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Coating Granite Monuments with Coconut Oil, As A Natural Technique for Preventive Protection of Sunken Antique, Alexandria – Egypt

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ABSTRACT

Granite artifacts are among the most important historical monuments. Many artifacts have been discovered submerged, highlighting their incredible durability and aesthetic appeal. However, these artifacts face threats from underwater degradation factors, so effective preservation is crucial to protect these treasures from further damage. This study investigates the potential of coconut oil as a protective coating for granite artifacts submerged in marine environments. Coconut oil's antimicrobial properties make it a promising candidate for counteracting the effects of marine environment. Achieving the study's objective requires simulating the actual conditions that submerged granite artifacts face. During the process, a comparison was made to evaluate this innovative natural technique. The compressive strength tests revealed a consistent improvement in peak strength and Young's modulus for coated samples, with increases of 6.21% and 4.3%, respectively. The coated granite samples demonstrated higher compressive strength (102.79 ± 0.59 MPa) compared to uncoated samples (96.78 ± 0.89 MPa), along with more consistent failure planes and enhanced crack resistance. X-ray diffraction analysis highlighted significant mineralogical differences between deteriorated and oil-coated samples. The oil treatment preserved structural integrity, reduced secondary mineral formation, and maintained better crystallinity, indicating effective protection against seawater-induced weathering. Scanning electron microscope observations further confirmed the protective capabilities of coconut oil, showing cohesive particle interactions in coated samples and significant wear and biological growth in uncoated samples. Overall, the results suggest that coconut oil treatment creates an effective barrier against water penetration and ion exchange, preventing weathering processes and offering substantial protection for granite structures in marine environments.

1. Introduction

Red granite was one of the most important and valued stones used in construction and decoration during ancient times, largely due to its remarkable durability and strength. This study material was a favorite among architects and artisans for its longevity, making it perfect for various monumental structures. It was commonly employed to create craft grand columns, towering obelisks, and intricate statues, all of which were integral to ancient societies' religious and cultural life. The red granite was primarily quarried from the renowned quarries in Aswan, a region known for its high-quality stone [1].

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The extraction process involved skilled laborers who expertly worked the stone, shaping it into large blocks that could be transported to various construction sites across Egypt. The striking color and texture of red granite not only added a remarkable visual appeal to these constructions but also conveyed a sense of permanence and strength, symbolizing the enduring legacy of the civilizations that used it [2]

The beaches of Alexandria are recognized as some of the world's most significant sites for discovering sunken granite artifacts. Over the years, many granite artifacts have been retrieved from these waters, highlighting the region's rich cultural heritage. These discoveries provide invaluable insights into the past, illuminating Alexandria's historical significance as a hub of trade, culture, and religious activity. Each artifact tells a story, enhancing our understanding of ancient civilizations and making the beaches of Alexandria a must-visit for history and archaeology enthusiasts [3-4].

Sunken artifacts are subjected to various damaging factors, including seawater salinity, pollution, temperature fluctuations, and other environmental influences. These elements can lead to severe deterioration, significantly impacting the structural integrity and aesthetic qualities of these precious historical items. Moreover, biological factors such as algae, fungi, and bacteria can cause considerable damage, especially in moist conditions. Lastly, mechanical erosion caused by the movement of water and waves can lead to the physical wear and tear of the granite's surface [5-9]. These combined factors make the preservation of sunken granite artifacts a challenging task. Therefore, it is essential to explore new methods and techniques for preserving sunken artifacts and protecting them from deterioration factors.

Based on this, this study aims to explore innovative methods for treating and protecting submerged artifacts, focusing on using effective, environmentally friendly, and non-destructive materials. One such material being investigated is essential oil (coconut oil), which has shown promising potential in preserving these invaluable treasures from the past [10-11]. Based on previous studies, coconut oil is a broad-spectrum antimicrobial agent that can combat biological damage to granite.

