Universidade de Évora - Instituto de Investigação e Formação Avançada
Università degli Studi di Roma "La Sapienza" Aristotle University of Thessaloniki

Mestrado em Ciência dos Materiais Arqueológicos (ARCHMAT)

Dissertação

A Foundation Deposit at the Chalcolithic Shrine of Ein Gedi, Israel: Micromorphology and Function

Gunel Nabisoy

Orientador(es) | Yuval Goren
Nicola Schiavon

Évora 2023

Esta dissertação não inclui as críticas e as sugestões feitas pelo júri.

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A Foundation Deposit at the Chalcolithic Shrine of Ein Gedi, Israel: Micromorphology and Function.

Thesis, submitted as part of the requirement for the master's degree of the 2021-2023 edition of the ARCHMAT EMJM Program in ARCHaeological MATerials science (ARCHMAT)

By

Gunel Nabisoy

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Supervised by Prof. Yuval Goren (Ben Gurion University of the Negev) and Prof. Nicola Schiavon, Universidade de Évora, co-supervisor in the EMJM ARCHMAT Master Thesis project.

ABSTRACT

The Chalcolithic period in the southern Levant (approximately 4500-3800 cal. B.C.E) holds significant importance in the region's history and raises several unanswered questions. Following the start of this period, the population grew, settlements became more diverse, and religious buildings improved (Rowan & Golden, 2009). To better understand this era, the Ein Gedi shrine, a Ghassulian cultic site, provides valuable insights for analysis.

The Ein Gedi site perches midway on a steep cliff that parallels the western side of the Dead Sea (part of the Syrian-African Rift Valley), demarcating the Judean Desert plateau's edge. Scientific conclusions are essential to unravel its function and shed light on its cultic significance within the Ghassulian Culture spanning about 700 years. Such insights could aid in scrutinizing the relationship between the Naḫal Mishmar hoard and Ein Gedi as an assumed Chalcolithic shrine.

Understanding the relationship between the Naḫal Mishmar hoard and Ein Gedi as a Chalcolithic cultic center is crucial. To achieve this goal, we will focus on the foundation deposit of the main structure of the shrine, which has recently been discovered. Our project involves conducting multiple microarchaeological and micromorphological analyses on this find and related soils and sediments. By doing so, we aim to evaluate the context and role of the site to gain insight into its significance. This information is essential to comprehend the site's importance.

First, we conducted a literature review and visited different sites (including Ein Gedi) as the primary research background. This was followed by a comprehensive analysis of the foundation deposit found during the 2021 season of the renewed excavations under the southwestern corner of the main building of the site complex. Various analytical techniques were employed, including

detailed micromorphological study, micro-artifact analysis, powder XRD, FTIR/ATR, and optical mineralogy (petrography). This research was conducted from May to September 2023.

RESUMO

O período calcolítico no sul do Levante (aproximadamente 4.500-3.800 cal. a.C.) tem uma importância significativa na história da região e levanta várias questões sem resposta. Após o início deste período, a população cresceu, os assentamentos tornaram-se mais diversificados e os edifícios religiosos melhoraram (Rowan & Golden, 2009). Para compreender melhor esta época, o santuário de Ein Gedi, um local de culto Ghasuliano, fornece informações valiosas para análise. O sítio de Ein Gedi fica no meio de um penhasco íngreme paralelo ao lado ocidental do Mar Morto (parte do Vale do Rift Sírio-Africano), demarcando a borda do planalto do deserto da Judéia. As conclusões científicas são essenciais para desvendar a sua função e lançar luz sobre o seu significado cultual dentro da Cultura Ghasuliana que abrange cerca de 700 anos. Tais percepções poderiam ajudar a examinar a relação entre o tesouro de Naẖal Mishmar e Ein Gedi como um suposto santuário calcolítico.

Compreender a relação entre o tesouro de Naẖal Mishmar e Ein Gedi como um centro de culto calcolítico é crucial. Para atingir este objetivo, centrar-nos-emos no depósito de fundação da estrutura principal do santuário, recentemente descoberto. Nosso projeto envolve a realização de múltiplas análises microarqueológicas e micromorfológicas nesta descoberta e nos solos e sedimentos relacionados. Ao fazer isso, pretendemos avaliar o contexto e a função do site para obter informações sobre sua importância. Essas informações são essenciais para compreender a importância do site.

Primeiro, conduzimos uma revisão da literatura e visitamos diferentes locais (incluindo Ein Gedi) como base principal da pesquisa. Isto foi seguido por uma análise abrangente do depósito de fundação encontrado durante a temporada de 2021 das novas escavações sob o canto sudoeste do edifício principal do complexo local. Várias técnicas analíticas foram empregadas, incluindo estudo micromorfológico detalhado, análise de microartefatos, XRD de pó, FTIR/ATR e mineralogia óptica (petrografia). Esta pesquisa foi realizada de maio a setembro de 2023.

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Many thanks are due to my supervisor, Professor Yuval Goren, for his tremendous supervision through this period and giving me opportunity to do research on the history of this beautiful landscape. Thanks are also due to Dr. Yotam Asher from the Israel Antiquities Authority for his help through the certain stage of the project.

I express my gratitude to my supervisor Prof. Nicola Schiavon and the ARCHMAT EMJM Committee, for making it possible for me to explore archaeology in different contexts and teaching me how to use scientific methods to understand history better.

To my dear friends (some I have met along the way, some I already had), thank you for your encouragements and being always there for me.

I am forever indebted to my family, especially my sister Nazrin, for her love and support, couldn't have done it without her.

"To see a World in a Grain of Sand
And a Heaven in a Wild Flower…"

William Blake

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List of Abbreviations

ARCHMAT	Archaeological material science
B.C.E.	before common era
BGU	Ben-Gurion University of the Negev
FTIR	Fourier-Transform Infrared Spectroscopy
IAA	Israel Antiquities Authority
ICDD	International Center for Diffraction Data
TGA	Thermo-Gravimetric Analysis
UHaifa	University of Haifa
XRD	X-ray Diffraction

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1 Introduction

1.1 The Chalcolithic Period in the Levant

To gain a better understanding of the growth patterns and challenges encountered by prehistoric societies, it is essential to study the prehistory of the Levant region. The Chalcolithic Period (approximately 4500-3800 cal. B.C.E) is a critical period in the spectrum of Levantine cultures. During this time, the innovations from the Neolithic age were still prevalent and continued to develop. While life persisted in some ancient settlements, people from this era began to move apart

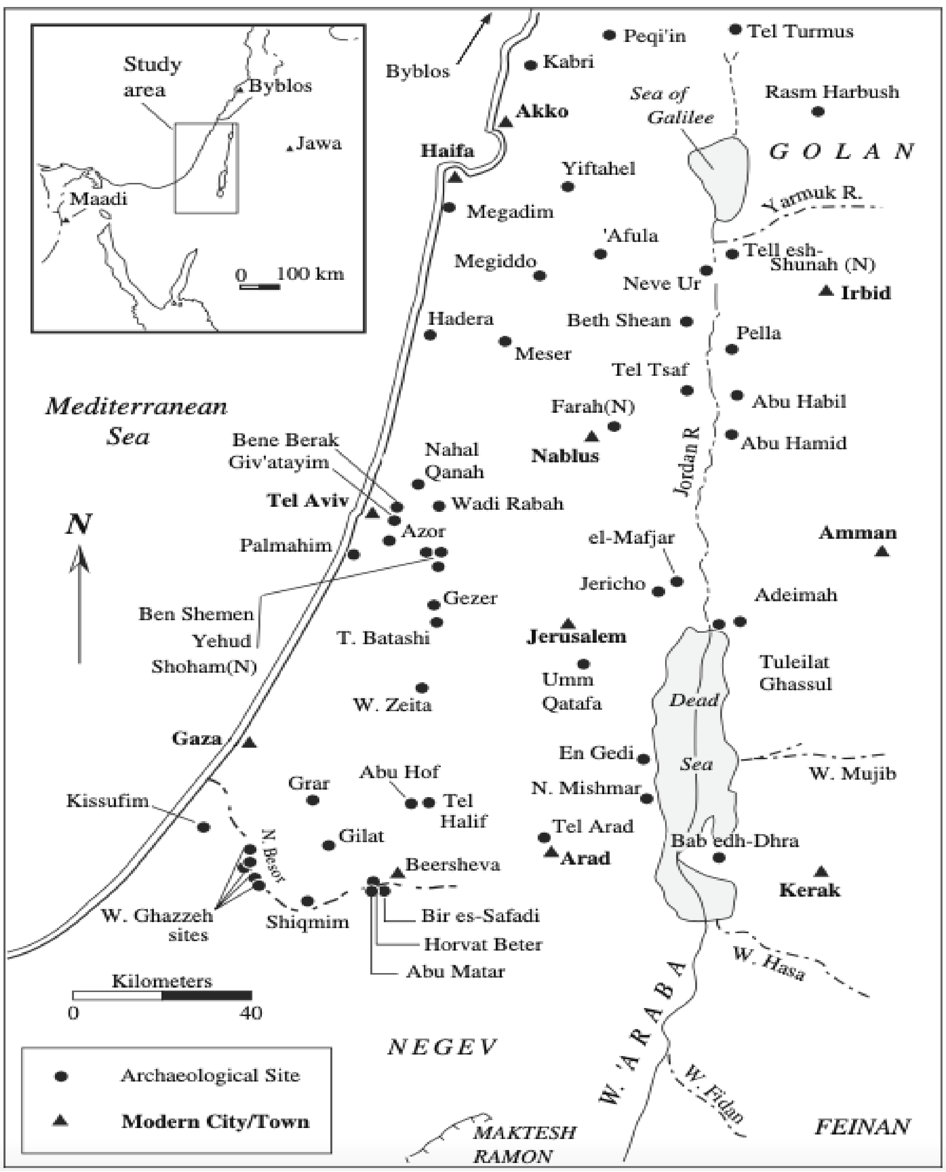

Figure 1: Late Neolithic and Chalcolithic sites in the S. Levant (after Golden 2009)

into vast areas. By analyzing this period, we can learn valuable insights into the evolution of Levantine societies, their cultural and technological advancements, and the challenges they faced.

In the southern Levant, copper metallurgy appears as a prevalent phenomenon during the Ghassulian Culture (named after the type site of Tulaylât al-Ghassûl, Jordan) of the Chalcolithic period (6.5–5.8 ka cal BP). Since its discovery in 1929, and two decades later in sites around Beer Sheva, Israel, the cultural interpretation of the southern Levant during the Chalcolithic period has been one of the most dynamic fields for nearly a century of archaeological research in this region (*e.g.*, Rowan & Golden 2009). Vociferously disputed, notions about chronology, socio-economic configuration, settlement patterns, regionalization, religious indicators, and technological innovations have elicited lively discussions.

When we compare the Chalcolithic and Neolithic cultures, we can observe significant differences in various aspects such as economy, society, politics, and religion in the Levant region. However, it is worth noting that these historical processes did not occur overnight and simultaneously. Hence, drawing definitive boundaries between these prehistoric periods can be a challenging task that requires critical analysis of previous works. Although radiocarbon dating provides a general chronology of the Chalcolithic period, we still need more clarity on the social and economic significance of metal production during this period. Microarchaeology, especially in uncovering pyrotechnology remains, seems to hold promising potential in revealing the social and economic life of Chalcolithic people.

Understanding the Chalcolithic era requires studying the transitional cultures such as the Wadi Rabah, Qatifian, Besorian, and Jericho IX cultures. The Wadi Rabah culture played a significant role in exploring the Chalcolithic phase of this region as it serves as an essential link between the late Neolithic and Early Chalcolithic (or Late Pottery Neolithic) periods. Kaplan (1958) is credited with discovering this culture. Exploring this culture offers a fresh perspective on the changes and advancements that characterized this pivotal transitional period.

The Wadi Rabah culture's pottery assemblage distinguishes itself from other Neolithic examples with a wide variety of bowl forms, jars, and pithoi, and the common use of burnished slip reminiscent of the Halafian culture in the northern Levant and beyond. The pottery style evolved over time, reflecting the richness of the Early Chalcolithic period. The abundance of various vessel forms, paired with advancements in pottery production techniques, suggests that Wadi Rabah was a significant hub for the development of Chalcolithic pottery traditions.

Additionally, lithic artifacts from this phase bear notable similarities to those found in the same chronological period (e.g., Rowan & Golden, 2009).

The Qatifian culture, which predates the Ghassulian culture, was extensively explored by Gilead and Alon (1988). Their work provides a deep understanding of the culture's characteristics and importance. The research by Goren (1988; 1993) mainly focused on the pottery traditions of this culture. His work utilized petrographic analysis techniques to offer insights into this era. The analysis sheds light on the materials used, production methods employed, and artistic expressions conveyed within the pottery tradition (Gilead & Alon, 1988; Goren 1988; 1993) In the latter article, Goren discussed pottery typology and settlement distribution along with the differences between Qatifian and Wadi Rabah cultures. However, determining the exact chronological order of pre-Chalcolithic cultures has been a challenging topic and has resulted in many debates. Nonetheless, Gilead's (2007) work has played a significant role in understanding the Chalcolithic chronological and cultural framework in this context. Gilead used radiocarbon dating to reach a crucial conclusion: the Qatifian culture is more similar to the Neolithic era than the Chalcolithic. Consequently, he classified the Qatifian culture as a Late Neolithic phenomenon. This conclusion, which was drawn from advanced dating methodologies, enhances our comprehension of the Qatifian culture's placement and its relationship to other cultures in the region (Gilead, 2007).

As we explore the history of Northern Negev semi-arid zone of Israel and the Gaza Stripe, we can observe a transition from the Qatifian culture to the emergence of the Ghassulian culture, which is depicted by the development of the Besorian phase. The unique pottery found at the Besor sites is a distinct feature of this culture, which includes tempering the jars with crushed calcite crystals together with chalk and limestone in the production process. Goren (1988) provides further insight into this phenomenon. Additionally, the noteworthy aspect of Besorian pottery is their clay composition, which is often made from Moza marl. These discoveries serve as indicators of a particular crafting style. Later, Goren (1993) shed more light on the materials and methods that defined the Besorian culture, emphasizing its unique role in the history of the Levant region.

