).

ANALYSIS OF SOIL PHOSPHATE AS A TOOL IN ARCHAEOLOGY, CASE STUDY, RIVI, NORTH KHORASAN, IRAN

Abdulmannan ROUHANI^{1✉}, Hamidreza AZIMZADEH², Ahad SOTOUDEH² and Bahman KIANI²

¹ Department of Environment, Faculty of Environment, the University of Jan Evangelista in Ústí nad Labem (UJEP), Ústí nad Labem, Czech Republic, (Corresponding author: a.rohani70@gmail.com).

² Department of Environmental Science, School of Natural Resources and Desert Studies, Yazd University, Yazd, Iran.

Received: 07 April 2021

Accepted: 01 June 2022

Available online: 20 June 2022

Abstract: Phosphate is unique among the elements in being a sensitive and persistent indicator of human occupation. It has long been of interest to archaeologists because of its potential to inform them about the presence of past human activity and to offer clues regarding the type and intensity of human occupation. In fact, the soil of settlements is part of the phosphorus reservoir. The reconstruction of the human activities areas of archaeological sites using soil phosphate analysis is a well-known technique. This study aims to identify and compare the activity area at ancient mounds of Rivi through the measurement of the quantity of phosphates in the soil. In this study, 29 soil samples were collected from the study area, and phosphorus quantity was measured using Spectrophotometry. Multivariate statistical methods were used to classify the obtained results. The results showed that the phosphorus concentrations in the ancient areas were higher than in the control area, and among the ancient areas, the phosphorus quantity related to Rivi B was higher than in other mounds. Previous studies have shown that the Rivi area has been inhabited from around 2900 years ago to the last Sassanian years (1,500 years ago), and in the middle of the Islamic age (1000 years ago), it was a great village. In total, the archaeological site of Rivi was inhabited during the Iron Age, Achaemenid, Parthian, Sassanid, and Islamic periods, and that is why there was a high concentration of phosphorus in the Rivi area compared to the control area.

Keywords: Phosphorus, Chemical Analysis of Soil, Rivi mounds, Ancient Human Activity, North Khorasan.

چکیده: فسفر در میان عناصر که نشانگر حساسیت و فعالیت‌های پایدار انسانی است، منحصر به فرد می‌باشد. باستان‌شناسان به دلیل پتانسیل فسفات در آگاهی بخشیدن به آن‌ها در مورد فعالیت‌های انسان در گذشته و ارائه سرنخ‌هایی در مورد نوع و شدت فعالیت انسانی، به مدت طولانی علاقه‌مند بوده‌اند. در واقع خاک سکونت‌گاه‌ها بخشی از مخزن فسفر است. بازسازی فعالیت‌های انسانی در مناطق باستان‌شناسی با استفاده از تجزیه و تحلیل فسفات خاک شیوه‌ای شناخته شده است. هدف از این تحقیق بررسی و مقایسه مکان‌های فعالیت در تپه‌های ریوی، استان خراسان شمالی با استفاده از آنالیز شیمیایی فسفات خاک می‌باشد. جهت انجام مطالعه ۲۹ نمونه خاک از منطقه مورد مطالعه برداشت شد و غلظت فسفر با استفاده از دستگاه اسپکتروفتومتری اندازه‌گیری شد. برای طبقه‌بندی نتایج به‌دست‌آمده از روش‌های چند متغیری آماری استفاده شد. نتایج نشان داد که غلظت فسفر در مناطق باستانی بسیار بیشتر از منطقه شاهد است و در بین مناطق داخل محوطه، مقادیر نمونه‌های مربوط به تپه ریوی B بیشتر از تپه‌های دیگر بود. تحقیقات پیشین نشان داد که محوطه ریوی از حدود ۲۹۰۰ سال پیش تا سال‌های پایانی دوران ساسانی (۱۵۰۰ سال پیش) با کاربری شهری مسکونی بوده است و در دوران میانه اسلامی (۱۰۰۰ سال پیش)، روستایی بزرگ بوده است. در مجموع محوطه ریوی در دوره‌های آهن، هخامنشی، اشکانی، ساسانی و اسلامی مسکونی بوده است. در حقیقت غلظت بالای فسفر در محوطه ریوی نسبت به منطقه شاهد به همین دلیل است.

کلمات کلیدی: فسفر، آنالیز شیمیایی خاک، تپه‌های ریوی، فعالیت‌های انسان باستان، روش آنالیز اسپکتروفتومتری، خراسان شمالی.

I. Introduction

At the beginning of the Neolithic period, humans played an essential role in changing soil properties as an important factor. Over time, the results of transformational farming activities, from natural soils to arable soils, and the direct and indirect effects of livestock, both in terms of fertilizer production and in a harmful way (overgrazing of animals), changed the physical and chemical properties of soils. These include human changes, soil erosion, changes in height and elevation to create different buildings, soil drainage, salinization of soil or the addition of organic nutrients to soil, soil compaction, etc. Studies over the past few decades have shown that human settlement, even in its short-term and temporary form, has significant effects on soil. For example, soil samples from two contemporary fishing camps in western Alaska were chemically decomposed in an archaeological study. In reviewing the results of this study, although one of the camps had been established for 30 years and the other

had been inhabited for one year, both camps showed significant traces of human contact in the soil. Different amounts of Al, Ba, Ca, Fe, K, Mg, Mn, P, Sr, Ti, and Zn were measured in each camp (Knudson *et al.*, 2004). Today, most urban dwellers may have lost their physical and emotional connection to the soil, but in the not-so-distant past, the soil was the first environment in which people worked, intervened, and lived off the soil. Increasing awareness of the importance of soil in several respects reveals the fact that soils alone are worth preserving for the future, and soils can be considered archives (Blum *et al.*, 2006). It can be argued that much of the cultural heritage is preserved in the soil, and on a much larger scale than it can be obtained by storage in museums. Soil is now crucial for human societies as well as the environment. Given that soils can easily be used as archives of information about human affairs in the past (Linderholm, 2007).

Many of the activities that we humans do remain biological and physical as time goes on. The main part

of these works is enclosed at the molecular level. Archaeologically, the soil should not be considered a discrete entity because soil (chemical) data reflects ongoing processes. Soil is a large mass that is constantly changing, but the rate of change is different. Soil information has a strong explanatory power that enables temporal interpretations of human activities and behaviors. The impact of the human environment on soil and sediments in terms of pollution is a well-known phenomenon because industrialization has intensified over historical periods and left its mark on pollution. However, humans have always stored or disposed of various materials and compounds related to their habitats for livelihood, but these early effects are not always available depending on the state of soil and sediment protection. Biological elements are in constant contact with humans and their habitats, especially phosphate, which is evident in this case. This was already the case in 1930 when iron age settlements were identified through high phosphate levels in soil phosphate mapping. With successive stages of human activity, the soil is like a manuscript on which writing is erased and rewritten (Entwistle *et al.*, 1998).

As a heterogeneous substance in nature, soil is generally a relatively complex object to study. Similarly, soils are studied in various scientific fields, such as physics, chemistry, biology, geology, soil science, geography, agriculture, forestry, and many others. For this reason, different analytical methods and techniques are used to study various soil phenomena. There are big differences in how we relate to the concept of soil due to the scientific context, and the methods of observing soil are also different: as sediment or as a growth medium for plants and organisms. Quaternary geology has a starting point in sediments and sediment formation. Soil science is dedicated to soil formation, focusing on plant-living interactions. General agricultural and forestry research is directed towards productivity, and geotechnology considers soils and sediments as building materials (Retallack, 2001). Adding archaeology to this list provides another angle from which the formation of sediments and soils must be recognized from a human cultural perspective.

Today, most studies related to soil chemical decomposition focus on phosphate groups because phosphates are a biological factor (including humans) in the sedimentary system and the concentrations and changes associated with them indicate places of human activity (Rapp and Hill, 1998). Studies show that some human activities increase soil phosphorus, while other activities reduce it or have no effect on soil phosphorus (Holliday and Gartner, 2007). Sources of phosphorus related to pre-industrial human activities include animal and human wastes, bone residues and waste, meat, fish and plants, burials, animal manures used in agriculture, and fire ash (Gurney, 1985; Farrell, 1997; Holliday and

Gartner, 2007). Therefore, it is natural that the amount of phosphate in places such as kitchens and food processing places, food storage points, slaughterhouses, stoves, cemeteries, fertile lands, stables, pastures, garbage dumps, gardens Fields, battlefields, industrial sites, passages, and routes where waste is dumped, are above normal levels (King, 2007; Farrell, 1997; Terry *et al.*, 2000). Natural phosphate levels in the soil are determined by the soil standard of each area as well as by sampling from a pristine area.

Olof Arrhenius was the first to discover the relationship between soil phosphate content and man-occupied sites. In the early 1930s, Arrhenius established a link between high levels of phosphorus and the presence of human cities and began a systematic analysis of phosphorus in soil samples. This type of analysis has become a useful tool for finding archaeological sites and research in human activity areas. The use of phosphate analysis in archaeology is possible because past human occupations and activities have increased soil phosphorus content in the regions. Phosphorus accumulated in archaeological sediments remains constant over time and can be measured through soil sampling and chemical analysis, making it a valuable tool for archaeology that can be used for many research conditions.

The application of soil phosphate analysis in archaeology can be divided into four general areas:

First: Phosphate levels are determined prior to excavation to identify archaeological sites prior to excavation, which is the most common use of phosphate analysis in archaeology.

Second: Researchers use phosphate analysis as a tool to explore specific places, such as cooking, and to help guide excavations.

Third: Phosphate analysis is used as a tool in landscape archaeology to study the location of agriculture.

Fourth: Description of characteristics and areas of activity through phosphate analysis during and after drilling (Parnell, 2001).

In general, a chemical element is only suitable for such research if it has the following characteristics:

First, human activity must have altered the natural concentration of that element in the soil of the ancient site.

Second, this change must be detectable in comparison with the normal concentration of the element.

Third, the element needs to be stabilized in a stable form in the soil (Entwistle *et al.*, 1998).

Heavy elements are naturally scarce in the soil, and their high concentrations are limited to certain minerals and activities. In the past, the most important way for heavy elements to enter the soil was to work with metals and other human activities, which play a major role in

the amount of heavy elements in the soil. Therefore, knowing the amount and type of them in this regard is very important and the results of this study can be of valuable help in archaeological studies.

II. Materials and methods

II. 1. Area of study

The study area is located in the Samalqan plain, between latitude 56 degrees and 32 minutes to 56 degrees and 49 minutes east longitude and 37 degrees and 27 minutes to 37 degrees and 37 minutes north latitude (Fig. 1). Samalqan plain is located in the west of

Bojnourd County and the southern part of the middle Atrak basin. This plain is limited to the main valley of Atrak from the north, the plain of Bojnourd from the east, the plain of Shoghan from the south, and the plain of Qarahmidan from the west and northwest. Samalqan plain is one of the second-degree catchments of the Atrak river, which has an area of more than 1148 square kilometers. This plain has also reached the national register and has a certificate. It is also located next to the Aladagh, Yaman Dagh, and Qorkhod heights (Rouhani, 2020).

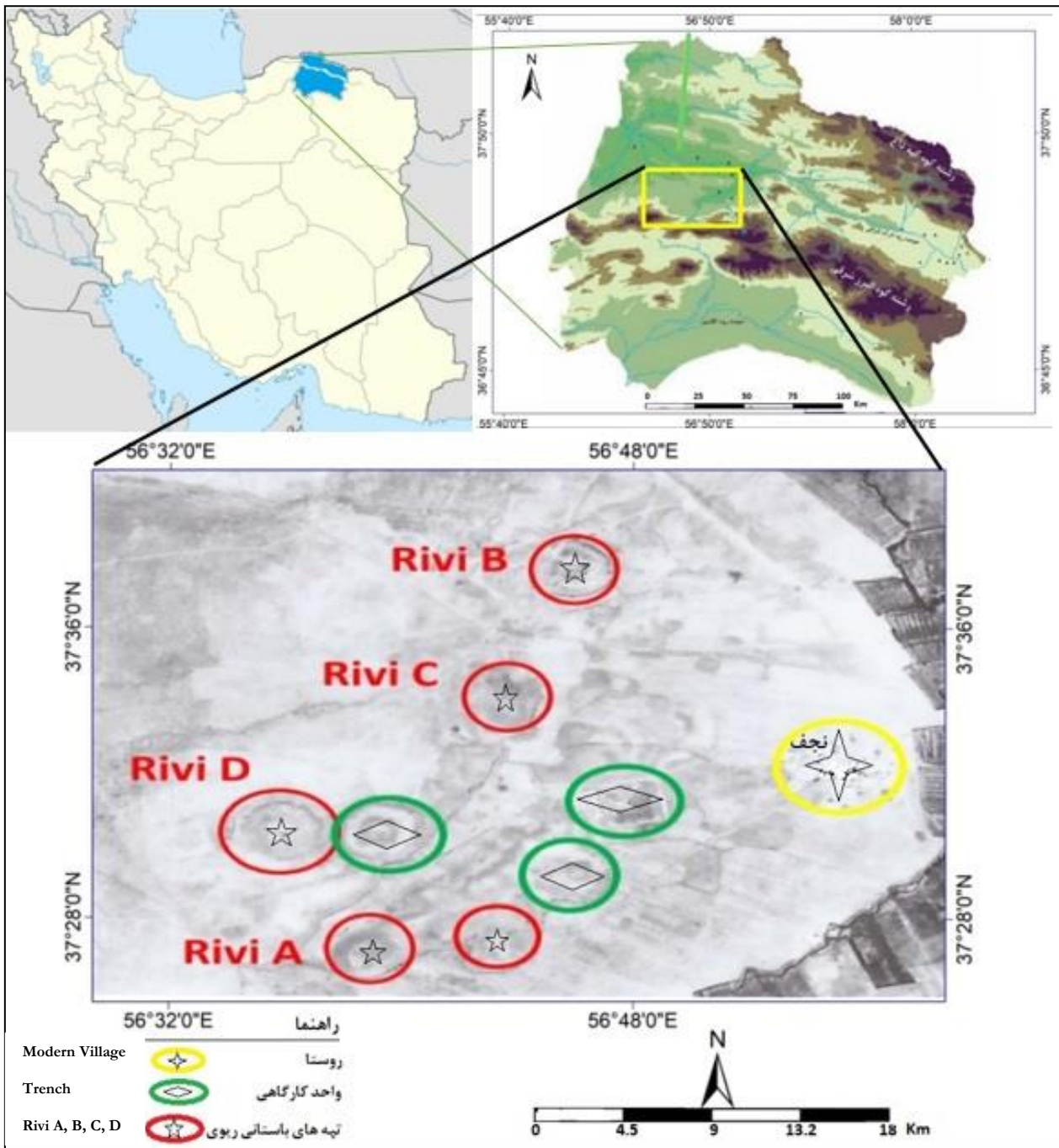


Figure 1. Location of the study area in North Khorasan and Iran.

Archaeological excavations since 2012 at the Rivi site near the village of Najaf in Maneh Va Samalqan County have uncovered the remains of a city from the Achaemenid period. Archaeological excavations in the county of Maneh Va Samalqan, which took place in 2012 and 2014 in the Rivi historical site, yielded significant results from the existence of a large historical site that has been established from about 900 BC to the late Sassanid era, about 1500 years. Its area during the Achaemenid period reached more than 110 hectares and seems to have been one of the most important cities of the Achaemenid period in the northeast of the country. According to these researches, from the Parthian and Sassanid eras, various architectural and archeological evidence have been obtained from Rivi Site, which has shown the settlement sequence in Rivi Site after the Achaemenid period. This ancient site consists of at least four hills A, B, C, and D and covers more than 110 hectares (Fig. 1) (Jafari, 2015). The central region has been damaged since the 1970s by soil collection activities of brick factories. According to satellite data, several ancient hills and features such as rectangular structures and hollow paths have disappeared over the past 40 years (Jafari and Thomalsky, 2016).

According to research conducted on this site in recent years, it was discovered.

1) Tepe Rivi B. In this map, the surface layers from zero to a depth of five meters belong to the Sassanid era (1800 to 1400 years ago).

2) Tepe Rivi A. At this point, the first meter is related to the last 500 years and from a depth of one to three meters is related to the Achaemenid period (2500 years ago).

3) Tepe Rivi D. There is a brick historical monument related to the Achaemenid period (2500 years ago), pristine and natural lower layers. In total, from the ground to a depth of 4 meters, the layers belong to the Achaemenid period and below 4 meters is virgin soil (Jafari, 2013; Rouhani *et al.*, 2021).

III. Sampling and analysis of soil samples

Soil sampling will be very important and will determine the degree of accuracy of the results obtained from the test. In this study, 29 samples were collected from 5 different areas to study and compare the changes in phosphorus concentration in soil profiles of the ancient Rivi area. In addition to the samples of Anthrosoils collected from inside the ancient site, several samples were taken as control from points located outside the ancient site with pristine soil and no ancient texture.

The purpose of collecting control samples was to compare the changes of elements in the Anthrosoil samples with the control and to measure the elemental changes outside and inside the ancient site. The classified sampling method was used to collect the samples from Rivi Site soil. This type of sampling is used when the sample units are not in the same condition. Table 1 shows the coordinates of the sampling points. To prevent contamination of the samples, tools such as brushes and stainless spatulas for collecting the samples were washed and distilled with distilled water after each sampling. The samples were poured into special plastic containers with lids, and after coding, they were transferred to the laboratory.

Table 1. Geographical location of the sampled areas.

Number	Name	Coordinate	
		Latitude	Longitude
1	Rivi A	37.34563	56.53077
2	Rivi B	37.57533951	56.88218401
3	Rivi D	37.57139356	56.87767161
4	Control	37.58231551	56.88546242

After transferring the samples to the laboratory, the samples were sieved through a 10 size 2 mm mesh sieve after drying in air. To determine the concentration, we first took 5 grams of soil, placed it in an Erlenmeyer flask, and then poured 100 ml of half a molar calcium bicarbonate. Shake the suspension for half an hour and then strain it through filter paper to obtain a clear extract. We inserted 15 ccs of the extract into a 25-laboratory flask by pipette and gently added 5cc of ammonium molybdate solution. Shake the Laboratory flask gradually to release the carbon dioxide. After this step, we added one cc of tin chloride and increased the volume of the laboratory flask to 25 ccs. We calibrated the light transmittance (I) after calibration of the standards 0.1, 0.9, 0.7, 0.3, and zero ppm at 660 nm.

Data were read by a UV-Visible model spectrophotometer (Rouhani *et al.*, 2021), and soil extraction was performed using the Olsen method (Olsen and Sommers, 1982).

In this study, statistical analysis of data was performed using SPSS 20 software, and the mean data were compared with a one-way analysis of variance, which determined the presence or absence of significant differences in the level of reliability. Duncan's test was used to compare the means.

IV. Results

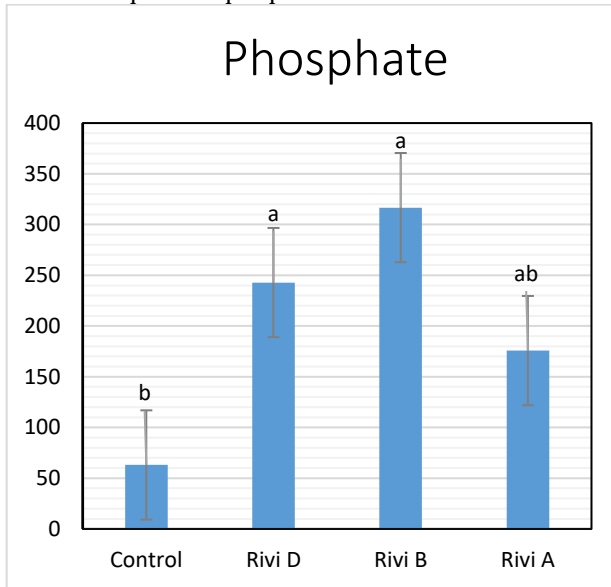
A statistical description of phosphorus concentration in the collected samples is given in **Table 2**. Its average concentration is 205.05 mg / kg. Phosphorus data were

normal according to the Kolmogorov-Smirnov test. The values obtained from the analysis of variance indicated a significant difference in phosphorus concentration in the hills of Rivi A, Rivi B, Rivi D, and the control area. The control area has the lowest concentration (63.04 mg/kg), and Tepe Rivi B has the highest concentration (316.67 mg/kg) (Table 3).

Table 2. Descriptive statistics of phosphorus concentration.

Sources of changes	Free	Average of squares	P-Value
Repeat	3	205.05	.055 ^c
Error	22	135.47	

Table 3. Comparison of phosphorus concentrations between sites.



V. Discussion

Sources of phosphorus related to pre-industrial human activities include animal and human wastes, bone residues and waste, meat, fish and plants, burials, animal manures used in agriculture, and fire ash (Gurney, 1985; Farrell, 1997; Holliday and Gartner, 2007). Therefore, it is natural that the amount of phosphate in places such as kitchens and food processing places, food storage points, slaughterhouses, stoves, cemeteries, fertile lands, stables, pastures, garbage dumps, gardens, fields, battlefields, industrial sites, passages, and routes where waste is dumped, are above normal levels (King, 2007; Farrell, 1997; Terry *et al.*, 2000).

The average phosphate concentration for the samples inside the site is much higher than the average of the control area. Undoubtedly, this significant increase in phosphorus can only be justified if we attribute it to the human impact on the soil of this hill. The lowest amount of phosphate among the samples is related to the samples in the control area. This clearly indicates a lack of human activity in such areas outside the site or at least a sharp decline. The highest

phosphate content is in Tepe Rivi B. During their research, Dr. Judith Tomalski and Dr. Mohammad Javad Jafari discovered a cemetery in this area. It is observed that the samples related to Tepe Rivi B have much more phosphate compared to Tepe Rivi A and D and the control area. Probably the main reason for this increase was the addition of human bones to the cemetery. It can be seen that the amount of phosphate in the samples taken from the site is so much that it can be stated with certainty that in these places the remnants of human activities have been added to the soil.

Phosphorus depletion may have been due to sweeping such areas immediately after the activity and cleaning them of various wastes and excreta, which ultimately prevented the stabilization and accumulation of phosphates in the soil (Wells, 2004). Such actions may prevent the deposition of organic matter residues and certain special elements in a religious building. For example, across Central America, sweeping was done primarily by women. Women have traditionally been responsible for preserving local temples in these areas, which has evoked a spiritual concept or burden for them (Wells *et al.*, 2000). The samples taken for Tepe Rivi A are from the points that have been proven during the research that these points were the royal mansion. The reason for the low concentration of phosphorus in the samples of this period could probably be due to the constant cleaning of this mansion by its crew. As a result, the accumulation and stabilization of phosphate in the soil are prevented.

VI. Conclusion

Humans can leave a geochemical artifact at an archeological site in a variety of ways. Together with other components of the biosphere, there is selective enrichment of elements in human body tissues that may lead to detectable abnormalities after death. Of the elements that are concentrated in this way, phosphorus is the most obvious. Analysis of soil samples taken from the site shows that there is a close relationship between points containing evidence of human activity and high levels of phosphorus. Some parts of the site, such as Tepe Rivi A, have low levels of elements such as phosphorus, so it can be said that in these places, there may not have been any significant activities such as cooking and food consumption, animal husbandry, industrial activities, etc., or its effects are gone. In contrast, the significant amount of phosphorus in the samples related to Tepe Rivi B indicates that certain activities such as animal and human wastes, bone waste, meat, fish and plants, burials and animal manures used in agriculture and fire ash have made in these places. Studies have shown that stoves are high in phosphate (Ryan Roth, 2002).

Soil and its formation are certainly archives, protection, and reflections of the remnants of human,

plant, and animal life, both in the present and in the past. The soil as a repository of information about cultural-natural phenomena must be protected. In natural heritage management, the focus is on conserving natural soils. "Cultural" soils, on the other hand, have received less attention. For this reason, it is suggested that the authorities prevent activities such as agriculture,

industry, etc. that cause the destruction of the site soil and do not allow agriculture in the area. Examination of phosphorus levels showed that the soil of the Rivi B site (Parthian and Sassanid period) has high amounts of P, which indicates the existence of a lot of evidence of ancient activities. It is suggested that this area be further explored.