Applying coconut oil forms a hydrophobic barrier [12] on the surface of the artifacts, repelling water and reducing the risk of salt crystallization and microbial colonization. This dual function of protecting against both physical and biological damage highlights the multifaceted benefits of using natural oils in conservation efforts. The findings could revolutionize conservation practices, inspiring the use of other natural substances in preserving submerged artifacts and ensuring their protection for future generations.

2. Materials and Methods

Red granite samples with inequigranular macrotexture (Figure 1) were collected for experimental simulation. To mimic the properties of red granite found in submerged artifacts, the samples were submerged in water from the Abu Qir region for 14 days. During this time, one sample was coated with coconut oil. This setup enabled a comparative study between the oil-coated sample and an uncoated control to evaluate the effects of the coconut oil treatment.

After the 14-day immersion period, several analytical procedures were performed. These included comparing the weights of the coconut oil-coated samples to the uncoated ones, assessing compressive strength, and conducting analyses using scanning electron microscopy (SEM) and X-ray diffraction (XRD).

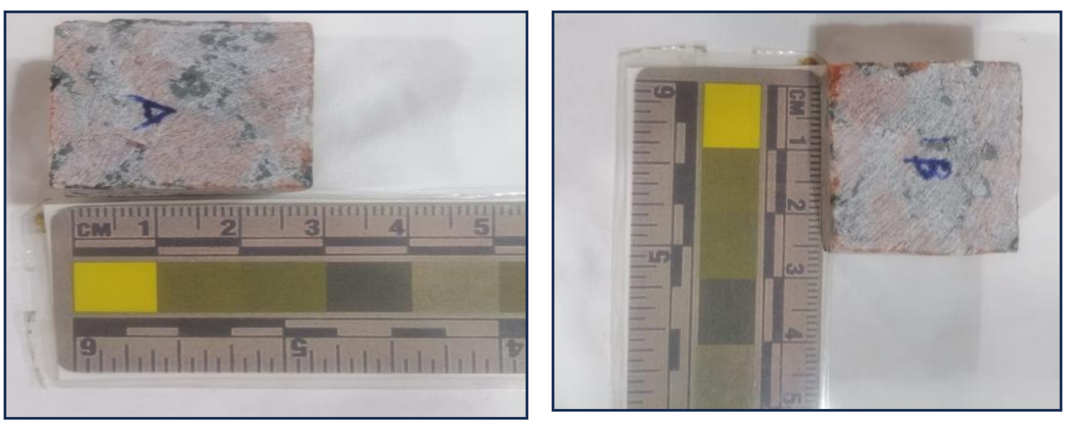

Fig. 1. Tested samples of granite with approximately equal sizes A) Uncoated sample, B) Coated Sample

2.1 Testing of mechanical properties (Uniaxial Compression Test)

Compressive strength testing (ASTM D7012) [13] was performed on 20 granite rock samples at the laboratories of the Faculty of Engineering at Alexandria University. Each sample is a 5 cm × 5 cm × 5 cm cube, giving a cross-sectional area of 25 cm². The samples were split into two groups: one control group with ten uncoated samples and another group with ten samples coated in coconut oil. UCS was defined as the peak stress before rupture. Young’s modulus was calculated from a segment of the linear elastic portion of the stress-strain curve. The purpose of this test was to evaluate the cohesion of granite when submerged in water and to determine the effectiveness of a coconut oil coating in protecting the granite from various damaging factors present in seawater.

2.2 X-Ray Diffraction Analysis

The examination was carried out in Cairo University's laboratories by a Bruker X-ray diffractometer with a radiation source Cu-Kα (λ = 1.5406 Å). The results from the X-ray diffraction analysis allow for a comparison between the damaged archaeological samples and those that have undergone treatment.

2.3 Scanning Electron Microscope Examination

An examination using a scanning electron microscope at Cairo University's laboratories was conducted to evaluate the extent of damage and deterioration in granite samples not coated with coconut oil, as opposed to the resilience of those coated with coconut oil. This analysis aimed to compare the effects of the coconut oil treatment on the structural integrity of the stone, providing valuable insights into its protective capabilities.