Exploring pottery, settlements, and chronology in these cultures provides us with valuable insights into the pre-Chalcolithic cultural entities of the Southern Levant. A notable difference between the Ghassulian and pre-Ghassulian cultures is the absence of metal artifacts during the transition period. This lack of metal finds sets them apart in terms of their technological and material cultures. The Ghassulian sites cover a wide range of regions, including the Northern

Negev, the vast expanses of the Dead Sea basin, the southern and central Coastal Plains, and the foothills of the Judean mountains. The widespread distribution of these sites demonstrates the influence of Ghassulian culture and its ability to adapt to various environments (Gošić & Gilead, 2015).

Archaeological finds from various sites provide us with valuable insights into the different phases of Ghassulian culture, revealing its evolution over time. The early and late phases of the culture can be observed in different sites such as Tulaylât Ghassûl, Gilat, a few Naḫal Besor sites, and Grar. These sites offer foundational elements that characterized the beginning of the Ghassulian culture, allowing us to recognize cultural shifts and adaptations after transition periods. The late Ghassulian culture flourished across a widespread array of sites, including Abu Matar, Bir es-Safadi, Horvat Beter, and Shiqmim, where remains of metalworking technology and objects have been found. Additionally, the Ghassulian culture thrived across various sites such as Abu Matar, Bir es-Safadi, Horvat Beter, and Shiqmim. Archaeological evidence of metalworking technology and objects was discovered at these sites.

Rectangular buildings dominate the architectural style found at Ghassulian sites. By analyzing the structural layout of these sites, we can gain insights into the architectural preferences of this culture. The artifacts recovered from Ghassulian sites offer valuable insights into their material culture. Of particular note is the discovery of basalt vessels, which demonstrates the Ghassulian culture's ability to work with volcanic rock. The finds also include arrow-sickle blades, fan scrapers, V-shaped bowls, cornets, and churns, each providing a glimpse into the Ghassulian culture's use of everyday tools. Furthermore, the Ghassulian culture is known for its unique pottery traditions, which are characterized by distinctive forms and decorative elements. These allow us to comprehend their aesthetic preferences, rituals, and functional practices. Finally, one of the most significant aspects of the Ghassulian culture is its introduction of copper metallurgy during this period (Rowan & Golden, 2009 with references).

The absence of metal artifacts during the transition period indicates technological and cultural advancements. However, the lack of metallurgical evidence at Ein Gedi, a cultic site, has sparked new discussions. The overall absence of metallurgical activity, including casting and smelting, makes Ein Gedi a topic open to further exploration and discussion (Goren, 2014a; Gošić & Gilead, 2015).

1.2 The Beginning of Metal production in the Southern Levant.

The discovery of metal production brought about significant economic and social changes. However, historical records reveal that the process of metal production is a complex undertaking. The origins of the Ghassulian culture’s copper metallurgy and its socio-economic role are still poorly understood. Levy and Shalev (1989) documented the monopoly held by the Beer Sheva Valley in the metal industry, highlighting the interplay between cultural landscapes and technological advancements. The Beer Sheva Valley's prominence in metal production not only attests to their sophisticated metallurgical expertise but also signifies that it served as a pivotal hub for trade networks, knowledge exchange, and cultural interactions.

Figure 2: Selected objects from the Naḥal Mishmar hoard (The Israel Museum, Jerusalem, by Yoram Lehmann https://www.imj.org.il/en/collections/197941-0)

Copper minerals were used not only during the Chalcolithic era but also before, during the Natufian and Pre-Pottery Neolithic periods to produce beads and pigments. However, during the Chalcolithic period, there was a significant shift from using copper ores to processing metallurgy including alloyed copper. Archaeological research has shed light on the use of alloyed copper in functional and artistic items due to its superior malleability, strength, and utility. This has raised questions about the resources used to produce these alloys and their applications, providing new insights into the past. In 1961, a significant hoard of over 400 copper objects was discovered in a cave in Naẖal Mishmar, the Judean Desert, Israel. This find marked a turning point in the study of early copper metallurgy, revealing highly skilled craftsmanship and a major database for the Levant's earliest copper industry. The artifacts from Naẖal Mishmar and other sites reveal a clear dichotomy between "working tools" made of unalloyed copper and "prestigious" items made of polymetallic copper alloys using the "lost wax" casting technique. The working tools were likely produced locally in smelting-melting-casting workshops found around Beer Sheva, using copper from Feinan and Timna in the Arabah Valley (Hauptmann *et al*., 1992; Golden *et al*., 2001; Shugar, 2018). However, the origin of the elaborate prestige objects remains unknown. They may have come from a center in the southern Levant, or from the remote sources of Cu-Sb-As bearing ores in eastern Anatolia or the Iranian highlands (Shalev & Northover, 1987; Levy & Shalev, 1989; Tadmor et al., 1995; Golden, 2009). Consequently, the Chalcolithic metallurgy of the southern Levant displays a remarkable range of casting techniques, compositional variations, and functional purposes. The diversity in casting techniques and compositional structure attests to the sophistication of the metallurgical processes used by ancient craftsmen (Bar Adon, 1980).

Various hypotheses regarding the historical context of the Naẖal Mishmar hoard and its possible relation with the Ghassulian shrine at Ein Gedi have been discussed in the literature. However, the precise link between the hoard and the Ein Gedi shrine remains subject to debate (Goren, 1995; 2014a; Ussishkin, 1971; 1980; 2014).

To gain a better understanding of the relationship between the Naẖal Mishmar hoard and the Chalcolithic site of Ein Gedi, and to expand our knowledge of Ein Gedi's importance during the Levantine Chalcolithic period, the use of microarchaeological techniques is necessary. Utilizing these methods to uncover evidence of human activities, environmental changes, and interactions that may have influenced the development of these sites is crucial. For this purpose, it would be helpful to compare artifacts from the two sites and place them onto the ca. 700 years of chronological sequence of the Ghassulian culture. As far as metallurgy is concerned, objects created of unalloyed copper using the open mold technique, such as axes, adzes, and awls, are considered "utilitarian." Meanwhile, objects crafted using the intricate "lost wax" technique of alloyed copper, such as standards, mace heads, crowns, and vessels, are deemed as "prestige" items. This classification explains the diverse functional and symbolic roles that these objects played within their respective context. However, based on their chemical attributes, these artifacts can be further classified into three groups. (Shugar & Gohm, 2011; Tadmor et al., 1995):

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1. Antimony-arsenic-rich objects: This group comprises artifacts that have a noteworthy content of antimony and arsenic elements, indicating the use of alloys in their creation.

2. Pure copper objects: This category includes objects that are made of pure copper.

3. High-nickel arsenic objects: The third group consists of artifacts that have a high level of both nickel and arsenic.

Examining the chemical composition of objects provides a unique insight into the techniques utilized during their production. By scrutinizing the origin of the ores used, we can gain a deeper understanding of the history of these items and their relationship with neighboring civilizations. Objects classified as "prestige" items are primarily composed of alloys, with arsenic and antimony being the dominant elements. These alloys were further enriched by small amounts of nickel and lead, as demonstrated by research conducted by Shalev and Northover (1993), Tadmor et al. (1995), and Shugar (2018). For example, Tadmor et al.'s research (1995) shed light on a macehead that is distinct from others because of its higher nickel content and lower antimony levels. This discovery helps us to better understand the metallurgical methods and cultural importance of these "prestige" items.

The origin of the alloyed items is still a topic of debate, with possible sources extending beyond the southern Levant to Anatolia or the Caucasus regions. This suggests the existence of long-distance trade networks and the transportation of raw materials over vast distances. Despite the known ore sources in the southern Levant, establishing a direct link between the alloyed objects and these specific sources remains a challenge due to the isotopic abundance ratios found in the "prestige" items not aligning with the composition of copper ores from the mentioned regions. (Levy & Shalev, 1989; Tadmor et al., 1995).

Apart from the high-end alloyed items, "utilitarian" objects are made from pure copper that is sourced from the Feinan region, which may include Timna. According to Golden, Levy, & Hauptmann (2001) and Shugar (2018), Feinan is the main source of copper ore in this region, but there is no evidence of on-site production within the mining center. This lack of production evidence suggests that the copper extracted from Feinan was probably transported northwards for processing. Such patterns of extraction and distribution contribute to the complexity of the intricate network of ancient trade and resource use.

Moreover, the petrography of Naẖal Mishmar displays a remarkable diversity. Although it has been proposed that the Naẖal Mishmar artifacts were brought from Ein Gedi, a comparison of the petrography of these two sites reveals that Naẖal Mishmar exhibits a wider range of classifications than the finds from Ein Gedi. The pottery discovered at the Chalcolithic site of Ein Gedi is associated with the Motza formation, which represents a distinct geological context. Results from the previous research reveal that pottery samples from the shrine belongs to two groups ("Motza clay-dolomitic" and "Motza marl-calcareous') of the Motza formation. In contrast, only a fraction of pottery finds from Naẖal Mishmar aligns with the same Motza formation. (Goren, 1995).

The analysis of the ceramic casting molds and cores found in the Naẖal Mishmar hoard's alloyed copper lost-wax cast objects showed that the copper was most likely sourced from the contact zone between the central hill country of Israel, where the Motza Formation is prevalent, and the eastern part of the Lower Jordan Valley, where Lower Cretaceous sandstones and ferruginous clays, and Neogene to recent olivine basalts are found. Additionally, a mace head from Shiqmim had a core made of glauconitic chalk, which is unique because this rock is typically found in the Arabah area (Goren, 2008; Shalev et al., 1992).

The exploration of Naẖal Mishmar and its copper artifacts has provided valuable insights for understanding the mystery of Chalcolithic cults and their potential connection to the cultic practices at Ein Gedi. However, it is worth noting that further information can be obtained from another cave in the area, namely Moringa Cave. This Pleistocene cave is located 120 meters above the Dead Sea level in Ein Gedi, just below the Chalcolithic shrine. Geological surveys and dating conducted by Lisker et al. in 2007 have revealed notable similarities between Chalcolithic artifacts discovered at Moringa Cave and the pottery found at Ein Gedi. Furthermore, residue analysis on the cornets from Moringa cave and Ein Gedi shows that they contain beeswax. This suggests that the beeswax was possibly used for illumination purposes or in the "lost wax technique" (Namdar, Neumann, Goren, & Weiner, 2009).

1.3 Chalcolithic cult

During the Chalcolithic period, metallurgy and ritualistic practices were highly significant. Copper objects were used in these practices, which provided an opportunity to learn about the connection between them. Although the person leading the ceremony played a central role, the copper objects were also essential elements of the ritual. They were used by shamans to display their power and connection to the spiritual world, which gave them their mystic meanings. The link between chalcolithic cults and metal production has been previously noted by Gošić & Gilead (2015). The symbolic importance of copper objects underscores the significance of the production process. This was restricted to a select group of people, which made it even more important. With the increase in cultic activities, the places where those ceremonies were held became more important in the social life of chalcolithic people. Gilead (2002) and Gošić & Gilead (2015) have highlighted the distinction between Ghassulian cultic sites such as Gilat and Ein Gedi and Tulaylât Ghassûl, which was another important ritual center during the Chalcolithic period.

Tulaylât Ghassûl is situated to the north of the Dead Sea and covers an area of 20 hectares. The complex consists of two rectangular structures, primarily constructed from stone pavements and mud-brick walls. It is worth noting that fragments of female figure limbs have been discovered within Building A. This discovery indicates a close resemblance to Gilat woman figures.

Gilat is situated in the Northern Negev area, adjacent to Naẖal Patish, and covers an area of 12 hectares. The walls of Gilat, made from mudbrick, make it a notable archaeological site. Despite being smaller than Tulaylât Ghassûl, Gilat is rich in artifacts. What distinguishes the finds from Gilat from other ritual sites is their unique nature. A notable feature of Gilat's archaeological landscape is the violin-shaped figurines that are exclusive to this site, known as the "Gilat woman figures." It can be concluded that the presence of these figures indicates the central role of feminine symbolism as representations of fertility within ritual centers.

2 The Chalcolithic shrine at Ein Gedi

Located midway up a near-vertical cliff that runs parallel to the western expanse of the Dead Sea, the Ein Gedi shrine serves as both a striking backdrop and a marker of the Judean Desert boundary. However, there is some debate over the appropriate terminology for Ein Gedi, which was first discovered by Y. Aharoni in 1956. The complex spans over an area of 400 sq m and comprises a main gatehouse, a postern, a lateral chamber, and a sanctuary. At the center of the courtyard, there is a circular installation. According to records predating its preservation, the original walls were made of limestone and filled with small stones and clay. In his meticulous description of the architectural characteristics of Ein Gedi, Ussishkin (1980) suggests that the walls were plastered on both sides and painted similarly to Teleilat el-Ghassul, with fragments of painted plaster serving as evidence.

On the eastern side of the shrine, there is a gatehouse. It is a rectangular chamber that has thickened jambs at both inner and outer entrances to strengthen the doorways. The outer entrance is 89cm wide and the inner entrance is 83cm wide. The postern gate has pilasters of similar construction, each measuring 1.65-1.70m in height and 1.20m in width. The sanctuary is located on the northern side of the shrine. It is 19.70m long and 5.20m wide. Another significant feature of the shrine is a rectangular chamber with a lime floor measuring 7.5x4.5m. Room A has been the source of Chalcolithic artifacts including fragments of pottery types such as bowls, cornets, and jars, as well as some pendants and beads. A few flint tools have also been discovered in Room A as lithic finds (Ussishkin, 1980).

Findings from the Ein Gedi shrine differ from other cultic sites of the Chalcolithic period, indicating that the shrine had distinct functions and that its occupants were different from habitants of the other sites. Unlike Gilat, it suggested that Ein Gedi was used by nomadic people for their religious activities ((Joffe, 2001).

2.1 The geological setting of the site

The Southern Levant, comprising of Israel, Jordan, and Palestine, has a varied and captivating landscape. From the Mediterranean coastal plains to the Rift Valley, this region is significant both historically and geologically. Distinct geological features like the Taurus Mountains in the north and the Sinai Peninsula in the south mark its borders (Rowan & Golden, 2009). The Africa-Arabia break-up caused the separation of the African and Arabian plates, which led to the formation of this unique region. The Southern Levant owes much of its cultural and geological identity to this transformative process.