References

- Aston, M. A., Martin, M. H. and Jackson, A.W. (1998). THE USE OF HEAVY METAL SOIL ANALYSIS FOR ARCHAEOLOGICAL SURVEYING. *Chemosphere*, Vol. 37, No. 3, 465-477.
- Aston, M. A., Martin, M. H. and Jackson, A. W. (1998). The potential for heavy metal soil analysis on low status archaeological sites at Shapwick, Somerset. *ANTIQUITY*, 72, 838-847.
- Aspinnal, A., Warren, S. E., Cmmmett, L. G. and Newton, R.G. (1972). Neutron activation analysis of faience beads. *Archaeometry*, 14, 27-40.
- Bachmann, H. g. (1982). The Identification of Slags from Archaeological sites, 37pp. *Occasional Publication No.6*. The Institute of Archaeology, London.
- Blum, W. E. H., Warkentin, B. P. and Frossard, E. (2006). Soil, human society and the environment. In Frossard, E., Blum, W. E. H & Warkentin, B. P. (Eds.). *Function of soils for human societies and the environment*. The Geological Society, London, 1-8.
- Entwistle, J. A., Dodgshon, R. A. and Abrahams, P.W. (1998). Multi-element analysis of soils from Scottish historical sites: interpreting land-use history through the physical and geochemical analysis of soil, *Journal of Archaeological Science*, 25, 53-68
- Farrell, M.P. (1997). *The garden city hypothesis in the Maya Lowlands*, PH. D dissertation, Department of Geography, University of Cincinnati.
- Gurney, D. A. (1985). Phosphate analysis of soils: a guide for the field archaeologist. *Technical Paper*, no. 3.
- Holliday, V.T. and Gartner, W.G. (2007). Methods of soil P analysis in archaeology. *Journal of Archaeological Science*, 34, 301-333.
- Hjulström, B. (2008). *Patterns in diversity: geochemical analyses and settlement changes during the Iron Age-Early Medieval time in the Lake Mälaren region, Sweden*. Edita Västra Aros.
- Jenkins, D. A. (1989). Trace element geochemistry in archaeological sites. Department of Biochemistry and Soil Science, University College of North Wales, Bangor, Gwynedd LL57 2UW, Wales.
- Jenkins, D. A. (1988). Trace element analysis in the study of ancient metallurgy. In: Ellis Jones, J. (ed.), *Aspects of Ancient Mining and Metallurgy*. Acta of B.S.A. Centenary Conference 1986, UCNW, Bangor.
- Jafari, J. (2013). The first Season of Archaeological study in Tape rivi, Samangan plain. Tehran: ICAR Unpublished Archive Report (in Persian).
- Jafari, J. (2015). The second Season of Archaeological study in Tape rivi, Samangan plain. Tehran: ICAR Unpublished Archive Report (in Persian).
- Jafari, J. and Thomalsky, J. (2016). The third Season of Archaeological Studies in Tape rivi, Samangan plain. Tehran: ICAR Unpublished Archive Report (in Persian).
- Kawahata, H., Yamashita, S., Yamaoka, K., Okai, T., Shimoda, G. and Imai, N. (2014). Heavy metal pollution in Ancient Nara, Japan, during the eighth century. Kawahata et al. *Progress in Earth and Planetary Science 2014*, 1:15
- King, S. M. (2007). The spatial organization of food sharing in early postclassic households: an application of soil chemistry in ancient Oaxaca, Mexico, *Journal of Archaeological Science*. 34, 1-16.
- Knudson, K. J., Frink, L., Hoffman, B. W. and Price, T. D. (2004). Chemical characterization of arctic soils: activity area analysis in contemporary Yup'ik Fish Camps using ICP-AES, *Journal of Archaeological Science*, 31, 443-456.
- Linderholm, J. (2007). Soil chemical surveying: A path to a deeper understanding of prehistoric sites and societies in Sweden. *Geoarchaeology*, 22 (4), 417-438.
- O'Neill, P (1993). *Environmental Chemistry*. 2nd ed. London
- Olsen, S. R. and Sommers, L. E. (1982). *Phosphorus*. In: Page, A.L., Ed., *Methods of Soil Analysis Part 2 Chemical and Microbiological Properties*, American Society of Agronomy, Soil Science Society of America, Madison, 403-430.
- Iyengar, V. and Woltitz, j. (1988). Trace elements in human clinical specimens: evaluation of literature data to identify reference values. *Clinical Chemistry*, 34, 474-481.
- Parnell, J. J. (2001). *Soil chemical analysis of activity areas in the archaeological site of Piedras Negras, Guatemala*, MSc thesis, faculty of Brigham Young University.
- Rapp, J. G. and Hill, C. (1998). *Geoarchaeology, the Earth-science approach to archaeological interpretation*, Yale University Press, New Haven and London.
- Retallack, G. J. (2001). *Soils of the past. An introduction to Paleopedology*. 2nd ed. Oxford.
- Rouhani, A. and Shahivand, R. (2020). Potential ecological risk assessment of heavy metals in archaeology on an example of the Tappe Rivi (Iran). *SN Appl. Sci*, 2, 1277. <https://doi.org/10.1007/s42452-020-3085-5>
- Rouhani, A. (2020). Hydrochemistry and quality assessment of qanat water compared to wells using laboratory studies and literature review (case study of Samalghan plain, North Khorasan, Iran). *Model. Earth Syst. Environ*, 7, 389-40. <https://doi.org/10.1007/s40808-020-01014-2>
- Rouhani, A., Azimzadeh, H. R., Sotoudeh, A., Thomalsky, J. and Emami, H. (2021). Geochemical analysis of multi-element in archaeological soils from Tappe Rivi in Northeast Iran. *Acta Geochimica*, 41, 132-146. <https://doi.org/10.1007/s11631-021-00500-3>
- Ryan Roth, L. T. (2002). *Total Phosphorus use area determination of Lucayan settlements, middle Caicos, Turks and Caicos Islands, British West Indies*, MA thesis Department of Archaeology, University of Calgary, Alberta.
- Tyleeote, R. F. (1986). *A History of Metallurgy in the British Isles*. The Institute of Metals, London.

Thomalsky, J. (2016). *Tappeh Rivi, Iran: Die iranisch-deutschen Arbeiten des Jahres 2016*. Berlin: Deutsches Archäologisches Institut.

Terry, E. R., Hardin, P. J., Houston, S. D., Nelson, S. D., Jackson, M. W., Carr, J. and Parnell, J. (2000). Quantitative Phosphorus measurement: a field test procedure for archaeological site analysis at Piedras Negras, Guatemala. *Geoarchaeology*, 15, 151-166.

Wells, E. C. (2004). Investigating activity patterns in prehispanic plazas: weak acid extraction ICP-AES analysis of

anthrosols at Classic period El Coyote, northwestern Honduras. *Archaeometry*, 46, 67-84.

Wells, E. C. (2006). Soil, human society and the environment. In Frossard, Emmanuel, Blum, Winfried E. H & Warkentin, Benno P (Eds). *Function of soils for human societies and the environment. Geological Society, London, Special Publications*, 125-132.

Wells, E. C., Terry, R. E., Parnell, J., Hardin, P. J., Jackson, M.W. and Houston, S. D. (2000). Chemical analyses of ancient anthrosols in residential areas at Piedras Negras, Guatemala, *Journal of Archaeological Science*, 27, 449-462.

A COMPARATIVE STUDY OF THE STRUCTURE AND CHEMICAL COMPOSITION OF BUFF WARE IN SHAHR-I SOKHTA WITH THE SURROUNDING SATELLITE SITES (CASE STUDY OF TEPE SADEGH), IRAN

Masoud BATER¹, Rouhollah SHIRAZI², Hossein BARKHORDAR³, and Reza BARANI³

¹ Assistant Professor, Department of Conservation and Restoration of Historical Relics, Faculty of Art and Architecture, University of Zabol, Zabol, Iran, (Corresponding author: masoud.bater@uoz.ac.ir).

² Associate Professor, Department of Archaeology, Faculty of Literature and Humanities, University of Sistan and Baluchestan, Zahedan, Iran.

³ Bachelor Graduate, Department of Conservation and Restoration of Historical Relics, Faculty of Art and Architecture, University of Zabol, Zabol, Iran.

Received: 12 April 2022

Accepted: 18 June 2022

Available online: 20 June 2022

Abstract: At the same time, with the expansion and flourishing of the ancient site of Shahr-i Sokhta in southeastern Iran in the third millennium BC, many satellite sites formed around it. Population growth, productivity boom, specialization, and the development of this ancient city led its residents to seek habitation in new and separate regions in connection with the main center of the colony; that is, Shahr-i Sokhta, to create these satellite villages around it. Thus, in the second and third periods of Shahr-i Sokhta, various satellite sites around this ancient city appeared. The most important is in the mounds of the Rud-i Biyaban in the second period of settlement in Shahr-i Sokhta. Tepe Sadegh in the southern area of Qale Rostam is one of the most significant satellite sites of the third millennium BC. Its excavations began in 2009 by the Archaeological Committee of Sistan and Baluchestan University. The result of the excavations is the discovery of remarkable and valuable cultural findings, including architectural structures, pottery, stone artifacts, metal artifacts, and statuettes. Valuable discoveries from the excavations of this ancient site indicate the depth of extensive cultural relations of this site with Shahr-i Sokhta and other neighboring historical regions. This research is done based on the data obtained from laboratory studies of buff ware obtained from the Tepe Sadegh by various instrumental methods, including X-ray diffraction (XRD) and X-ray fluorescence (XRF). A comparative study of this experimental study results with the results of the analysis of buff ware samples obtained from Shahr-i Sokhta has indicated that the pottery discovered from both areas has a very similar structure and chemical composition. It suggests that the potters of Shahr-i Sokhta and the surrounding satellite sites, such as the Tepe Sadegh, may have used the same clay deposits to produce their pottery. In addition, laboratory experiments indicate that with the establishment of specialized centers for the production of pottery products in the form of satellite sites around Shahr-i Sokhta, the quality of ceramic products in terms of construction, compared to Shahr-i Sokhta, has improved somewhat.

Keywords: Tepe Sadegh, Shahr-i Sokhta, buff ware, comparative study, X-ray diffraction (XRD), X-ray fluorescence (XRF).

چکیده: همزمان با گسترش و شکوفایی محوطه باستانی شهر سوخته در جنوب شرق ایران در هزاره سوم قبل از میلاد، در پیرامون آن، محوطه‌های اقماری بسیاری شکل گرفت. افزایش جمعیت، رونق تولیدات و تخصص‌گرایی، همزمان با توسعه این شهر باستانی، موجب شد تا ساکنان آن به دنبال اسکان در مناطق تازه و مجزایی در پیوند با مرکز اصلی این کلتی؛ یعنی شهر سوخته، این روستاهای اقماری را در اطراف آن، ایجاد نمایند. بدین ترتیب، در دوران‌های دوم و سوم شهر سوخته، محوطه‌های اقماری مختلفی در پیرامون این شهر باستانی، پدید آمد که مهمترین آنها در تپه‌های رود بیابان در دوره دوم استقرار در شهر سوخته است. تپه صادق در حوزه جنوب قلعه رستم، یکی از مهمترین این محوطه‌های اقماری در هزاره سوم پیش از میلاد است که کاوش‌های آن از سال ۱۳۸۸ هجری شمسی، توسط هیأت باستان‌شناسی دانشگاه سیستان و بلوچستان آغاز شد که دستاورد آن، کشف یافته‌های فرهنگی بسیار مهم و با ارزشی، شامل: ساختارهای معماری، سفال، اشیای سنگی، اشیای فلزی، پیکرک‌ها و غیره است. کشفیات ارزشمند حاصل از کاوش‌های این محوطه باستانی، حاکی از عمق ارتباطات گسترده فرهنگی این محوطه با شهر سوخته و سایر مناطق تاریخی همجوار است. در این پژوهش که مبتنی بر داده‌های حاصل از بررسی‌های آزمایشگاهی سفالینه‌های نخودی به‌دست‌آمده از تپه صادق به روش‌های مختلف دستگاهی، اعم از: پراش پرتوی ایکس (XRD) و فلورسانس اشعه ایکس (XRF) است؛ مقایسه تطبیقی نتایج حاصل از این پژوهش تجربی با نتایج آنالیز نمونه‌های سفال نخودی به‌دست‌آمده از شهر سوخته، نشان داده است که سفال‌های مکشوفه از هر دو منطقه، دارای ساختار و ترکیب شیمیایی بسیار مشابهی می‌باشند که احتمالاً، سفالگران شهر سوخته و محوطه‌های اقماری پیرامون آن، همچون تپه صادق از کانسارهای رسی یکسانی در تولید محصولات سفالی خود بهره می‌برده‌اند. علاوه بر این، مطالعات آزمایشگاهی انجام شده، نشان داد که با ایجاد مراکز تخصصی تولید فرآورده‌های سفالی در قالب محوطه‌های اقماری در اطراف شهر سوخته، کیفیت محصولات سفالی به لحاظ ساخت، نسبت به شهر سوخته تا حدی ارتقاء یافته است.

کلمات کلیدی: تپه صادق، شهر سوخته، سفال نخودی، مطالعه تطبیقی، پراش پرتوی ایکس (XRD)، فلورسانس اشعه ایکس (XRF).

I. Introduction

The ancient site of the Shahr-i Sokhta near Zabol in Sistan and Baluchestan province is one of the ancient civilizations in southeastern Iran. In fact, Shahr-i Sokhta is the most important ancient site of Sistan, located next to the Helmand River delta on the highest edge of the northwestern point of the old delta on the mounds of Ramrud Terrace (Sajjadi, 2003: 21). At the end of the Chalcolithic age, between 3200-4000 BC in this region,

due to the Helmand River and suitable climatic conditions, people of Indo-European descent built a large and advanced city that today is known as Shahr-i Sokhta. (Costantini, 1977: 88). The first scientific report on Shahr-i Sokhta was published by Stein in 1916 (Mortazavi, 2004: 43). In this study, Stein identified a series of ancient sites around Ramrud near the old bed of the Rud-i Biyaban, the largest of which was Shahr-i Sokhta (Tosi, 1968: 13). The first scientific archeological

excavations in this archaeological site were started by the ISMEO Archaeological Board from Italy under the supervision of Maurizio Tosi in 1967 and continued until 1978 (Sajjadi, *et al.*, 2003: 196, 271). The second round of archeological excavations in Shahr-i Sokhta began in 1997 by the Iranian Archaeological Board under the supervision of Seyed Mansour Seyed Sajjadi and continues (Seyed Sajjadi, 2006: 17).

Archaeological excavations in this area over the past few decades indicate that Shahr-i Sokhta had four different settlement periods, ranging from 3200 BC to 1800 BC. Studies conducted by archaeologists in this area are Protohistory, indicating the existence of eleven cultural layers (Tosi, 1973: 68-80). Archaeological excavations of Shahr-i Sokhta showed that this ancient city was founded in the first period (2800-3200 BC), that in the second period of its establishment (2800-2500 BC), it had achieved the peak of its development, expansion, and prosperity and that it disappeared at the end of the fourth period in 2000 or 1800 BC (Seyed Sajjadi, 2006: 17).

Continuation of archeological excavations in this ancient city by the Iranian delegation headed by Seyed Mansour Seyed Sajjadi showed that the area of this city included an area of 151 hectares (Seyed Sajjadi, 1995: 169). Archaeological excavations carried out by Italian and Iranian archaeologists over the decades have resulted in the discovery of thousands of valuable cultural finds of great diversity and richness. From this ancient city, many study pieces, including pottery, artifacts, and stone pieces from marble and lapis lazuli, have been obtained, indicating that this ancient city was a center for the production and distribution of such products (Tosi, 1978: 55). Simultaneously, with the expansion and prosperity of Shahr-i Sokhta and seeking to increase production, trade, and commerce, the cultural connections of this ancient city with neighboring and distant areas expanded. On the other hand, the population of this city also increased. Increasing the population of the city and specialization in it caused many satellite villages to appear around it (Allahpour *et al.*, 2019: 212).

Tepe Sadegh is one of the most important satellite sites of Shahr-i Sokhta, located 75 km southwest of Zabol city, near and south of Rostam Castle historical monument. This historic almost oval is located 13 km southwest of Shahr-i Sokhta and is about 6 meters high from the surrounding flat land. Various cultural finds have been obtained from the surface of this mound, including pottery, tool stone chips, stone tools, sculptures, kiln wasters, and bronze metal parts. Among these, pottery finds are more important in terms of quantity and quality (Allahpour *et al.*, 2017: 350-362).

This satellite mound of Shahr-i Sokhta was first identified by the Sistan Archaeological Board headed by Seyed Rasoul Mousavi Haji and Reza Mehr Afarin. The

initial registration and survey of this ancient mound were done by the same committee. Examination of its surface pottery showed that this place is one of the satellite villages of Shahr-i Sokhta, which was inhabited in the third millennium BC. The first chapter of archeological excavations in Tepe Sadegh began in November 2009, under the supervision of Ruhollah Shirazi and Mohammad Mehdi Tavassoli. In the following years, these excavations in the form of a training program for practical excavations courses for archaeology students of Sistan and Baluchestan University, and under the supervision of faculty members of this group, continued (Allahpour, 2011: 46).

During the excavations carried out in Tepe Sadegh by the Archaeological Board of Sistan and Baluchestan University over several seasons, different types of pottery with pastes in various colors, including buff, red, and gray, with different qualities in terms of make were obtained in a rough, medium to fine texture. Most of the pottery found from this ancient mound includes: buff ware and red and gray paste pottery are in the next ranks, respectively. The amount of gray pottery found in this satellite area of Shahr-i Sokhta is much less than that of buff and red pottery. Most of the pottery discovered from this ancient site has a medium-quality construction. These potteries can be seen in different forms, including cups, bowls, plates, pots, jars, etc., which are made by two methods: handmade and wheel-making (Shirazi, 2017).

Although most of the pottery obtained from Tepe Sadegh is of simple and unadorned type, in the category of painted pottery discovered, from different methods and techniques, such as painting, carving, augmentation, molding, and carving used to decorate them. The content of motifs used in decorating the painted pottery of Tepe Sadegh are geometric, plant, animal, and compositional motifs. The most obvious method of decoration used in the painted pottery of this ancient site is the use of the monochrome painting method, with colors, including black, red, brown, etc. In reviewing and dating the pottery finds obtained from this satellite village of Shahr-i Sokhta, in general, it can be said that most of the pottery belongs to the Bronze Age in the southern plain of Sistan with the third and fourth periods of Shahr-i Sokhta and other satellite areas. This ancient city is simultaneous (Shirazi, 2016).

Most of the studies on pottery found in the Shahr-i Sokhta focus on their historical studies, and little experimental research has been done on laboratory artifacts from this important Bronze Age site. Laboratory study by Moradi and his colleagues by XRF method on some of the pottery of the Shahr-i Sokhta in 2013 showed that limestone clay was used in the construction of the pottery of the Shahr-i Sokhta and

most of the pottery discovered from these ancient sites except a few are local (Moradi *et al.*, 2013).

Elemental analysis of the body of some of the pottery pieces of the Shahr-i Sokhta by Sarhadi Dadian and others, using the XRF method, showed that most of the buff pottery pieces are locally produced, but the red and gray pottery pieces are probably non-native and imported (Sarhadi Dadiyan, *et al.*, 2015).

Javanshah's laboratory studies by various methods of instrumental analysis including XRD, XRF, SED-EDS, and petrography on Shahr-i Sokhta pottery showed that the studied pottery was made of sandy clay that has a granular texture with a high amount of silica and is baked at 900 °C under oxidation conditions and all of them are native to the region (Javanshah, 2018).

Eftekhari and his colleagues 2021 examined several other potteries discovered in the Shahr-i Sokhta by XRF, SED-EDS, and petrographic methods. The results of these experiments showed a large number of potteries from Shahr-i Sokhta has been a matrix of fine-grained clay, among which samples of red and gray pottery are probably non-native and buff pottery is native to the region (Eftekhari *et al.*, 2021).

In this study, the bodies of a number of samples of buff ware pottery obtained from the archaeological excavations of Tepe Sadegh were examined in a comparative study with colored buff ware found in Shahr-i Sokhta by instrumental analysis. The most important issue in this study is a comparative study of the structure and chemical composition of buff ware in Shahr-i Sokhta with the surrounding satellite areas in the Bronze Age in comparison with each other. Technical developments, similarities, and differences in the structure and chemical composition of the body of these potteries can be examined and identified.

II. Materials and methods

This applied research has been done using experimental-analytical methods, in which various methods have been used to collect research information and data, such as library study, field study, and experimental methods with laboratory study. For this purpose, in this study, three pottery shards of plain buff ware obtained from Tepe Sadegh and three buff ware pots obtained from Shahr-i Sokhta excavations were selected for and for comparative study with each other (Fig. 1 and 2). It has been studied experimentally using various instrumental analysis methods, such as X-ray diffraction (XRD) and X-ray fluorescence (XRF). To know the mineralogical structure and chemical composition of the body of buff ware pottery obtained from these two ancient sites that are in deep cultural connection with each other, the results of a laboratory study of these two groups of pottery discovered from

these two ancient sites should be compared with each other. In this way, it becomes clear to us the changes, differences, and similarities in the crystal structure and phases in the pottery body of these two groups and the chemical composition of the elements in the soil used to make them, which is used as the main raw material for their production. It has been based on the use of clay obtained from local clay deposits in the area.

III. Results

The study and analysis of the body of buff ware were tested in these two areas by different methods of instrumental analysis, and the results of this study in the samples of colored buff ware discovered from Tepe Sadegh in comparison with buff ware obtained from Shahr-i Sokhta are as follows:

III.1. Appearance observations and sampling of colored buff ware

The pottery samples studied and tested in this study include three pieces of plain buff ware study belonging to Tepe Sadegh, in comparison with the three buff ware vessels discovered from Shahr-i Sokhta. The recent samples were in the form of jars and glasses (Fig. 1 and 2). The characteristics of the pottery studied in this research are presented in Tables 1 and 2 as follows. In order to study the laboratory structure and chemical composition of the elements of pottery, their bodies were sampled in a very small amount from both groups, to study and analyze the samples taken by different methods of instrumental analysis. Then, the results obtained from the analysis of the pottery body in these two ancient sites should be compared with each other.

III.2. Study of the structure of the body of pottery by X-ray diffraction (XRD) method

XRD was used for the identification of mineral phases of the sampled raw material. XRD analyses were performed on a Philips diffractometer under the following conditions: 5–60° 2 θ , radiation of CuK α 1,2 with a step scan. Samples were dried in an oven at 50°C for 1 h. After drying, each sample was pulverized manually in an agate mortar and then analyzed. To study the structure of the body of the desired clay samples and identify the constituent phases and their mineralogical composition, a very small amount of sample was taken from the body of each of the studied buff ware from Shahr-i Sokhta and Tepe Sadegh. X-ray diffraction (XRD) was tested and analyzed. The results and data obtained from the analysis of the pottery body in these two ancient sites were compared with each other based on the diffraction pattern and the phase analysis of their diffraction spectroscopy. The results of these studies are as follows (Fig. 3 and 4) (Tables 3 and 4).



Figure 1. Buffware pieces N25, N44, and N65 discovered from Tepe Sadegh.

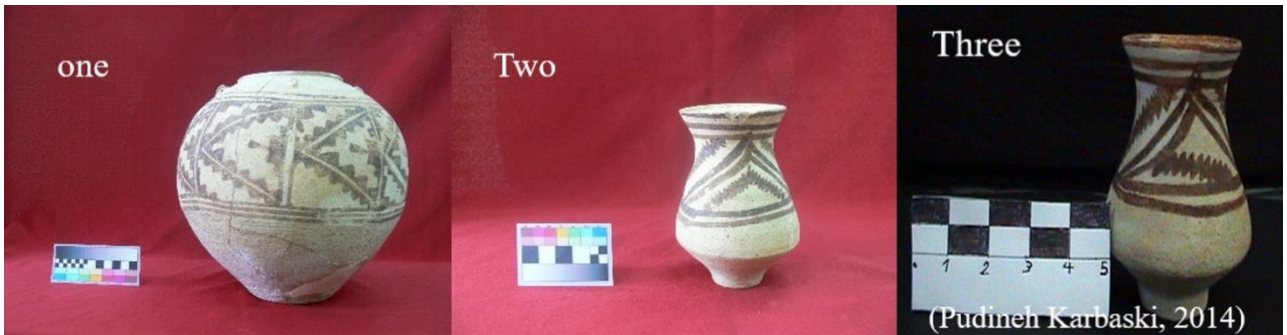
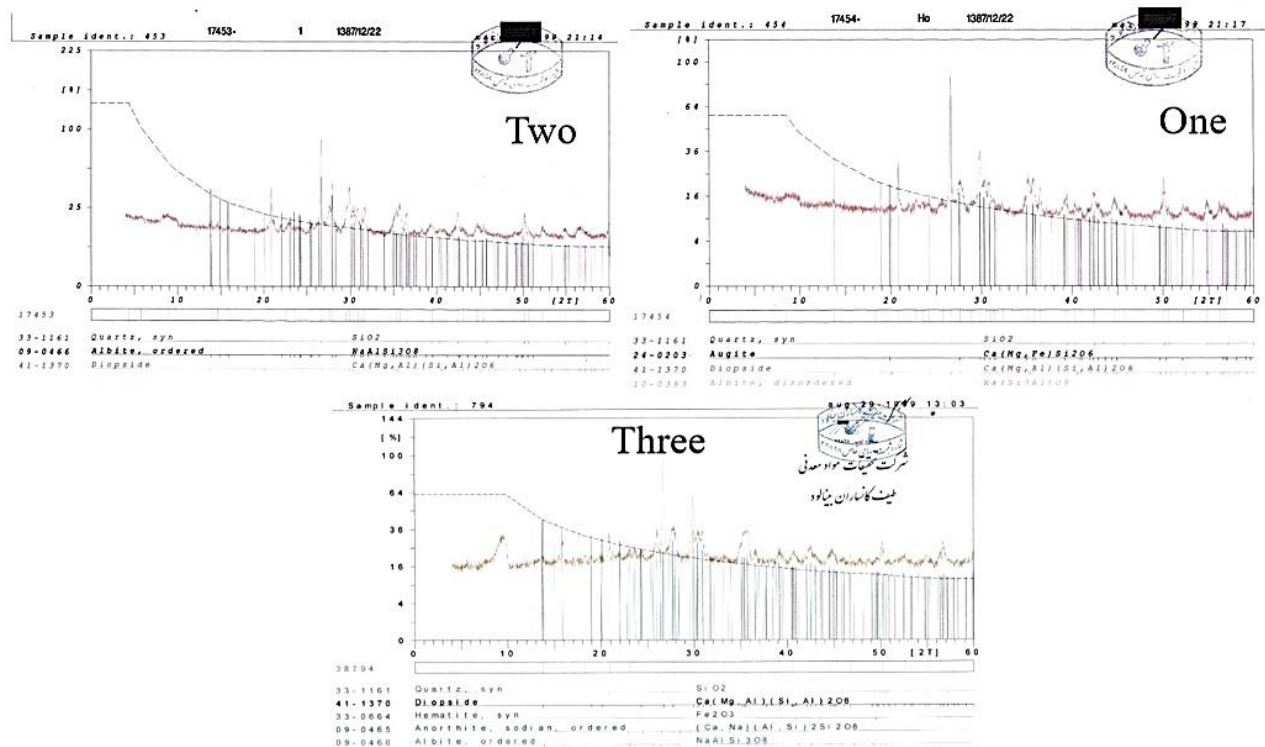


Figure 2. Buffwares number one, two, and three discovered from Shahr-i Sokhta.