3. Results and Discussion

3.1 Compressive Strength Test

Based on the compressive strength results, a consistent enhancement in peak strength was observed in the coated samples, with an average increase of 6.21%. Additionally, there was an average increase in Young's modulus of 4.3%. This significant rise in the required load indicates that coconut oil is highly effective in improving the structural integrity of submerged granite artifacts, offering substantial protection against deterioration factors such as seawater salinity, fungi, and other destructive biological agents.

The uniaxial compressive stress-strain curve of the sample can be divided into three stages: initial compaction, elasticity, and yield. However, due to the dense nature of the granite used in this study, the yield stage is not evident. Both groups displayed brittle failure patterns (Figure 2).

The average compressive strength of the granite samples coated with coconut oil was approximately 102.79 ± 0.59 MPa, while the uncoated samples showed an average compressive strength of approximately 96.78 ± 0.89 MPa. The coated samples exhibited more consistent failure planes and enhanced crack resistance. The average Young's modulus for the coated samples was 47± 0.20 GPa, while the uncoated samples showed an average of 45.03 ± 0.21 GPa

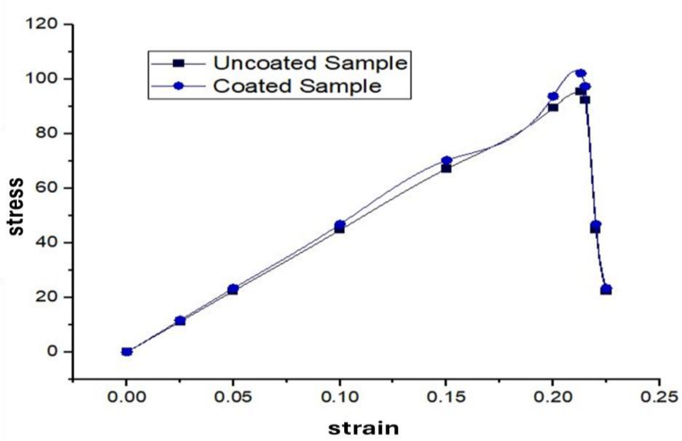

Fig. 2. Typical stress-strain curves obtained from uniaxial compression tests of coated and uncoated samples

3.2 X-Ray Diffraction Analysis:

The comparative XRD analysis (Figure 3) demonstrates significant differences between the deteriorated and oil-coated granite samples. The deterioration of seawater has significant effects on mineralogical transformations and weathering mechanisms. Feldspar alteration is evident through significant intensity changes in the 27-31° region, indicating extensive weathering, with peak broadening suggesting partial transformation to clay minerals and modified d-spacing values indicating structural alterations. New peak formation suggests the development of secondary phases. Secondary mineral development is marked by enhanced peaks in high-angle regions, indicating structural modifications and the formation of new peaks, which suggests the crystallization of weathering products. Broader peak profiles indicate poorly crystallized phases and a higher background suggests the presence of amorphous materials and surface roughening. Physical deterioration is indicated by peak broadening, suggesting reduced crystallinity. Variable peak intensities indicate uneven weathering, and peak profile changes suggest microstructural damage.

Oil treatment has protective effects on mineralogical preservation and protection mechanisms. Structural integrity is maintained with sharper peak profiles indicating better crystallinity, more consistent d-spacing values suggesting structural stability, better preservation of original peak positions, and lower background indicating reduced amorphous phase formation. Protection evidence includes fewer secondary peaks indicating reduced weathering, better maintenance of primary peak intensities, more uniform peak distribution, and reduced peak broadening. Physical barrier effects are seen with maintained peak sharpness indicating reduced water interaction, better peak resolution suggesting preserved crystallinity, lower secondary peak intensities indicating reduced ion exchange, and minimal peak shifts suggesting reduced chemical alteration.

