Restoration and Reassembly of the Shattered Stone Sarcophagus lid of Sanit from the Late Period - 26th Dynasty, Preserved in Museum Storage at Saqqara

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Abstract

Eighteen stone pieces representing the limestone lid of Sanit's sarcophagus were received, making it necessary to assemble these fragments to preserve them from loss and restore the lid as one piece. This assembly process will stop the deterioration and damage to the stone components of the lid.

The limestone lid of Sanit was received in museum storage number (2) in the Saqqara. The lid dates back to the 26th Dynasty of the Late Period when officials of the 26th Dynasty were buried in Saqqara. Sanit was likely a high-ranking official of this dynasty. In 1921, the archaeologist Firth discovered the double-shaft tomb of Nefer-ib-Ra Sanit/Wah-ib-Ra. Upon opening the tomb, the sarcophagus lid was shattered into many pieces and transferred to a secondary storage facility with a worn wooden roof in the Saqqara area.

The lid was later moved again to museum storage number (2) due to its severely damaged state, as it consisted of separate stone pieces, some large, some medium, and others small, along with missing sections.

A visual inspection of the lid was conducted to initiate the restoration process. A polarized microscope was used to identify the components of the lid, and a scanning electron microscope was employed to identify the lid's components and examine the morphology of its surface. Additionally, X-ray diffraction analysis was utilized to determine the composition of the stone from which the sarcophagus lid was carved. Stainless steel rods were used in the assembly operations, along with epoxy adhesive (Araldite 110).

The assembly of Sanit's sarcophagus lid demonstrated that epoxy adhesives are effective for bonding limestone, especially in cases involving heavy and large stone blocks. The use of stainless steel rods also ensured the secure assembly of these massive fragments while minimizing the risk to the lid's pieces, thus contributing to their preservation.

Key words:
Reassembly –Shattered –-limestone-stainless steel rods -Museum store -Sarcophagus lid-Saqqara.

الملخص

تم استلام 18 قطعة حجرية تمثل غطاء تابوت سانيت الحجري لذا كان من الضروري تجميع تلك القطع الحجرية المكونه لغطاء تابوت سانيت للحفاظ عليها من الضياع و إعادة الغطاء قطعة واحدة مرة أخرى فعملية التجميع سيتنج عنها إيقاف عمليات التلف والتدهور بالقطع الحجرية المكونة للغطاء.

تم استلام غطاء تابوت سانيت الحجري في المخزن المتحفي رقم (2) بمنطقة سقارة ويرجع الغطاء إلى الأسرة السادسة والعشرين من العصر المتأخر حيث دفن موظفو الأسرة السادسة والعشرين في سقارة ومن المرجح ان سانيت كان من كبار موظفي الأسرة السادسة والعشرين وقد اكتشف فيرث عام 1921المقبرة البئرية المزدوجة نفر ايب رع سانيت / واح ايب رع من وعد فتح المقبرة وجد غطاء التابوت مهشما إلى العديد من القطع وتم نقلة إلى مخزن فرعي ذو سقف خشبي متهالك بمنطقة سقارة .

وتم نقل الغطاء مرة اخرى إلى المخزن المتحفي رقم (2) لما يعانية من تهشم كامل فالغطاء عبارة عن قطع حجرية منفصلة منها ما هو كبير ومتوسط وقطع صغيرة وأجزاء مفقودة .

وتم فحص الغطاء فحصا بصريا للوقوف على البدء في عملية ترميمة , وتم استخدام الميكروسكوب المستقطب في التعرف على المكونات المعدنية المكونة للغطاء , وتم استخدام الميكروسكوب الألكتروني الماسح للتعرف على مكونات الغطاء وفحص مورفولجية سطح الغطاء , ايضا تم استخدام التحليل بحيود الأشعة السينية للتعرف على مكونات الحجر المنحوت منه غطاء التابوت , وتم استخدام اعواد من الأستانلس استيل المقاوم للصدأ في عمليات التجميع واستخدام لاصق من الأيبوكسي (الاردايت 110) ومن خلال نا تم من عمليات تجميع لغطاء تابوت سانيت يتضح أن استخدام لواصق الأيبوكسي مفيد في تجميع الحجر الجيري خاصة في حالات الكتل الحجرية ثقيلة الوزن والضخمه وأيضا استخدام اعواد الأستانلس استيل حتى يتثنى لنا تأمين تلك الكتل الضخمه وضمان اتمام عمليات التجميع دون تعريض قطع الغطاء للخطر والحفاظ عليها.