(Pudineh Karbaski, 2014)

Figure 3. X-ray diffraction spectroscopy (XRD) of N25 and N65 buff ware pieces discovered from Tepe Sadegh.

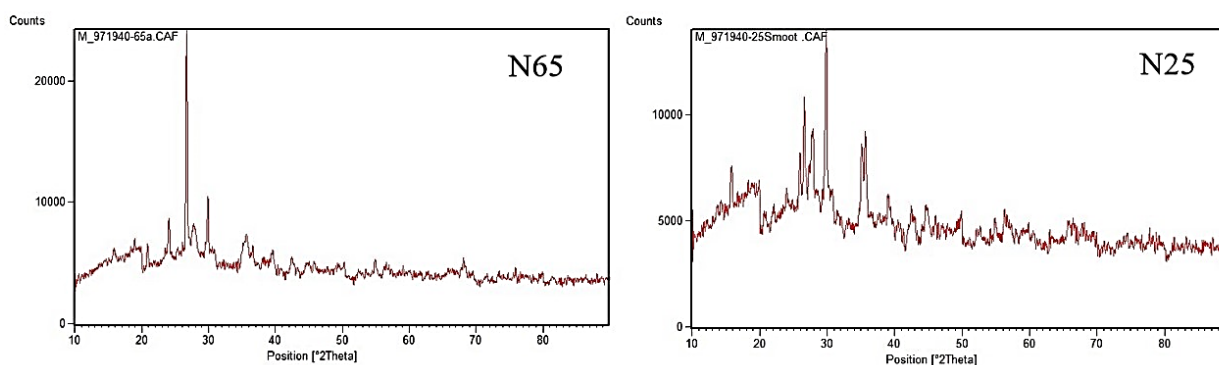


Figure 4. X-ray diffraction spectroscopy (XRD) of buff wares number one, two, and three discovered from Shahr-i Sokhta.

Table 1. Specifications of the studied buff ware pieces, discovered from Tepe Sadegh.

	Pottery piece number one	Pottery piece number two	Pottery piece number three
Pottery Code	Ts: 1396 T: 9 Su :69 N:25	Ts: 1396 T: 9 Su :6 N:44	Ts: 1396 T: 10 Su :1 N:65
Place of discovery	Tepe Sadegh	Tepe Sadegh	Tepe Sadegh
Year of discovery	2017	2017	2017
Trench code and number	T: 9	T: 9	T: 10
Layering unit	Su :69	Su :6	Su :1
Type of piece	Floor (base)	Edge (container opening)	The body of the vessel
Type of pottery	Simple buff ware	Painted buff ware	Simple buff ware
The historical period	third period	third period	third period
Dating	Bronze Age, millennium 3-4 BC	Bronze Age, millennium 3-4 BC	Bronze Age, millennium 3-4 BC
Substrate	deep	superficial	superficial
Pottery base color	buff	buff	buff
Filler type	sand	sand	sand
Forming method	Wheel maker	Wheel maker	Wheel maker

Table 2. Specifications of the studied buff ware, discovered from Shahr-i Sokhta.

	buff ware number one	buff ware number two	buff ware number three
Place of discovery	Shahr-i Sokhta Cemetery	Shahr-i Sokhta Cemetery	Shahr-i Sokhta Cemetery
Year of discovery	2006	2006	2005
Code and Trench number	MJN6700	MJN6700	MJJ
Funeral number	6703	6703	-----
Pottery shape	jar	pear-shaped cup	pear-shaped cup
Type of pottery	Painted buff ware	Painted buff ware	Painted buff ware
The historical period	First period	Second period	Second period
Dating	Bronze Age, 2900 BC	Bronze Age, 2800-2900 BC	Bronze Age, 2800-2900 BC
Substrate	deep	superficial	deep
Pottery base color	buff	buff	buff
Filler type	sand	sand	sand
Forming method	Wheel maker	Wheel maker	Wheel maker

Table 3. Results of structural study of a buff ware body discovered from Tepe Sadegh by X-ray diffraction (XRD) method.

Pottery number	Combination mineralization and identified phases	Chemical properties of phases	PDF Number Card
buff ware N25	Augite	$\text{Ca}(\text{Mg,Fe})\text{Si}_2\text{O}_6$	00-024-0203
	Diopside	$\text{Ca}(\text{Mg, AL})(\text{Si, Al})_2\text{O}_6$	01-071-1067
	Huntite	$\text{Mg}_3\text{Ca}(\text{CO}_3)_4$	00-006-0462
buff ware N65	Quartz	SiO_2	00-005-0490
	Epidote	$\text{Ca}_2(\text{Al,Fe})_3(\text{Si}_2\text{O}_7)(\text{SiO}_4)(\text{OH})_2$	00-045-1446
	Chloritoid	$\text{Al}_5\text{Fe}_7\text{Mg}_{1.2}\text{Si}_8(\text{OH})_{13.6}\text{O}_{40}$	01-072-1183
	Sodium Silicate	Na_4SiO_4	00-036-0112

Table 4. Results of a structural study of a buff ware body discovered from Shahr-i Sokhta by X-ray diffraction (XRD) method.

Pottery number	Combination mineralization and identified phases	Chemical properties of phases	PDF Number Card
buff ware number one	Quartz	SiO_2	33-1161
	Augite	$\text{Ca}(\text{Mg,Fe})\text{Si}_2\text{O}_6$	24-0203
	Diopside	$\text{Ca}(\text{Mg, AL})(\text{Si, Al})_2\text{O}_6$	41-1370
	Albit	$\text{Na}(\text{Si}_3\text{Al})\text{O}_8$	10-0393
buff ware number two	Quartz	SiO_2	33-1161
	Albit	$\text{Na}(\text{Si}_3\text{Al})\text{O}_8$	09-0466
	Diopside	$\text{Ca}(\text{Mg, AL})(\text{Si, Al})_2\text{O}_6$	41-1370
buff ware number three	Quartz	SiO_2	33-1161
	Diopside	$\text{Ca}(\text{Mg, AL})(\text{Si, Al})_2\text{O}_6$	41-1370
	Hematite	Fe_2O_3	33-0664
	Anorthite	$(\text{Ca, Na})(\text{Al, Si})_2\text{Si}_2\text{O}_8$	09-0465
	Albit	$\text{Na}(\text{Si}_3\text{Al})\text{O}_8$	09-0466

A study of the structure of a buff ware body of the Tepe Sadegh satellite site in comparison with painted buff ware obtained from Shahr-i Sokhta was studied to identify the mineral composition and phases formed in the pottery body in both groups. X-ray diffraction method showed that the phases identified in both groups of buff wares in these two areas are very similar to each other and in many cases similar. In all samples of buff ware studied, quartz, augite, and diopside minerals are the same, and the other identified phases are similar in terms of chemical composition and the classification of crystalline structure and are in the group of silicate minerals (Tables 3 and 4).

III.3. Analysis of the composition of pottery body elements by X-ray fluorescence (XRF) method

The samples were cut, pulverized, pressed into powder pellets, and analyzed by X-ray Fluorescence Spectroscopy. Loss on ignition (LOI), which is a measure of the content of carbon dioxide and any other volatile components, including organic materials, was determined by weighing the samples before and after heating at 1000°C.

Using the X-ray fluorescence (XRF) method, the results of qualitative and quantitative analysis of the chemical composition of the elements in the body of

buff ware of Tepe Sadegh in comparison with the samples of buff ware discovered from Shahr-i Sokhta, indicated that the chemical composition of the body buff ware in both ancient sites have many similarities in comparison with each other, both qualitatively and quantitatively, is very close to each other. The amount of SiO_2 silica in Tepe Sadegh buff ware is between 55.3 to 55.7% by weight, and in Shahr-i Sokhta, this amount in the body of the buff ware tested is 46.75 to 51.5%.

The amount of alumina in the body of Tepe Sadegh buff ware is 14.3% to 15.5%, and in similar pottery in Shahr-i Sokhta, the amount of alumina is 8.64% to 11.99%. Similarly, the amount of iron oxide in Tepe Sadegh buff ware is 5.4 to 6.7 percent, and in Shahr-i Sokhta is 4.98 to 5.58 percent (Tables 5 and 6).

On the other hand, the composition and amount of fluxes used in the body of pottery of Tepe Sadegh and Shahr-i Sokhta, including calcium oxide, sodium oxide, and magnesium oxide, were studied. They are very similar to each other, and the percentage of their presence in the pottery samples of the two areas is close, so that the amount of calcium oxide in Tepe Sadegh pottery is 9.5% to 16.1%16.1%, and in Shahr-i Sokhta buff ware, the amount of this important flux is 10.70% to 14.04%. Magnesium oxide is 3.5 to 9.3 percent in Tepe Sadegh buff ware, and 6.69 to 9.67 percent in the body of Shahr-i Sokhta buff ware. The amount of these

compounds in both groups of pottery obtained from these two areas is similar to each other (Tables 5 and 6).

The situation is similar for other compounds in the body of buff ware in these two ancient sites in comparison with each other, such as different impurities like titanium oxide, sulfur oxide, barium, strontium, and chlorine (Tables 5 and 6).

Overall, due to the diffraction measurement and mineralogical composition of the studied pottery, the

findings of the analysis of the buff ware body obtained from these two Bronze Age archeological sites in comparison with each other are in good agreement.

It was shown that the composition of the body of buff ware discovered from the satellite village of Tepe Sadegh is similar to the buff ware obtained from Shahr-i Sokhta in terms of the chemical composition of the elements that make up the body.

Table 5. Results of elemental analysis of the body of buff ware discovered from Tepe Sadegh by X-ray fluorescence (XRF) method.

Pottery sample	Pottery number one N:25	Pottery number two N:44	Pottery number three N:65
Na ₂ O	1.7	1.6	1.3
MgO	5.3	8.6	9.3
Al ₂ O ₃	15.5	14.3	14.5
SiO ₂	51.3	54	55.7
P ₂ O ₅	0.30	0.24	0.36
SO ₃	---	0.34	---
Cl	0.096	0.054	0.048
K ₂ O	0.13	0.25	0.36
CaO	16.1	12.9	9.5
TiO ₂	0.53	0.48	0.44
MnO	0.025	0.024	0.024
Fe ₂ O ₃	6.7	5.5	5.4
SrO	0.017	0.026	0.031
BaO	0.010	0.013	0.017
LOI	1.90	1.51	2.75

Table 6. Results of elemental analysis of the body of buff ware discovered from Shahr-i Sokhta by X-ray fluorescence (XRF) method.

Compound	Pottery number one (wt.%)	Pottery number two (wt.%)	Pottery number three (wt.%) (Pudineh Karbaski, 2014)
Na ₂ O	1.64	3.69	3.76
MgO	8.66	9.67	6.69
Al ₂ O ₃	10.32	8.64	11.99
SiO ₂	50.62	46.75	51.05
P ₂ O ₅	1.36	0.43	0.33
SO ₃	0.32	2.45	0.98
Cl	0.10	0.93	0.058
K ₂ O	2.07	2.69	1.48
CaO	14.04	13.46	10.70
TiO ₂	0.47	0.45	0.54
MnO	0.09	0.10	0.10
Fe ₂ O ₃	4.98	4.99	5.58
SrO	0.071	0.043	0.015
BaO	0.036	0.024	0.030
LOI	5.16	5.62	6.64

IV. Discussion of research findings

The results of the analysis of the structure and chemical composition of buff ware discovered from the satellite site of Tepe Sadegh in comparison with the colored buff ware obtained from Shahr-i Sokhta indicate the similarity of the structure and chemical composition of the body of buff ware in both archaeological sites. The presence of similar and identical phases in the body of buff ware in both sites, as well as the very similar chemical composition in terms of the composition of the constituent elements in terms

of quality and quantity, indicate that probably in both ancient sites of the same clay deposits to supply soil used to make buff ware in the Bronze Age. The use of similar resources and raw materials in supplying the soil used to prepare pottery clay in both areas has caused after firing pottery products in the body of buff ware in both Tepe Sadegh and Shahr-i Sokhta areas, the presence of mineral compounds is the same, such as quartz, augite, diopside, and other silicate minerals.

On the other hand, the study and elemental analysis of the chemical composition of the pottery body also

showed that the amount of important and main chemical compounds and elements in the pottery body in both groups of buff ware in these two ancient sites are very similar to each other. In addition, the study of the crystal structure of the Tepe Sadegh pottery body in comparison with the samples of Shahr-i Sokhta shows that the quality of construction and firing of pottery and soil used have changed to some extent in the pottery of Tepe Sadegh.

As the results of diffraction analysis of pottery bodies have shown, in the mineralogical composition of Tepe Sadegh buff ware in comparison with Shahr-i Sokhta samples, although the same phases with similar chemical composition and crystal structure are observed, in Shahr-i Sokhta buff wares, there is a lot of scattering in the type of phases in the pottery body of this ancient site. That is why in the body of these potteries we are faced with the multiplicity of crystalline phases in their diffraction spectrum. On the other hand, the study of the composition of the elements that make up the body of buff ware in these two areas in comparison with each other also shows the same thing. The amount of silica in the Tepe Sadegh pottery body has been increased to 55%, which results in combination with various flux compounds found in the pottery body of this area, especially calcium oxide in the pottery body, which causes better durability and strength of the product body.

In addition, according to the results of the analysis of the pottery body, in these two ancient sites comparison, the amount of alumina in the pottery body of Tepe Sadegh is slightly higher than in the samples of Shahr-i Sokhta. Therefore, in Tepe Sadegh, we encounter an increase of about 3.5% in the amount of alumina in the pottery body. The percentage and amount of alumina in the pottery body are directly related to the clay minerals in the pottery body. One of the effective factors is soil quality and processing of pottery, according to the results obtained in the samples of buff ware analyzed in Tepe Sadegh. The amount of this compound is more and higher than the amount of aluminum in the samples of buff ware discovered from Shahr-i Sokhta. This shows that the quality of pottery in this area has improved somewhat compared to the colored buff ware of Shahr-i Sokhta. Examination of the number of important impurities in the body of pottery, such as sulfur, manganese, and chlorine, also indicates that the amount of impurities in the body of colored buff ware, in the samples obtained from Tepe Sadegh in comparison with the buff ware of Shahr-i Sokhta, has been reduced to some extent. Conversely, the amount of main and important compounds

influencing the formation of the crystal structure of pottery has increased in Tepe Sadegh buff ware, which has caused the quality of buff ware in Tepe Sadegh compared to similar pottery of Shahr-i Sokhta to improve a little.

V. Conclusion

Experimental and structure studies of the chemical composition of the elements forming the body of buff ware in the Tepe Sadegh satellite area in comparison with similar pottery samples discovered from Shahr-i Sokhta from the Bronze Age were done. Different laboratory methods, such as X-ray diffraction (XRD) and X-ray fluorescence (XRF) in comparative comparison with each other, indicate that due to the great similarity due to the presence of the same crystalline phases in the body of buff ware in both areas. The chemical composition is relatively the same as the results of elemental analysis of the body of both pottery groups. In both archeological sites, natural and native clay mines and deposits of the region, which were probably the same and close to each other, were used to supply the soil used to make colored buff ware. On the other hand, there are slight differences in the composition of the body and the type of minerals formed in the body of the two groups of buff ware obtained from these two areas. It has been shown that the body of buff ware obtained from Tepe Sadegh has probably been slightly changed in terms of processing, firing, use of raw materials, and additives for making pottery products, in comparison with Shahr-i Sokhta pottery.

As a result, the quality of pottery products in this area has slightly improved. Therefore, it seems that according to the results of laboratory studies performed on the body of the samples of buff ware studied in these two ancient sites, by establishing specialized centers for the production of pottery products in the satellite areas of Shahr-i Sokhta, such as Tepe Sadegh, the quality of these products has also slightly enhanced due to the more specialized pottery profession in these satellite villages compared to Shahr-i Sokhta. Of course, it is clear that a definite statement on this issue requires further laboratory studies.

Acknowledgments

In writing this article, the support of the University of Zabol in the grant of research has been used with the code IR-UOZ-GR-7987, by which the Vice-Chancellor's research and technology of the university are thanked and appreciated.

References

- Allahpour, A. (2011). *Classification and typology of pottery of the first chapter of Sadegh mound of Sistan excavation*. Unpublished: University of Sistan and Baluchestan, Master Thesis, (in Persian)
- Allahpour, A. Tavassoli, M. M. and Shirazi, R. (2017). Study of cultural relations of satellite sites of Shahr-i Sokhta based on the results of typological comparisons of pottery data (case study of Sadegh mound). *the third national conference of Iranian Archaeology*, November 2017, University of Birjand, (in Persian).
- Allahpour, A., Rustaei, M. S. and Fallah Mahneh, M. (2019). Study of cultural relations of satellite sites of Shahr-i Sokhta with Baluchistan, Pakistan based on comparative comparisons of pottery data (Sadegh mound case study), *the first biennial national conference on archaeology and art history of Iran*, May 11 and 12, 2019, University of Mazandaran, (in Persian).
- Costantini, L., (1977). Wood remains from Shahr-i Sokhta: a source of information for the ancient environment and technology in protohistoric Sistan. *In South Asian Archaeology*, pp. 87-121.
- Eftekhari, N., Holakoei, P., Marrocchino, E. and Vaccaro, C., (2021). To be or not to be local: a provenance study of archaeological ceramics from Shahr-i Sokhta, eastern Iran. *Archaeological and Anthropological Sciences*, 13(4), pp.1-13.
- Javanshah, Z., (2018). Chemical and mineralogical analysis for provenancing of the Bronze Age pottery from Shahr-i-Sokhta, southeastern Iran. *Scientific Culture*, 4(1), pp.83-92.
- Moradi, H; Sarhaddi Dadian, H; Ramli, Z and Rahman, A., (2013). Compositional analysis of the pottery shards of Shahr-I Sokhta, South Eastern Iran. *Research Journal of Applied Sciences, Engineering and Technology*, 6(4), pp.654-659.
- Mortazavi, M. (2004). *Systems Collapse: A Comparative Study of the Collapse of the Urban Communities of Southeast Iran in the Second Millennium BC*. Unpublished: University of Bradford. PhD.
- Pudineh Karbaski, F., (2014), *Restoration and protection of three buff wares in Shahr-i Sokhta*. Unpublished: Zabol University. Undergraduate Thesis, (in Persian).
- Sarhadi Dadiyan, H., Pourzarghan, V., Moradi, H. and Razani, M., (2015). Traces of Indigenous Buff Pottery Industry of Shahr-I Sokhta; Using Semi-Quantitative Analysis of Elements XRF. *Journal of Research on Archaeometry*, 1(1), pp.47-54, (in Persian).
- Seyed Sajjadi, S. M., (1995), *Archaeology and History of Balochistan (Eight Speeches)*. Tehran: Cultural Heritage Organization, (in Persian).
- Seyed Sajjadi, S. M., (2006). *Shahr-i Sokhta, a large laboratory in a small desert*. Zahedan: cultural heritage and tourism base of Shahr-i Sokhta, (in Persian).
- Sajjadi, S. M. S., Foruzanfar, F., Shirazi, R., & Baghestani, S., (2003). *Excavations at Shahr-I Sokhta. First Preliminary Report on the Excavations of the Graveyard, 1997-2000*. Iran, 21-97, (in Persian).
- Shirazi, R. (2016). *Report of the sixth chapter of excavation in Sadegh mound*. Unpublished: Zahedan, University of Sistan & Baluchestan, Faculty of Literature and Humanities, Department of Archaeology (in Persian).
- Shirazi, R. (2017), *Report of the seventh chapter of excavation in Sadegh mound*. Unpublished: Zahedan, University of Sistan & Baluchestan, Faculty of Literature and Humanities, Department of Archaeology (unpublished), (in Persian).
- Tosi, M., (1968). *Excavations at Shahr-i Sokhta, a Chalcolithic settlement in the Iranian Sistan*. preliminary report on the first campaign, October-December 1967. *East and West* 18 (1/2): 9-66.
- Tosi, M., (1973). *The Cultural Sequence of Shahr-i Sokhta*. *Bull. Asia Instit. Pahlavi Univ.*, 3: 64-80.
- Tosi, M., (1978). The development of urban societies in Turan and the Mesopotamian trade with the East: the evidence from Shahr-i Sokhta. *Mesopotamien und seine nachbarn: politische und kulturelle wechselbeziehungen im alten vorderasien vom 4. bis 1. Jahrtausend v. Chr.*, Bd 1, pp. 57-77.

ARCHAEOLOGICAL STUDY OF MINES AND METAL SMELTING FURNACES IN THE CENTRAL DISTRICT OF SARBISHEH COUNTY - SOUTH KHORASAN, IRAN

Ali ZAREI^{1✉}, Mohammad FARJAMI² and Ali Asqar MAHMUDI NASAB³¹ Department of Archaeology, University of Birjand, Birjand, Iran, (Corresponding author: azareie@birjand.ac.ir).² Expert of the General Administration of Cultural Heritage, Handicrafts and Tourism of South Khorasan, Iran.³ Ph.D. in Islamic Archaeology, University of Mazandaran, Iran.

Received: 09 April 2022

Accepted: 10 June 2022

Available online: 20 June 2022

Abstract: The eastern and southeastern regions of Iran have long been of great importance due to the existence of metal mines. Although new research has been conducted in recent years on geology and mining, little research has been done on the site's ancient mines. In 2013, an archaeological survey in Sarbisheh County identified a number of mines and metal smelting furnaces. These historic sites are located in the central district of Sarbisheh County in the southern part of the county and in places called Koohakrud, Mesgaran, and Kasrab. In all, nine mines and three metal smelting furnaces were discovered, the largest of which is located in the Koohakrud area, 25 km south of Sarbisheh. The purpose of this research is to introduce the mines and study sites in the central district of Sarbisheh County, how to extract ores, and how to melt metals. In this regard, questions have been raised about the period of mines and metal extraction furnaces. What metal is the most extracted metal and how was the metal extraction method done? Mineral fragments from all these mines and a large amount of slag from the furnaces, and in some of these mines, clay finds have been obtained. The dating of identified mines is very difficult due to the lack of data. However, according to the cultural materials obtained from around these mines and furnaces, the Middle Ages to the late Islamic Middle Ages can be considered for these sites. According to the evidence of metal smelting, the most common mineral used in smelted rocks is copper, and the method of extracting metal mines has been surface and underground mining. The research method in this research was descriptive-analytical, and data collection has been done in a field and library method.

Keywords: Sarbisheh County, Ancient Mines, Metal Smelting Furnaces, Copper, Pottery.

چکیده: مناطق شرقی و جنوب شرقی ایران به دلیل داشتن معادن فلزی از گذشته تاکنون از اهمیت زیادی برخوردار بوده است. هر چند در سالهای گذشته تحقیقات جدیدی در زمینه زمین شناسی و معادن انجام شده است، با این وجود در رابطه با معادن باستانی این منطقه تحقیقات اندکی صورت گرفته است. در بررسی باستان شناسی شهرستان سریشه در سال ۱۳۹۲ تعدادی معدن و کوره ذوب فلز شناسایی شد، این آثار در بخش مرکزی شهرستان سریشه در منطقه جنوبی شهرستان و در مکان هایی به نام کوهک رود، مسگران و کسراب واقع شده اند. در مجموع، از این بررسی ها، نه معدن و سه کوره ذوب فلز کشف گردید که بزرگترین این کوره ها و معادن در منطقه کوهک رود در ۲۵ کیلومتری جنوب سریشه واقع شده است. هدف از انجام این تحقیق معرفی معادن و محوطه های مورد مطالعه در بخش مرکزی شهرستان سریشه، نحوه برداشت و استخراج کانسار و شیوه ذوب فلزات است. در این راستا پرسش هایی مطرح شده اینک معادن و کوره استخراج فلزات مربوط به چه دوره ای است؟ و فلز مورد استخراج بیشتر چه فلزی بوده و شیوه استخراج فلزات به چه شکل انجام می شده است؟ از تمامی این معادن، قطعات سنگ های معدنی و از کوره ها، حجم بسیار زیاد سرباره و در تعدادی از این معادن یافته های سفالی نیز به دست آمده است. تاریخ گذاری معادن شناسایی شده به دلیل کمی داده ها بسیار مشکل است. ولی با توجه به مواد فرهنگی به دست آمده از اطراف این معادن و کوره ها، می توان قرون میانی تا متأخر اسلامی را برای استخراج و ذوب فلز در این محوطه ها در نظر گرفت و با توجه به شواهد ذوب فلزات بیشترین کانی مورد استفاده در سنگ های ذوب شده فلز مس است. نحوه استخراج معادن فلزات به صورت معدن روباز و زیرزمینی بوده است. روش تحقیق در این پژوهش، از نوع توصیفی-تحلیلی و جمع آوری اطلاعات به شیوه میدانی و کتابخانه ای انجام شده است.