To study Levantine archaeology, it is crucial to understand the geological features of the region. These features play an important role in preserving and modifying artifacts and structures over time. In the context of this archaeological site, the geological factors play two key roles. Firstly, they provide insight into the effects of the arid Levantine environment on the samples obtained from this location, which can influence treatment methods and the interpretation of results. Secondly, studying the geological characteristics of the area helps us uncover links between the Ein Gedi Chalcolithic site and its neighboring settlements, thereby enhancing the accuracy of interpretations.

Figure 3: An aerial (drone) view of the Ein Gedi site and environment (photo: Y. Goren).

The Ein Gedi shrine is located above the Ein Gedi oasis, a desert oasis on the western side of the Dead Sea. This area has unique geographical features, with the rift valley of the Judean Desert and the Dead Sea creating a stunning view. During the chalcolithic period, the lake levels were approximately 200 meters below the shrine, at around -370 meters below sea level. The ground in this area rises towards the west and ends in a near-vertical cliff. Ein Gedi is surrounded by the Lisan deposits high stand and Naḫal David Pleistocene conglomerates.

The Lisan conglomerate is in the immediate vicinity of the Ein Gedi site and is a polymictic, indurated conglomerate containing mostly flat gravel. The Dead Sea basin was formed as a result of the Dead Sea transformation and was covered by late Quaternary to recent sediments. Calcite, dolomites, aragonite, gypsum, and halite make up the Dead Sea basin. The fill formed results from Sedom, Amora, Lisan, and Ze'elim formations. Hazave Formation is characterized by sandstones and conglomerates of fluviatile and lacustrine, Sedom Formation consists of halite and lagoonal, and the post-evaporitic series (Lisan Formation) is clastic of fluviatile and lacustrine origins. (Garfunkel, 1996; Lisker, 2009).

A detailed geomorphological report of the 2021 excavation by Dr. Nurit Shtober-Zisu (UHaifa, personal communication), provides data about the setting of the Chalcolithic site in the context of the Ein Gedi geology. The report reveals the presence of two types of conglomerate rocks in the area: the Lisan high stand conglomerate and the Naẖal David Pleistocene conglomerate. The Lisan conglomerate, which is a polymictic conglomerate made up of limestone, dolomite, and chert, forms the bedrock of the site. The report also states that the upper layers of the conglomerate have been hardened and compacted by calcium carbonate ($CaCO_3$), while the matrix of the conglomerate is composed of calcite, iron oxide, or silica. However, the layers beneath the upper layers have only a moderate level of cementation.

2.2 The 1961 Excavations at Ein Gedi

The initial excavation season at the site occurred in 1961 and was led by David Ussishkin on behalf of the Hebrew University in Jerusalem (Ussishkin, 1980; 2014).

Based on the excavation reports, the process was straightforward. Visible wall lines and debris mounds indicated the presence of structures. The stratigraphy of the structures remained consistent. After removing the upper sun-dried bricks layer, a grey-brown-earth layer and ashy materials were found. This layer was observed in all the structures at the site.

In 1958, Naveh excavated a lateral chamber, where he found chalcolithic pottery fragments, flint flakes, bones, and shells. During the 1961 excavation season, artifacts such as pottery fragments, a pendant, and a damaged animal figure were discovered on the northern side of the chamber. The excavation notes mention an accumulation layer that contains a significant number of crumbly materials. The thickness of the layer varies. It is thinner in the center and thicker at the sides. In the southwest part of the sanctuary, ashy soil was observed, and the pits located there contained accumulation layers and remains of human activities, especially offerings and rituals.

The papers from the 1961 excavation indicate that ashy materials are common in these structures, though the amount of ash varies by location (Ussishkin, 1980; 2014).

As previously mentioned, pottery fragments are the primary discoveries from this archaeological site. Upon examination of ash samples collected from the altar area, it was discovered that a range of components underwent firing, including bitumen, twigs, small bones, non-marine mollusks, beads, and fragments of broken clay items. These findings shed light on the materials and activities associated with the site's historical use. This season's pottery finds have been briefly outlined above, and while the types of pottery share similarities, closer inspection reveals variations in the fabric of the vessels and differences in firing temperatures. These nuances in composition and craftsmanship may indicate distinct phases or styles of pottery production throughout the history of this site, signifying shifts in cultural practices or technological advancements over time. The pottery uncovered during this excavation can be characterized into two modes of decoration. The first involves intricate paintings or slips applied to the surface, adding aesthetic appeal and cultural significance to the vessels. The second technique includes incised or impressed designs that exhibit a more tactile and sculptural quality. This range of decorative approaches offers valuable insights into the artistic expressions and craftsmanship of the individuals responsible for creating these pottery pieces.

The pottery finds are a crucial aspect of this excavation, providing significant insights into the daily life, rituals, and interactions of the people who once inhabited or utilized this archaeological site. These ash remains hold paramount significance in unraveling the historical context and significance of the monument.

To gain a deeper understanding, a closer examination of the ash samples is necessary. This can potentially reveal more information about the rituals, practices, and lifestyle of the ancient people who used this monument. According to Ussishkin (1980), the cessation of activity within the structure was due to abandonment, rather than destruction. The absence of remains such as burnt wooden doors or door frames suggests that there was no destruction caused by enemies.

2.3 The Renewed Excavations at Ein Gedi

In 2021, a new excavation has been organized as a part of the “An Integrative Study of the Chalcolithic Copper Production in the Southern Levant” project by Prof. Yuval Goren (BGU) and Prof. Dany Rosenberg (UHaifa).

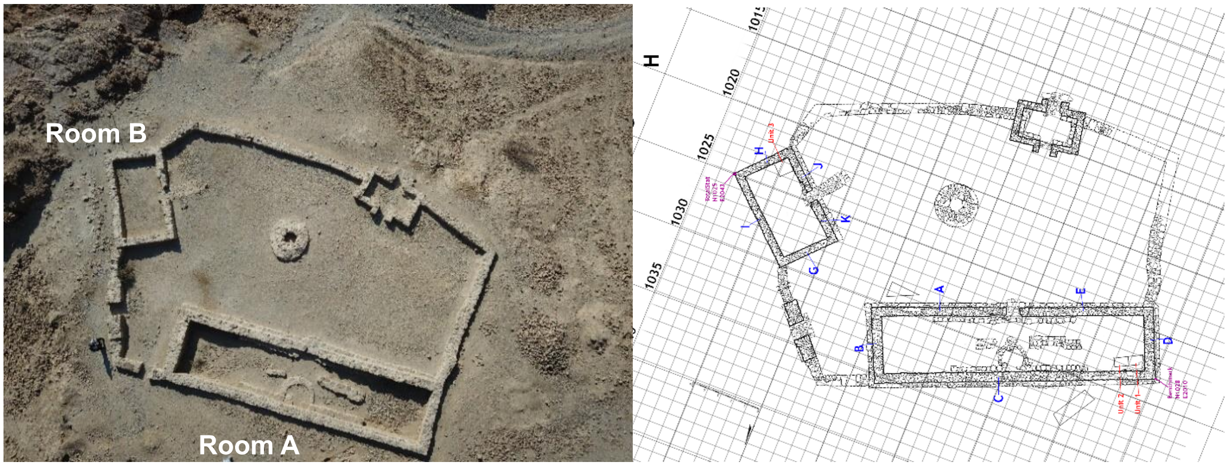

Figure 4: The Ein Gedi shrine excavations, arrows show the sample points of the 2021 season (drone photo by Y. Goren, top plan compiled by Y. Goren after Ussishkin 2014)

During this season's excavation, the team searched the dump area from the 1960's investigation to see if any artifacts were overlooked. However, they only found a few pottery fragments. The team was thrilled to discover new brown sediments in Room A, Locus 23 (shown in the figure), and focused on this area for six days. In the complex north Room B, the team rediscovered a drainage hole from the previous excavation (as seen in Fig. 5). Under a stone of

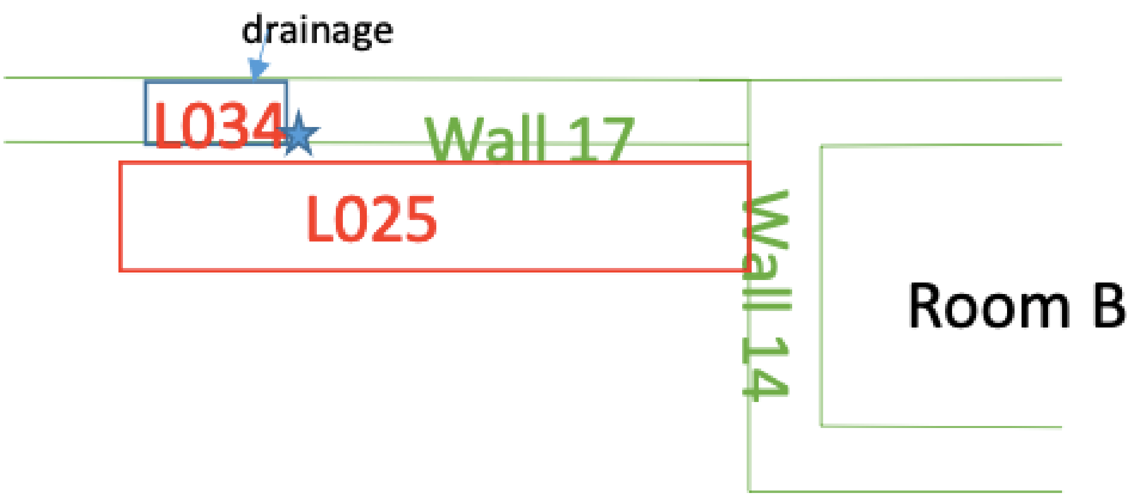

Figure 5 Explanation of the structure walls. The star shows the place the chalice sherd was found (2021 Exacation Report)

wall W17 (as seen in Fig. 6), they uncovered a fragment of a Chalcolithic chalice.

During the excavation process, Room B was investigated but no significant finds or artifacts were discovered. The outcome of the excavation revealed only bedrock and a sign of a hearth, which the excavation team believed was of modern origin. In contrast, excavation of Room A yielded better results. Ashes were found in several spots under locus 27, and an ashy area was excavated under the southwestern corner of Building A, revealing a new pit (document number 1, Fig. 7).

Figure 6: a) drainage before 2021 excavation b) drainage after 2021 excavation c) the chalice sherd location d) drainage from outside view. Photos: D. Rosenberg.

During the excavation, a new unit (unit 20) was uncovered on the northern side of Building A. This unit revealed a large feature (document number 2) that contained many hearths, with one even containing a piece of cornet. Sediments of different colors were found in the area, suggesting that they were heated to varying temperatures. Additionally, flat stones and stone accumulation were discovered in the same spot. Dr. Yotam Asscher sampled the full feature based on color differences and then excavated the "inner sanctum" in Room A to explore the entire structure. This revealed small areas of black material, labeled as locus 42 and locus 48, with samples taken from locus 48. In summary, the 2021 excavation confirmed that the Ein Gedi site is a complex archaeological site that requires further investigation. Recent discoveries of foundation deposits, hearths, and ashy sediment in Room A could provide valuable insights into the enigmatic history of the Ein Gedi shrine.

2.4 *The Foundation deposit of Building A*

Figure 7 a) patches of charcoal in the pebbles Lo27 b)pottery sherds in charcoal, under stone in Lo28 c) stones in the SW corner of Room A d) pottery sherds in the charcoal, L28 e)some pottery sherds in charcoal L28 f) sketches of the pit and wall 1. Photos: Y. Goren and D. Rosenberg.

An intriguing discovery arises in this particular context. The pit can be distinguished by the copious amounts of charcoal particles and burnt sediments found within it. As the excavation progressed, fragments of mud plaster were discovered between the stones, as seen in Fig. 7. Initially a small pit, it was later revealed to be a larger one. Within this pit, three substantial boulders/cobbles were uncovered.

Following the removal of the last stone, more examples of mud plaster have been discovered. In addition, pottery fragments have been found beneath the stones. These pottery pieces, collected for residue analysis, were found within the pit. The excavation of the pit continued until it reached the bedrock conglomerate. The presence of layers of mud plaster, ash samples, and pottery fragments suggest that human activity occurred in this pit.

2.5 *Research Goals*

The purpose of this study is to investigate the history of the Southern Levant during the Chalcolithic era by examining the micromorphological features of the Ein Gedi site. The research will focus on the use of metal production in cultic practices and the Ein Gedi Chalcolithic complex.

To achieve this, deposit samples will undergo micromorphological analysis using optical microscopy, Fourier Transform Infrared (FTIR), X-Ray Diffraction (XRD), and Thermogravimetric Analysis (TGA). The aim is to gain a better understanding of the Ein Gedi Chalcolithic site. The analysis of the foundation deposit will serve three primary purposes: to highlight the importance of microscale analysis, to determine its composition, formation, and use, and to address questions raised by previous researchers.

3 Materials and Methods

3.1 Materials

3.1.1 Explanation of foundation deposit of Building A

During the 2021 excavation, a new pit was uncovered, revealing a complex set of symptoms that require detailed analysis. This pit is filled with ash, charcoal, pottery, and mud plaster between the stones, as shown in Fig. 8.

The excavators discovered charcoal samples from the pit located under the southwest corner of Room A. These samples were gathered to find the exact date of the Ein Gedi shrine. Since the pit was sealed and undisturbed, the samples from this area could give us an almost precise date. The University of Groningen subjected five samples of charred twigs to radiocarbon dating, including the ones from Ein Gedi (labeled as Ein Gedi EG1, Ein Gedi EG2, Ein Gedi EG3, Ein Gedi EG4, Ein Gedi EG5). A dataset for radiocarbon dating was formed by analyzing these samples, along with the charred plant remains from Naḫal Mishmar, at the University of Groningen. It is important to note that the results of this dating have not been published yet and will not be discussed here.