الكلمات المفتاحية:

إعادة التجميع - مهشم - حجر جيري - اعواد الفولاذ المقاوم للصدأ – مخزن متحفي - غطاء تابوت - سقارة.

1- Introduction

Many ancient artifacts have been discovered in Saqqara dating back to the Late Period, specifically the 26th Dynasty. During this time, arts, sculpture, and architecture saw significant development, with the artistic works, statues, and temples reflecting the unique character of ancient Egyptian civilization (Yahya Salah Saber El-Masry, 1994). Saqqara is located 28 km south of Cairo and was a special burial site in ancient times (Abdel Halim Nour Eldin, 1998). The Late Period (26-27) was characterized by shaft tombs, a feature unique to this era. Coffins were an essential and prominent element in these tombs, often filling the burial chambers to the brim (Mohamed Mohamed Youssef, 2005). The limestone coffin lid of Sanit was discovered in a double-shaft tomb. It is a large limestone coffin lid intricately carved with hieroglyphs, shattered into numerous pieces ranging from small to large, with some pieces exhibiting fine fractures and cracks. Some parts are missing, as shown in figure number (1). Therefore, it was necessary to assemble Sanit's coffin lid to preserve it from further loss and restore its original form before the fragmentation process. Assembly operations are crucial for preserving archaeological pieces, preventing their loss, halting their deterioration, and restoring their original shape. Assembly is achieved using various methods, including modern technology

like 3D scanning to reimagine the original shape of the artifact and calculate missing proportions, documenting each broken piece individually and virtually assembling them based on the angles of the shattered fragments to obtain a complete model of the artifact and models of the missing pieces with their dimensions (Young Hoon Jo, Seonghyuk Hong, 2020). Carbon fibers are also used in assembly operations for their high mechanical properties of strength, hardness, tensile modulus, and flexibility (Abdullah Sayam, A. N. M. Masudur Rahman, 2022). They are lightweight, corrosion-resistant, and possess the necessary hardness (Sharun Hegde, B. Satish Shenoy, K.N. Chetha, 2019). Carbon fiber pins or stainless steel rods are used in assembly, as they offer high strength, hardness, and weight-bearing capacity without affecting the artifacts or causing internal stress, ensuring stability without bending the pins within the artifact (Saman Dehrooyeh, Majid Vaseghi, 2021). Fiberglass fibers are utilized for their high durability, load-bearing strength, and stability without damaging the artifact (Frida Hermansson, Sara Heimersson, 2022). Assembly is carried out using stainless steel pins or rods resistant to corrosion, known for their high strength, hardness, weight-bearing capacity, stability, and resistance to bending, also being cost-effective and readily available (Jessica Rosewitz, Christina Muir, 2016).

In the case of Princess Eline's tombstone, stone pieces were assembled using stainless steel screws sized 6mm cut to various lengths according to the stone's size. Stainless steel screws were inserted into the drilled holes, and the stone pieces were tested together to ensure complete closure of the gaps and that the stone surface level remains consistent (Mohamed Hassane, Saly Azar, 2022). The process of reassembling the stone blocks for Sanit's coffin cover involved using stainless steel rods to reinforce and securely assemble them due to their heavy weight, numerous large pieces, and the need to strengthen the structure of Sanit's coffin lid. Epoxy compounds were also used as adhesive materials for reassembly, to secure small pieces and connect large pieces with stainless steel rods.

fig (1) shows the stone pieces representing Sanit's Sarcophagus lid are shown before restoration.

2-Materials and Methods

2-1 Documentation

Scientific documentation is considered one of the most important steps in conservation. Without various documentation processes, we will not be able to protect, treat, and restore artifacts. The scientific registration of Sanit's coffin cover is the first step in the treatment

process and must be done in multiple ways to ensure a complete registration process. Registration does not only involve damage but also includes treatment and restoration stages, resulting in a comprehensive file with the artifact's history (Abeer Fouad Abdel Moez, 2010).

- **Archaeological Documentation**

In this type, everything related to the artifact is studied, including its history, nature, shape, decorations, inscriptions, and the study of damages to the artifact, documenting them. The object is a massive coffin lid made of pure limestone, but it is in a bad state of preservation. It has been stored in storage room number (2) at the Saqqara archaeological site, leading to an increase in its deterioration. The coffin lid is engraved with deeply incised hieroglyphic inscriptions, sculpted in relief, featuring the goddess Nut with her wings spread below her and funerary texts from the Pyramid Texts in a vertical orientation. The protective deities flank her on both sides. The coffin lid of Sanet dates back to the late 26th Dynasty. It exhibits various signs of damage including a layer of dust on its surface, and spider webs, and is broken into several pieces, some of which are large and others small. Additionally, there are missing parts at the edges, in the middle, and sections of the inscriptions.