کلمات کلیدی: شهرستان سریشه، معادن باستانی، کوره های ذوب فلز، مس، سفال.

I. Introduction

The antiquity of civilization in Iran and its richness in terms of mineral reserves are the main reasons for the growth of mining and metal smelting in this part of the world (Momenzadeh, 2005). The first metals used by humans were not obtained by mining or smelting ore but existed in pure form in nature and formed pure metals by hot and cold hammering techniques (Vatandoust, 2000: 2). The first known metals in nature were gold, copper, silver, and iron. The small amount of metal that was naturally available to humans and the intensification of the need for metal products caused a great change in the art and industry of metalworking, and this revolution occurred in the smelting of mineral

copper ore in Iran in the late fifth millennium BC (Talaie, 2002: 548; Vatandoust, 2000: 2; Oudbashi et.al: 2012: 157; Nezafati, et.al, 2008: 3). Copper is one of the most useful and probably the first metal used to make various tools and objects. The first use of this metal in the Middle East and the plateau of Iran dates back more than ten thousand years ago (Oudbashi et.al: 2012: 157). The first use of copper to make tools in Iran is from a Neolithic site in southwestern Iran and the Dehloran plain called Ali-Kosh, for which the date of the late eighth and the early seventh millennium is considered (Oudbashi et al., 2012: 157). From the surviving artifacts, it is inferred that miners in ancient Iran

crushed and then melted pure natural copper (hammer copper) and oxidized copper, which were mostly found on the surface of the earth. They did not know how to melt sulfur ores, so in dealing with such mines, they would abandon their extraction. These show that the regions of northern Azerbaijan, Shiraz, Baluchistan and southern Khorasan, Mashhad, Sabzevar, Kerman, Anarak region, the Karkas mountains of Kashan, and Alborz have been the oldest sources of copper (Faizi, 2003: 26). In ancient times, in the early stages, oxide, and carbonate minerals were first used and exploited, and early miners used ores that were close to the ground (Hojabari Nobari and Mazaheri, 2005: 7). Geologists believe that most of the ores that are known today and the mines that are known as active mines today have the type of minerals known and used in the ancient world (Vatandoust, 2000: 2; Momenzadeh, 2003: 1). In fact, they have been identified by tracing mining artifacts and smelting ancient metals. This is especially true in countries such as Iran (Momenzadeh, 2002: 7; Momenzadeh, 2003: 5). The existence of natural copper deposits in a very high amount in different parts of the country has led to the development and advancement of metallurgy in different periods. One of these important sources of copper in the southern region of Khorasan is the Ghale Zari¹ copper deposit, which has also been used as an ancient mine (Vatandoust, 2000: 2). Based on the evidence obtained, smelting of copper ores to obtain copper was first performed in 3500 BC in Ilam and northeast of the Euphrates Valley (Faizi, 2003: 26). Among the ancient mineral resources used by ancient metalworkers, the two most important mines are Ghale Zari in South Khorasan and Vashnove between Qom and Kashan, 45 km from Tepe Sialk (Chegini *et al.*, 2000: 281).

Not much research has been done so far on the study of mineral extraction from ancient mines and the smelting of these minerals in the eastern regions. Although new research has been done in the field of geology and mining in recent years, little research has been done on the site's ancient mines. The Sarbisheh County archaeological survey, which was conducted for two months in June and July 2013, aimed to study the pattern of dispersal and spatial distribution of human settlements in the Sarbisheh site. The purpose of this research was to study the pattern of dispersal and spatial distribution of human settlements in the Sarbisheh region, and many ancient mines and smelting furnaces (Shaddadi) were discovered. Most of these furnaces and metal mines have been identified 25 km south of Sarbisheh. Among the nearly 250 results identified, three metal smelting furnaces and nine copper mines have been identified. According to the sampling done

by the Industry, Mining, and Trade Organization of the province in the mines of this place, the mines of this region have a very high percentage of purity (grade). In addition to this county, this mineral vein extends to Tabas, Nehbandan, and Khouf counties, which is connected to the mineral masses in the Nayband region (Se Changi - Dayhuk section of Tabas county) and Ghale Zari (Khouf). In addition to this county, this mineral vein extends to Tabas, Nehbandan, and Khouf counties, which is connected to the mineral masses in the Nayband region (Se Changi - Dayhuk section of Tabas county) and Ghale Zari (Khouf). In this research, the history of ancient mining activities in the southern region of Khorasan, the introduction of the most important mines and smelting furnaces in Sarbisheh County, as well as methods of metal extraction in the past have been discussed. Sarbisheh County is an unknown site for mining archeology despite its high potential compared to other parts of Iran. For this reason, the identification of these sites is important from the economic, technical, and technological points of view used and the sustainability of the ecosystem. Archaeological studies at ancient mining and smelting sites also increase our knowledge of the process of mineral ores extraction and smelting.

II. Research Methods

Data collection in this research has been done in the form of library studies and archaeological field studies. Historical and geological books and reports of archaeological studies of the region have been used in library studies. Field studies and surveys include mapping, photography, identification of sites and mines and determining the site and type of mines, identification of smelting furnaces, and finally simple random sampling of the studied data such as pottery documents and slag.

III. Research background and mining activities in South Khorasan

Ancient Iranian copper mines exist in the layers of the Tertiary geological period and Ahar, Tarom, Hashtajin, Central Iran, Kerman, and the regions of Eastern Iran. The accumulation of copper, tin, tungsten, and gold in pre-Cretaceous metamorphic Pluto sites, although not known to modern miners, has been widespread since ancient times. Chah Kelap and Chah Chahar Nafari in the triangular site of Mokhtaran, Sahlabad, and Basiran in the south of Birjand (eastern Iran) are two examples of the accumulation of copper, tin, tungsten, and gold, which were also known in ancient times. Ancient mining activities focused on the contrast of the metamorphic Paleozoic schist and

¹ Ghale Zari means castle attributed to gold (Momenzadeh, 2006: 17).

marble complex. Some slag massifs (20 km from Basiran and other places) indicate ancient mining and metalworking activities at this site. Geochemical studies by the Geological Survey show anomalies in Shahkooh, southeast of the Ghale Zari mine in eastern Iran. These sites and southwest of Arak are the places that are the most important sites for archaeological studies to discover the main source of raw materials for bronze production. In these mines, several rows of ancient carvings have been done in opposition to two units of metamorphic carbonate and schist in the metamorphic rock complex (Momenzadeh, 2004: 13; Momenzadeh, 2006: 17). Ebn-e Hoghal has mentioned the existence of copper mines in the Islamic period in the Khorasan region (Ebn-e Hoghal, 1966: 169) and Hamdollah Mostofi has considered copper mines in most parts of Iran (Mostofi, 1983: 203) and iron mines in different parts of Iran, including Khaf Quhestan (*Ibid.*, 202). Moghadasi also mentions mummy, wire, and gold mines in the Quhestan region (Moghadasi, 1982: 594). Among other research works in South Khorasan province, we can refer to “Archaeological researches of ancient mines in South Khorasan, a case study of discoveries of ancient metal smelting centers of Nehbandan”, (Hashemi Zarajabadi and Taghavi, 2012), “Archaeological study of Shousf Nehbandan section, the introduction of metal smelting centers”, (Hashemi

Zarajabadi, 2013), "Archaeometallurgical and ancient mining research in South Khorasan (based on archaeological studies and petrographic experiments)," (Beigi Herchegani *et al.*, 2015) “Archaeological Research of Metal Smelting in Eastern Iran: A Case Study of the Mesgaran Site of One of the Largest Metal Smelting Workshops in South Khorasan,” (Hashemi Zarajabadi *et al.*, 2016), “Archaeological study of ancient metalwork sites in northeastern South Khorasan Case study: Zirkouh region.

Master Thesis in Archeology,” (Qasemnejad *et al.*, 2017), and “Research on ancient metal mining and smelting activities in Khouf county, South Khorasan,” (Nikzad *et al.*, 2018).

IV. Geographical and geological features of Sarbisheh County

Sarbisheh County is located between Darmian and Birjand in the north, Nehbandan in the south, Khouf in the west, and Afghanistan in the east (Fig. 1). In terms of geographical coordinates of this county is located between the coordinates 59 degrees and 13 minutes to 60 degrees and 53 minutes east longitude and 32 degrees and 02 minutes and 32 degrees and 56 minutes north latitude (Statistical Yearbook of South Khorasan Province, 2010: 46).

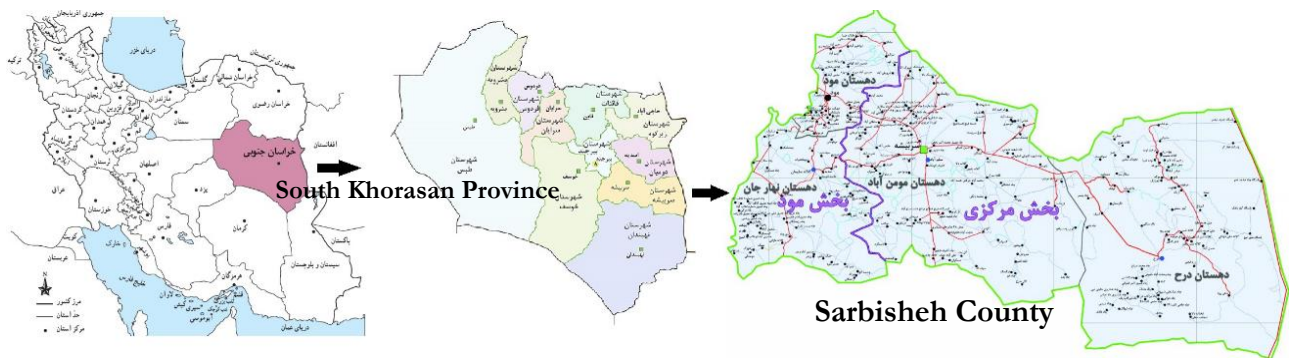


Figure 1. Location of South Khorasan Province in the map of Iran and Sarbisheh County in South Khorasan Province (by Authors).

From the point of view of topography and geology, the scope of this study leads from the east to the low-lying plains of eastern Afghanistan, including Daq-e Tondi, Dasht-e Na’omid, Dasht-e Atashkhaneh, and Dasht-e Chah-e Gandeh. These sites are at the end of the Farah catchment area. These lands do not seem to have been inhabited by human groups in different historical periods due to unsuitable soil and special climatic conditions, because the research is done in this region only revealed tin and copper smelting furnaces in the south of Shindand (Sabzevaran) and northwest of Farah (Cleuziou & Berthoud, 1982). From the south, the Sarbisheh area ends at Bibi Maryam and Kuh-e Baran with a height of 2518 meters at the southeastern tip of the county. Along the south of the county to the

west, Mesgaran heights are located northeast of Mazar-e Seyed Ali (Sahlabad) and the heights north of Arabkhaneh and the famous Gulreg mountain with a height of 2481 meters. On the west side, Post-Mokhtaran plain with a height of 1474 meters and Bagheran heights with the highest height in the west of Ferizmorgh with a height of 2697 meters above sea level, and the plains of Maud and Mehdi Abad are located. In the north, the famous Momenabad mountain range with fertile slopes and the highest altitude in "Buneh Dar" in the north of Bushgaz village at an altitude of 2787 meters above sea level, Hosseinabad plain, Kamar Rازه mountain at a height of 2112 meters and Rask Mountain at an altitude of 2039 meters above sea level, the most important

topographic and geomorphological features that surround this county. The county has a geographical area of 8,252 square kilometers, which includes not very wide plains and impassable heights.

The oldest geological formation in Sarbisheh County consists of a thick flysch zone consisting of clay-silica sediments and fine-grained sediments in which small and insignificant volumes of limestone are also seen (Fig 2). In some places, diabase stones and tuff are also associated. These flysches are strongly folded and, in some cases, slightly altered, and the ophiolites of the melanges of eastern Iran have penetrated inside them. Calorics and melanges are severely disorganized and come in small and sometimes large as kilometers. Gradual changes are seen between these melanges and flysch associated with volcanic rocks (Stocklin *et al.*, 1973). These flysches are more widespread in Maud and Mo'menabad villages. Volcanic and Middle Eocene

materials have spread in the southwest of Naharjan village, which is known the Karaj Formation. This formation is composed of submarine pyroclastic materials in almost its entire volume, which is accompanied by volcanic and intrusive materials such as lava, dykes, floods, alomera, etc., and sedimentary materials such as shale and lime. What is most important in this formation is the green tuffs that are formed as a result of the alignment of volcanic eruption materials near sea level (Vatan and Yasini, 1969). Paleogene flysch is also more widespread in the east and southeast of the Sarbisheh County, located on the border, and Eocene-Oligocene sandstones are exposed in the same area in the north of the Lanu district. Neogene Arari rocks and Pliocene folded conglomerates are other Cenozoic formations that are more widespread in the south and southwest of the county.

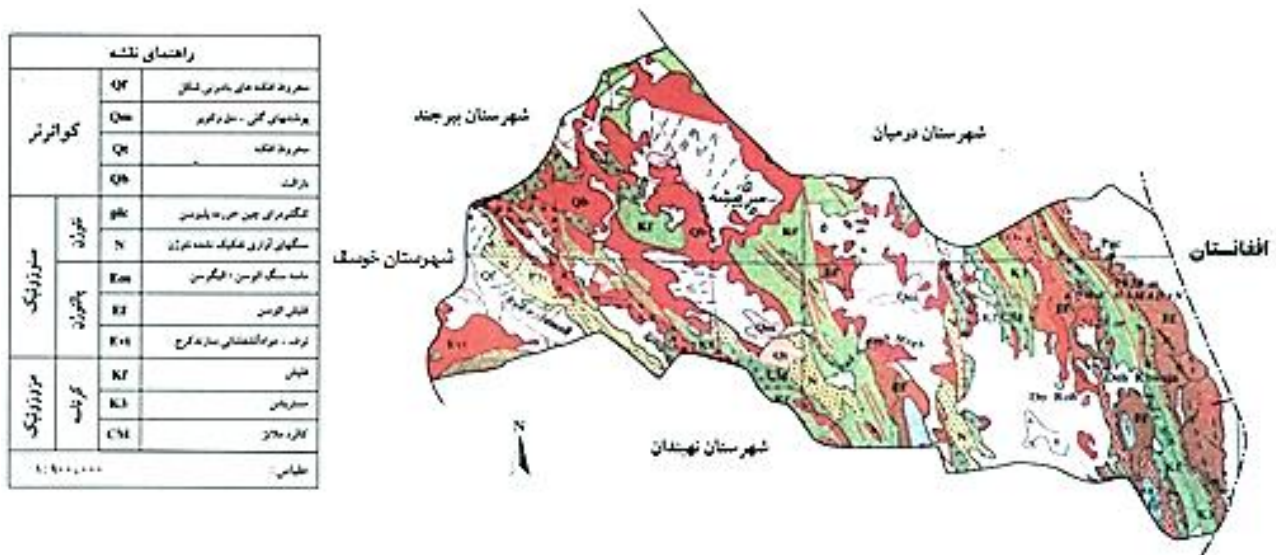


Figure 2. Geology of Sarbisheh County (Geographical Organization of the Armed Forces, 2009).

V. Introduction of Sarbisheh mines

The Sarbisheh County survey identified three smelting furnaces and more than nine metal mining mines, which with the exception of one mine, are located in the southern and southeastern mountains of Sarbisheh. These mines are located in a geological vein of the eastern block of Iran, which can be traced in today's Ghale Zari mines, 80 km south of Birjand. The identified mines are mostly surface mines and only three underground mines have been identified that have been extracted by digging tunnels and underground tunnels. Unfortunately, due to high human traffic, in the study of these mines, no findings were found that are involved in smelting and metal extraction. The largest mines in the region are the Cheng-e Sorkh and Mesgaran mines, the first of which is surface and the second of which are surface and underground. The largest metal smelting furnace was also identified in the Koohakrud area next

to the Koohakrud caravanserai, which could also have been used to house people who worked in these smelting furnaces during the Safavid period. The mines of Sarbisheh area are as follows:

V.1. Mesgaran Naystan Mine

Nayestan mine is located at longitude 772597, latitude 3573168, and altitude 1851 meters above sea level, 10 km south of Mesgaran village and 30 km south of Sarbisheh (Fig. 3). This mine is located in the south of Mesgaran, east of Birjand-Zahedan communication road in the northeastern heights of Sahlabad, and north of Shirshotor village. The Nayestan is the most important mine in the region for copper mining, according to locals. Of course, other large mines such as Shirshotor and Chah Anjir mines are located in the Nehbandan region in the southeast of this place. The wells of the Nayestan mine are located entirely on the slopes or top of a mountain known as Nayestan. The

holes and tunnels in this mine indicate surface and underground excavations. It is possible that due to the existence of many underground tunnels in this mountain range, some of these tunnels have been connected to each other. Most of these holes and underground tunnels for copper ore extraction have been destroyed in recent years due to road construction and mining activities, and some due to scouring of the northern slopes of the mountain and higher parts, and its deposition in these holes is filled. At the foot of the mountain and in several places, there are slag traces and in several other places, there are traces of residential constructions to accommodate the miners. It seems that in this area all mining activities were done to some extent. After extracting the ore at the foot of the mountain, it carried out the purification and separation of some of the impurities from the ore and later transferred the mineral to a more advanced furnace, which was probably the Koohakrud smelting furnace.



Figure 3. Nayestan Mesgaran Mining Pits (by Authors, 2013).

V.2. Mines of Koohakrud

These mines are located in a metamorphic geological structure of melange, metadiabia, and serpentinite from the Upper Cretaceous and include the five mines of Cheng Sorkh, Johar Cheshmeh, Sarab Koohakrud, Posht Koohakrud Bala and Masir Kasrab mine. The largest of these mines are the Cheng-e Sorkh and Joharcheshmeh mines, the former being mined surface and the latter underground. Their location is from northeast to southwest. In continuation of this mineral vein, other mines such as Tag Mir Alam Kasrab mine, Fooladabad Arabkhaneh, and also the famous Ghale Zari mine such as Shadadi Roghani, Shadadi Trangabin, etc. are located.

V.2.a. Johar Cheshmeh Mine

Johar Cheshmeh mine is located three kilometers southwest of Koohakrud Bala village and three kilometers east of Akhund shafi village and east of Birjand - Zahedan transit road. The mine is an underground mine with a length of 30 meters in the east-west direction (762852) and a latitude of 1724 meters above sea level, which forms the main structure of the mine (Fig. 4). The entrance of the mine, which is

created in the highest part of the mountain facing east, is oval and about 150 cm in diameter, which is first dug vertically into the ground and then at a depth of about two meters, a horizontal tunnel about one meter wide extending to the west. The continuation of this tunnel can be seen in the western part and the end of the mineral vein in the west of the mountain. The western portal is much narrower than the eastern portal of the tunnel and is about 75 cm high, which is not possible to enter due to sedimentation and soil deposition. There is no sign of digging in the tunnel walls of this ancient mine. At various intervals along the tunnel, wells have been dug by the Ministry of Industry, Mines, and Trade to test the purity of the mine, which has destroyed parts of the tunnel. Around this mine, discarded mineral masses can be seen in the form of ridges. The Johar Cheshmeh mine is located next to a spring of the same name belonging to the Zabuli - Kurdish family, who have now left the area due to successive droughts and a lack of water resources. After the Mesgaran mine and the Cheng-e Sorkh surface mine, the largest mine in the region appears to have been the Johar Cheshmeh mine.



Figure 4. Johar Cheshmeh Underground Mine Tunnel Entrance (by Authors, 2013).

V.2.b. Cheng-e Sorkh Mine:

This mine is located on the access road to the village of Koohakrud Bala, 1500 meters west of the village, three kilometers north of the Johar Cheshmeh mine, and one kilometer from the Koohakrud copper smelter. The longitude of this mine is 3580036 its latitude is 770550 and its height above sea level is 1711 meters (Fig. 5). Cheng-e Sorkh is a surface mine with abundant pits and a very wide range (Fig. 6). This mine is known as Cheng-e Sorkh because it is located in the east of the same name mountain.

In addition, in the area of the mine, two pieces of pottery of local species with colored and handmade brick paste belonging to the late Islamic centuries (12th and 13th centuries AH) have been obtained, which shows that the later periods the extraction of the mine has taken place (Fig. 6).



Figure 5. Cheng-e Sorkh Mining Pits (by Authors, 2013).

The presence of rock masses in the area of the extraction holes indicates the existence of rooms and architectural spaces for miners to live in. In the scattered rocks of this mine, blue azure traces and veins can be seen along with malachite green veins (Farjami, 2013).

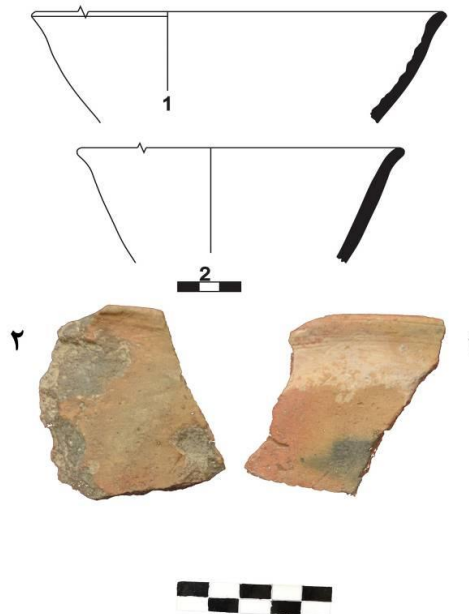
V.2.c. Posht-e-Koohakrud Bala mine

This mine is located in the north of Koohakrud Bala

village at longitude 772510, latitude 3578961, and a height of 1736 meters above sea level. Some of it is a surface mine, and a tunnel has been created in the middle of the mine hole in the east-west direction in the center of the mineral vein. The tunnel portal is currently closed by the Department of Industry, Mines, and Trade, and purity and grade testing wells have been drilled around the mine. Minerals were extracted from this relatively small mine in both surface and underground forms (Farjami, 2013).

V.2.d. Koohakrud Bala Mine

This mine is located at 770973 longitudes, 3579214 latitudes, and 1708 meters above sea level. The mine is located to the west of the Koohakrud Bala smelters and on the slopes of a hill overlooking the surrounding land. This mine is of surface type from which a copper mineral vein has been extracted. The Sarab Koohakrud's mine is a relatively small mine with only two wells. In addition, this mine is the closest mine to Bala Koohakrud's smelting furnaces (Farjami, 2013).



No.	Site name	Site code	Temper	Made	Period	cooking	Fabric	Inner Slip	Outter Slip	Granulation Type	height cm	Rim D. cm	Sherd Type
1	Cheng-e Sorkh		Mineral	wheel made	12 - 13 century	✓	red	red	buff		6.5	26	rim
2	Cheng-e Sorkh		Mineral	wheel made	13 - 13 century	×	grey	red	grey		6.5	18	rim

Figure 6. Cheng-e Sorkh mine Pottery (by Authors).

V.2.e. Masir Kasrab mine

This mine is located at 772176 longitudes, 3580153 latitudes, and 1715 meters above sea level. In the northernmost part of the Koohakrud Bala plain, along with the villages of Gazdez and Kasrab, there is a mine that, according to mining engineers, contains the purest type of copper ore. This mine is of surface type and it is a very small mine that has only two very small extraction holes. In this mine, like other mines in the region, mine test trenches and test wells have been created by the Mining Industry and Trade Department to check the

purity and capacity of the mine. The mine is located north of the current Posht-e- Koohakrud mine. The reason for the small extraction of copper from this mineral vein, despite its richness and high grade, may have been its non-surface Vein in this part of the plain.

V.2.f. Nerro Mine

This mine is located at 767441 longitudes, 3577469 latitudes, and 1615 meters above sea level. Nerro mine is located 500 meters east of Birjand - Zahedan transit road and 500 meters southwest of Koohakrud Payeen village. This mine is a collection of small and large

tunnels and mining pits that can be considered part of the mineral vein of the Koohakrud Bala region and the mines of this region. In the northern part of the extraction holes, it can be seen the remains of the settlements of miners who have been engaged in extraction in this area.

V.2.g. Tag Mir Alam Kasrab Mine (Ghare ezhdeha)

This mine is located at 219885 longitudes and 3586261 latitude zone 41 and 1760 meters above sea level. Tag Mir Alam mine is one of the most important mines in the southern region of Khorasan. This mine can be extracted both underground and surface (groove). Mir Alam mine has three extraction tunnels in the main location and extraction holes in its mineral vein in other parts of (ag) Mir Alam valley on the surface (Fig. 7). Due to the unknown nature of these mines, local people know the tunnels of this mine as natural caves and call them Ghare Ezhdeha. The diameter of the main entrance of the underground mine is 170 cm to the south. The material extracted from this mine was most likely transported to the Koohakrud area, ten kilometers away from the mine, as no signs of metal melting were detected in the vicinity of Kasrab village.



Figure 7. Entrance to the underground mine tunnel of Tag Mir Alam Kasrab (by Authors, 2013).