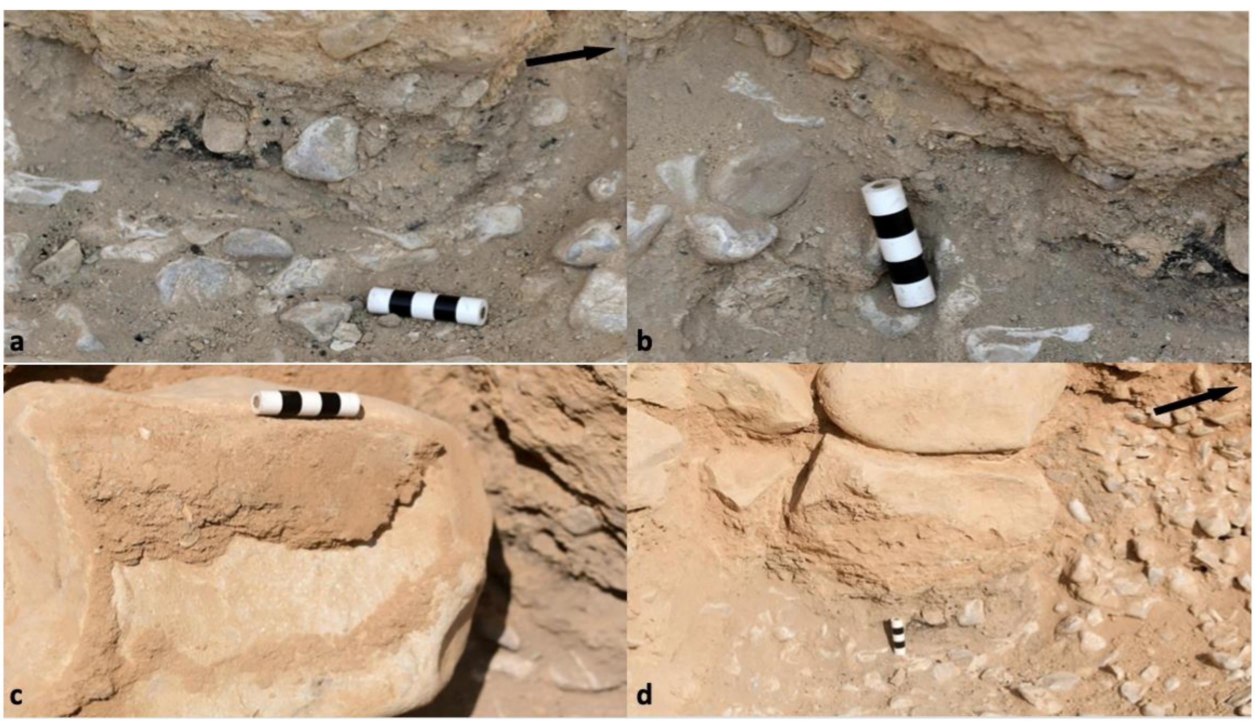

Figure 8: a) mud plaster under the stones b) ashes in the pit c) the stones in the corner of Room A d) closer picture of stones in the corner of Room A (Ein Gedi report 2021)

The excavation site has a significant accumulation of ash materials. Ash is a valuable substance for extracting a wide range of data about the site's history and role. Ash is defined as "the powdery residue that remains after the combustion of organic material." When ash is well-preserved, it contains several key components, such as calcite, photoliths, and, in some cases, siliceous aggregates (Weiner, 2010).

Irrespective of the organic origin of ash, it is important to understand how ash calcite behaves during the combustion process. This understanding is crucial for a comprehensive analysis of the material. When working with ash samples, it is especially important to take into account the two different stages of transformation that calcium oxalate undergoes as the temperature rises. In the initial stage, which occurs within the temperature range of approximately 500°C to 600°C, carbon monoxide (CO) is released and oxalate changes into calcite. If the temperature continues to rise beyond this point, typically around 700°C to 800°C, calcite undergoes a secondary transformation and degrades into calcium oxide (CaO). It should be noted that the temperature within a single firing event can vary, and therefore ash may contain either one or both types of calcite (Weiner, 2010).

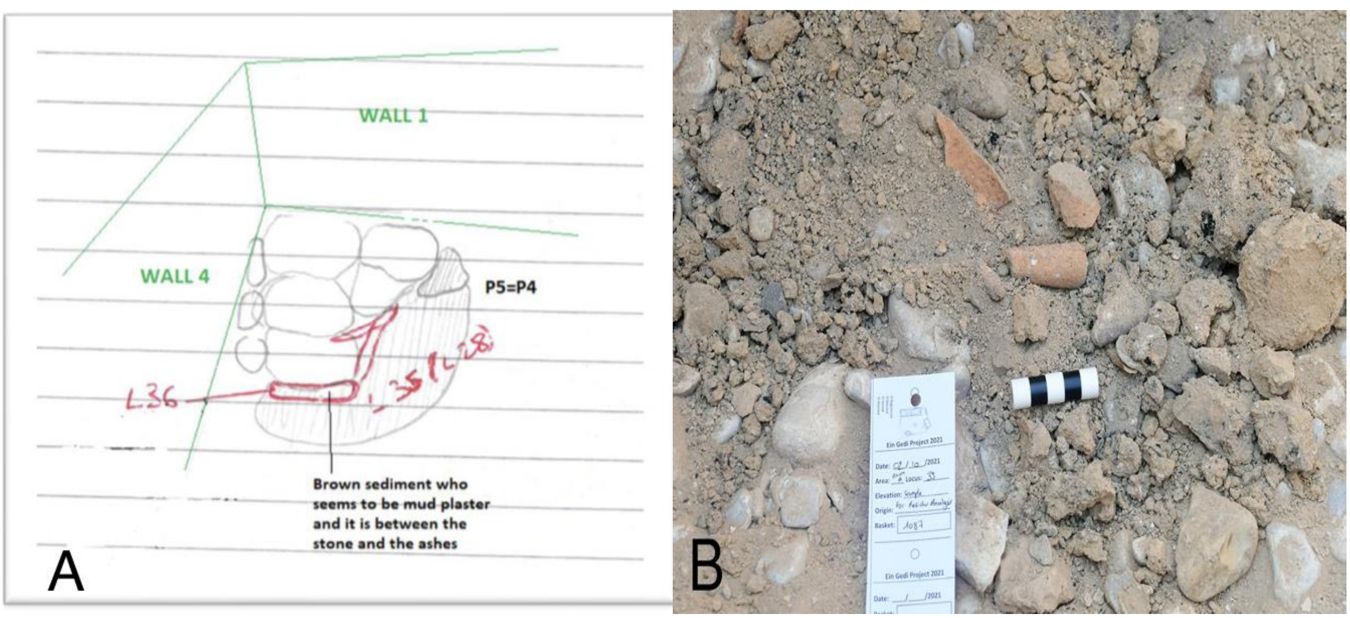

Figure 9: A) drawing of the corner of Room A (Ein Gedi report 20021) B) Room A, Locus 35 showing the ashy layer and the fragments of the cornet (cone-shaped vessel) within the foundation deposit.

Understanding the behavior of calcium oxalate and calcite at different temperatures is essential for interpreting the archaeological significance of ash residues in various contexts. It is therefore worth understanding the atomic structure of calcite and the changes it undergoes at elevated temperatures. These changes are reflected in the ratio of the v2 and v4 peaks in the infrared spectrum, as discussed by Chu (2008) and Regev (2010). The grinding curves method, developed based on these changes, has also been discussed by Regev (2010), and will be elaborated on in the FTIR section of this chapter. It should be noted, however, that high temperatures are not required for ash calcite formation; it mostly occurs around 500°C to 600°C (Weiner, 2010).

Please note that charcoal is not the same as ash, although they are often found together in archaeological contexts. Charred materials such as plants or wood still retain their tissue structure and are not the result of a complete combustion process. This makes it possible to determine the origin of the burned material (Weiner, 2010). In addition to ash and charcoal, we will also be working with mud plaster, which was described earlier.

3.2 Sampling

The materials used in this research were obtained from the recent excavation season at Ein Gedi. Firstly, the samples from locus 36 will be examined using stereomicroscopy, followed by Optical Microscopy for a better analysis. Fourier Transform Infrared Spectroscopy was performed on the samples from Locus 35 basket 1070 (L35 B1070) and Locus 36 basket 1085 (L36 B1085). Sample from Locus 36, basket 1085 was analyzed using Thermogravimetric Analyzer to determine the characteristics of the firing activity. All the samples were collected by Dr. Yotam Asher from the Israel Antiquities Authority. Fragments of the cornet9cone-shaped vessel) from the pit, locus 35 (fig:9) have been collected and subjected to petrographic analysis.

No	Sample labels	FTIR	TGA	Optical Microscopy	XRD	Sample type
1	Locus 35 basket 1070	+	+			ash
2	Locus 36 basket 1085	+				mud plaster
3	Locus 27 basket 1077			+		Soil sample
4	Locus 36 basket 1091				+	soil sample

Table 1: table of the samples

3.3 Methods

3.3.1 Surface microscopy

Before proceeding with sample preparation, all samples were examined using a stereomicroscope and the Dino-Lite digital microscope. This allowed for detailed observation of individual features of the unimpregnated materials (FitzPatrick, 1993). During this preliminary observation, charcoal particles were found in the samples, indicating plant firing in the area. However, depending on the context, burning of the plants could have been for different purposes. While charcoal may not be significant in an overall archaeological context, it may be present in high concentrations in the smallest sediment fractions. Therefore, all sedimentary fractions need to be analyzed thoroughly to provide accurate information about previous fire activity. The process of charcoalification occurs when the temperature is between 280 and 500°C, and due to its resistance to degradation, charcoal continues to preserve specific plant data even after combustion. However, charcoals are extremely fragile and can be found in different sizes (Marquer, 2020). Therefore, charcoal particles have been collected for future analyses. In addition to stereomicroscopy, the Dino-Lite digital microscope was used to examine the samples (Fig. 10).

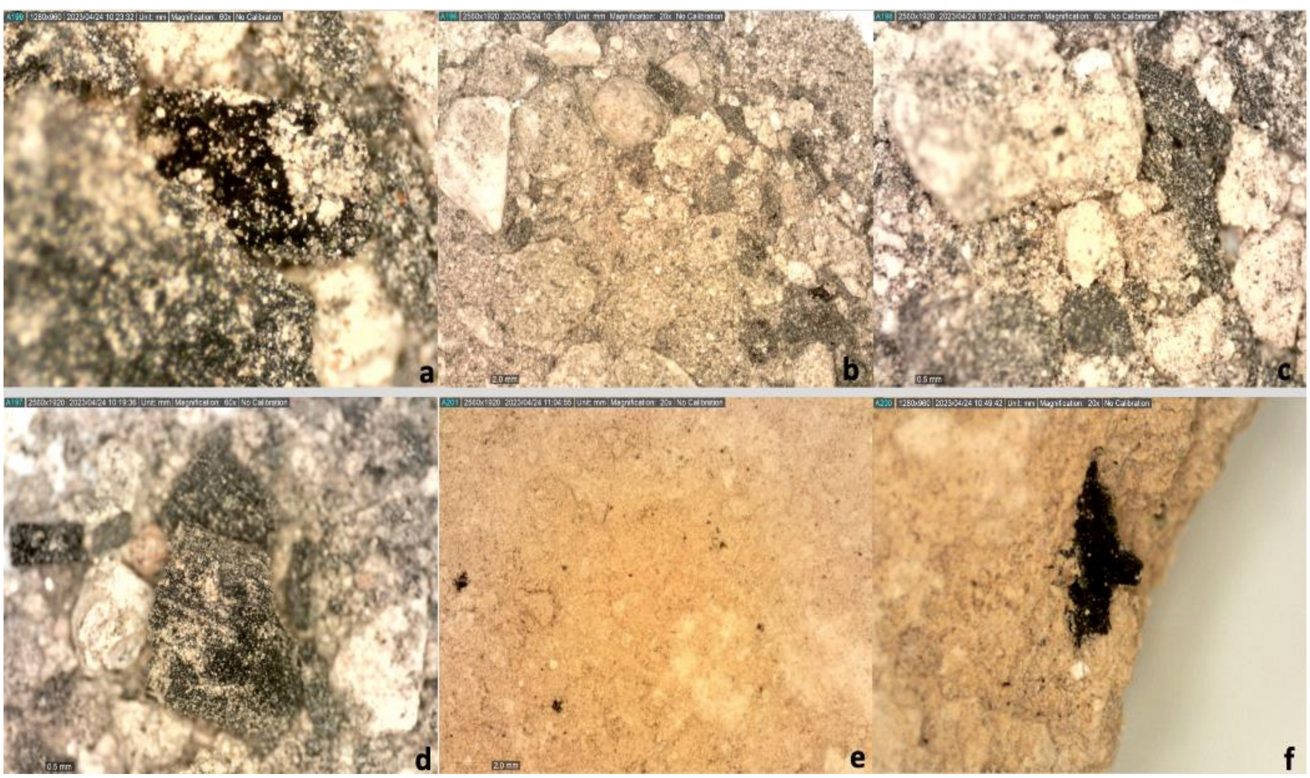

Figure 10: Dino-Lite pictures of a) L35 B1070 ash magX90 b) L35 B1070 ash magX20 c) L35 B1070 magX90 d) L35 B1070 magX60 e) L36 B 1085 magX20 f) L36 b1085 mag20

3.3.2 Micromorphology and petrography

Archaeological micromorphology is a soil analysis technique that helps us understand how sites were formed. It involves observing the physical properties of sediment at both the microscopic and macroscopic level to determine the origin and integrity of archaeological strata (FitzPatrick, 1993). Micromorphological samples provide valuable context for analyzing artifacts, waste products, and microscopic remains of plants and animals. This technique allows us to study these remains in their original location and better understand the history of the site (Goren, 2014b).

Micromorphology is a straightforward but significant method that can help us understand the mineralogical and micromorphological context of a sample. By combining this data with the geological characteristics of the site, we can uncover important information about the research material and the site itself.