- **Photographic Documentation of the Shattered Stone Coffin Lid of Sanit**

Before any intervention and starting the restoration process, the restorer must identify damages and document them photographically (photographic documentation helps set a suitable plan for necessary treatment and maintenance operations) (Adel Nasri, Xian Feng Huang, 2020). Using (A Canon Digital EOS 2000D camera).

Photos numbered 2-19 represent the components of the stone coffin lid of Sanet.

fig (2) piece number (1) and illustrates a fragment of the head of the coffin lid of Sanit .

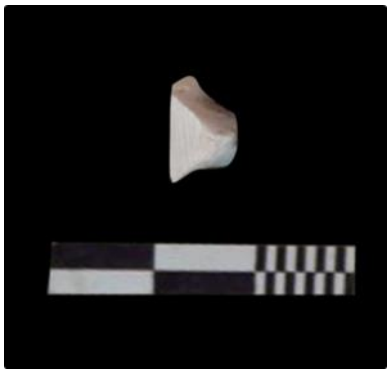


fig (3) piece number (2) and illustrates a fragment of the head on the right side of the coffin lid of Sanit.

fig (4) piece number (3) and illustrates a fragment of the beard and the left side of the coffin lid of Sanit .

fig (5) piece number (4) and illustrates a fragment of the head and face of the coffin lid of Sanit.

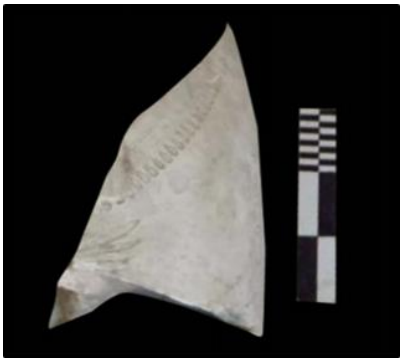


fig (6) piece number (5) and illustrates a fragment of the right side of the coffin lid of Sanit.

fig (7) represents piece number (6) and illustrates a fragment of the left side of the coffin lid of Sanit.

fig (8) represents piece number (7) and illustrates a fragment from the left side of the coffin lid of Sanit.

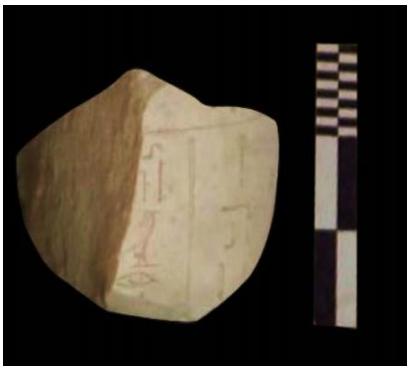


fig (9) represents piece number (8) and illustrates a fragment from the middle of the body of the coffin lid of Sanit.

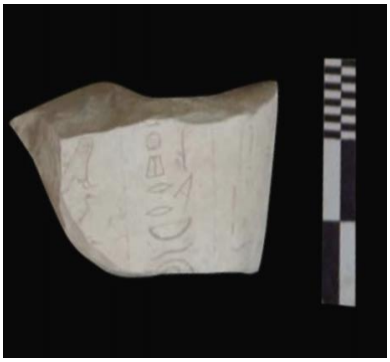


fig (10) represents piece number (9) and illustrates a fragment from the right side of the coffin lid of Sanit.

fig (11) represents piece number (10) and illustrates a fragment from the middle of the body of the coffin lid of Sanit.

fig (12) represents piece number (11) and illustrates a fragment from the left side of the end of the body of the coffin lid of Sanit.

fig (13) represents piece number (12) and illustrates a fragment from the right side of the coffin lid of Sanit.

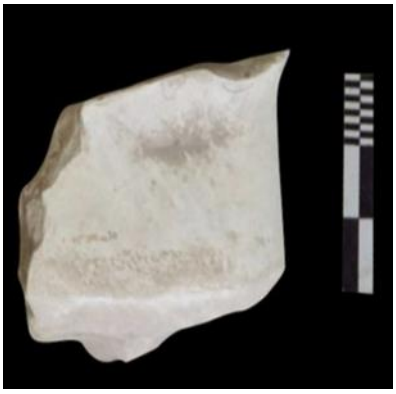


fig (14) represents piece number (13) and illustrates a fragment of the foot of the coffin lid of Sanit.

fig (15) represents piece number (14) and illustrates a fragment from the middle of the body of the coffin lid of Sanit.

fig (16) represents piece number (15) and illustrates a detached fragment from the coffin lid of Sanit.