V.2.h. Payvand-e-bala Copper Mine

This mine is located at 742766 longitude and 3616854 latitude and 1963 meters above sea level. Payvand-e-bala Copper Mine is located 30 km west of Sarbisheh and 2 km north of Payvand-e-bala village of Mood District of Sarbisheh County. The veins of this mine are located in the middle of the green layers of Serpentine and the northern hills of Payvand-e-bala village and overlook this village. The mine has two large mineral extraction pits for extraction, and smaller mining pits are formed around the large pits (Fig. 8). Scattered around the mine are rocks scattered on the surface with blue veins (azurite) along with green veins (malachite). At the highest point of the excavated area, spaces for workers and miners seem to have been built. Payvand-e-bala copper mine is located among the

serpentine veins and is a surface mine. The copper of this mine was probably transferred to Koohakrud smelting furnaces 60 km away or Keydasht smelting furnaces in its southeast.

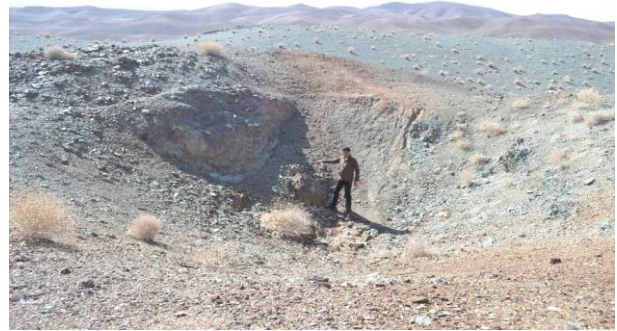


Figure 8. Payvand-e-bala Mining Pits (Authors, 2013)

VI. Metal extraction methods

The extraction of old mines such as new mines has been based on two main types of underground and open space operations. The underground method was to dig a pit vertically in the soil and then move in horizontal corridors until they reached the mineral veins. The technique of digging vertical pits and horizontal tunnels was a familiar technique in the Islamic world that was used to build aqueducts. Indeed, most miners preferred to dig horizontal corridors and follow the veins instead of digging vertical pits on the slopes of a mountain. This method could only be used when the land was suitable, but it was easier and less expensive for the miners who worked privately. Remarkably, reports of mines with vertical pits have often been used for state-owned mines (Hill, 2002: 19). The Abul fada provided a clear description of private silver mining activities in the Panjshir Valley. "The people of Panjshir pierce the earth like a sieve, and the veins that are likely to lead to silver, they dig enough to reach silver ... Sometimes a man found a vein, and another from another position finds the same vein, and both of them dig. In such cases, it is supposed that whoever gets the silver sooner, belongs to him. The people of Panjshir should commit deeds in this contest that do not even reach the mind of the devil, and when one of them reaches silver, the one who is left is miserable and his capital is wasted. If they both come together, they will share and dig in the tunnel until the light is on, and when the lights go out they will stop, so whoever goes beyond this position will die in a few moments ..." (Abul Fada, 1970: 539).

In surface mines, minerals are known on the surface and there is no need for tunneling or tracing of mineral veins in the form of horizontal and vertical wells. In surface mining, due to the large volume of minerals, these mines are extracted in the form of holes on the surface. This type of mineral extraction does not require much effort and time, and usually, a slope level to the

mineral extraction site is added by deepening the extraction hole, to transfer, separate the mineral (ore formation), and transfer it to smelting furnaces. In the mineralization stage, impure materials such as rocks and insignificant minerals were separated so that the metal ore could be fired with more purity. At this stage, the ore was crushed and separated. Crushing of stones in the past was done with a heavy metal mallet. Air conditioning was one of the major issues in underground mining. In private mines, they stopped working as soon as the lights went out. However, in state-owned mines, equipment was usually found to ventilate the mines, and especially in mercury-deep mines, proper ventilation was mandatory. Ventilation was a major problem, especially in very deep mines. According to the conventional method, either a well was drilled in a suitable place for ventilation of deep tunnels or, as is common in the method of digging aqueducts in Iran, they used several rods that also provided fresh air to the horizontal tunnel. This method of ventilation had ancient roots that date back to pre-Islamic times (Yousef Hassan and Hill, 1996: 318).

The main tool of the miners was a kind of double-edged pickaxe, which in Arabic was called “Menghar”. It had a sharp end for splitting rocks and a flat end for pounding or sinking. In other words, on one side it had a long, sharp blade that was used for digging, and on the other side, it had a kind of hammer-like piece that was used to pound the edges. They also had other tools such as hammers, styluses, pounders, crowbars, hoes, dustpans, and so on. Well, wheels were used to extract minerals and other materials from the depths of the rods. One of the simplest and most effective types of good cycles is the one that is still used in Iran for digging aqueducts or in construction workshops (Yousef Hassan and Hill, 1996: 314; Hill, 2002: 19). Tallow burning lamps were used to illuminate the underground mineral space. These lights, when turned off, indicate a lack of oxygen in the miners' workspace. In order to place lamps and tallow burning lamps inside the mine, the miners created small ledges in the mine wall so that they would not be hindered in their work.

Drilling systems in the past consisted of tunnels and shafts that were always dug in the heart of the mountain either parallel to or perpendicular to the spread of the mineral. Vertical trenches in this area sometimes extend to great depths. One of the effects of mining activities in those tunnels is the presence of polished walls due to the blows of stony and primary hammers. Some parts of the mine were mined by heat due to their high hardness (Emami, 2003: 268). The process is such that first the work front is heated and then cold water is sprayed on the walls, causing the walls to crack or break, and then the mineral is collected. Most of the mining activities took place in the areas where people live or close to residential centers. This is exactly what

happened in the Kasrab and Koohakrud areas, where minerals were transferred from the Kasrab and Koohakrud mines to the Koohakrud smelters. Mining of mineral veins was done in one area and horizontally in a tunnel, but in other parts, mining activity inside the veins was done superficially.

VII. Metal smelting furnaces

Unlike mines, which are located in some places as complexes, smelting furnaces are located separately at a distance from each other. The largest of these furnaces is the Koohakrud smelting complex, located south of the Koohakrud mineral vein and southwest of the current village of Koohakrud. No structural or architectural effects were observed in these furnaces, and only metal slag determined the location of these furnaces. All three furnaces identified are located in three important ancient, and habitat areas related to the Islamic era. These situations show the importance of these areas and the importance of metal in the daily lives of the people of that time.

VII.1. Koohakrud Bala Melting Furnaces

This furnace complex can be considered the largest furnace identified so far in eastern Iran. This furnace is located south of Koohakrud Bala Caravanserai and 300 meters west of Koohakrud Bala Village. Furnace slag is widely dispersed around (Fig. 9).

The copper ore required for these furnaces, as mentioned earlier, was extracted and supplied from six mines in the Koohakrud region and the Mesgaran copper mine or the Payvand-e-bala copper mine. There is no trace of architecture in the area of the furnaces, and only holes that may have been the site of metal smelting can be found everywhere in the Koohakrud area.



Figure 9. Slag accumulation in Koohakrud Bala melting furnace (by Authors, 2013).

There is only one caravanserai (latitude 771429/3578915) belonging to the Safavid period in the eastern part of the furnace, which is likely to have been used by Safavid metalworkers as their residence (Fig. 10). The sahn of the caravanserai, which has a very simple space and is far from decorative components,

includes other spaces and houses. This caravanserai, which is made of materials such as stone, mud, clay, and plaster, has appropriate and harmonious spaces. The rooms are located on either side of the central courtyard or sahn. Among the interesting components in the rooms are very simple and practical niches that do not even have a special geometric order and are created in the form of indentations and different ways. In addition, the presence of wall heaters shows that this caravanserai was also the residence of miners in the cold season. The ceilings of the rooms were generally in the dome form made of clay and stone, and the capacity of each room was for three or four people.

The interesting and important thing about Koohakrud furnaces is that the water spring that flows next to the caravanserai is unusable due to its water passing through the copper mineral veins and is very poisonous and deadly. Melting metals has always been the main step in exploiting the early stages of extraction. In this area, smelting activities have been carried out

along the existing mining area and trenches. The presence of smelting furnaces, smelting workshops, and most importantly smelting slag at very short distances adjacent to each other indicates this. The slag in this area is all dark or light brown (Fig. 11). Metal smelting furnaces are usually located in areas close to mines or are located in areas where suitable and sufficient fuels are available to metalworkers. It seems that the Koohakrud region, in the periods when these furnaces were active, had suitable vegetation of trees and shrubs suitable for fueling the furnace, or that this fuel was supplied from areas in Sarbisheh or Doroh area because these areas have been a good place to grow *Haloxylon* and *Pistacia Atlantica* shrubs. Charcoal from pistachio trees is an excellent reducing agent for metallurgy, and the dry wood of *Haloxylon* trees produces high heat and leaves little ash (Junidi, 1974: 147). The pottery obtained from around the upper Koohakrud site belongs to the Middle Ages to the late Islamic Middle Ages and is divided into two groups unglazed and glazed pottery (Fig. 12).



Figure 10. West side of Koohakrud Caravanserai (by Authors, 2019).

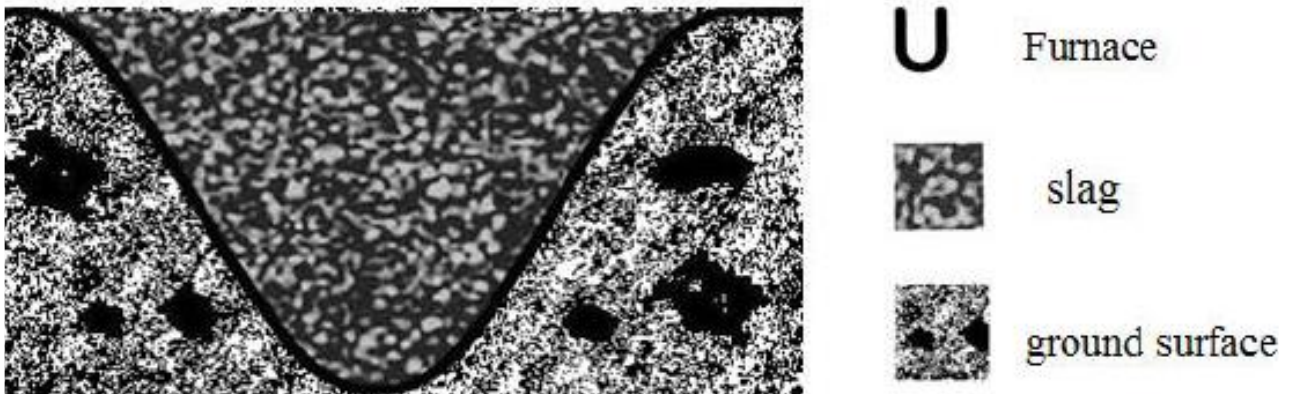


Figure 11. Melting hole in the Koohakrud Bala area (Hashemi Zarjabad *et al.*, 2015).



Figure 12. Pottery from around Koohakrud Bala Furnace (by Authors, 2013).

VII.2. Keydasht smelter

This work is located in the west of Keydasht village and one kilometer west of the village and overlooking it. There are no architectural works left from this furnace and only the slag of the furnace can be seen on the surface to a large extent. This furnace is part of a set of furnaces located in the southern part of Sarbisheh County and its minerals were supplied from the mineral veins of Koohakrud or west of Sahlabad. The southern region of Sarbisheh County has many mines and furnaces due to its natural richness and copper veins. The village of Keydasht has many ancient monuments, the oldest of which is the site of the Ghale kohneh related to the late historical period and early Islam. There is also a patriarchal castle in the village that was used until the Pahlavi period. These artifacts indicate that Keydasht residents may have used the furnace in historical and Islamic times. It should be noted that the distance from Koohakrud to Keydasht smelter is about 20 km southeast of a straight line.

VII.3. Shirkohak Melting Furnace

Shirkohak Furnace is a place located in the middle of the plain (Tag) Doroh and fifteen kilometers south of the county in a relatively wide plain covered with Haloxylon and Tamarisk bushes (Fig. 13). This smelting furnace is completely destroyed and the only signs of its existence are slag. At present, there is no water source near this monument, but in the past, the Shirkohak aqueduct flowed in the south of this place, which dried up due to drought and was later completely destroyed by seasonal floods in Doroh Plain. Copper mines are likely to exist in the mountains around Doroh, as only this furnace has been identified in the area of Doroh and no traces of ancient mines have been found. Shirkoohak furnace can be related to the Middle Islamic (Seljuk-Ismaili) period according to the archeological monuments in the region and the sayings of the inhabitants of Doroh. As is mentioned in historical

books, Doroh (valley) region was one of the important centers of the gathering of human groups in the Islamic Middle Ages, especially in the Seljuk era (Jovaini, 2012; Fazlullah Hamedani, 2008: 107). Ismaili metalworkers, just as they used the mines of the Ghale Zari region to their advantage to make weapons and other livelihoods, also took advantage of these furnaces at that time.



Figure 13. Slag Dispersion and Shirkoohak Melting Furnace Position (Authors, 2013)

VIII. Conclusion

Sarbisheh County, due to its location in the Iranian copper belt and its special geological structure, has many mineral veins that have turned this county into a miners' paradise. In the past, these mineral veins were considered by ancient metalworkers, especially in the Islamic period. They have extracted minerals from both surface and underground mines, of which nine mines have been identified, of which three mines are underground and the rest are surface mining. Most of these mines are located in the southern Sarbisheh mining area, which extends to the southwest and the Ghale Zari mines.

It seems that all metal smelting activities in this area were carried out in the Koohakrud area and minerals were transferred to these furnaces from different areas. Of course, the two furnaces that have been built in the Keydasht and Doroh area also have performed some of

the metal smelting activities, which due to the relatively long distance (especially the Doroh smelter), other mines should be located near these melting furnaces. In general, the southern Sarbisheh region is one of the most important economic regions in the historical and Islamic periods due to the number of mines, extraction volume, and the number of smelting furnaces in the Koohakrud region and has played an important role in economic exchanges and social issues in the region. One of the problems in studying mines in the region is the

lack of data that can date these furnaces and mines. Only two pottery pieces from the late Islamic centuries were identified from the Cheng-e Sorkh mine. Also, mining activities on the remains of ancient mines in recent decades have caused many of these mines to be destroyed. Further studies in this mineral vein, which are located in the county of Khouf and Nehbandan, will lead to the discovery of new furnaces and mines and will show the capabilities of the people of this region in different periods in the field of smelting different metals.

References

- Beigi Herchegani, T., Hashemi Zarjabad, H., Ghorbani, H. R.; and Barani, H. (2015). Archeometallurgical and ancient mining research in South Khorasan (based on archaeological studies and petrographic experiments). *The Second National Archaeological Conference of Iran, Mashhad*, (in Persian).
- Berthoud, T., and Cleuziou, S. (1982). Early in the Near East, a reassessment in the light of new evidence from western Afghanistan. *Expedition*, 25 (1), 14-19.
- Chegini, N., Momenzadeh, M., Parzinger, H., Pernicka, E., Stollner, T., Vatandoust, R. and Weisgerber, G. (2000). Preliminary report on archaeometallurgical investigations around the prehistoric site of Arisman near Kashan, western central Iran, *Archaeologische Mitteilungen Aus Iran und Turan, Band 32*, 281-318.
- Ibn Hawqal. (1966). *Surat al-'Arḍ*. Translated by Jafar Shoaa. Tehran: Iran Culture Foundation Publications, (in Persian).
- Abul fada, A. A. E. E. (1970). *Calendar of countries*. Translated by Abdul Hamid Ayati. Tehran: Iranian Culture Foundation, (in Persian).
- Emami, S. M. A. (2004). The importance of mineralogical studies on old smelting slag in the paragenesis of metal ores. Tarbiat Modares University. *Iran Mining Engineering Conference*, (in Persian).
- Emami, S. M. A. (2003). Mineralogical studies on copper smelting slag in Chah Mousa mine in Taroud, Shahroud. *Appendix: Journal of the Monthly Report of the Cultural Heritage Organization of the country*, 29, 265-272, (in Persian).
- Fazlullah Hamedani, R. (2008). *Comprehensive Chronicles (Ismaili History)*, Mohammad Roshan (ed.). Tehran: Written Heritage Research Center, (in Persian).
- Farjami, M. (2013). *Archaeological Survey Report of Sarbisheh, Birjand*. Archive of the General Directorate of Cultural Heritage, Handicrafts and Tourism of South Khorasan, (in Persian).
- Faizi, F. (2003). Copper and its ores. *Journal of Geological Education*, 34 (1), 26-30, (in Persian).
- Geographical Organization of the Armed Forces. (2009). *Geographical culture of the country's settlements, South Khorasan province - Sarbisheh County*. Tehran: Geographical Organization of the Armed Forces Publications, (in Persian).
- Hashemi Zarjabad, H. and Taghavi, A. (2012). Archaeological research of ancient mines in South Khorasan, a case study of new discoveries of ancient metal smelting centers of Nehbandan. *Quarterly Journal of Khorasan Socio-Cultural Studies*, 25, 145-170, (in Persian).
- Hashemi Zarjabad, H. (2013). Archaeological study of Shousf Nehbandan section, introduction of metal smelting centers. Birjand: The first national conference on archeology in Iran, (in Persian).
- Hashemi Zarjabad, H., Zareie, A., Beige Harchegani T., and Farjami, M. (2015). Archaeological Investigation of Metal Smelting in Eastern Iran Case Study: Mesgaran Area, One of the Most Ancient Metal Smelting Plants in South Khorasan, *International Journal of Review in Life Sciences*, 5 (8) 1092-1104.
- Hashemi Zarjabad, H.; Beigi Herchegani, T., Zarei, A. and Farjami, M. (2016). Archaeological Research of Metal Smelting in Eastern Iran: A Case Study of the Mesgaran Site of One of the Largest Metal Smelting Workshops in South Khorasan. In: R. Khazaei and B. Annani, (eds.), *Collection of Qubestan in Dineh Essays*, Birjand: Chahar Derakht Publications, pp. 80 - 97, (in Persian).
- Hejbari Nobari, A., Mazaheri, K. (2005). Arsenic Copper: Copper or Bronze. *Bi-Quarterly Journal of Archaeologist Message*, 2 (3), 5-32, (in Persian).
- Hill, D. (2002). Mining in the Islamic period. Translator: Shahram Zare, *Journal of Archeology*, 10, 17-22, (in Persian).
- Jovaini, A. M. A. (2012). *History of Jabangoshaye Jovaini*, Mohammad Qazvini (ed.). Tehran: Negah Publishing Institute, (in Persian).
- Kahen, C. (2008). Society Economics and Institutions. *Cambridge History of Islam Volume 2*. P. M. Holt, Bernard Lewis, Anne Lambton (Eds.). Translator: Timur Ghaderi. Tehran: Mahtab Publication, pp. 1639 - 1674, (in Persian).
- Moghadasi, M. A. (1982). *The best division in the battle of the dead*. Translated by Alinaghi Manzavi. Tehran: Iranian Authors and Translators Company, (in Persian).
- Mostofi, H. (1983). *Nozhat al-Qulub*. Guy Lesterling (ed.). Tehran: Book World Publications, (in Persian).
- Momenzadeh, M. (2002). A review of the effects of mining and smelting of metals in the Kerman region. *Kerman Studies Conference, the need to re-read the history of Iranian copper Sarcheshmeh mine*, Kerman, (in Persian).
- Momenzadeh, M. (2003). Ancient mining and smelting of metals in Kerman province. *Cheshmeh Magazine*, pp. 7 - 19.
- Momenzadeh, M. (2005). Introduction to the introduction of Iran-Zamin mines. *Journal of Development of Geological Education*, 10 (2), 2523 - 2525, (in Persian).
- Momenzadeh, M. (2006). A Review of Ancient Iranian Mines and Mining - Part Two. *Cheshmeh Magazine*, 6, 21- 59, (in Persian).
- Momenzadeh, M. (2004). Metallic mineral resources of Iran, mined in ancient times, A brief review, In: T. Stöllner, R. Slotta and A. Vatandoust, (eds.), *Persia's Ancient Splendour, Mining, Handicraft and Archaeology*, Deutsches Bergbau-Museum, Bochum, pp. 8-21.

- Nikzad, M. Sedighiyan, H. Ahmadi, K. (2018). Research on ancient metal mining and smelting activities in Khosf county, South Khorasan. *Proceedings of the Conference of Young Archaeologists*. M. H. Azizi Kharanaghi, M. Khanipour and R. Naseri (Eds.). Tehran: Iranology Foundation, Pp. 1028-1072, (in Persian).
- Nezafati, N., Momenzadeh, M., Pernicka, E. (2005). Darhand copper occurrence: An example of Michigan-type native copper deposits in central Iran. *Mineral Deposit Research: Meeting the Global Challenge*, Pp. 165-166.
- Nezafati, N., Momenzadeh, M. and Pernicka, E. 2008 *New insights into the ancient mining and metallurgical researches in Iran*.
- Oudbashi, O., Emami, S. M. A. and Davami. (2012). *Bronze in Archaeology: A Review of the Archaeometallurgy of Bronze in Ancient Iran. Copper Alloys - Early Applications and Current Performance Enhancing Processes*. L. Collini (Ed.). InTech, Rijeka, Croatia, Pp. 153-178, (in Persian).
- Qasemnejad, M. (2017). *Archaeological study of ancient Metalwork sites in northeastern South Khorasan Case study: Zirkoub region*. Unpublished: University of Birjand. Master Thesis, (in Persian).
- Qasemnejad, M. Hashemi Zarjabad, H. Farjami, M. and Abbasnejad Sorsti, R. (2017). Introduction of ancient industrial smelting workshops based on archaeological studies (case study of Zirkouh region). Tehran: *Third National Archaeological Conference of Iran*, (in Persian).
- Statistical Yearbook of South Khorasan Province*. (2010).
- Stocklin, Y., Eftekharnjad, J. and Hooshmandzadeh, A. (1973). *Preliminary Geological Survey in Central Lut, Eastern Iran*. Translated by Ali Entezam and Jamshid Iftikharnejad, Report of 22 Geological Survey of Iran, (in Persian).
- Junidi, M. J. (1974). History of Metalworking. *Journal of Tabriz Faculty of Literature and Humanities* 110, 139-155, (in Persian).
- Sharifzadeh, A. M. (2007). Metalworking in Iran. *Journal of the Development of Art Education* 5 (1) 4-9, (in Persian).
- Talaei, H. (2002). Ancient metalworking technology in Sagzabad site of Qazvin plain. *Journal of the Faculty of Literature and Humanities, University of Tebran*, 547 - 564, (in Persian).
- Vatandoust, A. (2004). Old Mining and Metallurgy in Iran past and future of a research perspective, In *Persia's Ancient Splendour, Mining, Handicraft and Archaeology*. T. Stöllner, R. Slotta & Vatandoust, A. (Eds.). Deutsches Bergbau-Museum, Bochum, Pp. (2-7).
- Vatan, A., Yasini, I. (1969). *Les grandes lignes de la geologie de LE Albourz Central dans la region de Teheran et la plaine de la Caspienne*. *Rev. de L institut Francais du petrole* 26 (7, 8 and 9) 841-878.
- Wertime, T. A. (1968). *A Metallurgical expedition through the Persian desert* (unpublished).
- Yousef Hassan, A. and Hill, D. (1996). *Illustrated history of Islamic technology*. Translator: Nasser Tofighian. Tehran: Scientific and Cultural Publications, (in Persian).

ARCHAEOLOGY OF THE ANCIENT MINING AND SMELTING IN THE CENTRAL PART OF TABAS COUNTY, ON THE EDGE OF LUT DESERT

Zabihollah MASOUDI^{1✉}, Abed TAGHAVI², Hasan HASHEMI ZARJABAD³, Parastou NAEIMI TARAEE⁴

¹ Ph.D. Candidate in Archaeology, University of Mazandaran, Babolsar, Iran, (Corresponding author: z.masoudi@stu.umz.ac.ir).

² Assistant Professor, Department of Archaeology, University of Mazandaran, Babolsar, Iran.

³ Associate Professor, Department of Archaeology, University of Mazandaran, Babolsar, Iran.

⁴ Conservation Scientist, Research Center for Conservation of Cultural Relics, Research Institute of Cultural Heritage and Tourism, Tehran, Iran.

Received: 09 April 2022

Accepted: 14 June 2022

Available online: 20 June 2022

Abstract: Tabas County in South Khorasan province is one of the regions that have high capacities in terms of mining and metallurgy studies, and compared with the other regions of Iran, this region is unknown. The abundance of smelting areas and accumulated slag and the presence of mineral cavities to extract minerals in the central part of Tabas are proof of extensive mining and metal production in this region, which plays an important role in the economy and ecological sustainability of the region along with other economic activities. Regarding the quantity and quality of the studies prepared so far on mining and metallurgy in this city, the cultural and historical capacities of this cultural area have not been introduced as they should be. During the archaeological studies conducted by experts hired by the Cultural Heritage Office of South Khorasan, working in the central part of Tabas county, a mining site, and two slag sites have been identified and studied, which indicates the role and importance of the mining and metalworking in the social and economic life of the central cultural region. Citing the results of the field method, reviewing texts and written sources related to the central part, and identifying evidence related to the metalworking industry, smelting technology, and type of ore deposit thoroughly, this study has been provided to understand better the process and cycle of ancient metalworking, which includes three stages of mining, extraction, and melting. By typological and comparative studies of discovered slag with adjacent metal centers, it seems that the composition of slag includes the main elements of iron, lead, and copper. The typological and comparative studies of slag discovered in neighboring metal centers indicate that the composition of slag includes the main elements of iron, lead, and copper. The archaeological field studies conducted on the mines and smelting verify the fact that metallurgists in this area used open and underground methods to extract the ore, and after transferring the mineral parts to the smelting workshops and furnaces, they used the roasting method.