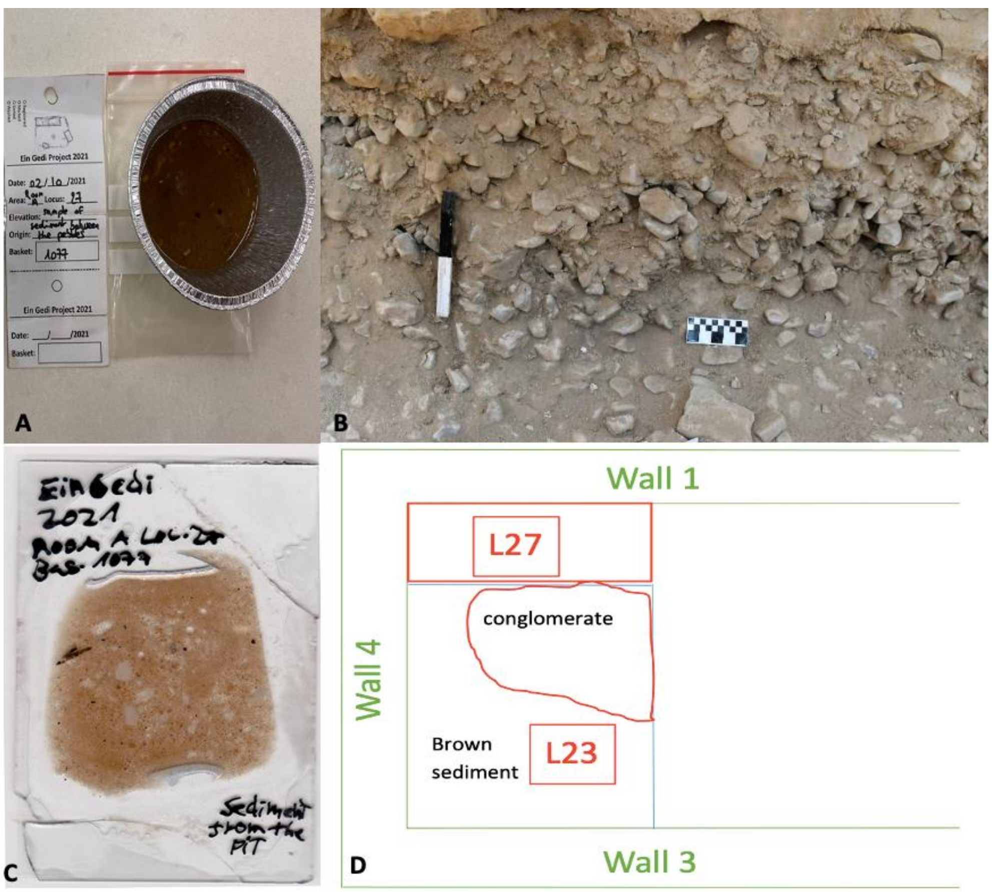

Figure 11: Micromorphology sample a) sample preparation b) location of the sample c) thin section of sample L27 B1077 d) sketch of the location (Ein Gedi Report 2021)

Optical microscopy analyses are conducted using a polarized light microscope that works by transmitting light either through plane-polarized or cross-polarized modes (Kerr, 1977). The combination of both modes allows for the identification of crystalline materials based on their optical characteristics. To perform the analysis, we first need to prepare a thin section of the sample from a polished surface of a block. It is important to note that this technique is invasive, but it provides quick and cost-effective information on the micromorphological properties of materials. This includes identifying the phase, grain size, shape, and distribution (Artioli, 2010).

A micromorphology analysis was conducted on a sample taken from locus 27 basket 1077 (as displayed in Fig. 11). The sample was collected from the foundation deposit sediment in room A. To impregnate the sample, a mixture of epoxy resin and fast hardener was used in a 5:1 ratio. The sample was then left in an oven at 50°C for 48 hours to completely remove any humidity. Afterwards, a thin section of the sample was prepared using a Micromet semi-automatic cutter, followed by grinding and polishing with a Metkon FORCIPOL 2V machine. The slide was ground to an exact thickness of 30 microns and then covered.

Ceramic petrography is another aspect of micromorphology (Quinn, 2013). A sample from the cornet found in the foundation deposit underwent petrographic analysis to compare it with previous analyses of the pottery assemblage from the old excavation at the site (Goren, 1995).

3.3.3 X-ray Diffraction

Approximately 10 grams of material from Locus 36 basket 1091 were analyzed using X-ray Diffraction (XRD) analysis to determine its mineralogical composition. The analysis was conducted at the Ilse Katz Institute for Nanoscale Science & Technology at Ben-Gurion University of Negev. The sample was ground using an agate mortar. The powder material obtained was subjected to analysis using powder X-ray diffraction (XRD). The analysis was carried out using a Panalytical Empyrean II Diffractometer equipped with a position-sensitive X'Celerator detector. The instrument was operated at 40 kV and 30 mA with Cu Kα radiation (λ = 1.54178 Å). The data was collected in Bragg-Brentano geometry ($\theta/2\theta$) over a range of 2θ degrees between 4-60° with a step size of approximately 0.033°. The scanning process took about 15 minutes. Phase analysis was conducted using the Match! (Version 2) semi-automated search-match program, with the International Center for Diffraction Data (ICDD) Powder Diffraction File (PDF-4) diffractogram library, version 2022. The X-ray diffraction technique is highly effective in identifying numerous types of crystalline minerals.

Figure 12:a) sample from Locus 36 basket 1091 b) XRD instrument

3.3.4 Fourier transform infrared (FTIR)

Fourier transform infrared (FTIR) spectroscopy is a technique that uses light to analyze the composition and structure of minerals. It is based on the fact that molecules have unique vibrational and rotational modes that are determined by their molecular structures. When atoms are bonded together to form molecules, they are in constant motion, vibrating and rotating around their equilibrium positions. The nature of these motions is determined by the atoms and bonds present within the molecule (Fig. 13).

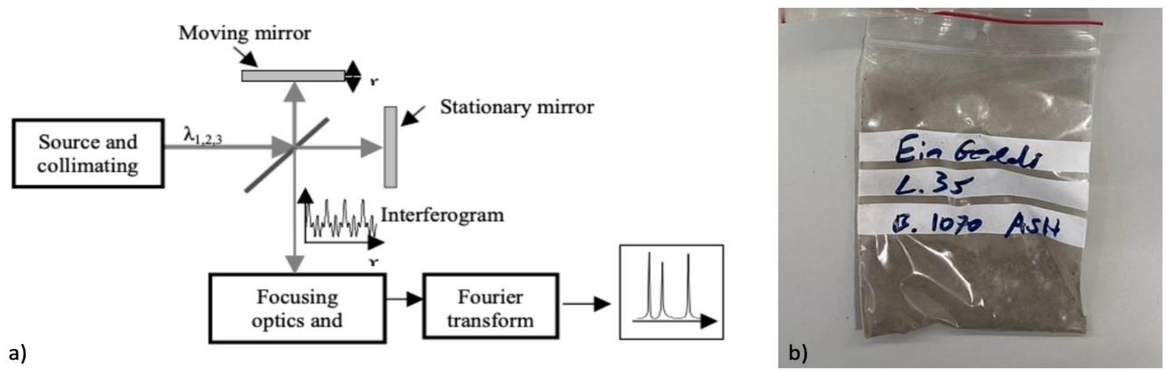

Figure 13: scheme explains using a Michelson interferometer (Saptari,2003) and Sample from Locus 35 basket 1070, ash for FTIR

These internal vibrations and rotations correspond to specific energy levels, resulting in specific frequencies of infrared radiation absorption. These frequencies typically fall within the range of

14,000 to 20 cm-1, which is the infrared region of the electromagnetic spectrum. When a molecule absorbs infrared radiation, it creates an IR spectrum, which is a graphical representation of absorption intensity plotted against frequency. Different functional groups within a molecule have distinctive vibrational modes, leading to peaks at specific frequencies in their IR spectra. By comparing these spectra with reference spectra of known compounds, it is possible to identify the components of the sample.

The Michelson interferometer generates an interferogram, which can be transformed into an infrared spectrum using the Fourier transform technique (as shown in Fig. 14). In most cases,

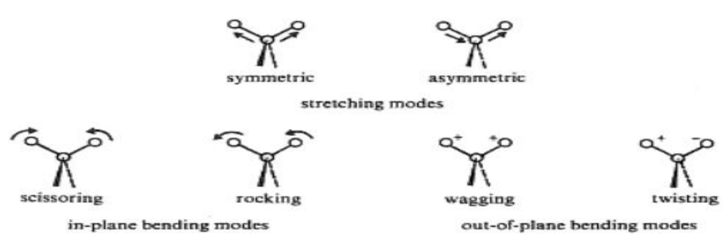

Figure 14: vibrational modes (Fifield,2000)

FTIR measurements are conducted in transmission mode, which involves determining the absorbed portion of the incident beam as a function of frequency (Toffolo, 2018). Therefore, this methodology is particularly useful in the fields of organic and inorganic chemistry, as well as in diverse applications such as material characterization and archaeological research.

After conducting XRD analyses, FTIR was used due to its suitability for determining mineral composition. There are various methods of sample preparation for FTIR analyses. The KBr method involves manually taking a small amount of the sample, typically a few milligrams, and mixing it with an IR-transparent KBr matrix in a mortar. It is then compressed into a pellet for FTIR analyses. Typically, quartz peaks can be detected within the spectral range spanning from 1200 to 900 cm−1. The spectrum shows the characteristic absorption bands of the carbonate minerals calcite and dolomite in the spectral region from 1400 cm−1 to 875 cm−1 (Müller, 2014).

Calcite is a commonly found and informative mineral in archaeological contexts. Calcite can be geogenic or a sign of human activity. FTIR is a rapid method for identifying the origin of calcite. The interaction between radiation in the infrared region and the molecular structure of the sample shapes the Infrared spectra (Price, 2010). Therefore, any change in these bonds will be reflected in the spectra as a shift in shape, width, height, and position of the peak (Regev, 2010).

In transmission mode, three absorption peaks can be detected in calcite, namely the asymmetric stretch (1420 cm−1), out of-plane bending (874 cm−1), and in-plane bending (713 cm−1) vibrations of the CO3 group, which is called V3, V2, and V4. The V2/V4 ratio can provide information regarding atomic disorder. It was also found that this ratio is higher when calcite is of anthropogenic origin (Chu, 2008). These changes in the ratio occur because V2 in calcite is less affected by the heating process compared to V4 (Maor, 2023).

Samples of L35 B1070 and L36 B1085 were pressed into KBr pellets and their spectra were acquired using Fourier Transform Infrared Spectroscopy (The Thermo Scientific Nicolet iS5) at the Israel Antiquities Authority (IAA) in Jerusalem, Israel. The spectra were obtained in absorbance mode within the range of 4000 to 400 cm-1. They were recorded and analyzed using the Omnic software version 8.2.

The grinding curves method was used in this research to identify the origin of calcite immediately. The method is based on the observation that calcite from different origins has different peak heights. A unique trend line is created for each type of calcite by plotting the normalized heights of V2 versus V4 from various grindings of the same sample. The positions of trend lines are formed based on the origin of the calcite (Regev, 2010).

3.3.5 Thermogravimetric Analysis (TGA)

Thermogravimetric analysis, or TGA, is a method used to measure the weight loss of materials as a function of temperature or time. Different materials react differently to specific temperatures based on their heat history, resulting in a unique TGA curve for each material. This allows us to determine the heating history of the sample. TGA has several advantages, including the need for only a small number of samples and less time, which is particularly beneficial for research purposes. (Stuart, 2007).

Thermogravimetric analysis is a useful technique to determine the thermal properties and fire activity characteristics of a sample. As in previous ceramic studies (e.g., Moropoulou et al., 1995), loss of mechanically combined water was observed at ~100ºC – 200ºC; combustion of organic material at ~200ºC – 500ºC; dehydroxylation of clay minerals such as kaolinite or montmorillonite at ~350ºC – 600ºC, and decalcination of calcium carbonates at ~700ºC – 900ºC. This apparatus is not designed to go beyond 1000°C.

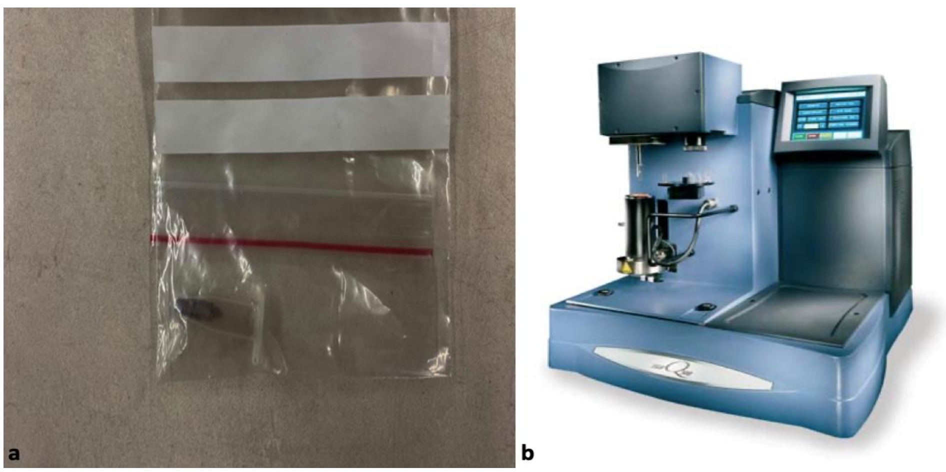

Figure 15; a) ash sample b) TGA instrument

TGA analyses were performed on ash samples from the Locus 36 Basket 1085. The TGA Instrument Model used for the analysis was TGA Q500 V20.13 Build 39, located at the Ilse Katz Institute for Nanoscale Science and Technology at Ben-Gurion University of the Negev. The samples were heated from room temperature to 1000°C at a heating rate of 10 K/min. The instrument's operational details include an isothermal temperature accuracy of 1°C, an isothermal temperature precision of 0.1°C, a continuous weighing capacity of 1.0g, and a sensitivity and weighing precision of 0.1µg. Air was used as the carrier gas.

4 Results

4.1 Micromorphology

A micromorphological analysis was conducted to determine the sedimentological, depositional, and post-depositional characteristics of the foundation deposit. Micromorphology provides a detailed understanding of the micro-features present within an undisturbed, block sample taken from a site's feature, which can help reflect a complex depositional background.

Initial observation under the polarizing microscope (Fig. 16) revealed that the sediment is made of a loose, uncemented accumulation of rock fragments and their derived minerals, badly sorted and ranging between sub-rounded to sub-angular in shape. Most of the sediment is made of limestone and dolomite, and their derived minerals (rhombic crystals of dolomite and cleavage crystals of calcite, see Fig. 17). All these grains exhibit clay coating typical of rolling in a slope. Singular growth of gypsum spar appears, as well as some aeolian silt, made mostly of quartz but with some accessory minerals (e.g., the zircon seen in Fig. 16).

The sediment's overall nature suggests that it was formed by the deposition of thallus, which is the erosion products from the local Upper Cretaceous limestone and dolomite formations. The sample also contains some locally created soil and aeolian silt. The brownish clay coating around the minerals confirms that this sample was taken from the sediment in the slope.