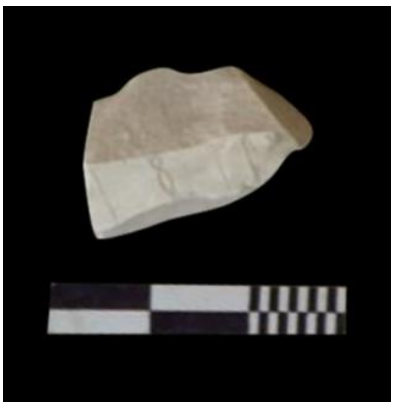


fig (17) represents piece number (16) and illustrates a detached fragment from the coffin lid of Sanit.

fig (18) represents piece number (17) and illustrates a detached fragment from the coffin lid of Sanit.

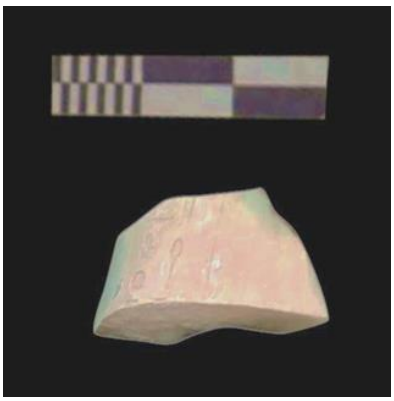


fig (19) represents piece number (18) and illustrates a fragment from the left side of the coffin lid.

- **Documentation of Saint's Stone Coffin Lid using AutoCAD**

Through AutoCAD, we can obtain a specific damage map for the stone coffin lid; by documenting with AutoCAD 2018, we have obtained a damage map with a scale and a horizontal projection of the lid. (2003, F. Summers, N. Atalan).

AutoCAD was used to document and draw a section for each of the stone pieces that make up the sarcophagus lid. An additional horizontal section of the sarcophagus lid was drawn to illustrate the locations of any missing pieces Fig 19-20.

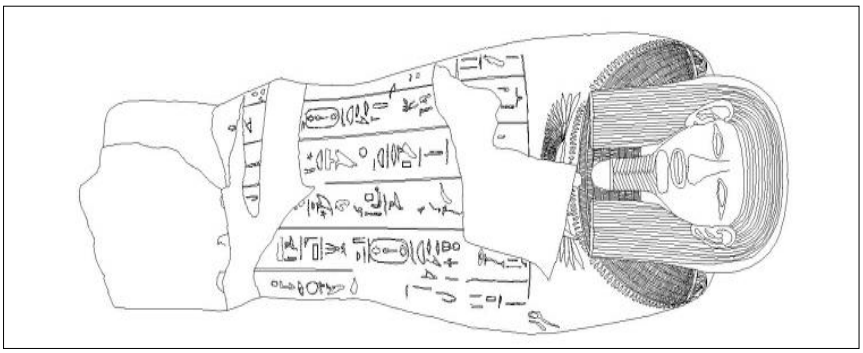


Fig (19) Shows a horizontal section of the Sanit sarcophagus lid.