Long-term implications include preserving the original mineralogical composition, reduced secondary mineral formation, better structural integrity maintenance, and enhanced weathering resistance. Performance assessment shows better-preserved primary mineral peaks, reduced evidence of weathering products and maintained crystallinity. An effective barrier demonstrates protection efficiency against water penetration, prevention of extensive mineral alteration, maintenance of structural integrity, and reduced weathering susceptibility.

The deteriorated sample shows clear evidence of weathering through peak modifications, secondary mineral formation, and reduced crystallinity. In contrast, the oil-coated sample exhibits better preservation of original mineralogy, reduced weathering effects, and maintained structural integrity, indicating the effectiveness of oil treatment as a protective measure against seawater deterioration.

The results suggest that oil treatment creates an effective barrier against water penetration and ion exchange, thereby preventing the initiation and progression of weathering processes. This has important implications for conserving granite structures in marine environments, where seawater exposure significantly threatens stone durability.

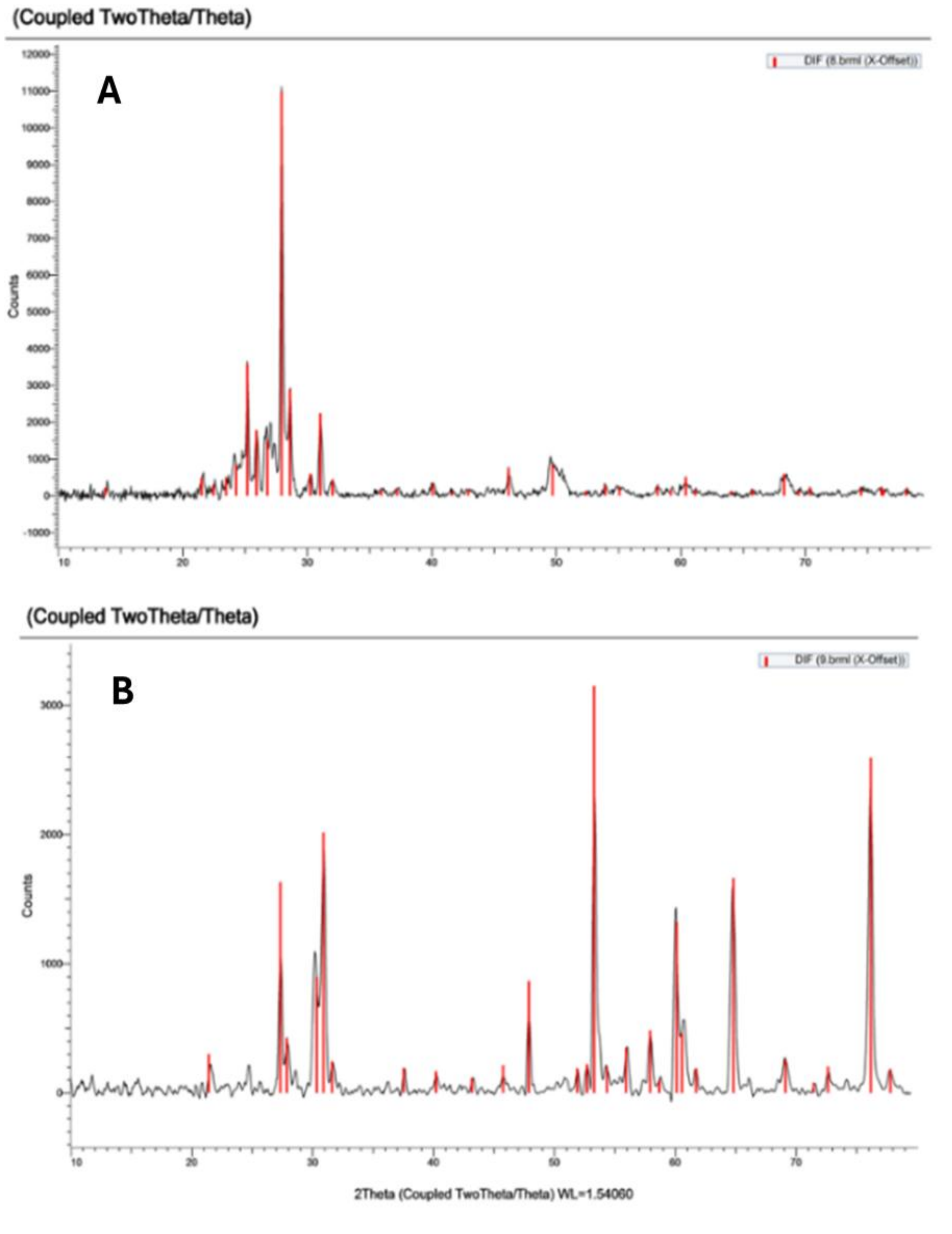

Fig. 3. Comparative XRD analysis demonstrates significant differences between A) oil-coated granite samples and B) deteriorated (uncoated granite samples)

3.3 Scanning Electron Microscope:

Figure 4 illustrates the comparison of granite samples treated with coconut oil. The findings show that the coated samples exhibited cohesive particle interactions, while the uncoated samples displayed disintegration and large pores and gaps. Moreover, the scanning electron microscope examination vividly illustrated the extent of damage to the uncoated sample compared to the coated one. The uncoated granite showed significant signs of wear and biological growth, while the sample treated with coconut oil maintained its integrity, with no visible signs of such damage. This visual evidence underlines the protective capabilities of coconut oil in a marine environment.