Keywords: Tabas county, central part, archaeology, mining, smelting furnace.

چکیده: شهرستان طبس در استان خراسان جنوبی از جمله مناطقی است که از منظر مطالعات معدن کاوی و فلزگری دارای قابلیت‌های بالایی است و در قیاس با دیگر مناطق ایران منطقه‌ای ناشناخته است. در این میان بخش مرکزی طبس به جهت انبوه محوطه‌های ذوب و سرباره‌های انباشته از یک جهت و وجود حفره‌های مواد معدنی به‌منظور استخراج کانی فلز مورد استحصال شاهدهی بر فعالیت گسترده معدن کاری و استحصال فلز در این منطقه است که نقش مهمی در اقتصاد و پایداری زیست بوم منطقه در کنار سایر فعالیت‌های اقتصادی داشته است. با این وجود حجم و کیفیت مطالعاتی که تاکنون در مورد مطالعات معدن کاوی و فلزکاری در این شهرستان صورت گرفته درخور استعدادها و فرهنگ - تاریخی این پهنه فرهنگی نبوده است و آن‌گونه که شایسته است معرفی نشده‌اند. طی بررسی‌های باستان‌شناسی انجام شده توسط کارشناسان اداره میراث فرهنگی خراسان جنوبی و بازننگری این بررسی‌ها توسط نویسندگان در بخش مرکزی شهرستان طبس یک معدن و دو محوطه سرباره مورد شناسایی و بررسی قرار گرفته است که بیانگر نقش و اهمیت معدن کاوی و فلزکاری در حیات اجتماعی و اقتصادی منطقه فرهنگی مرکزی است. این پژوهش سعی دارد به استناد نتایج بررسی روشمند میدانی باستان‌شناسی، متون و منابع نوشتاری در بخش مرکزی، شواهد مرتبط با صنعت فلزکاری، فناوری ذوب و نوع کاناسر استحصال شده را باز شناساند تا امکان درک بهتر فرایند و چرخه فلزکاری شامل سه مرحله معدن کاوی، استخراج و ذوب فلزات فراهم آید. با بررسی‌های انجام شده، گونه‌شناسی و مقایسه تطبیقی سرباره‌های مکشوفه با مراکز فلزی شناخته شده همجوار به نظر می‌رسد ترکیب سرباره‌ها شامل عناصر اصلی آهن، سرب و مس باشد مطالعات و بررسی‌های میدانی باستان‌شناسی انجام گرفته در معادن و محوطه‌های ذوب فلز شناسایی شده نشان می‌دهد، فلزگران این منطقه از روش‌های روباز و زیرزمینی برای استخراج کانی استفاده کردند و پس از انتقال قطعات کانی به کارگاه‌ها و کوره‌های ذوب به روش تشویه (برشته کردن) برای ذوب فلزات بهره برده‌اند.

کلمات کلیدی: شهرستان طبس، بخش مرکزی، باستان‌شناسی، معدن کاری، کوره ذوب.

I. Introduction

According to the studies conducted by researchers inside Iran and abroad, the land of Iran has been the birthplace, center, and cradle of various types of ancient technologies. One of the important technologies in studying Iranian culture and history is mining and metalworking, which has a long history from ancient times. Agreeing with the numerous surviving evidence, we can assume that Iranians have been one of the effective

pioneers in the mining and metallurgical industry, and it can be said that the history of metallurgy in Iran dates back to the 7th millennium BC (Thornton, 2009: 303).

The first metals used by humans were not obtained by mining or smelting ore but existed in pure forms in nature, the first blacksmiths shaped, and purified pure metals by hammering (Chegini *et al.*, 2000: 281).

The first known metals in the natural environment are gold, copper, silver, and iron. The limited amounts of metals that were naturally available to humans and

the urgent need for metal products were the first causes that made a great change in the art and industry of metalworking. The revolution occurred moving from identification to smelting the copper ore in Iran in the late fifth millennium BC (Talaei, 2002: 548, Vatandoust, 2000: 2, Oudbashi *et al.*, 2012: 157, Nezafati *et al.*, 2008: 3). The Iranian plateau naturally ensures a great mineral reservoir. All the geological and archaeological facts confirm that Iran is one of the oldest metalworking industries in the ancient world. It is obvious that our primate ancestry could only realize the usefulness of metal in a land where there are many metals and minerals (Farmani A. and Sadati, 2015: 1). The richness of Iran's mineral resources and the identification of the ancient industrial settlements in connection with metal smelting are present in various sites such as Tapeh Yahya, Tapeh Qabrestan, Shahdad, Tapeh Iblis, Tapeh Damghan, Arisman (Nikzad *et al.*, 2018: 2).

The cycle of the metalworking industry, like other types of industries, includes chain stages that start from the mining stage and continue with the extraction of mineral ore, eventually, in the end, the melting stage, and then standing in the following production and distribution lines. These regular cycles over the centuries and millennia, present in each piece of the fragments of these stages, produce reliable archaeological evidence left for the researchers. By identifying and studying them, it is possible to corner the potential metalworking sites in the region and agree with the ability of its inhabitants to exploit the facilities and capacities of the environment, water resources, vegetation, and ore deposits (Haji A., Laleh 2013: 101).

In this regard, one should identify the remains and artifacts associated with each of these metallurgic activities in order to start the recycling and rebuilding process, representing the metalworking industry as in ancient times. The central part of Tabas in South Khorasan province is one of the areas that hold a large amount of smelting slag as well as many deposit extraction holes. However, the mining and metal smelting studies with rich instances and a high capacity have not received much attention. Tabas County is very important in terms of mining activities. Over recent years, various studies have been conducted by geologists to identify the new mines around the city. However, few archaeological research papers have been published studying the ancient mining sites of the region. During the archaeological excavations in the central part of Tabas County (Mahmoodi Nasab, 2018), evidence from two smelting sites and a mine related to the Middle, and Late Islamic Ages were examined and identified. By studying them, we can better understand the process of the metalworking industry, including mining, metal extraction, and smelting, and finally, recognize the metalworking of the region and the socio-economic role and effects of

the metalworking industry in the context of historical and cultural developments in Tabas. In line with the significance of the subject, three questions and hypotheses were considered when initiating the present research: 1- Considering the importance of Tabas County from the point of mining studies, in which period did the oldest mining evidence in this region emerge? 2. The evidence of extraction of which metals from mines and furnaces was identified. 3- What was the first method of extracting the ores from the mine? Research hypotheses are 1- The identified cultural materials indicate that this mine lingered for centuries (Seljuk to Timurid). 2- Considering the typology and comparison of the discovered slag with the known metal centers, it seems that the composition of the slag includes the main elements of iron, lead, and copper. Archaeological field studies demonstrate the identified mines and metal smelting sites. 3- Metalworkers of this region used open and underground methods to extract minerals, and after transferring mineral parts to the smelting workshops and furnaces, they used roasting methods.

II. Research method

The present study is based on the research objectives defined in the limits of the standard basic research and focuses on the function and methodology, representing the type of historical research. The given data is collected based on the two pillars of library studies and archaeological field studies. Historical and geological books, articles, dissertations, and reports of the archaeological studies of the region have been used in library studies. Field studies and surveys, including topographic mapping of the area, photography, identification of sites and mines, determining the area and the type of mines, identification of smelting furnaces, and finally, sampling of the metal smelting sites performed randomly.

III. Research background of mining activities in Tabas

Research and surveys conducted in relation to the mining activities in Tabas County in South Khorasan Province, the documents of which are available in the research archives of the General Directorate of the Cultural Heritage, provide evidence of mining and metalworking activities. These mines and kilns were identified only in the archaeological study of Tabas County (Annani, 2015; Mahmoodi Nasab, 2015). These ancient mines show the role and importance of ancient mining and metallurgy in the social and economic life of this cultural region.

Most of the research is related to other cities in South Khorasan province. In addition, as mentioned in the historical texts, there are references to the existence of mines in this cultural region, including

the comments noting the copper mines in Khorasan in the Islamic era (Ibn Huql, 1966: 169).

Moghaddasi also mentioned the existence of the mummification elements, and silver and gold mines in the Ghahestan region (Moghaddasi, 1982: 594). Some of the reference points are “Metalworking in the southeastern region of Iran” (Abbasnejad, 1997: 73-65). “Archaeological research of ancient mines in South Khorasan, a case study of discoveries of ancient metal smelting centers of Shosaf Nehbandan” (Hashemi Zarjabad, 2013). “Archaeological study of Shosaf region of Nehbandan, the introduction of metal smelting centers” (Hashemi Zarjabad, 2012).

“An article entitled Archaeometallurgical and ancient mining research in South Khorasan based on the archaeological studies and petrographic analysis” (Beigi Herchgani *et al.*, 2015), “Archaeological Research of Metal Smelting in Eastern Iran: A Case Study of the Coppersmith Site of One of the Largest Metal Smelting plants in the South Khorasan” (Hashemi Zarjabad *et al.*, 2016),

“Introduction of the ancient industrial smelting workshops based on the archaeological studies, the case study of Zirkuh region)” (Qasemnejad *et al.*, 2017), “Investigation of the ancient mining and metallurgy activities in Khosf county, South Khorasan province, Eastern edge of Lut Desert, Iran (Nikzad, 2015)”, In this article, the metal smelting furnaces and yards of Dehuk district of Tabas county are examined for the first time. According to the cultural artifacts obtained from the surface of these yards, relative historiography was considered for this site.

IV. Geographical location

Tabas County is located west of South Khorasan province, with an area of 55,460 square kilometers divided into three parts and eight villages.

The three parts of the city are 1- Markazi, the central part, 2-the Dastgerdan part, and 3- the Dehuk part, located on the edge of the Lut desert (Fig. 1).



Figure 1. Divisions of Tabas County and its location on the edge of the Lut desert (Mahmoodi Nasab, 2018).

V. Traces and evidence of mining and smelting in the central part of Tabas

Today, from an economic point of view, due to the mining-related activities in the central part of Tabas County, it is considered one of the most important areas in the country.

In the past, mining and metalworking have played a major role in the economic and social structures of the

region. The area under study, located in the central part of Tabas County, is an unknown area in terms of archaeological studies in comparison to the other regions of Iran. Archaeological studies conducted in the studied area provided evidence of an ancient mine and two slag sites, including the Talkhab mountain mine, the desert lead site, and the Talkhab smelting area (Mahmoodi Nasab, 2018) (Fig. 2).

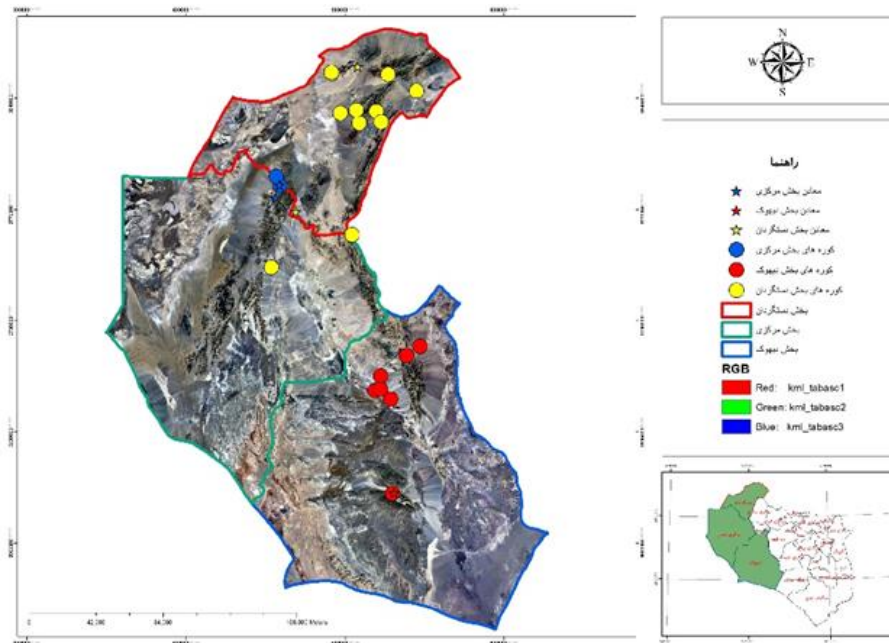


Figure 2. Location and distribution of mines and smelting sites in three parts of Dehuk, Markazi, and Dastgerdan in Tabas County (Authors, 2021).

VI. Desert metal smelting site:

The kiln site, located on the edge of the desert, is accessible to Ashgabat via a road crossing the northeast of Pir Hajat village (Fig. 3). Along this route, after 27 km begins, another route separated from the old unpaved road that, through a river, leads to the livestock neighborhood of Mr. Ahmad Rahimi, a resident of the province. From this place, after crossing the river and ending the mountainous route for three kilometers on the edge of the central desert and the added seven kilometers along the Talkhab Mountains, access to this furnace is possible.



Figure 3. Position of desert smelting furnace, (Google Earth).

This kiln is surrounded by a wide plain. The source of water nourishing the metal plant is the temporary presence of the seasonal rivers that pass through the north-south direction. The vegetation around this kiln is composed of hawthorn, bean caper, and turmeric trees.

This brook flows from the Talkhab and Gomorgh mountains towards the desert. The Desert lead kiln is located at the foot of the Talkhab Mountains, and on the edge of the central desert. This kiln is destroyed,

and the only sign of the existing kiln is the slag and architectural remains in the residential space on the surface (Fig. 4, 5, and 6).



Figure 4. Remains of the Kavir lead smelting furnace (Authors, 2021).

The height of this furnace is half a meter above the ground. The lead ore used for smelting in this kiln was supplied from the Shahdad mines on the Talkhab Mountain, located six kilometers southeast of the heights of the Talkhab Mountains.

The remains of the furnace architecture show that the perimeter of the furnace was circular and had dimensions of $2 \times 2/5$ meters. There are also quartz rocks around the kiln, which were probably used to better melt metals, and locally it is called auxiliary smelting. This furnace was probably a type of furnace that was usually lit with wood to generate heat. The stove-type Kiln probably had a dome cover.



Figure 5. Remains of the Kavir lead smelting furnace (Authors, 2021).

The smoke from the fire inside the stove was carried to the outside by the chimney on the roof. In addition to the chimney on the roof of the furnace, some pipes were placed inside the furnace and on the body of the wall to transfer smoke. Only scattered slag was found in the area around the kiln site. On the southern side of the kiln, the architectural remains of two residential spaces are available with access to the ruined space from the south.

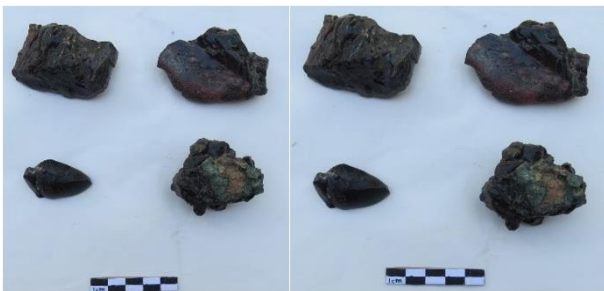


Figure 6. Desert smelting furnace slag (Authors, 2021).

VII. Telkhab metal smelting site

Telkhab metal smelting site, based on the UTM, is located at latitude and longitude 0458465/3785233 with an average altitude of 1170 above sea level. This area is located near the Talkhab mine 50 meters distance. Access to this area is through an unpaved road in the northeast of Pir Hajat village which leads to Ashgabat.

After 17 km, the route separates from the unpaved road and leads through a river to the livestock neighborhood of Mr. Ahmad Rahimi, a resident of the province.

From this livestock neighborhood on the northwest, after crossing the mountains and valleys 2.5 km, we reach this area and the nearby mine. The water source of this area is the seasonal rivers flowing on four sides. The only visible mark of the furnace on the surface is the remaining slag (Fig. 7 and 8).



Figure 7. Talbak metal smelting slag (Authors, 2021).

At the surface of the site, as found in other similar areas, there is no trace of the architectural structure except for the remnants of the metal-smelting furnaces such as copper and lead. The vegetation around the area consists of Almond trees and Artemisia bushes.

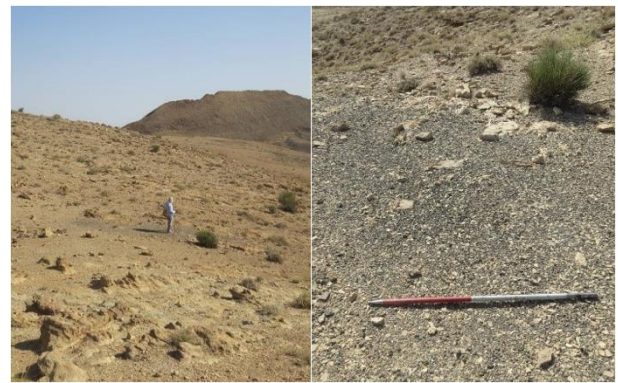


Figure 8. Talkhab metal smelting site (Authors, 2021).

VIII. Talkhab Mountain Mine

The Talkhab mine is located in a mountainous area on a mountain known as Talkhab. One of the reasons for the designation of this mountain is the existence of a spring one-kilometer northwest, and at the foot of the mountain, which is known as Talkhab spring, which means the bitter water. The central desert of Iran is in the west of this bitter spring. Access to this mine is through an unpaved road in the northeast of Pir Hajat village, which leads to Ashgabat (Fig. 9). After 17 km, the route separates from the unpaved road and leads through a river to the livestock neighborhood of Mr. Ahmad Rahimi, who is a resident of the province. From this livestock neighborhood on the northwest, after crossing the mountains and valleys 2.5 km, we reach this area and the nearby mine. The water source of this area is the seasonal rivers flowing on four sides.

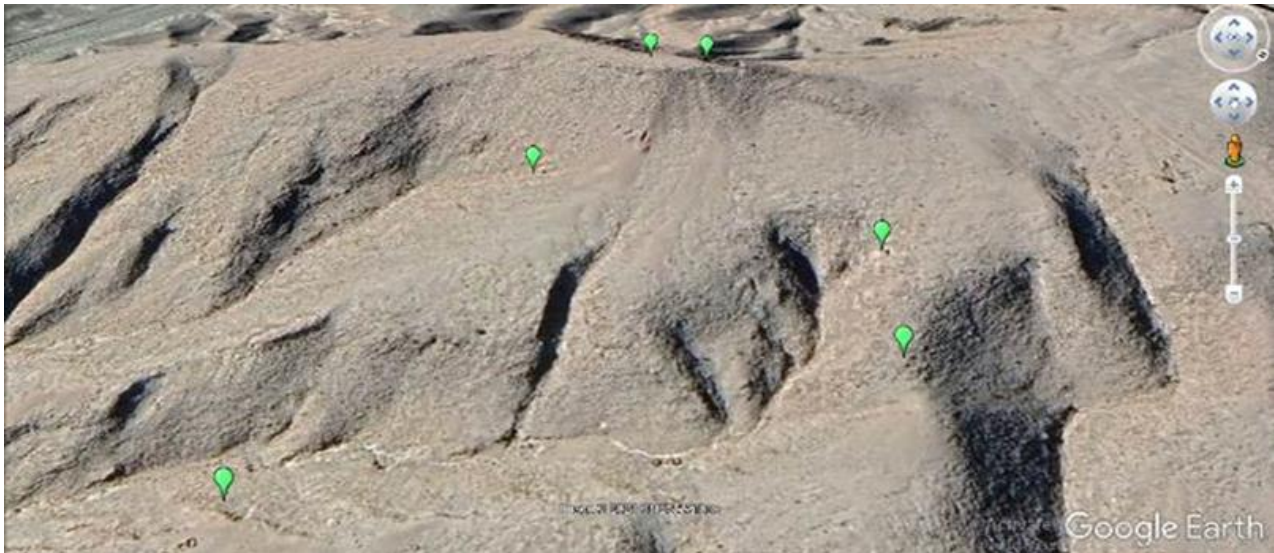


Figure 9. Location of the Talkhab mine, the satellite image (Google Earth).

The plants growing in this area consist of Almond trees and Artemisia bushes.

The mineral extraction from this mine has been done by digging horizontal and vertical tunnels (Fig.

10). The lead extraction was carried out in the Talkhab Mountain mine (Fig. 11). There are also rooms next to the mine for workers to rest. These chambers were usually dry-stack without roofs (Fig. 12).



Figure 10. Talkhab Mine and Ore Mining Tunnels (Authors, 2021).



Figure 11. Lead grains of Talkhab mine (Mahmoodi Nasab 2018).



Figure 12. Residential spaces of Talkhab mine (Authors, 2021).

IV. Conclusion:

Lut Desert is important in terms of archaeology, metalworking, and mining. The most important archaeological sites on both sides of this desert are Shahdad, Tape Yahya, Tal Iblis, and Shahr-i Sokhta, containing the oldest metalworks of ancient Iran. Therefore, the Lut Desert and its environs most likely played a major role in supplying the raw materials feeding these ancient metalworking plants. Today, more than ever, it has become clear that the Lut block and its surrounding areas are home to a variety of minerals such as copper, lead, zinc, etc. One of these areas is the central part of Tabas County on the edge of the Lut desert in South Khorasan province. In addition to the mining during the current period, the existence of ancient mines in this area reveals the geological importance of this area in the past. The most important areas to mention are the Kavir and Talkhab lead sites as well as the Talkhab Kal mountain mine. The obtained cultural materials spread throughout the area are regularly scattered slag. The sampling of metal smelting in slag sites was done randomly. In this sampling, an attempt was made to sample both the surface of the sites and the inside of the furnaces. The selected

samples had a glossy and glassy shape in terms of form and appearance, as well as samples with porosity on their surface. The slag collected from the site, due to the high percentage of iron silicate compounds, tends to be blacker and darker gray. The surface of the samples is very shiny and glossy. The slag obtained from the copper smelting site is black to light brown and has red grooves in its texture due to the presence of copper oxides. The texture, powder color, and porosity are seen immediately in most slags. This porosity is either due to the exit of gas from cavities that were heated and escaped due to smelting operations and detached from the system or in some samples, the presence of minor minerals causes porosity in the slag tissue. In some samples, the presence of a type of rare gas in the environment or deposit such as arsenic can be detected according to the amount of porosity and the geological location of the area. In highly porous slags, parts of combustible materials such as charcoal are sometimes seen. The structure, corrosion, and volumetric weight display different appearance characteristics due to the temperature of the furnace, which according to the physical evidence such as color, texture, and porosity in the slag, indicate the extraction of the lead and copper (Fig. 13).



Figure 13. Sample of the slag in the central part (Authors).

In addition to the slag remains, the residential architecture related to the accommodation of workers and employers around the kiln is observable, in which approximately 25 rooms can be identified. The dimensions of the rooms are typically 2.5 x 4 meters and are made of dry-stack stone or mud bricks. Most of these rooms are covered with stone boards, wood, and artichoke bushes. The residential spaces accommodating the employers have larger dimensions and are made of raw clay, and the walls are plastered. In addition to the residential spaces along the way to the kilns, the remains of the road leading to the kilns are also visible, and in some parts, due to the slope of the ground, the stone walls were installed to facilitate access from the kilns to the mines. The extraction procedure in the old mines, similar to the new mines, is based on the two main types of underground and open space operations. The underground method was to dig a pit vertically and then move in the horizontal corridors until they reached the mineral grains. The method of digging vertical pits and horizontal tunnels was a familiar technique in the Islamic world that was used to build aqueducts. In contrast, most of the miners preferred to dig horizontal corridors and follow the ridges instead of digging vertical pits on the slopes of a mountain. This method could only be used when the land was suitable and was easier and less expensive for the miners who worked individually. In open mines, the presence of minerals on the surface is clean, and there is no need for tunneling or tracking of the mineral veins

in the form of horizontal and vertical mineshafts. Due to the large volume of minerals in open mines, these minerals are extracted in the form of pits dug on the surface. This type of mineral extraction does not require much effort and time. Usually, the slope surface to the mineral extraction site is created by deepening the extraction hole to transfer and separate the mineral and transfer it to the smelting furnaces. In the central region, we see the underground extraction method (Fig. 10).

After transferring the mineral parts to the smelting workshops and furnaces, miners use the roasting method to melt down the extracted ores. In the land around the smelters to provide fuel for smelting minerals, almond trees, and artichoke shrubs are abundant in the Mazkazi area. The main problem in studying such works is the chronological question. With the small number of cultural materials, such as distinguished pottery, is usually not possible to date these handcrafts easily and define the exact time they were used. Also, the location of the mentioned section in the Lut desert facing the regular movement of quick-sands causes the cultural evidence to be buried under the dunes. The exact location of many of these ancient evidences has not been identified. Therefore, we have less information about the mentioned area and its relationship to the mines in the neighboring areas. On the other hand, due to the length of its tunnels and the large volume of extraction, it must be said that the extraction from this mine must have been done over a long period.

References

- Abbasnejad Sarasti, R. (1995). *Research project of metallurgy in the southeast region*. University of Sistan and Baluchistan, unpublished, (in Persian).
- Annani, B. (2015). *Archaeological survey report of Montazerieh village in the central district of Tabas county*. Birjand: Archive of the General Directorate of the Cultural Heritage, Handicrafts and Tourism of South Khorasan Province, unpublished, (in Persian).
- Beigi Herchani, T., Hashemi Zarjabad, H., Gorbani, H. R. and Barani, H. (2015). Archaeo-metallurgical research on the ancient sites in South Khorasan based on the petrographic experiments. *Proceedings of The Second National Archaeological Conference*, (in Persian).
- Chegini, N., Momenzadeh, M., Parzinger, H., Pernicka, E. Stollner, T., Vatandoust, R., Weisgerber, G. (2000). Preliminary report on archaeometallurgical investigations

around the prehistoric site of Arisman near Kashan, western central Iran. *Archaeologische Mitteilungen Aus Iran und Turan*, 32, 281-318.