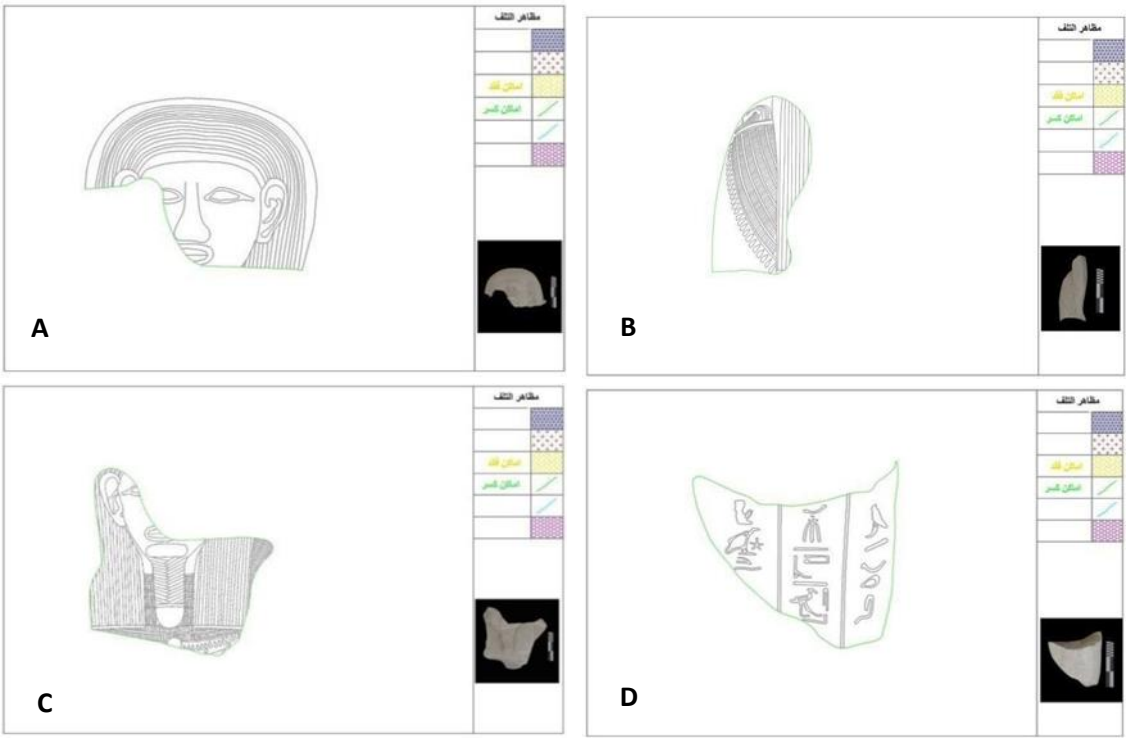


Fig (20) Shows Sections representing parts of Sanit's sarcophagus lid.

2-2 Examination and analysis

Conducting examinations and analyses provides accurate information about the composition and nature of limestone, which is beneficial for performing the necessary treatment and maintenance for the sarcophagus lid of Sanit, the subject of this study Visual examination is one of the most important and effective methods for identifying certain physicochemical and mechanical properties of the material from which the artifact is made (Stephanie Parisi, **2023).** It is one of the initial techniques used in studying the artifact's material to understand its quality and condition of deterioration. This method relies on expertise in the field and can be supplemented with magnifying lenses to help us see smaller components. Visual examination is a diagnostic process aimed at understanding the construction techniques of the artifact, the decorative techniques used, the causes and mechanisms of deterioration, assessing the level of damage, and determining the priorities for maintenance and restoration processes (Davide Gulotta**, 2022).**

A polarizing microscope (PL) was used to identify the minerals that make up the limestone, the material used for the sarcophagus lid of Sanit **(A Japanese-made Olympus BX50 polarizing microscope was used, connected to a Japanese digital camera, which was linked to a computer to directly upload the images).**

Additionally, a scanning electron microscope (SEM) was employed to magnify the particles of the archaeological material constituting the sarcophagus lid.

X-ray diffraction (XRD) can also be used to identify the mineral composition of the limestone and analyze samples accurately (Marcos A.S. Anjos, Tomaz R. Araújo, 2020). The device (*X'Pert HighScore Software 2006 X'Pert Pro PANalytical – Manufactured by Panalytical B.V

Co., Netherlands) was used under the following operating conditions: scan type: continuous, anode material: copper (Cu), general settings: 30 mA and 40 kV.

2-3 Stainless Steel Rods and Epoxy

Stainless steel 316 is commonly used as a fixing material in the assembly of stone artifacts, chosen for its strength, corrosion resistance, and high mechanical properties (Carolyn Riccardelli, George Wheeler, 2010). Stainless steel rods are used as reinforcing materials with adhesive in reassembly operations to strengthen and secure the assembly of stone blocks with each other. The diameter of the metal rods used is 12 mm. The number of metal rods used the thickness of the rods, and the depth of the slot inside the stone for inserting the rods primarily depend on the weight and thickness of the stone piece to be assembled, as well as the condition of the stone. Stainless steel rods were cut and prepared for the stone block assembly process according to the specified sizes and thicknesses. An initial test was conducted to control and insert them into the slots made in the stone before the final assembly (Stainless steel metal rods provided by CTS, Rome, Italy). Epoxy resins consist of an epoxy component that reacts with a hardener; epoxy resins are widely used in bonding glass, stone, and wood, known for their heat-curable adhesive properties, strength, and corrosion resistance (Jessica Rosewitz, Nima Rahbar, 2018). Due to their excellent mechanical properties, high bonding strength, and good resistance to heat and chemicals, epoxy resins are significantly important as adhesive materials for stone, reinforcement, and gap filling due to their durability, strong bonding, and exceptional mechanical strength, Although the use of epoxy adhesives is preferred with igneous rocks, due to the large size of the limestone blocks that make up the sarcophagus lid of Sanit, epoxy (Araldite 110) was used to achieve strong bonds and ensure the durability of the assembly process, thereby aiding in the preservation of the lid. Reassembling archaeological pieces poses a significant challenge for restorers. Recently, researchers turning to new techniques to enhance the properties of traditional adhesives and techniques used in reassembling large broken stones. Epoxy resins are widely used in stone preservation and reassembly of broken stones due to their exceptional mechanical properties. There are many opinions emphasizing the necessity of using epoxy in certain stone preservation cases, especially in reassembling large broken stones, where epoxy is sometimes required because nothing else provides the necessary strength; it is excellent when durable bond is needed. Despite some objections to its use in preservation, preservation experts always confirm that the high mechanical properties of epoxy are why epoxy resins reinforced with other materials like stainless steel are typically suitable for reassembling and rebuilding large stone artifacts. Epoxy resin type 110 and its hardener, commercially known as Araldite 110®, were used. The weight ratio of epoxy resin to hardener was 2:1 (Mohammad A. Aldosari, Sawsan S. Darwish, 2020).