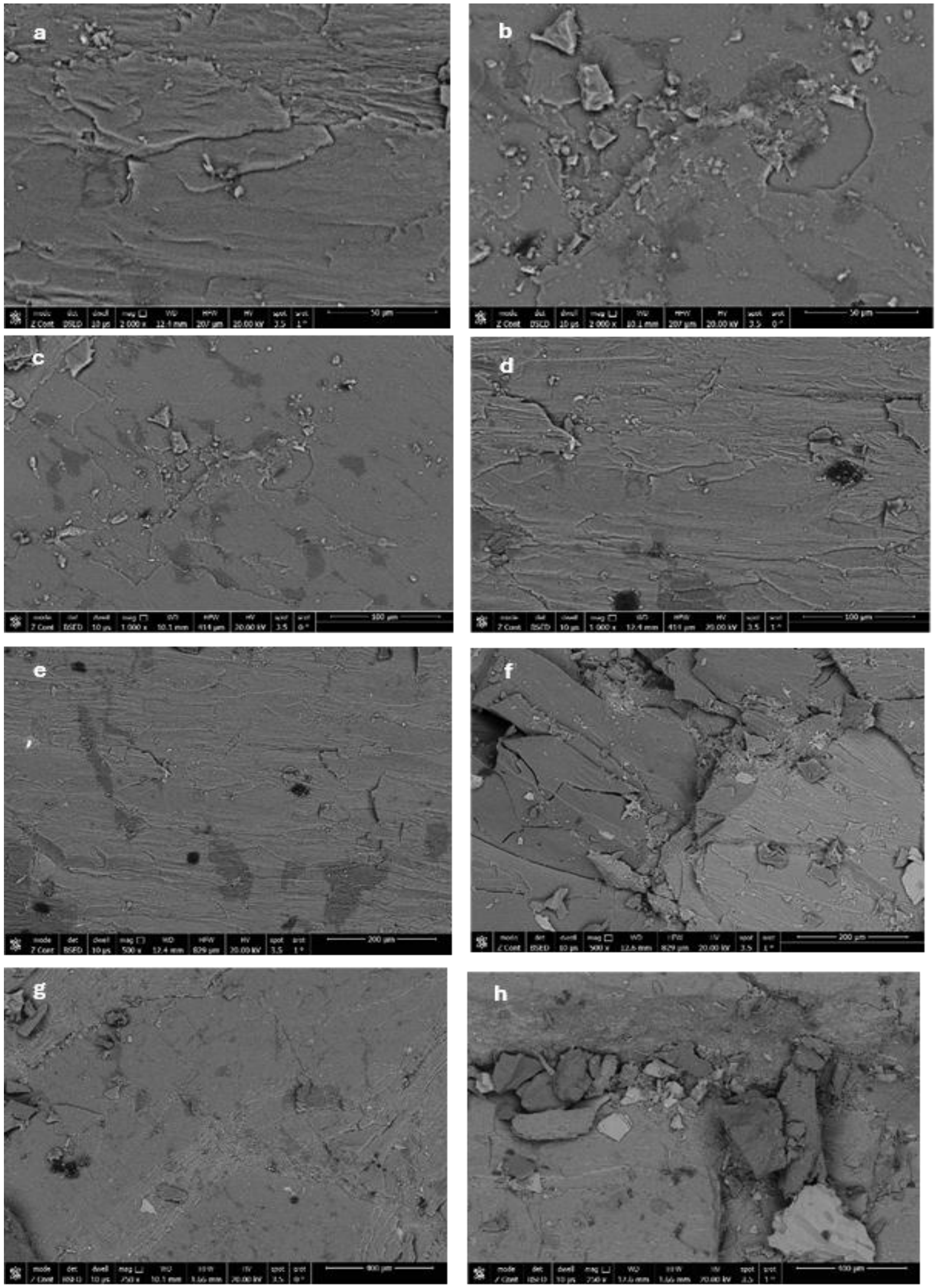

Fig. 4. Scanning electron microscope images of coated samples of varying scales (a at 50µm, , c at 100µm, and e at 200µm and g 400µm) against those without the oil-coating (b at 50µm, d at 100µm, f at 200µm, and h at 400µm).

4. Conclusions

The study successfully demonstrated the effectiveness of coconut oil as a protective coating for sunken granite artifacts against various deterioration factors present in seawater, such as salinity, fungi, and destructive biological agents. The fracture load tests revealed an increase in the strength of the granite samples coated with coconut oil, while the uncoated samples showed substantial degradation. Scanning electron microscope examinations confirmed the reduced damage in the oil-coated samples, further substantiating the protective role of coconut oil. X-ray diffraction analysis highlighted the absence of salt deposits on the treated samples, reinforcing the oil's ability to prevent salt crystallization. These findings validate the hypothesis that coconut oil can be a viable, natural preservative for submerged granite artifacts. The study not only highlights the practical application of coconut oil in preserving cultural heritage but also paves the way for future research into other eco-friendly preservation methods. This innovative approach ensures the longevity and integrity of underwater artifacts, contributing significantly to the field of marine archaeology and conservation science. By demonstrating the dual benefits of antimicrobial and hydrophobic properties, the research sets a new standard for sustainable and effective preservation techniques, safeguarding these invaluable treasures for future generations.

5. Recommendations

1. **Use of Coconut Oil as a Protective Coating**: Coconut oil should be adopted as an effective means to protect submerged granite artifacts against environmental deterioration factors like salinity, fungi, and destructive biological agents.
2. **Implementation of Coating Protocols**: Develop standard protocols for applying coconut oil on artifacts to ensure maximum protection. This includes determining the optimal coating thickness and scheduling reapplication intervals to maintain effectiveness.
3. **Continuous Monitoring**: Conduct periodic inspections using techniques like Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD) to monitor the integrity of the coated artifacts and ensure the protection remains effective.
4. **Integration with Modern Conservation Techniques**: Combine the use of coconut oil with modern conservation techniques such as remote sensing and underwater robotics. This integration enhances the monitoring and protection capabilities, offering a comprehensive approach to preservation.
5. **Ongoing Research**: Encourage further research to discover other natural materials that can be used similarly to coconut oil for the preservation of submerged artifacts. Exploring new materials could lead to even more effective and sustainable preservation methods.

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