Farmani A. N. and Sadati S. N. (2015). A profound view of copper and the Associated Minerals (Emerald and Zinc) in Persian Poetry with a Geological Approach. *Collection of Reports of the 10th International Conference on the Promotion of the Persian Language and Literature*. Mohaghegh Ardabili University, pp. 565-657, (in Persian).

Haji, A. L. and Laleh, H. (2013). Archaeological study of the Neishabour cultural area from the perspective of ancient mining and metalworking in the Islamic era. *Iranian Archaeological Research Journal*, 3 (5), 101-120, (in Persian).

Hashemi Zarjabad, H. (2012). Archaeological researches of the ancient mines in south Khorasan, a case study of the ancient metal smelting centers of Shosaf Nehbandan, *Quarterly Journal of Khorasan Socio-Cultural Studies*, 25, 145-170, (in Persian).

Hashemi Zarjabad, H. (2013). Archaeological study of Shosaf Nehbandan region, the introduction of metal smelting centers. *Proceedings of the first national conference on archaeology in Iran*, (in Persian).

Hashemi Zarjabad, H., Beigi Harchgani, T., Zarei, A. and Farjami, M. (2016). Archaeological research of metal smelting sites in eastern Iran: A case study of the copper site of one of the largest metal smelting workshops in south Khorasan. In: R. Khazaei and B. Annani, (eds.), *Collection of Ghabestan in Dineh Articles*, Birjand: Chahar Derakht Publications. pp. 80-97, (in Persian).

Ibn Huql. (1966). *Sowar Al-Arḥ*, (Geology), translated by Jafar Shaar, Tehran: Iranian Culture Foundation, (in Persian).

Mahmoodi Nasab, A. A. (2018). *Archaeological study of Dehuk district and Pir Hajat village of Tabas county, Birjand*. Archive of the General Directorate of the Cultural Heritage,

Handicrafts and Tourism of South Khorasan, unpublished, (in Persian).

Moghaddasi, M. I. A. (1982). *Ahsan al-Taqasim fi Ma'arqa al-Aqalim*, Volume 2, translated by Alinaghi Manzavi. Tehran: Iranian Authors and Translators Company, (in Persian).

Nezafati, N., Momenzadeh, M. and Pernicka, E. (2008). *New insights into the ancient mining and metallurgical research in Iran, Ancient Mining in Turkey, and the Eastern Mediterranean*. Ankara: Atılım University. pp. 307- 328.

Nikzad, M., Sedigiyan, H. and Ahmadi, K. (2018). Research on the activities of mining and smelting of the ancient metal in the city of Khosf, South Khorasan. In: M. H. Azizi Kharanaghi, M. Khanipour and R. Naseri, (eds.), *Proceedings of the Conference of Young Archaeologists*, Tehran, Iranology Foundation, pp. 1028-1072, (in Persian).

Oudbashi. O., Emami, S. and Davami, M. A. (2012). Bronze in Archaeology: A Review of the Archaeometallurgy of Bronze in Ancient Iran. In: L. Collini, (Ed.), *Copper Alloys - Early Applications and Current Performance Enhancing Processes*, InTech, Rijeka, Croatia. pp. 153-178.

Qasemnejad, M., Hashemi Zarjabad H., Farjami M. and AbbasNejad Sarasti, R. (2017). Introduction of ancient industrial smelting workshops based on archaeological studies (special study of Zirkuh region). *Proceedings Third Iranian National Archaeological Conference*, (in Persian).

Talaei, H. (2002). Ancient metalworking technology in Sagzabad site on the Qazvin plain. *Journal of Literature and Humanities, University of Tebran*. pp. 547-564, (in Persian).

Thornton, C. P. (2009). The emergence of complex metallurgy on the Iranian plateau: Escaping the Levantine paradigm, *Journal of World Prehistory*, 22 (3), 301-327.

Vahdati, A. A. (2010). *Archaeological Research in the city of Belqis (ancient Esfarayen)*. General Directorate of the Cultural Heritage, Handicrafts and Tourism of North Khorasan, (in Persian).

STUDY OF THE PROCESS AND REASONS FOR THE DESTRUCTION OF QOBBEH SABZ IN KERMAN BASED ON THE RESULTS OF ARCHAEOLOGICAL SOUNDINGS

Saeed AMIRHAJLOO¹ and Reza RIAHIYAN GOHORTI²¹ Department of Archaeology, Tarbiat Modares University, Tehran, Iran, (Corresponding author: saeed.hajloo@gmail.com).² Department of Archaeology, Administration of Cultural Heritage, Handicrafts and Tourism of Kerman, Iran.

Received: 18 April 2022

Accepted: 01 June 2022

Available online: 20 June 2022

Abstract: The Qobbeh Sabz building in the historical context of Kerman was one of the relics of the Qutlugh-Khanids period in southeastern Iran and part of an extensive architectural complex including educational, religious, and mausoleum buildings in the city. Today, the only main porch of the Qutlugh-Khanids complex survives, and it is called the Qobbeh Sabz porch. During the Qajar period, a building was built in the southeastern corner of this porch as a Tekiyeh Qobbeh Sabz and still stands. One of the serious ambiguities about this Qutlugh-Khanids multipurpose complex is the process of its formation and historical course, as well as the reasons for its destruction. Accordingly, the present article studies the evidence from archaeological soundings in this complex. It analyzes the content of historical sources in order to answer these questions: What was the formation process, historical developments, and reasons for the destruction of the Qobbeh Sabz complex? What are the factors that caused its widespread destruction? However, some scholars have suggested the role of the 1896 earthquake in the widespread destruction of the complex. They believe that Qobbeh Sabz survived before this earthquake. The results of the second author's archeological soundings in 2020 and the analysis of historical texts by the method of "content analysis" showed that the process of extensive destruction of Qobbeh Sabz began some time ago, and probably some of these destructions consciously took place during the reign of Vakil al-Molk Nouri, ruler of Kerman from 1261 to 1284 AH. Based on these results, after the destruction of many parts of this multipurpose complex, part of its debris was scattered and leveled in the surrounding area. Another part of its debris was moved to another place - probably Qal'eh Dokhtar in Kerman - and then constructions took place in the Qobbeh Sabz area in the late Qajar period. Finally, the earthquake of 1896 caused damage to the last remnants of the Qutlugh-Khanids's complex, the main dome.

Keywords: Qobbeh Sabz, Qutlugh-Khanids, Qajar architecture, the historical context of Kerman.

چکیده: بنای قبه سبز در بافت تاریخی شهر کرمان، یکی از آثار دوره حاکمیت قراختایان در جنوب شرقی ایران و بخشی از یک مجموعه معماری گسترده شامل بناهای آموزشی، مذهبی و آرامگاهی در این شهر بود. اما امروزه از آن مجموعه متعلق به عصر قراختایی، تنها ایوان اصلی بنا برجای مانده و به نام گنبدی که در پشت آن قرار داشته، سردر یا ایوان قبه سبز نامیده می‌شود. در زمان قاجار در گوشه جنوب شرقی این ایوان، بنایی به عنوان تکیه قبه سبز ساخته شد و تا امروز پابرجاست. یکی از ابهامات جدی درباره این مجموعه چندمنظوره قراختایی، روند شکل‌گیری، سیر تاریخی و همچنین دلایل تخریب آن است. بر این اساس، در مقاله حاضر به مطالعه شواهد باستان‌شناختی حاصل از گمانه‌زنی باستان‌شناسی در این مجموعه و تحلیل محتوای منابع اسنادی پرداخته شده تا بتوان بدین پرسش پاسخ داد که روند شکل‌گیری، سیر تاریخی و دلایل تخریب مجموعه قبه سبز چگونه بوده و چه عواملی سبب تخریب گسترده آن شده است؟ اگرچه برخی پژوهشگران از نقش زمین لرزه سال ۱۲۷۶ خورشیدی در تخریب گسترده این مجموعه سخن گفته‌اند و به باور آنان، قبه سبز تا قبل از این زمین‌لرزه پابرجا بوده، اما نتایج گمانه‌زنی‌های باستان‌شناسی نگارنده دوم در سال ۱۳۹۹ و تحلیل متون تاریخی به شیوه «تحلیل محتوا» نشان داد که روند تخریب گسترده قبه سبز از زمانی پیشتر آغاز شده و احتمالاً بخشی از این تخریب‌ها به صورت آگاهانه، در زمان وکیل‌الملک نوری، حاکم کرمان در فاصله سال‌های ۱۲۶۱ تا ۱۲۸۴ قمری صورت گرفته است. بر پایه این نتایج، پس از تخریب بخش‌های زیادی از این مجموعه چند منظوره، بخشی از آوار آن در محدوده پیرامون بنا پراکنده و تسطیح شده و بخش دیگری از آوار آن به مکانی دیگر - احتمالاً قلعه‌دختر کرمان - منتقل شده و سپس ساخت‌وسازهایی در دوره متأخر قاجار در محدوده قبه سبز صورت گرفته است. در نهایت زمین لرزه سال ۱۲۷۶ خورشیدی، آسیب‌هایی بر آخرین بقایای مجموعه قراختایی یعنی گنبد اصلی وارد کرده است.

کلمات کلیدی: قبه سبز، قراختایی، معماری قاجار، بافت تاریخی کرمان.

I. Introduction

Qobbeh Sabz building in the Khajeh Khezr quarter in the historical context of Kerman (Fig. 1) is part of an educational, religious, and tomb architecture complex. It was built during the reign of Qutlugh-Khanids in southeastern Iran, specially developed during the rule of Turkan Khatun in the middle of the seventh century AH. The quarter in which this complex was formed was called the Turkabad quarter (Royal History of Qutlugh-Khanids, 1976, corrected introduction: 67). The expansion of this complex was completed with the construction of the school and the completion of the dome of the shrine by order of Turkan Khatun in its vicinity (Royal History of Qutlugh-Khanids, 1976: 108). Turkan Khatun worked hard to develop and maintain

the complex. At her command, the best architecture and arrays were used. This complex enjoyed an important position in the time of Turkan Khatun and became one of the most important scientific centers in southeastern Iran. Today, only the main porch of Qobbeh Sabz and the Tekiyeh belonging to the Qajar era remain on its eastern front (Fig. 2). One of the serious ambiguities about this Qutlugh-Khanids multipurpose complex is the formation process, the historical evolution as well as the reasons for its destruction. In a few studies on this complex, its destruction has been considered a consequence of the earthquake of 1896 (Gabriel, 2004: 143; Javadi, 2000: 14; Mohammadi *et al.*, 2013: 80). It has been suggested that Qobbeh Sabz existed before the earthquake. Laleh and colleagues in the study of this

complex have stated that a collection of buildings of the Qutlugh-Khanids era is buried in this part of the historical context of Kerman (Laleh *et al.*, 2012: 377).

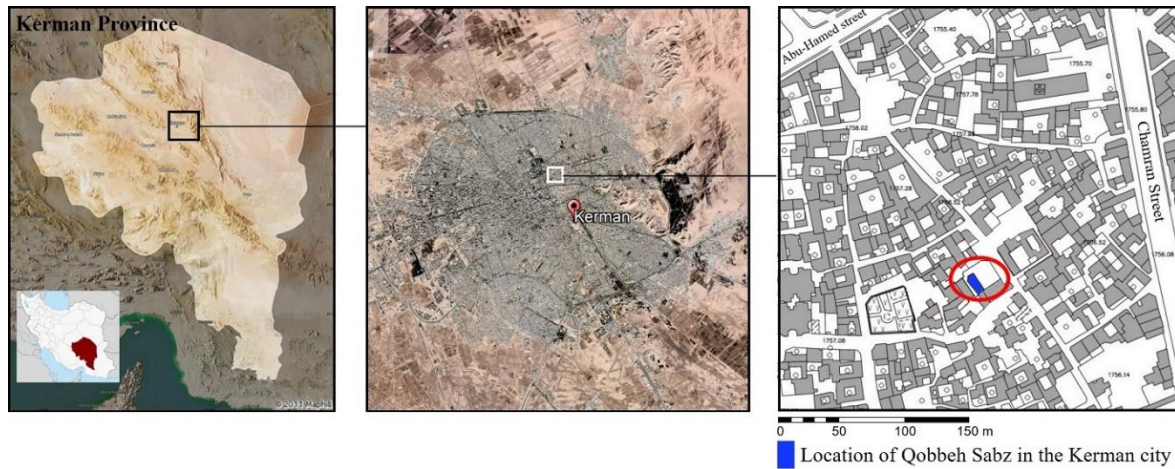


Figure 1. Qobbeh Sabz location in the urban context of Kerman (maps and satellite images taken from Mohammadi *et al.*, 2013: 86; Google Earth 2021; maphill.com; redesigned and revised by the authors).

In the present article, the archaeological evidence obtained from soundings in this collection has been studied, and the article has been formed based on two questions: First, what was the formation process, the historical evolution, and the reasons for the destruction of the Qobbeh Sabz complex? Second, what factors have led to the widespread destruction of Qobbeh Sabz?

The importance of this research is that it provides new information about the process of continuation and destruction of architectural structures buried in the Qobbeh Sabz area, based on the latest archaeological soundings. With a critical approach, it rejects previous theories about the architectural evolution of the Qobbeh Sabz complex up to the time of the earthquake of 1896 and the beginning of the destruction of the complex due to it. It also challenges previous hypotheses about the existence of identifiable architectural structures from the Qutlugh-Khanids era beneath the soil layers. It provides new information about the destruction of the architectural elements of the Qutlugh-Khanids era and its possible causes.



Figure 2. Overview of the Remaining Porch of the Qobbeh Sabz Building (Authors).

II. Research background

Qobbeh Sabz was first noticed by Sykes's direction and is listed as a tomb from the Qutlugh-Khanids period and a part of the Turkabad school. In his travelogue, Sykes described the architectural features of Qobbeh Sabz (Sykes, 1902: 194—195). The English version of Sykes's travelogue also includes a photograph of the semi-ruined dome of Qobbeh Sabz (*Ibid.*: 264) (Fig. 3). In contrast, the Persian translation of this travelogue does not provide the image. Wilber made a brief reference to Qobbeh Sabz and he described the structure of architecture, decoration, and inscriptions, and explained its chronology (Wilber, 1986: 116). Also, Wilber and Golombek have studied the school and the tomb of the Qobbeh Sabz and studied the porch as the only remnants of this architectural complex. According to them, in 1965, there were no signs of the dome. However, referring to a photograph taken by Sykes before the dome's destruction, they compared it with other domes of 15th-century buildings in Iran and Turan (Wilber and Golombek, 1995: 559). Laleh and colleagues (2008) have also studied the archaeology of Qobbeh Sabz and the role of Qutlugh-Khanids development measures in the development of Kerman. During the primarily archaeological studies, they have also studied this complex by geophysical methods. Their geophysical surveys have been concentrated at three points around Qobbeh Sabz, Zaki Zadeh's house behind the Qobbeh Sabz porch, adjacent to the south wall of Sadat Khoshrou's tomb, and at one of the houses on the north side of the green area west of Qobbeh Sabz. Also, the first and only archaeological excavation in the Qobbeh Sabz complex took place in

the 1970s or 1980s in some parts in front of the main porch of Qobbeh Sabz and the surrounding area.

However, there is no written report of these excavations in the administration of Cultural Heritage in Kerman Province or the Archaeological Research Institute. Only Laleh and colleagues have provided information based on a few photographs of this excavation and conversations with the excavator and restorer Qobbeh Sabz (Laleh *et al.*, 2012: 24) (Fig. 4).

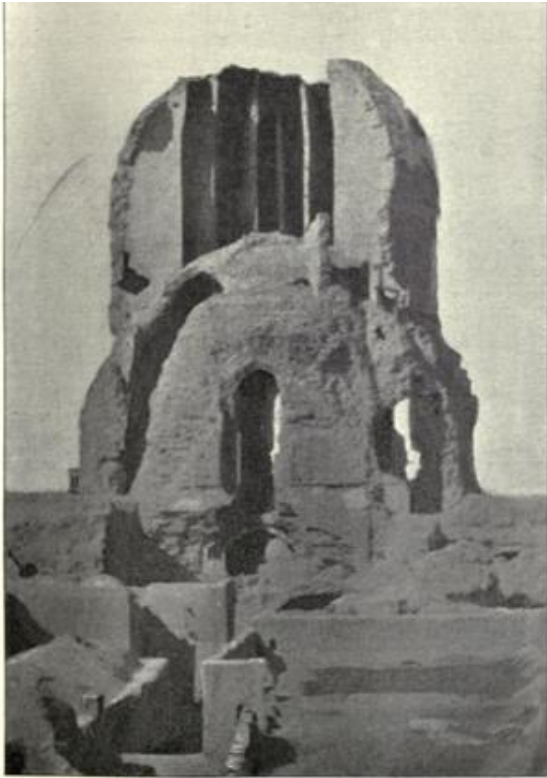


Figure 3. The Dome of the Qobbeh Sabz in the Early Twentieth Century (Sykes, 1902: 264).



Figure 4. Archaeological excavations of the 1970s or 1980s in front of the Qobbeh Sabz porch (Laleh *et al.*, 2012: 36, Fig. 13).

III. Research method

Archaeological studies in the Qobbeh Sabz complex were started in order to organize and revive it with the support of the administration of Cultural Heritage in Kerman Province and Kerman Municipality. In the first phase of this project, in 2020, soundings were put on the agenda to delimit the Qobbeh Sabz complex. After the permit was issued by the Archaeological Research Institute, this project was implemented under the direction of the second author of the article. In this project, the area around Qobbeh Sabz was divided into three sections, and soundings were made in each section. This division was made in order to achieve a clear understanding of the scope of the complex. Due to the existence of residential houses and the network of passages, there were many restrictions in choosing the location of the test trenches, but in total, 11 test trenches were created (Fig. 5). After that, the process of survival and destruction of this complex was explained by studying evidence from archaeological soundings and comparing and evaluating of this evidence, surface evidence, ancient visual documents, and analysis of the content of written historical and geographical sources. Analyzes were presented on the factors and reasons affecting the widespread destruction.



Figure 5. Location of the current Qobbeh Sabz (Blue Rectangle) and eleven archaeological test trenches around it (Authors).

IV. Current features of Qobbeh Sabz

Today, the Qutlugh-Khanids era, religious tomb, and educational complex, which included a mosque, hospital, dormitory, school, and tomb, only one tomb with large marble, the main porch of the school with exquisite tiles, and the large wall at the base of the dome remain (Mohammadi *et al.*, 2013: 83). The tomb of Qobbeh Sabz is the burial place of some of the rulers of Qutlugh-Khanids, namely Buraq Hajib, Turkan Khatun, Jalaluddin Sivar Ghatmash, Padeshah Khatun and Mohammad Shah (Bastani Parizi, 1972: 673). Comprehensive and complete information is not available about the style and architectural features of other buildings in this complex. However, at least we know about the Qutbiyeh school, built on the orders of the Turkan Khatun in this place, which was probably a four-aisled building. Because of historical sources, the phrase "Chahar Soffeh" is used to refer to it and is described by the following statement: "Its four platforms are like five roads of direct senses, and its six directions are like the foundation of seven strong constellations" (Imperial History of Qutlugh-Khanids, 1976: 336). Wilber stated that at the time of Schroeder's visit to the building [mid-twentieth century], only the lower parts of the tomb walls and porch remained. The porch arch was later rebuilt and attributed to a school that no longer exists (Wilber, 1986: 116).

Of the interior remains of the porch, written in white Thuluth script on an azure mosaic tile, only the words "Abde Abdul R ..." are read with difficulty, and for this reason, it is known among the people as the school of Khaja Abdul Rashid (Islampanah, 1991: 402-403). Some of the architectural arrays, such as mosaic tiles and screw tiles on the edges of the porch, with a very advanced technique, are probably related to the reconstructions and additions of the periods after

Qutlugh-Khanids (Javadi, 2000: 14). In the past, there was an inscription around the dome from the outside, and the inside of the dome was decorated with a large Toranj style of gold and azure. The tile design of the dome is exactly the same as the tile design of Shah Nematullah Vali in Mahan (Islampanah, 1991: 402). Above the main porch, there were two minarets collapsed along with the porch arch, and at the same time¹, only the porch arch was rebuilt (Islampanah, 1991: 402—403). Although much of the complex has been destroyed, according to historical sources, the construction and development of the multipurpose complex around Qobbeh Sabz began in the Qutlugh-Khanids period and culminated in the Turkan Khatun period. The situation of Qobbeh Sabz and the buildings around it from the Qutlugh-Khanids era onwards is examined based on written historical sources.

V. Qobbeh Sabz's appearance in historical sources

After Buraq Hajib, the founder of the Qutlugh-Khanids dynasty, died on the twentieth of Dhu al-Hijjah in 632 AH (September 1235), he was buried in a school he had built in the Torkabad quarter of Kerman (Munshi Kermani, 1983: 26). His tomb became a place to develop the educational, religious, and tomb architecture complex of Qutlugh-Khanids. A few years later, Turkan Khatun of Qutlugh-Khanids, to develop the complex, ordered the demolition of the buildings around the glorious Qutlugh-Khanids shrine so that their land could be used for school buildings and other buildings (Imperial History of Qutlugh-Khanids, 1976: corrected introduction: 67). Accordingly, although the tomb of Qobbeh Sabz and the school were built in the glorious era of Buraq Hajib, the porch was tiled eight years after his death, and the school was completed from the time of Turkan Khatun onwards (Imperial History of Qutlugh-Khanids, 1976: corrected introduction: 69). The school built on the orders of Turkan Khatun was originally named after her husband, Qutbuddin, "Qutbiyeh". It later became known as the Esmatiyeh School due to the title of Turkan Khatun, "Esmat al-Din" (Imperial History of Qutlugh-Khanids, 1976: corrected introduction: 70).

Turkan Khatun entrusted the tutelage and teaching of law in the Qutbiyeh school to one of the jurists named "Taj al-Mallah va al-Din Sadidi al-Zozani" (Munshi Kermani, 1983: 42). The importance and beauty of the Qutbiyeh school are mentioned in historical sources: "When the Turkan, may God have mercy on them, finished the Qutbiyeh school, I did not

¹ Islampanah has pointed out that the two minarets above the porch have collapsed along with the arch of the porch due to the earthquake of 1896 (Islampanah, 1991: 402). While in the introduction of the book of royal history Bastani Parizi stated that

these two minarets were destroyed in the attack of Agha Mohammad Khan on Kerman by a cannon shot (Imperial History of Qutlugh-Khanids, 1976: corrected introduction: 69).

see a building with such delicacy and I did not hear a building with this elegance" (Imperial History of Qutlugh-Khanids, 1976: 336). In 681 AH/1283 AD, after the death of Turkan Khatun, she was also buried in the dome of the school- the remains of the porch are now known as Qobbeh Sabz (Le Strange, 2004: 328-329). Thus, the complex of buildings around Qobbeh Sabz was built or reconstructed in the Qutlugh-Khanids era – the seventh century AH/13th AD - and from the seventh century AH onwards, significant narratives and descriptions of this architectural complex have been included in historical sources. The oldest historical source about the Qutlugh-Khanids and Qobbeh Sabz complex is the Marco Polo Travelogue. Alfonso Gabriel wrote in "Marco Polo in Iran" his book that "When Marco Polo last came to Kerman, Turkan Khatun was buried in the tomb of his dynasty, Qobbeh Sabz, for ten years. This dome was an octagonal building about 17 meters high with blue-green (turquoise) tiles" (Gabriel, 2004: 143). Sykes, in his travelogue about 120 years ago, referred to Qobbeh Sabz as one of the most prominent buildings in Kerman and wrote about it: "The dome had a strange cylindrical structure that was probably about 50 feet high, and outside of its enclosure, charming inlays and gilding dazzled the viewer's eyes. In the interior plastering of the area, there were also distinct golden and gilding designs" (Sykes, 1902: 194). The inscription under the dome of Qobbeh Sabz contained a text entitled "A work by Master Khajeh Shokrallah and Master Enayatullah Valdan, Master Nizamuddin Isfahani Architecture". According to a person who accompanied him as a guide, Sykes wrote that the date of construction of the dome, the date of this building, is 640 AH [1243 AD] and that was built eight years after the death of Buraq Hajib of Qutlugh-Khanids, the founder of the Qutlugh-Khanids dynasty. Sykes has expressed doubts about the veracity of his guide (*Ibid.*: 194-195).

Two years after the 1896 earthquake, Vaziri reported on Qobbeh Sabz: "Today there are no altitude traces of Qobbeh Sabz. First, some of the sticks and tiles were cut and taken away by someone, and two years ago, when there was a strong earthquake in Kerman at dawn, the traces of it were destroyed" (Vaziri, 2006: 230). George Curzon also mentions Qobbeh Sabz as one of the most important buildings in Kerman in his travelogue. He described the Qobbeh Sabz as a round, domed structure built between 1100 and 1155 AD, where the damaged marble tomb and the blue tiles were located (Curzon, 1994: 298). According to some historical and geographical sources, Le Strange also referred to the inscriptions under the Qobbeh Sabz dome, the names of the architects, and the date of its construction (Le Strange, 2004: 329).