2-4 Reassembly of the Shattered Stone Coffin Lid of Sanit

The reconstruction or bonding process involves joining the broken parts together to restore the shattered artifact to its natural form and shape before the breakage. This process can be referred to as "rebuilding the archaeological piece." Reassembling archaeological fractures is very necessary as it allows the artifact to regain its shape and function, preventing the loss or disappearance of small parts. The reassembly of stone blocks was carried out using specialized

tools for handling heavy stone pieces, such as chain blocks, cranes, wheels, small cranes, wood, and sleds.

3-Results

Through the visual examination of the sarcophagus lid of Sanit, the overall condition was assessed. It is a massive stone lid made of limestone, intricately carved with deep hieroglyphic inscriptions. The lid is shattered into numerous pieces; some of the pieces have fractures and fine cracks, while others are missing.

Through the PL examination of the stone, it was found to be soft with a light grayish-white color. Upon studying the cross-section, it was determined to be fine-grained limestone. Visually, the stone appears soft and is primarily composed of calcite, featuring very fine fossils as evidenced by images numbered (21-22).

Using a scanning electron microscope (SEM), high-resolution micrographs of the sample were obtained, allowing for detailed observation of the internal and surface structure of the limestone. The examination revealed that the sample mainly contains the mineral calcite, along with some impurities, as shown in image numbered (23).

X-ray diffraction (XRD) analysis of the sample taken from the broken pieces beneath the foot of the sarcophagus lid of Sanit predominantly contained calcite ($CaCO_3$), as shown in figure number (24), along with a small percentage of quartz (SiO_2) and the mineral dolomite ($CaMg(CO_3)_2$).

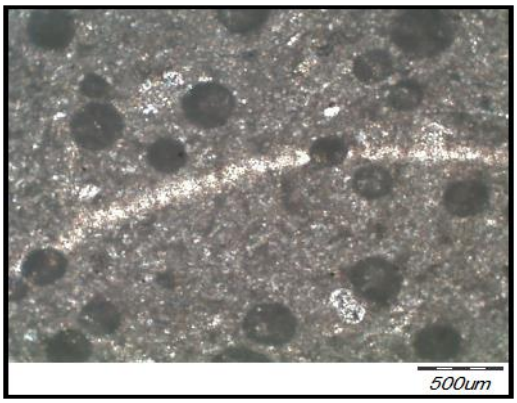


Fig (21) Shows (x500, C,N) reveals the presence of complete fossils and some remnants or fossil parts surrounded by a finely granular matrix.

Fig (22) The examination at (x500, C,N) shows that the sample is composed of finely granular limestone with a small percentage of quartz and iron oxides.

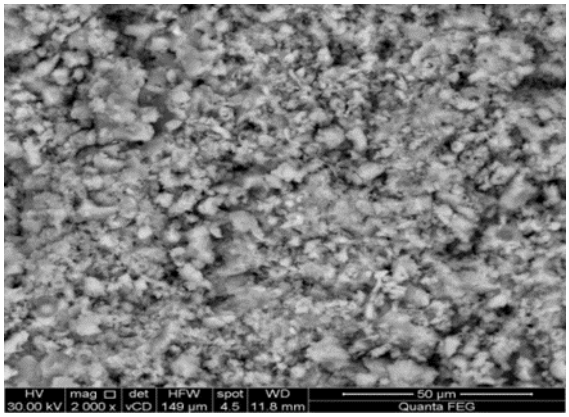


Fig (21) Shows The calcite crystals that constitute the stone and the morphology of the surface of the sarcophagus lid are illustrated.