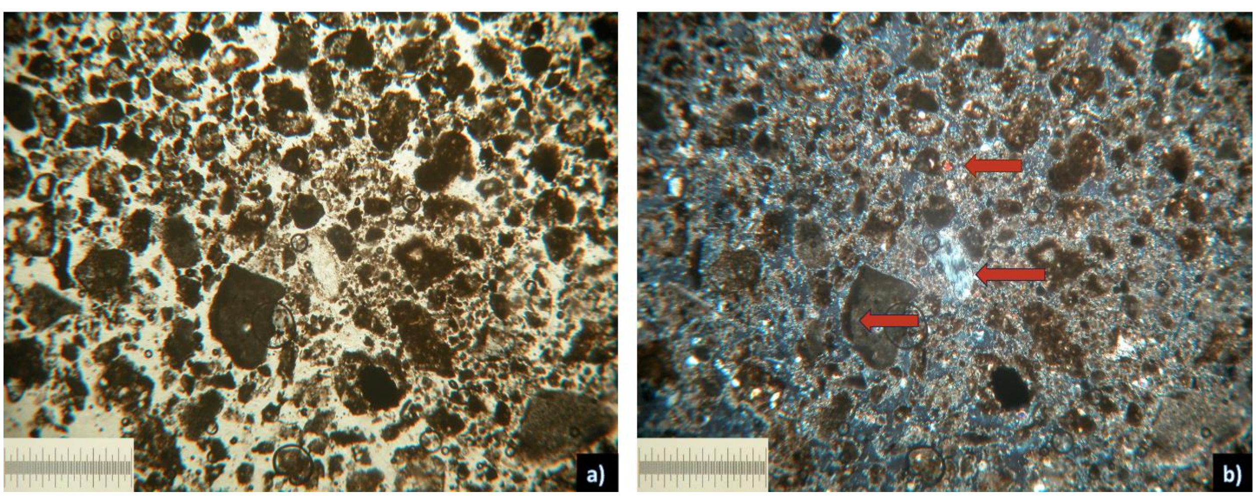

Figure 16: Photomicrographs of the sediment block taken from the foundation deposit, two views of the same location where the left was taken under plane-polarized light (PPL) and the right between crossed polarizers (XPL). The lower arrow shows a clay-coated grain of limestone. The middle arrow points at a gypsum spar crystal. The upper arrow shows a zircon particle within the silt fraction. The scale bar length is 1 mm.

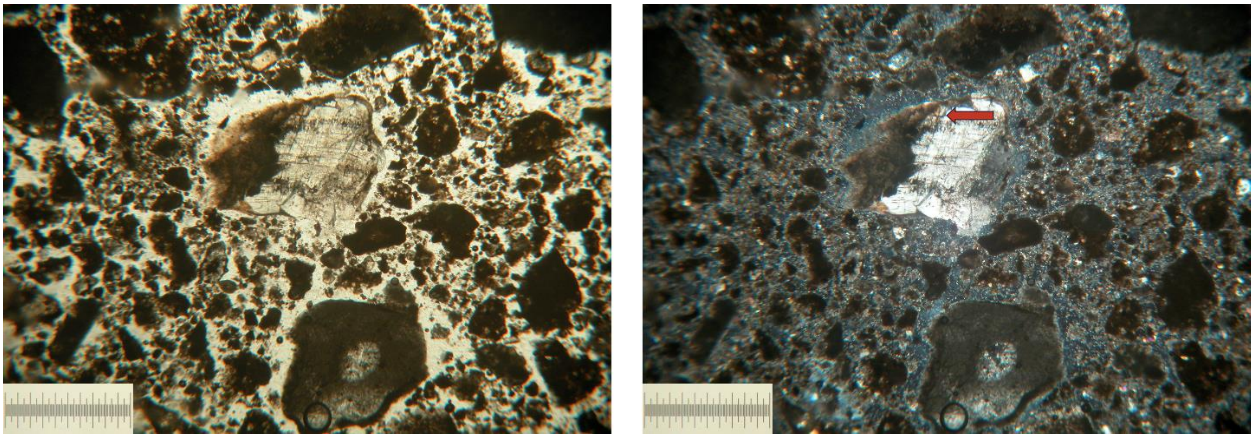

Figure 17: Calcite crystal within the sediment. Left: PPL; right: XPL. Bar length: 1 mm.

To sum up, the sediment mainly consists of dolomite and limestone, which are two types of rocks that are often found in the immediate vicinity. Gypsum naturally forms in arid soils in deserts, such as the Judan Desert. However, the presence of gypsum in this area can also be explained by the fact that the site is situated at an elevation where the Pleistocene Lisan Lake once existed, which is the dominant source of this mineral in the region (Dr. Nurit Shtober-Zisu, personal communication).

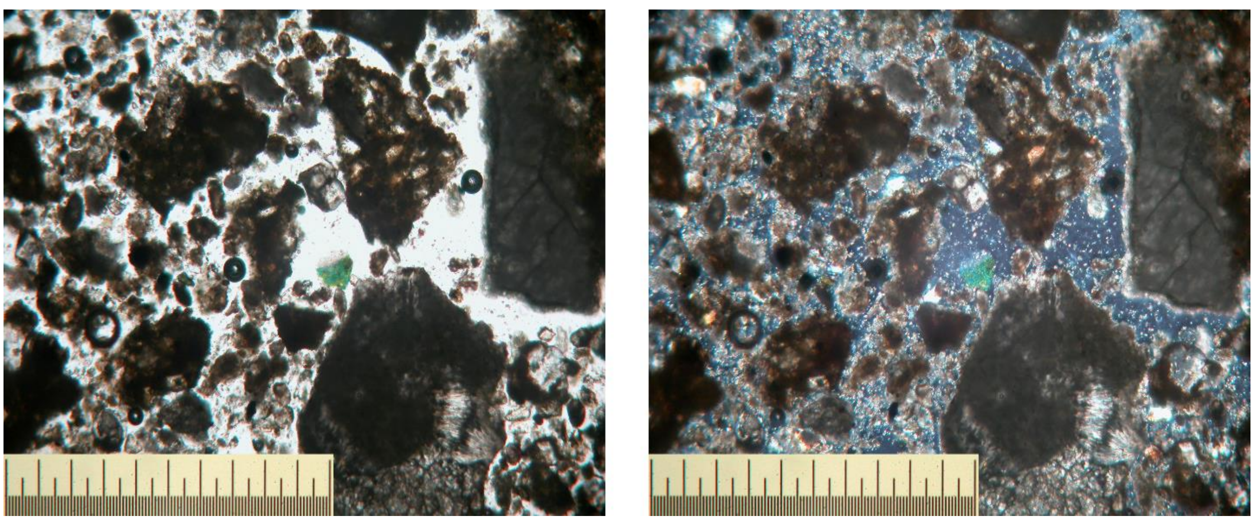

Figure 18: Green particle in the foundation deposit sediment, representing malachite or copper corrosion product. Left: PPL, right: XPL. Bar length: 1 mm.

Upon examining the petrography of the calcite crystals, it was found that there has been no alteration or abnormalities in the crystal structure. This indicates that the sample has not undergone extreme heating. Instead, it appears that the local sediment has been mixed with charred vegetal materials. Although the sample may have been exposed to relatively low temperatures, it seems that the temperature was not enough to induce significant changes in the crystal structure of calcite minerals. These results lead us to assume that charred vegetables were mixed with the sediments after being exposed to the heating. A conclusive decision can only be made by considering all of the results collectively, including the FTIR results.

During the micromorphological study, a green particle was observed in the sediment (Fig. 18). This particle could either be Malachite $Cu_2CO_3(OH)_2$ or the corrosion product of copper. Due to the size of the particle, it was not possible to ascertain its identity through interference figure or surface XRF. However, in the future, an attempt will be made to uncover the slide and examine it by SEM-EDS. The discovery of this particle in the foundation deposit beneath the main building, which may be a sanctuary, is significant to the discussion regarding the possible presence of copper. This finding has bearing on the relevance of the Naẖal Mishmar hoard or copper production in or around the site, as mentioned by Goren (2014a) and Ussishkin (2014).

4.2 Petrographic analysis of the cornet

A petrographic thin section of the cornet, Locus 35, was examined under the petrographic microscope and the results were surprising. The analysis revealed that by its petrographic traits, the cornet was made of marl from the Taqiya formation, typically with *Bolivina* sp. microfossils, with inclusions made of quartz, limestone, chert, hematite, and some quartz silt including some accessory minerals such as zircon (Fig. 19). This indicated that the cornet from the pit (L35) belonged to the Taqiye petrographic group (Goren et al., 2004, p. 256 with references).

As mentioned in the first chapter, previous petrographic data from the site mostly belonged to the Motza formation which is common in the area (Goren, 1995). However, the Taqiye formation only appears on the far northern side of the site and is not the available clay source in the immediate surrounding area (as shown in fig 20).

The Taqiye marl is made up of calcareous clay and has a Paleocene-Eocene age matrix that is rich in foraminifera. The matrix of the Taqiye formation is rich in fine carbonate crystals and occasionally well-sorted silty quartz. Chalky shales, which range in color from green to grey, and a locally gypsiferous, hard bank of silicified chalk capped by chalky shales are further characteristics of this formation. Limonitic concentrations, pseudomorphic after marcasite, are abundant in its shaly parts. The Taqiye formation is found in the Negev, the Shephelah, the Judean Desert, the central Jordan Valley, the western Galilee, the Lebanese Beqa, and along the Mediterranean coast of Lebanon (Goren, 1995; Goren et al., 2004, p. 262).

The Taqiye formation is not exposed in the Ein Gedi vicinity. It outcrops mainly in the Shephela area and in vast locations in the Central Negev and Sinai. The closest location where it is distributed is the Beit Shemesh area where many Ghassulian sites prevail. The results of petrographic analysis, including the origin of the clay, production location, and purpose of the cornet found in the pit, raise new questions related to the Ein Gedi shrine. It makes it necessary to reconsider the relationship between the Ein Gedi Shrine and other sites from the Chalcolithic period. Pottery assemblages from Nahal Mishmar and Gilat contain vessels made of the Taqiya marl in significant amounts (Goren Y. 1995). It appears that the materials used to make the cornet do not match the geology of the local area. This suggests that the cornet may have been produced elsewhere and brought to the Ein Gedi shrine. The closest possible source for the materials is the Shephela area, where the Taqiye formation is found. Investigating the origin of the cornet could shed light on trade and exchange patterns in the shrine. Furthermore, studying the aplastic and plastic materials used in the cornet could be helpful for future research.

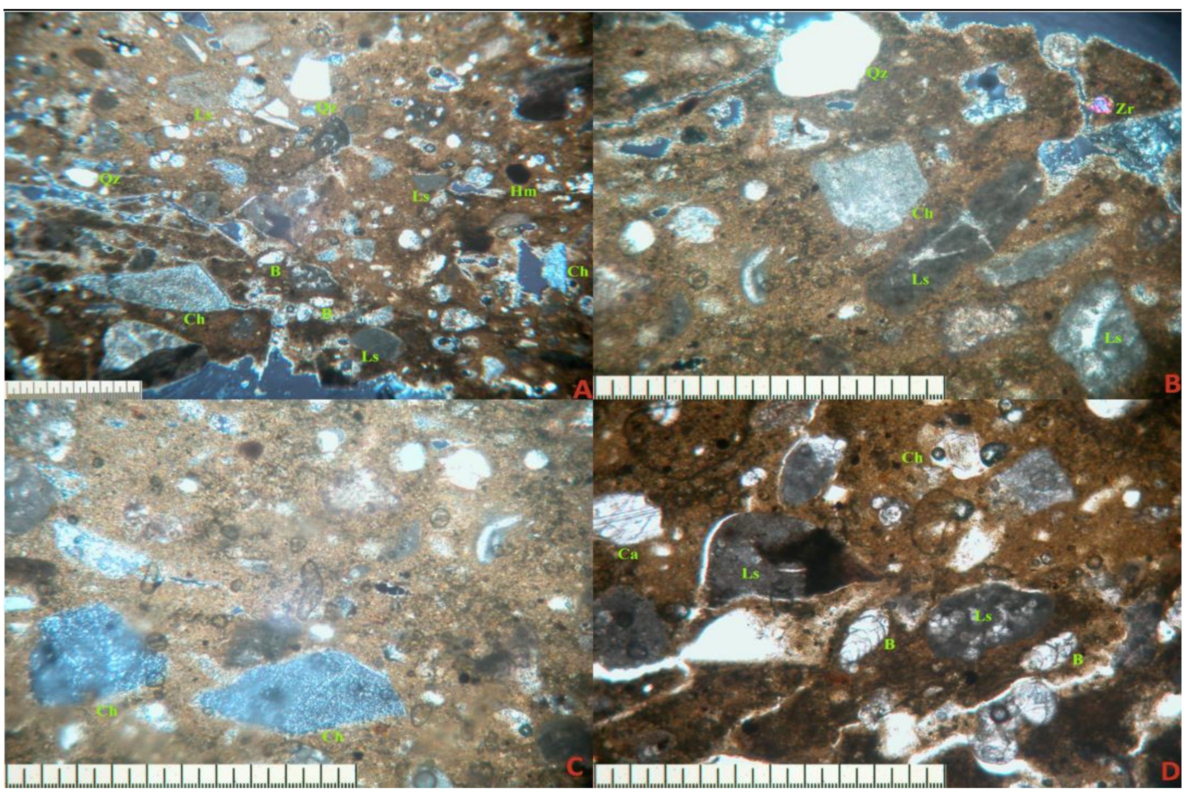

Figure 19: photomicrographs of the cornet sample under the petrographic microscope. Scale bar: 1 mm. Legend: A) Qz-quartz, Ls- limestone, Ch-chert, Hm-hematite, B- Bolivina sp. Microfossil (XPL). B) Ch- chert (XPL). C) Qz-quartz, Zr-zircon, Ch- chert, Ls-limestone (XPL). D) B- Bolivina sp.Ch- chert Ls- limestone Ca-calcite (PPL)