VI. Results of sounding in the Qobbeh Sabz site

In and around Qobbeh Sabz, eleven test trenches were created in architectural spaces, walkways, and open spaces. The position of these test trenches is given in Table 1. Test trench I and II were created at points previously studied by Laleh and her colleagues, in geophysical studies using GPR ground penetration radar. Based on these studies, they introduced these areas as areas containing the architecture of the Qutlugh-Khanids era (Laleh *et al.*, 2009: 21).

While what is introduced in the research of Laleh and her colleagues as Qutlugh-Khanids architecture in these places includes the works of late Qajar architecture because the second author's archeological soundings showed that the architectural works of the Qutlugh-Khanids era were completely destroyed in these places and there is no insitu structure from that period in these places. Test trench I contains evidence of stable and cluttered architecture, including brick walls and irregular brick accumulation. At the highest level and from a depth of 20 cm to 55 cm, a brick wall with bricks measuring 19.5×19.5×4 cm was identified. Below it, from a depth of 55 cm to 100 cm, an irregular accumulation of bricks with later ceramic fragments was identified, and beneath this accumulation of bricks is an older brick wall (Figs. 6 and 7). Considering the dimensions of the upper wall bricks and the presence of Qajar ceramic pieces in the irregular accumulation below it (Fig. 9), it seems that the upper wall belongs to the Qajar era, and that probably after the destruction of the older brick structure in this part, its surface is smooth with the bricks resulting from the destruction of the building. Due to the formation of the late Qajar brick structure on the accumulation of irregular bricks, it seems that the destruction of the old brick structure occurred in the Qajar era or before it. Then a new structure was built on it. The ceramic on the surface of irregular brick accumulation is of the late type of simple unglazed or monochromatic glazed ceramic. An accumulation of irregular bricks in test trench II was also detected at a depth of 68 cm, which continued to a depth of 110 cm and was almost flush with the accumulation of bricks in borehole I. This irregular accumulation of bricks at a depth of 70 cm was also detected in test trench III. On this brick surface, there were also simple potteries, and in front of it, there were a large number of pieces of mosaic tiles that remained from the destruction of the architecture of older buildings (Fig. 10).

Irregular brick accumulation continued at a depth of 10 to 80 cm in test trench V, 170 cm deep in test trench VIII, and 160 cm deep in test trench IX. The reason why the mentioned brick accumulation was detected in test trenches VIII and IX at a lower depth than in other test trench is that the initial level of these two test

trenches is higher than in other test trenches. In other words, the fixed point of test trenches VIII and IX is 80 and 100 cm higher than the fixed point of the other four test trenches, respectively. Therefore, the depth of irregular accumulation of bricks in these two test trenches compared to the four test trenches I, II, III, and V is greater. If the difference in the height of the fixed point of test trenches VIII and IX is subtracted from the depth of irregular brick accumulation, the level of irregular brick accumulation in these two test trenches is equal to the level of brick accumulation detected in other test trenches. Therefore, the accumulation of irregular bricks resulting from the destruction of ancient buildings was identified in 6 of the 11 test trenches. The depth of this irregular accumulation in these six test trenches is on, average, 50 to 110 cm. The study of architectural evidence and cultural materials obtained from different depths in 11 test trenches excavated, shows that most of the identified architectural works in the Qobbeh Sabz area belong to the late period and specifically belong to the late Qajar period, with the exception of test trench VIII,

which is the lower part of the entablature and the Qobbeh Sabz porch appeared, with no other evidence of Qutlugh-Khanids-era architecture has been found in other test trenches. While glazed ceramic of monochromatic paste of the 6th and 7th centuries AH, painting glazed ceramic of the middle Islamic centuries, and luster wares and tiles of the 7th century AH are among the most significant findings in most test trenches.

The presence of these cultural materials, along with fragments of mosaic tiles from the 7th to 10th centuries AH, in unstable layers of debris from brick structures, indicates that the entire area around Qobbeh Sabz in the middle Islamic centuries was probably part of the urban texture and certainly included medieval architecture, was specific to the Qutlugh-Khanids, Al-Muzaffar, and Timurids. Therefore, in spite of this movable evidence, one must look for the reasons for the lack of stable Qutlugh-Khanids, Al-Muzaffar, and Timurid architecture in these test trenches. In the next section, the reasons for the lack of sustainable architecture from these periods are analyzed.

Table 1. Location and dimensions of excavated test trenches and their findings.

No. test trench	Position of test trench	Dimensions (cm)	Last exploration depth (cm)	Fundings
I	Room on the north side of Zakizadeh's house, attached to the west side behind Qobbeh Sabz porch	130 × 330	180	Late brick walls, irregular accumulation of bricks at a depth of 55 to 100 cm, plain and late carved ceramic without glaze, mosaic tile pieces
II	South of Sadat Khoshrou Tomb, 40 meters west of Qobbeh Sabz Porch	130 × 230	234	Irregular brick accumulation at a depth of 68 to 110 cm, simple late ceramic without glaze and glazed with turquoise and blue frit ware
III	Outdoors between Zaki's house and green space 35 meters southwest of Qobbeh Sabz	130 × 130	80	Irregular brick accumulation at a depth of 70 cm, simple late ceramic without glaze, large quantities of mosaic tiles from the ruins of the building
IV	In the green space located 50 meters west of Qobbeh Sabz porch	130 × 150	370	Mud-brick wall, plain unglazed ceramic, blue and white and molded, glazed frit ware, mosaic tile pieces
V	In the courtyard of Qobbeh Sabz, in front of Qobbeh Sabz porch	130 × 130	270	Irregular brick accumulation at a depth of 10 to 80 cm
VI	In the courtyard of Qobbeh Sabz, six meters east of borehole V in front of Qobbeh Sabz porch	130 × 130	165	Simple unglazed c, under-glazed paintings, mosaic tile pieces
VII	Near the eastern wall of the Qobbeh Sabz courtyard, three meters east of borehole VI	130 × 130	140	Late brick wall, simple unglazed ceramic, under-glazed painting, luster ware, luster tile pieces, and mosaics.
VIII	Attached to the north entablature of the Qobbeh Sabz porch	130 × 130	170	Brick walls and the lower part of the main porch of Qobbeh Sabz, irregular accumulation of bricks at a depth of 170 cm, simple unglazed ceramic, glazed monochromatic clay

				paste and frit ware, under-glazed paintings, mosaic tiles
IX	On the east side of the Qobbeh Sabz courtyard, attached to the Qajar's Tekiye wall on the east porch	110 × 130	165	Irregular brick accumulation at a depth of 160 cm, plain unglazed ceramic, under-glazed painting, Qajar blue and white
X	Passage and open space 20 meters southeast of Qobbeh Sabz porch	130 × 130	215	Late brick walls, irregular brick accumulation, plain unglazed ceramic, monochromatic glazed, under-glazed painting, mosaic tiles
XI	In the middle of the green space square 65 meters west of Qobbeh Sabz porch	130 × 130	310	Unglazed plain ceramic, under-glazed painting, monochromatic glazed, Qajar blue and white, mosaic tile pieces



Figure 6. Qajar era brick wall at the highest level of the test trench I, the accumulation of bricks below it, and part of the older structures at the lowest depth of this test trench.

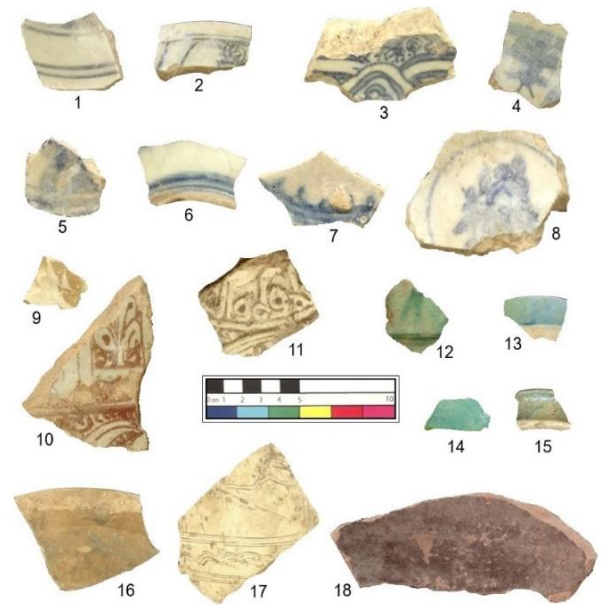


Figure 8. Medieval Islamic ceramics and tiles in test trenches.



Figure 7. Qajar period brick structure above and irregular brick accumulation below it in test trench X.

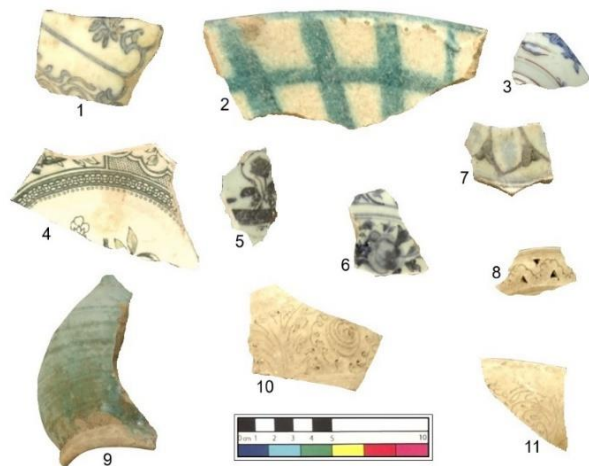


Figure 9. Qajar ceramic pieces in test trenches.

VII. Discussion and analysis

According to historical sources, after the formation of the Qutlugh-Khanids complex, the complex was developed by Turkan Khatun, and the development of Qobbeh Sabz and the surrounding buildings continued into later periods. During the Timurid period, a major reconstruction of the Qobbeh Sabz seems to have taken place. According to the oldest known image of the main dome of Qobbeh Sabz (Fig. 3), the dome was a double-shell dome with a high Gariv (tambour) and the interior space between the inner and outer shells with septums called "Khashkhashi". This dome form was a significant element in the architecture of the Qobbeh Sabz complex. There is no trace of this dome now (Islampanah, 1991: 402). Wilber believes that the dome that stands on top of this building, in terms of architectural style, is not from the pre-ninth AH [15th AD]. Sykes probably misread the date of 840 AH by 640 AH (Wilber, 1986: 115-116). Wilber also cited the theory of Eric Schroeder and considered the builder of the dome, namely Master Enayatullah, son of Nizamuddin, as the father of Haji Beg Ibn Enayatullah and explains that the name of Haji Beg Ibn Enayatullah appears on the altar of the Kerman Grand Mosque and is related to the reconstruction of the Grand Mosque in 967 AH (Wilber, 1986, 116). Accordingly, Wilber and Schroeder believe that the Qobbeh Sabz dome dates to the post-Qutlugh-Khanids period. These views seem logical considering the type of double-shell dome with a high tambour and the Khashkhashi between the space of the inner and outer shells, as well as the role and technique of the building's mosaic tiles and indicate the reconstruction of the building about three centuries after its foundation. Looking at the photo of the dome in Sykes's travelogue, the form of the dome of Qobbeh Sabz with two discontinuous shells with Timurid domes, including the dome of the shrine of Khajeh Abu Nasr Parsa in Balkh (Wilber and Golombek, 1995: 964), the dome of Goharshad shrine in Herat (*Ibid.*, 966), and the large dome of the tomb of the Imam of Isfahan (Rahravi Podedeh *et al.*, 2016: 88) is identical. Islampanah, for several reasons, believes that Qobbeh Sabz was rebuilt in 940 AH under the direction of a man named Abdul Rashid (Islampanah, 1991: 404). Contrary to the process of expansion, reconstruction, and continuation of the life of Qobbeh Sabz and the surrounding buildings from the Qutlugh-Khanids era to the tenth century AH, there is no archaeological and historical evidence about the reconstruction and life of this complex from the tenth century AH to the Qajar era. In some contemporary studies, the earthquake of 1896 has been identified as the cause of the destruction of Qobbeh Sabz (Gabriel, 2004: 143; Javadi, 2000: 14; Mohammadi *et al.*, 2013: 80). Analyzing the content of some historical sources, it seems that the collapse of this



Figure 10. A number of pieces of medieval mosaic tiles in the test trenches.

Qutlugh-Khanids architectural complex occurred before the 1896 earthquake, and the earthquake only dealt the last blows to the semi-ruined structures of Qobbeh Sabz. For example, in 1209 AH/1795 AD, when Agha Mohammad Khan Qajar besieged Kerman because the people of Kerman took refuge in the domes and minarets of mosques, and from there they fired at Agha Mohammad Khan's camp, at the order of Agha Mohammad Khan, the minarets were shelled, including the long minarets of Qobbeh Sabz were destroyed (Imperial History of Qutlugh-Khanids, 1976; corrected introduction: 69). Decades later, Vakil al-Molk Nouri destroyed parts of Qobbeh Sabz in the guise of finding treasure (Sykes, 1902: 194). Bastani Parizi, in the preface of imperial history, referring to the same narration, stated that another part of this building was destroyed by Jalal al-Dawlah to find treasure (Imperial History of Qutlugh-Khanids, 1976: 68). Content analysis of Sykes's descriptions also confirms the demolition of the Qobbeh Sabz complex before the 1896 earthquake. Sykes wrote in his travelogue that the earthquake of 1896 completely destroyed the Qobbeh Sabz building, which was "on the verge of destruction" (Sykes, 1902: 194). Thus, the phrase "on the verge of destruction" in the text of Sykes's travelogue indicates that the process of destroying the green dome probably began some time ago and that the final blow was dealt with its body by an earthquake.

Archaeological evidence in the test trenches excavated in 2020 also confirms the narratives of historical sources. It indicates the widespread destruction of this complex and then new constructions on it in the last decades of the Qajar era. Due to the identification of surviving architecture from the late Qajar period at the highest level of trenches, the existence of extensive accumulation of bricks from the destruction of the building in most trenches, and the lack of identification of intact architecture from the Qutlugh-Khanids period to before the Qajar, it seems

that this complex was widely destroyed in the late Islamic centuries until the Qajar period. In other words, archaeological soundings show the level of irregular brick accumulation that was detected at almost the same height level in most of the trenches and under the Qajar architectural buildings is probably due to the extensive destruction of older buildings. After that destruction, new structures were created in the late Qajar period. Accordingly, it seems that the Qutlugh-Khanids complex in this area, during the Qajar period or before, was extensively destroyed, and a level of brick accumulation was created due to the destruction of the building. Then, Late Qajar structures were formed on this brick pile.

Another issue that shows the widespread destruction of the Qutlugh-Khanids complex around Qobbeh Sabz in the Qajar era and before the earthquake of 1896 is the valuable tiles, along with the accumulation of architectural debris, were discovered in the archeological excavations of the second author from 2016 to 2018 in Qal'eh Dokhtar Kerman, 1500 meters southeast of Qobbeh Sabz. The study on these tiles showed that the tiles did not belong to the Qal'eh Dokhtar structure and were transferred from another building (probably Qobbeh Sabz) to the Qal'eh Dokhtar (Amirhajloo *et al.* 2020: 2) (Fig. 11). The historical inscription on one of these tiles (dated 661 AH/1263 AD, fig. 11; No. 6) and the stylistic study of the other tiles show that they all belong to the middle of the seventh century AH and coincide with the date of construction of Qobbeh Sabz (*Ibid*). These tiles were discovered among the rubble in Qal'eh Dokhtar that resulted from the collapse of the third floor in the space of the corridor of the platform (Fig. 12). Surveying the third floor above the platform, it was found that there is no trace of tiling in the structural elements of the third floor, including the plinths. Also, the structures of the third floor were created in the Qajar period according to the type of arches and the dimensions of mud bricks. Because the tiles are from the middle of the seventh century AH, the tiles cannot be considered a decoration of the third-floor spaces of the Qal'eh Dokhtar platform. Accordingly, in the Qajar period, these tiles,

along with other architectural rubble, were probably used as a pile of materials for flooring (third-floor filler). Their use on the third floor of Qal'eh Dokhtar was secondary (Amirhajloo *et al.*, 2020b: 7). On the other hand, the boxes containing the tiles attributed to Qobbeh Sabz of Kerman, which are currently kept in the same building, are luster tiles similar to the Qal'eh Dokhtar samples (Fig. 11: 14). In the soundings of 2020 on the Qobbeh Sabz site, similar luster tiles were discovered (Fig. 8: 10).

Thus, the Qobbeh Sabz complex in the middle Islamic centuries and before its demolition was adorned with similar luster tiles. As stated in the Imperial history: "... When the Grand Sultan [Turkan Khatun Qutlugh-Khanid] ordered the construction of a holy school, she insisted that large platforms be decorated with tiles" (Imperial History of Qutlugh-Khanids, 1976: 122). Therefore, it seems that the luster tiles from Qal'eh Dokhtar in Kerman were transferred from Qobbeh Sabz there. In other words, probably during the demolition of the tomb of the Qutlugh-Khanids at Qobbeh Sabz and the Turkan Khatun school next to it during the Qajar period, a large amount of rubble was left, some of which was scattered and flattened around Qobbeh Sabz (The form of brick accumulation in the trenches has been identified) and some of this debris has been transferred to Qal'eh Dokhtar on the outskirts of the city. By doing so, the Qobbeh Sabz site was cleared and prepared for further civil works. On the other hand, the Qobbeh Sabz architectural rubble was used in the flooring of the third floor of the Qal'eh Dokhtar platform (Amirhajloo *et al.*, 2020b: 8).

Another point is that in the northwest of Qal'eh Dokhtar, there was a deep well that Vakil al-Molk Nouri ordered to fill at the same time as the destruction of Qobbeh Sabz so that people could not be thrown into it (Sykes, 1902: 190). Accordingly, the transfer of Qobbeh Sabz debris to Qal'eh Dokhtar by Vakil al-Molk the use of part of the debris to fill the well, and the use of another part of the debris for flooring and third-floor construction of the platform are not unexpected (Amirhajloo *et al.*, 2020b: 8).



Figure 11. luster tiles of Qal'eh Dokhtar (No 1-13) and Qobbeh Sabz Kerman (No. 14).



Figure 12. Qal'eh Dokhtar platform and the site of the discovery of luster tiles amid the accumulation of architectural debris.

VIII. Conclusion

The complex of educational, religious, and tomb buildings developed in the Qutlugh-Khanids era, especially during the reign of Turkan Khatun in the middle of the seventh century AH/ 13th AD in the city

of Kerman, had become one of the most important scientific centers in southeastern Iran. It seems that this place was preserved at least until the Timurid era and the tenth century AH. Some of the architectural elements of the Qobbeh Sabz, such as the discontinuous double-shell dome with a high tambour and the Khashkhashi between the space of the inner and outer shells, as well as the abundant mosaic tiles on its architectural surfaces, clearly indicate the reconstruction of the complex in the post-Qutlugh-Khanids period, especially the Timurid era. However, not much is known about the status of this complex and its status and importance in the Safavid to Qajar periods. There is no data about Qobbeh Sabz and the surrounding buildings in historical sources from the Safavid period to the Qajar period. Archaeological soundings do not provide information about the reconstruction of architectural structures in the Safavid period before the Qajar period. Some scholars have commented on the role of the 1896 earthquake in the massive destruction of Qobbeh Sabz and the surrounding Qutlugh-Khanids, and Qobbeh Sabz has been shown to have survived before the earthquake. However, the results of the second author's archeological soundings in 2020 and the analysis of historical texts using "content analysis" showed that the process of extensive destruction of Qobbeh Sabz began long ago in the Qajar period, and probably some of these destructions consciously took place during the reign of Vakil al-Molk Nouri, the ruler of Kerman

between 1261 and 1284 AH/1845-1867 AD. Based on the results of archaeological soundings in the Qobbeh Sabz site and archaeological studies in Qal'eh Dokhtar in eastern Kerman, it seems that after the destruction of many parts of the buildings around Qobbeh Sabz, part of the debris was scattered and leveled in the area around the building and another part of the debris, has been transferred to Qal'eh Dokhtar on the eastern outskirts of Kerman. Later, constructions in the late Qajar period took place on the site of the leveled structures of the Qutlugh-Khanids era. Finally, the earthquake of 1896 dealt the final blow to the only remaining member of the Qutlugh-Khanids, the main dome. In GPR geophysical surveys by Laleh and her colleagues, some points have been identified as areas containing Qutlugh-Khanids architecture around Qobbeh Sabz. Extensive and conscious demolition of the Qobbeh Sabz complex and the leveling of the area during the Qajar period and then Qajar constructions on its site makes it difficult to reconstruct the Qutlugh-Khanids space and architectural form in the complex in future archaeological studies. In the 2020 soundings, no Qutlugh-Khanids architectural space was identified

completely. In GPR geophysical surveys, what was previously referred to as Qutlugh-Khanids structures are in fact, late Qajar architectural structures.

Acknowledgments

Archaeological soundings in the Qobbeh Sabz complex have been made possible with the help of individuals and the following executive agencies:

Dear Mr. Fereydoon Fa'ali, Director of the Administration of Cultural Heritage in Kerman Province, Mr. Shafiei, Deputy Head of the Administration of Cultural Heritage in Kerman Province, Dr. Shirazi, former director of the Archaeological Research Institute, Dr. Siamak Sarlak, Deputy Director of the Archaeological Research Institute, Engineer Alamzadeh, Mayor of Kerman, Dr. Qutbuddini, Mayor of District 5 of Kerman (old texture), and Mr. Sadeghzadeh, Executive Deputy of District 5 Municipality, Thanks to all these nobles. Also, thanks to the archaeological team members: Sareh Tahmasbizadeh, Amin Mahani (Bildar), and Alireza Zabanavar.

References

- Amirhajloo, S., Emami, M., Agha-Aligol, D., Riahiyan Gohorti, R. (2020a). Preliminary studies on polychrome luster tiles excavated from Qal'eh Dokhtar in Kerman by X-ray, SEM-EDX, and micro-PIXE spectroscopy; Insight into a new production center of lusterware in Southeast Iran. *Journal of Archaeological Science Reports*, 33, 1-14.
- Amirhajloo, S., Emami, S. M., Agha Ali Gol, D., Riahiyan Goharti, R. (2020b). Introduction, classification and structure of luster tiles found in the Qal'eh Dokhtar in Kerman, *Journal of Research on Archaeometry*, 6 (2), 1-23, (in Persian).
- Imperial History of Qutlugh-Khanids*. (1976). edited and corrected by Mohammad Ibrahim Bastani Parizi. Tehran: Iranian Culture Foundation, (in Persian).
- Bastani Parizi, M. I. (1972). Historical complexes in Kerman; Ganjali Khan Collection. *Yaghma*, No. 293, 670-676, (in Persian).
- Curzon, G. N. (1994). *Iran and the Case of Iran*, Volume 2, translated by Gholam Ali Vahid Mazandarani, Fourth Edition, Tehran: Scientific and Cultural Publications, (in Persian).
- Gabriel, A. (2004). *Marco Polo in Iran*, translated by Kikavous Jahandari, Tehran: Dr. Afshar Endowment Foundation, (in Persian).
- Islampannah, M.H., (1991). History of the inscription of the Qobbeh Sabz of Kerman. *Yaghma*, yadnameh Yaghma, 32: 400—405, (in Persian).
- Javadi, S., (2000). Qobbeh Sabz; The oldest example of mosaic tile in Iran. *Fine Arts*, 7, 12-20, (in Persian).
- Laleh, H., Shojaei Isfahani, A., Haji Alilo, S., Lorzadeh, Z., Varahram, L., Rafiei Alavi, B. (2012). Archaeological Survey of Kerman: Qobbeh Sabz and the role of Qutlugh-Khanids's road management in the development of Kerman, *11th Annual Archaeological Conference of Iran*. Tehran: Cultural Heritage Research Institute, (in Persian).
- Le Strange, G. (2004). *Historical Geography of the Eastern Caliphate*. Sixth Edition, translated by Mahmoud Erfan, Tehran: Scientific and Cultural, (in Persian).
- Mohammadi, M., Mohammadi, M. Khajehpour, M. (2013). Recognition and protection of values in the historical monument Qobbeh Sabz Kerman. *Studies of the Iranian Islamic City*, 12: 79—88, (in Persian).
- Munshi Kermani, N. al-D., (1983). *Samat al-ola le-al-hazrat al-ohya*. under the supervision of Mohammad Qazvini, edited by Abbas Iqbal Ashtiani, Tehran: Asatir, (in Persian).
- Rahravi Podeh, S., Valibig N., Rahimi Ariaei A. (2016). Analysis of geometric and executive details in discontinuous double-shell domes in Isfahan. *Soffeh*, Volume 26, Number 2: 85—104, (in Persian).
- Sykes, P. M. (1902). *Ten Thousand Miles in Persia; or Eight Years in Iran*. London: Murray.
- Vaziri, A.A.K. (2006). *History of Kerman*. edited by Mohammad Ibrahim Bastani Parizi, Tehran: Elm, (in Persian).
- Wilber, D. (1986). *Islamic architecture of Iran in the Ilkhanate period*. translated by Abdullah Faryar, second edition, Tehran: scientific and cultural, (in Persian).
- Wilber, D., Golombek, L. (1995). *Timurid architecture in Iran and Turan*. translated by Keramatullah Afsar and Mohammad Yousef Kiani, Tehran: Cultural Heritage Organization, (in Persian).