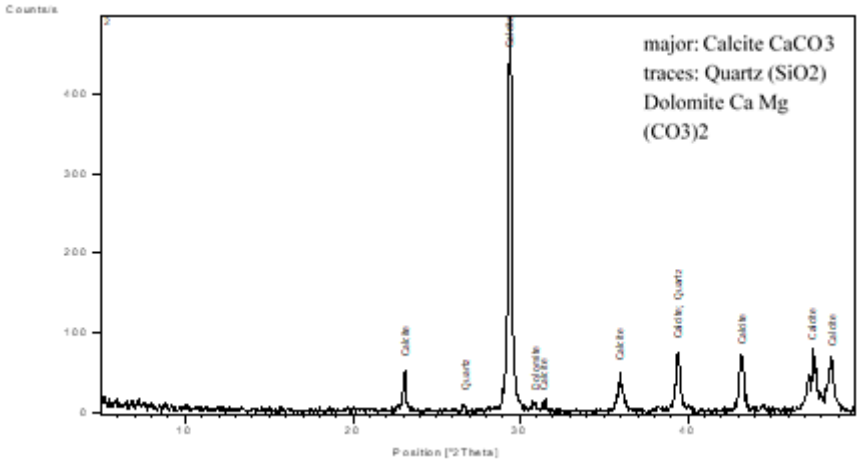


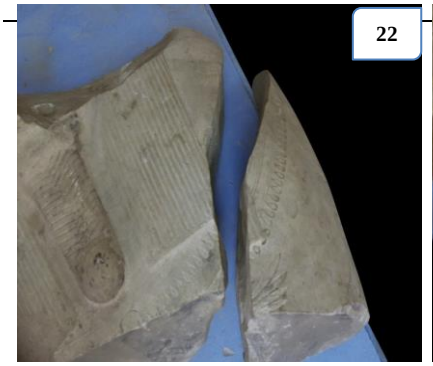
Fig (21) Shows X-ray diffraction pattern of a sample of limestone from the sarcophagus lid of Sanit is illustrated.

– **Reassembly of the Stone Blocks Comprising the Sanet Sarcophagus Lid**

The reassembly of the stone blocks was carried out using specialized tools for handling large archaeological stones, along with epoxy adhesives and stainless steel rods to strengthen and secure the reassembly process. This was accomplished in three stages.

- **Stage One**

In this stage, two small pieces were assembled to form part of the lid's body. Suitable drilling locations were determined to distribute the load evenly across the stone pieces to avoid cracks, fissures, or damage from drill vibrations. The drilling areas were cleaned thoroughly of stone dust resulting from the drilling process to prevent interference with the stainless steel rods that would join the stone blocks. The powder was then mixed with epoxy to create a filling material for the gaps before inserting the stainless steel rods. After placing the rods, the assembly was set for a while. The other piece to be assembled was then placed on the opposite side, and the two pieces were secured with a strap around the stone to ensure proper assembly and drying figures (22-29).



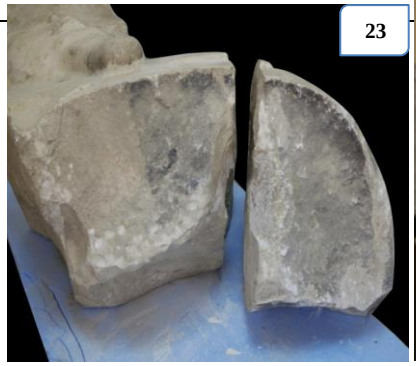


Fig (22-23) shows Two pieces from the head and right side of the stone coffin lid of Sanit during their preparation for the assembly process.

Fig (24)shows The stainless steel rods after being placed into the holes to complete the assembly process.

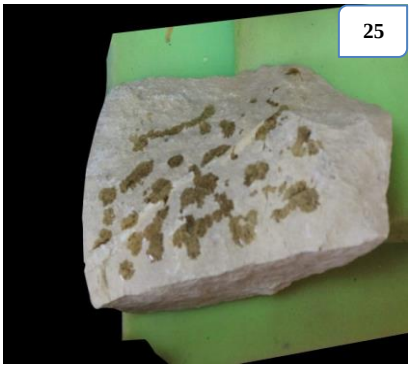


Fig (25-27) shows The application of epoxy on a small stone piece in preparation for bonding it and completing the attachment of the two stone pieces.

Fig (28-29)shows The application of epoxy on a small stone piece in preparation for bonding it and completing the adhesion process.