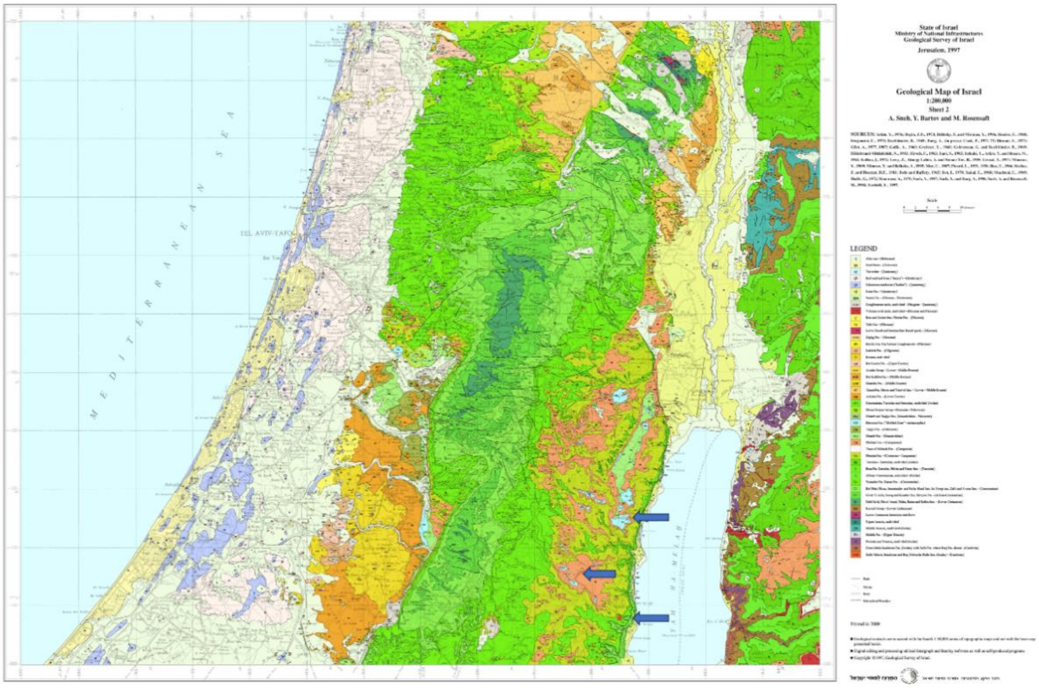

Figure 20: Geological map of Israel (arrows show location of site, and signs of Taqiya formation). Compiled over Sneh, et al., 1998.

4.3 X-ray Diffraction

To support and compare the micromorphological findings, sample from locus 36 basket 1091 underwent XRD analysis. The results of the XRD analysis revealed the presence of several minerals in the soil sample, including quartz (SiO_2), gypsum ($Ca(SO_4)(H_2O)_2$), dolomite ($CaMg(CO_3)_2$), kaolinite ($AI_2Si_2O_5(OH)_4$), calcite ($Ca(CO_3)$), anorthite ($Ca\ AI_2\ Si_2\ O_8$), and ankerite ($Ca(Fe+_2\ Mg)(CO_3)_2$).

Quartz belongs to the Silicates mineral group, and it is the second most abundant mineral found in the earth's crust. It can be found in various forms. The discovery of minerals such as quartz, gypsum, dolomite, and calcite in this specific geographical region is not surprising, as they are highly typical of the area (as mentioned in chapter 1.4.1). Kaolinite, classified as a clay mineral, undergoes structural breakdown when exposed to temperatures exceeding 550ºC (Bellotto, 1995).

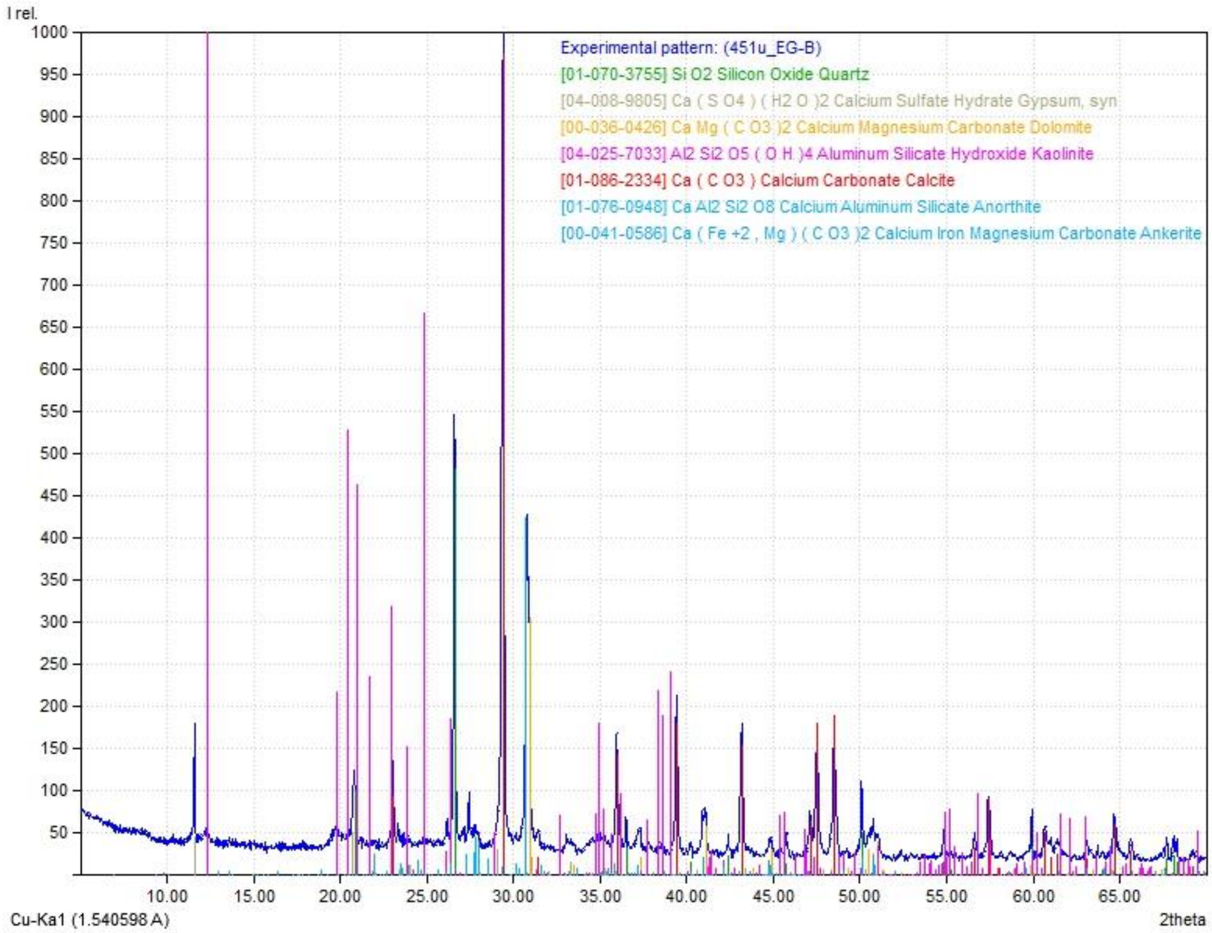

Figure 21: XRD pattern for the sample L 36 B1091

4.4 Fourier-Transform Infrared Spectroscopy

In order to compare and confirm XRD results on the sample L36 B1091 from the pit, FTIR spectra of the sample L35 B1070 (ash) and L36 B1085 (mud plaster) were obtained.

After conducting XRD analyses, it has been confirmed through FTIR that calcite is present in both L35 B1070 and L36 B1095 samples. To determine if the calcite in the plaster is from anthropogenic sources (connected to pyrotechnology) or geogenic sources, the grinding curves method was employed. This method is based on the principle that calcite from distinct sources exhibits unique peak height characteristics (Regev, 2010).

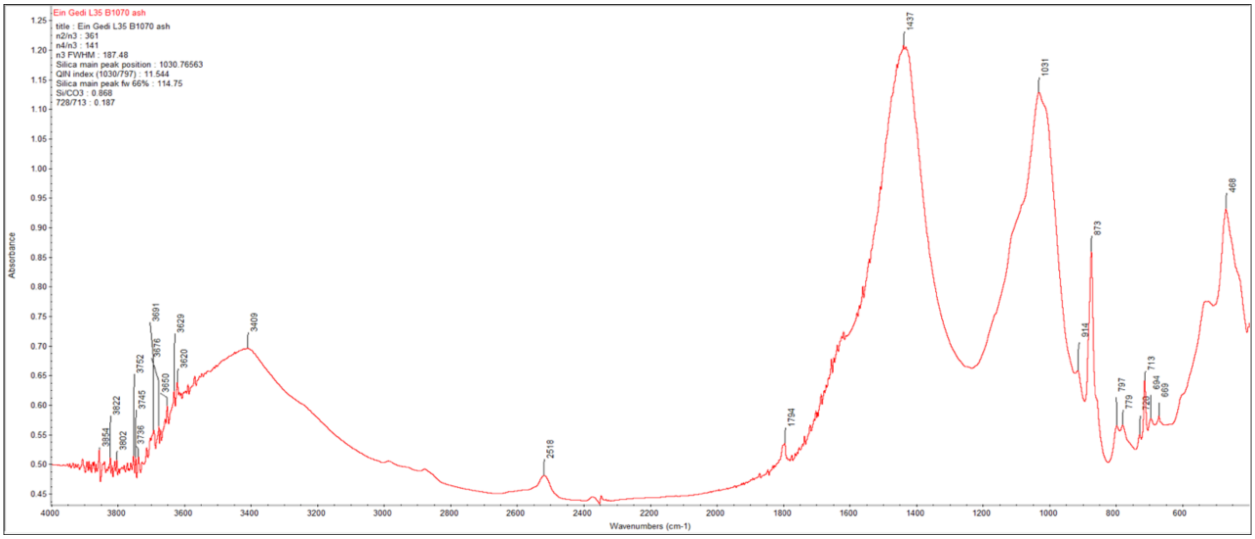

Figure 22: FTIR pattern of the sample L35 B1070(ash)

Before applying this method, it is essential to take into account that the FTIR spectra of the sample indicate the presence of dolomite. This observation raises a potential concern as it could interference when using the grinding curve method to determine the origin of the calcite in the mud plaster. Dolomite, with its mineral structure represented as CaMg(CO3)s, bears similarities to calcite, despite exhibiting different peaks at V4 (728cm-1 for dolomite, 713cm-1 for calcite). The v_2 peak at 881 cm^{-1} overlaps with the calcite v2 peak at 875 cm^{-1} making it hard to isolate the calcite signal without considering the dolomite. (Maor, 2023)

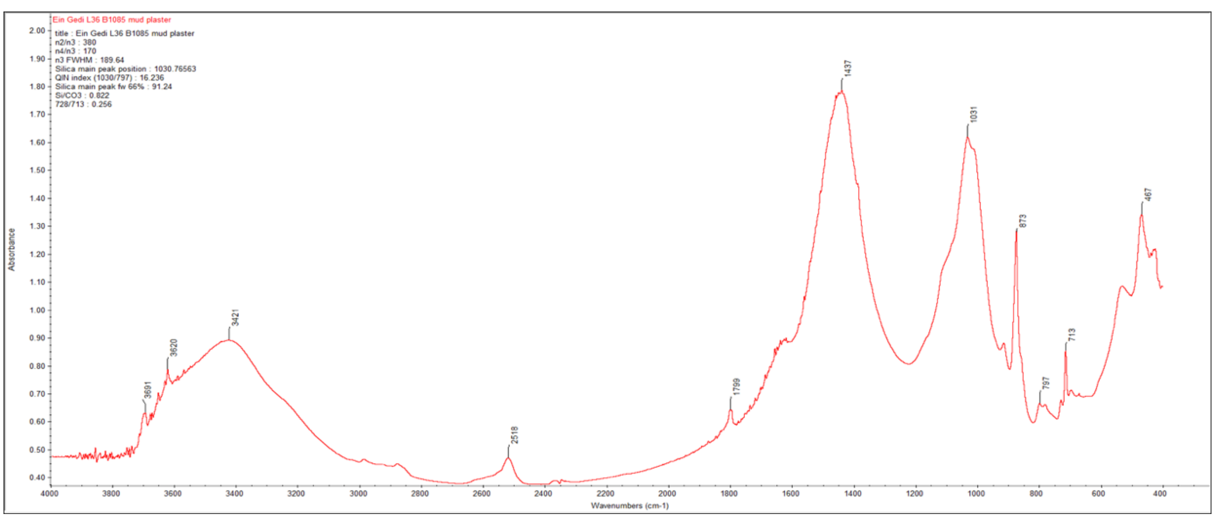

Figure 23: FTIR spectra of the sample L36 B1085

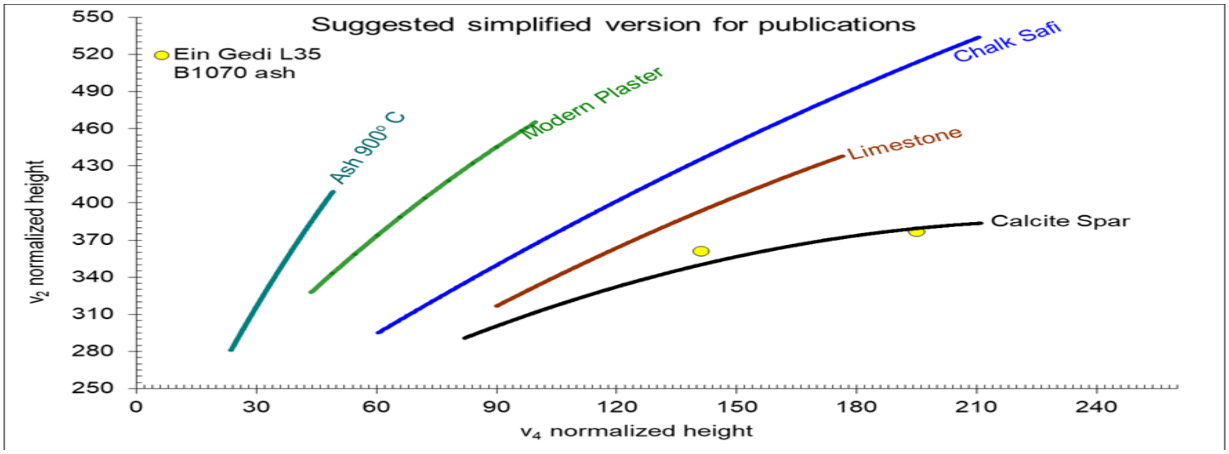

Figure 24: Grinding curve plot of the sample L35 B1070 with reference from Regev (2010)

Based on the spectra, the quantity of dolomite present in our specific case is insufficient to have any notable influence on the method. This observation is confirmed by the XRD results obtained from the same locus (L36 B1091). Therefore, we analyzed sample L35 B1070 and L36 B1085 to determine the level of calcite disorder within the composition, as shown in Fig. 24 and Fig. 25.

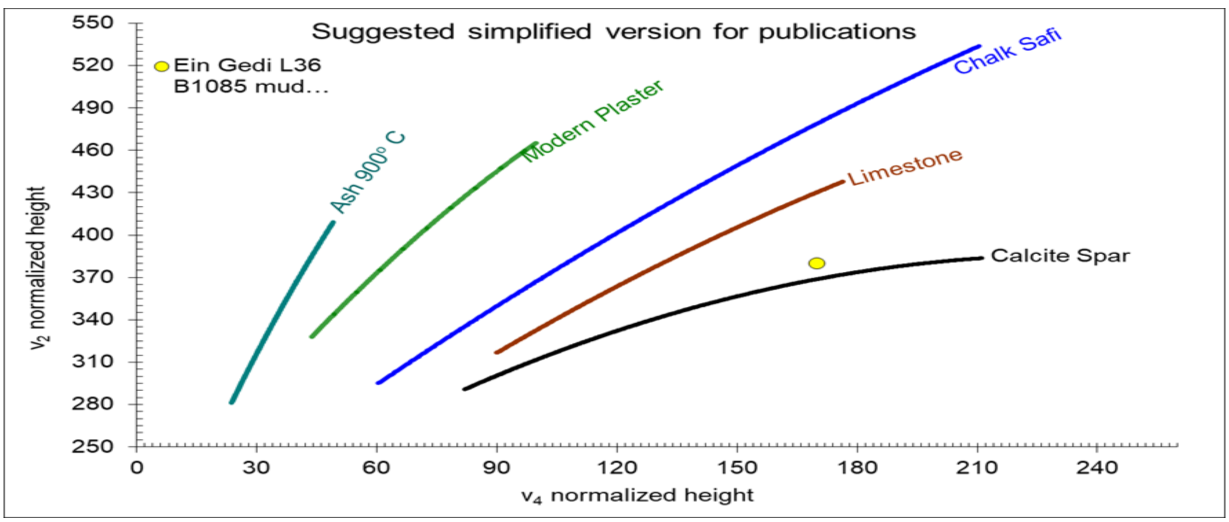

Figure 25: Grinding curve plot of the sample L36 B1085 (Regev 2010)

The results from both samples indicate that the detected calcite is geogenic and falls nearly to the geogenic origin calcite line. This observation suggests that the samples extracted from this pit, L35 B1070 and L36 B1085, have not undergone any substantial heating capable of influencing the calcite structure. This information is valuable in our efforts to investigate the plaster technology applied at this site.

4.5 Thermogravimetric analysis

TGA was conducted on the ash sample extracted from the pit in order to study its response to the heating process. The basic assumption of this analysis is that, upon experimental reheating, the irreproducible changes will take place only when the upper limit of the original heating is surpassed. It is essential to note that the assumption that clays retain their properties after firing has some limitations. According to Drebushchak et al. (2005), post-firing processes occurring over thousands of years of deposition under ambient conditions play a significant role in altering the characteristics of fired clays. Three aspects require special attention in this regard. Firstly, after clays are fired, they experience mass gain due to a set of slow reactions that occur in the newly formed meta-clay by water adsorption from the environment and the recovery of some structural hydroxyl groups (Shoval & Paz, 2013). While dehydroxylation is not entirely irreversible, it has been shown that ceramics gain mass and expand continuously after firing due to rehydroxylation, which is the chemical recombination with environmental moisture (Hamilton & Hall 2012). However, it is unlikely for these processes to occur in the extreme arid conditions of the Judean Desert.

The results of the TGA are presented in Fig. 26. Mass loss of absorbed water at ~120°C is extremely low, due to the arid environmental conditions. Furthermore, no significant mass occurs until ca. 500°C, indicating that low-level sintering processes were taking place already prior to this analysis. Only around 550°C, and again at 700°C, clay dehydroxylation and calcite decalcination took place respectively.

Based on the findings, it appears that either the pit was heated at a low temperature, or the materials placed in it were heated to around 400°C before being poured in. This could be the reason for the charring of the twigs and other plant materials present in the pit. The nature of these findings suggests that the green twigs and seeds may have been heated slowly for aromatic purposes or for consumption.

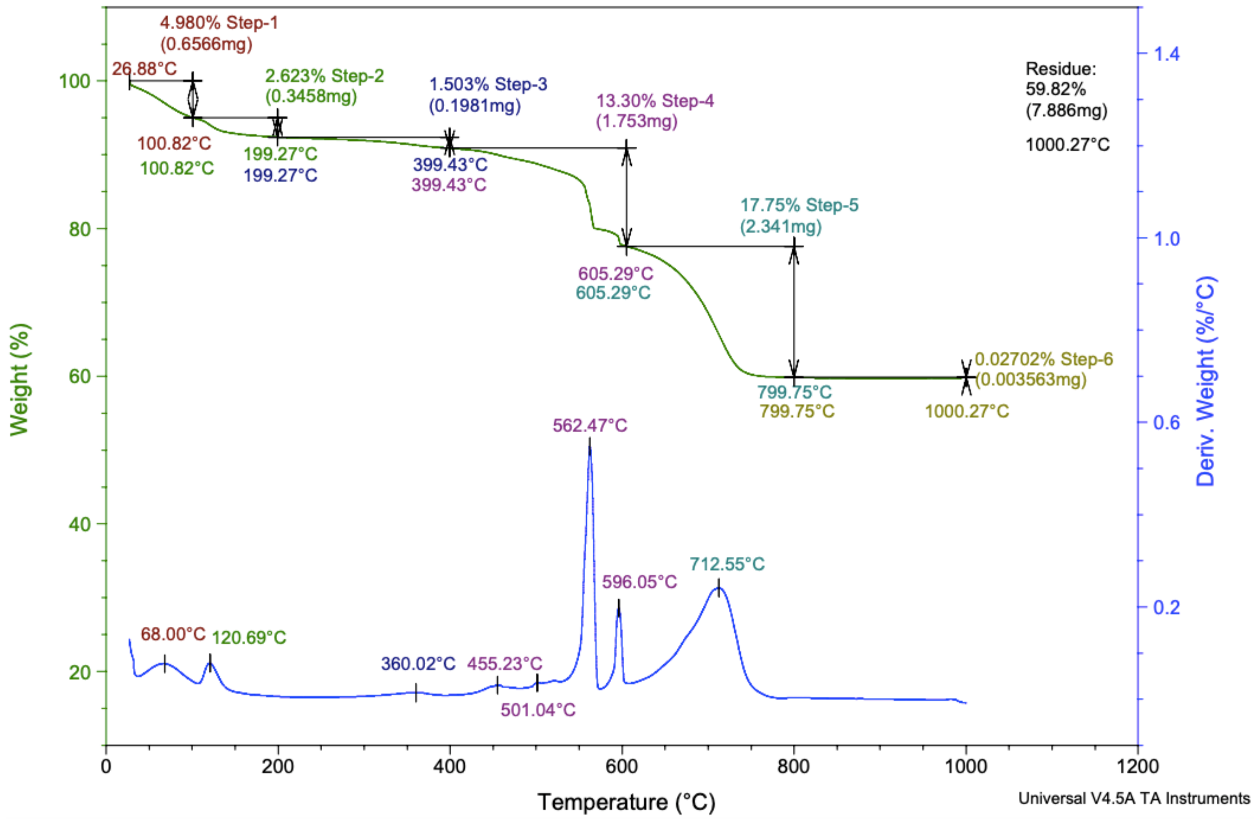

Figure 26: TGA results of the ashy sediment.

5 Discussion

After conducting a micromorphology analysis, it was discovered through stereomicroscopy examination that composite dolomite mineral formations existed within the structure. The fragmented rocks displayed a distinct clay coating, indicating that they were sediments containing embedded rock particles. This analysis has conclusively established that these sediments mainly consist of dolomite and limestone, which are characteristic rocks of the local region. Although both calcite and dolomite minerals were identified in the sample, calcite was found to be the dominant mineral. Furthermore, microscopic analysis revealed the presence of gypsum and quartz, which are commonly found in the geological settings of the region. Interestingly, a green feature was observed in sample L27 B1077. Further analyses need to be conducted to understand the origin of this feature and confirm if there is a continuous pattern.

Upon examining the calcite crystals through FTIR, we have discovered some valuable insights. We observed that there is no alteration in the crystal structure, which indicates that the sample has not undergone extreme heating. Instead, it appears that the local sediment is mixed with charred vegetal materials, suggesting exposure to relatively low temperatures.

X-ray Diffraction (XRD) analysis was carried out to provide additional evidence and compare the micro-morphological findings of the soil sample taken from the pit. The analysis showed the existence of several minerals such as quartz, gypsum, dolomite, kaolinite, calcite, anorthite, and ankerite. These minerals are consistent with the geological features of the area.

The FTIR technique was employed to verify and compare the results obtained from XRD analysis. The presence of calcite was confirmed in both L35 B1070 and L46 B1085 samples. The grinding curve method was then utilized to determine the origin of calcite in the mud plaster. This method uses the distinctive peak height characteristics of calcite from different sources, as described by Regev (2010).

It was necessary to first examine the FTIR spectra of the sample prior to utilizing this method. The spectra indicated the presence of dolomite, which shares a similar structure with calcite. This similarity could have resulted in potential issues since both minerals have overlapping peaks. However, subsequent analysis revealed that the amount of dolomite present was insufficient to significantly impact the method. This conclusion was supported by XRD results from the same location (L36 B1091). Consequently, both samples, L35 B1070 and L36 B1085, were examined to determine the level of calcite disorder in their composition.

Both samples indicate that the detected calcite is of geogenic origin and falls near the geogenic calcite line. This suggests that the samples taken from the pit have not undergone significant heating that could alter the calcite structure. The FTIR, especially the grinding curves method, is an excellent way to study the thermal history of the foundation deposit. However, a comprehensive conclusion can only be reached when all results are considered together.

Once the ashy sediment sample was collected from the pit, it underwent thermogravimetric analysis to determine if it had been heated in ancient times. The analysis revealed that the sample had been subjected to low-level heating of around 450ºC during the firing process. This indicates that the green, fine vegetal matter was most likely charred for aromatic or consumption purposes before or during its deposition in the pit.

The analysis of the cornet found in the pit showed that it was made from marl and inclusions that came from the Taqiye formation, unlike the other pottery vessels found at the site which were made from the local clay of the Moza formation. This discovery provides us with new information that may change our previous conclusions and lead to a better understanding of the early history of the Ein Gedi shrine.

After conducting a multi-faceted analysis, we have achieved a comprehensive understanding of the Ein Gedi shrine, including its historical chronology and geological context. The precise dating has confirmed that the shrine belongs to the early Ghassulian culture, which challenges previous assumptions. The presence of various local minerals, the absence of extreme heating, and the dietary diversity observed in the botanical evidence all contribute to the study of the site.

It was discovered that the pit in the largest room of the site was used as a small fire location where plant materials were burned at low temperatures. This burning was likely conducted as part of a ritual since pottery fragments were found at the site. After the burning, the pit was then closed. However, it is possible that the fire activity was done outside of the pit and the burned substances were later carried to the pit since there was no evidence of heating on the minerals. Additionally, the foundation deposit does not provide evidence of a connection between the Ein Gedi Shrine and external sources apart from the pottery findings.

6 Conclusion

In this study, we aimed to gain a better understanding of the significance of the Ein Gedi shrine in the context of Chalcolithic history in the southern Levant. To achieve this, we conducted a thorough review of existing literature and provided an overview of the Chalcolithic period and the geographical area of interest. Additionally, we examined the intended use of the shrine and the cultic practices prevalent during the Chalcolithic period in this area. Our ultimate goal was to establish a more nuanced comprehension of the site.

A fascinating discovery that led to further exploration of human activity within the Ein Gedi Shrine was the discovery of a newly discovered foundation pit in Room A of the site. This discovery sparked a captivating discussion about the intricate nature of the activities that took place within the confines of the shrine.

Ash remains are scattered around the site, but the pit itself was the central focus of this research. Various anthropogenic features were found within the pit, and a detailed analysis of these features provided new insights into the pit's function. This has helped to broaden our understanding of the Ein Gedi shrine as a whole.

Microscopy and XRD analyses did not reveal any external characteristics of the samples. However, when examining the dolomite content using FTIR and XRD methods, a notable correlation was established. This correlation was crucial in determining that the fire temperatures employed were relatively low, up to ~400ºC.

Finally, pottery analyses provided us with another perspective of the Ein Gedi shrine. The composition of the cornet from the pit is not local characterized. However, it shows similarities with Nahal Mishmar and Gilat petrography. Additionally, location of the cornet increases complicity of the shrine history.

In summary, the research concludes that the pit had a specific function: burning locally gathered plants, potentially for ritualistic purposes. However, absence of the significant heating on sediments from the pit with the charred materials and charcoals rise questions.

It was later discovered that the pit was promptly closed or abandoned once it had served its purpose. This discovery not only provided insight into the activities that took place in the Eind Gedi shrine, but also improved our overall understanding of the Chalcolithic history in the southern Levant.

Moreover, the research conducted on the Ein Gedi shrine lays a strong foundation for further exploration, particularly with regards to anthropogenic activities that are locally oriented and purpose of the pottery fragment in the pit. The insights obtained from this study offer a starting point for future investigations into the intricacies of the shrine. The discovery presented here makes it clear that there is sufficient reason to delve deeper into the history of the site and uncover more localized human activities that may have taken place within its boundaries.

The findings of this research can be a starting point for future fieldwork and research. It opens up exciting possibilities for developing more detailed and nuanced theories about the Ein Gedi shrine. By continuing to build on the knowledge acquired through this study and conducting further research in the field, a more comprehensive and refined understanding of the shrine's role in the Chalcolithic history of the southern Levant can be achieved. This ongoing exploration promises to uncover more about the human activities and culture that once existed within the site.

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