Stage Two

After completing the assembly of the smaller pieces, we began reconstructing the Sanit sarcophagus lid by reassembling the previously joined pieces. First, the section for the head area of the sarcophagus lid was constructed. The pieces representing the head were assembled and secured with a strap (see Figures 30-31). Next, the components of the lid's body were assembled, and the stone blocks were reconnected to form the complete stone lid (see Figures 32-33).

Fig (30) shows The head of Sanit's stone coffin lid after assembly.

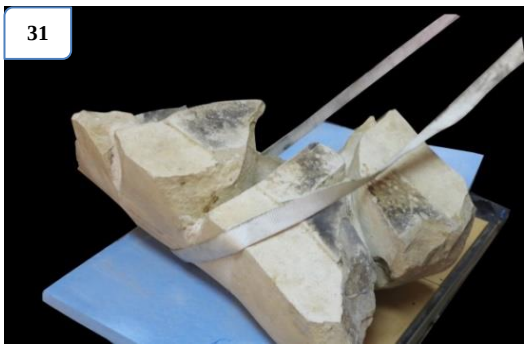


Fig (31) shows A part of the body of Sanit's coffin lid after assembly and secured with a strap for transport and completion of its assembly with the rest of the lid.

Fig (32-33) shows The assembly of the body of Sanit's stone coffin lid.

– **Stage Three**

The base block was positioned on the ground to complete the assembly of the Sanit sarcophagus lid (see Figure 34). The strap was removed from the piece representing the head of the lid, and it was moved using lifting equipment designed for heavy stones. The piece was then secured with a lifting strap in preparation for raising and positioning it horizontally to continue the assembly of the stone lid.

Once the piece was raised, it was supported on a pre-prepared stand, primarily resting against the wall for added safety, given the heavy weight of the pieces. This precaution was crucial to prevent the stand from collapsing and causing damage to the components of the Sanit sarcophagus lid. Ensuring the stability of the pieces during assembly is a critical aspect of preservation and restoration; our role is to maintain and protect the pieces, not expose them to further risk.

With the block positioned horizontally, longitudinal holes were drilled in the previously assembled head section. The drilling locations had been predetermined to avoid excessive stress during drilling, minimizing the impact on the piece. The holes were cleaned of stone dust using a brush dipped in water and alcohol to remove all debris. Additional deep longitudinal holes were then made on both sides and the center of the body of the lid to connect the body block with the head block.

Stainless steel rods were installed after cleaning the holes as described. Stone dust from the drilling was mixed with epoxy to fill gaps around the stainless steel rods and complete the assembly process (see Figures 35-40).

Next, the body block was secured with foam cushions around the external surface to protect the engraved areas and was strapped with the lifting belt. The block was lifted of the head block to align and join the two pieces horizontally, forming the first section of the Sanit sarcophagus lid structure (see Figures 41-46).

Fig (34-35) shows The installation of the fixed chain block and the lifting of the head into a horizontal position to complete the assembly process.

Fig (36-37) shows Securing the head of Sanit's coffin lid in preparation for drilling and installing stainless steel rods to complete the assembly process.

Fig (38-40) shows The midpoint of Sanit's coffin lid body and the installation of stainless steel rods to complete the assembly of the body with the head.

Fig (41-43) shows Drilling holes in the head of Sanit's coffin lid to secure the second part in the head area.

Fig (44-46)shows The process of assembling the head of the lid with the body of Sanit's coffin lid.

Fig (47)shows Sanit's stone coffin lid after the completion of the assembly process.

Conclusion

Based on the above, it is clear that although epoxy adhesives and stainless steel are preferred for assembling igneous rocks, they can also be used in some cases of sedimentary rocks with large and massive blocks. This allows us to complete the assembly process and achieve strong bonds between the stone blocks that need to be assembled. Therefore, stainless steel rods were used to support the assembly process.

Eighteen stone pieces representing the sarcophagus lid of Sanit from the 26th Dynasty in Saqqara were received from storage Museum No(2). These pieces were arranged and numbered in preparation for assembly. Additionally, stainless steel rods were prepared and cut into various lengths for use in assembling, connecting, and reinforcing the stone blocks with epoxy adhesives.

The assembly process was carried out in several stages. Initially, the lid was documented archaeologically, photographically, and architecturally, including using AutoCAD to record the lid and identify missing sections. The process began with the preliminary joining of the

smaller pieces. Then, the structure representing the body of the sarcophagus lid of Sanit was assembled, and the pieces were connected to recreate the complete structure of the lid.

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