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GEOLOGY

The Effectiveness of Different Fossil Preparation Methods for Fossil Shrimp from The Crato Formation, Araripe Basin

A Eficácia de Diferentes Métodos de Preparação de Camarão Fóssil da Formação Crato, Bacia do Araripe

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Abstract

This research presents the mechanical and chemical preparation techniques of a shrimp fossil from the Crato Formation, Araripe Basin. The mechanical preparation used precision tools to remove the rock matrix, whereas the chemical preparation applied acetic acid contained in vinegar to selectively dissolve the carbonate matrix and preserve the morphological details. Ultraviolet light revealed structures that were not visible under conventional light, and detailed scientific illustrations helped document diagnostic features. The integration of these methods ensured structural preservation and enhanced the taxonomic and paleoecological understanding of the sample. This study provides a methodological basis for future research on invertebrates in the Araripe Basin.

Keywords: Preservation; Mechanical techniques; Chemical techniques

Resumo

Este estudo apresenta as técnicas de preparação mecânica e química de um fóssil de camarão da Formação Crato, Bacia do Araripe. Para a preparação mecânica foram utilizadas ferramentas de precisão para remover a matriz rochosa, enquanto para a preparação química foi aplicado ácido acético contido no vinagre para dissolver seletivamente a matriz carbonática e preservar os detalhes morfológicos. A luz ultravioleta revelou estruturas não visíveis sob luz convencional e ilustrações científicas detalhadas auxiliaram na documentação das características diagnósticas. A integração dessas metodologias garantiu a preservação estrutural e aprimorou a compreensão taxonômica e paleoecológica da amostra. Este estudo fornece uma base metodológica para futuras pesquisas sobre invertebrados na Bacia do Araripe.

Palavras-chave: Preservação; Técnicas mecânicas; Técnicas químicas

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1 Introduction

Fossil preparation is a fundamental step in paleontology, aimed at highlighting the morphological details of samples found in rock matrices. This detailed and highly important task requires patience and manual skill, as improper handling can result in irreparable damage to unique samples and compromise paleontological research (May, Reser & Leiggi 1994). Preparation involves not only the separation of the matrix rock but also washing, gluing, waterproofing, and proper packaging to ensure the preservation and integrity of fossils (May, Reser & Leiggi 1994; Viegas & Bento 2014).

Depending on characteristics of the fossil and the matrix rock both mechanical and chemical techniques can be used. These techniques range from the use of physical tools to the application of specific chemical substances, according to the nature of the fossil and the matrix rock. Techniques for fossil material preparation have been developed and applied by various researchers (Junger & Bergqvist 2007; Landucci *et al.* 2000; Parenti & Valli 2004; Roubach *et al.* 2014; Santos 1985). Among these techniques, chemical preparation, which involves the application of specific acids to dissolve the rock matrix, is particularly prominent. This method is especially advantageous for high-density rocks or fragile materials, where mechanical methods can cause irreparable damage to the sample (Green 2001; Leiggi & Horner 2005; Leal & Brito 2010; Toombs & Rixon 1959).

Chemical preparations methods are frequently reported in the literature utilizing solutions of organic and inorganic acids. Among the organic acids, acetic acid P.A. (CH_3COOH) and formic acid (CH_2O_2) are commonly used, whereas the inorganic acids include hydrochloric acid P.A. (HCl), phosphoric acid P.A. (H_3PO_4), sulfamic acid P.A. (H_3NSO_3), and nitric acid PA (HNO_3). These solutions, generally employed at concentrations of 5%, 10% or 15%, are already applied in the preparation of ichthyolites from the Araripe Basin (Teófilo-Guedes *et al.* 2019).

Although the applied methods are recognized as effective, there is a notable lack of specific studies addressing the preparation of fossil invertebrates, with this deficiency being even more pronounced in the case of decapod crustaceans. Moreover, the available literature does not provide detailed descriptions of the procedural steps, limiting the replication and standardization of methods in the field. This significant gap highlights the need for further investigations in this area (Crippa *et al.* 2016; Feldmann & Schweitzer 2017).

The use of acetic acid, which is widely used in white culinary vinegar, was first reported in the Araripe Basin by Barros, Oliveira & Saraiva (2025) for the preparation of fossil shrimp preserved in calcareous concretions. This technique has shown promising results, especially in the preparation of *Kellnerius jamacaruensis* Santana *et al.* (2013) and permits the exposure of important anatomical structures and facilitates detailed taxonomic analyses.

Another type of preparation used in fossils is mechanical, which employs abrasive tools, such as hammers, chisels, pointers, brushes, dental instruments, and needles, to remove the surrounding rock. The mechanical preparation of invertebrate fossils, such as fossil shrimp, requires a set of specialized tools to ensure the preservation of the delicate and complex structures of these organisms without the loss of anatomical parts during preparation.

Unlike more robust equipment, such as pneumatic pens, hammers, and chisels, which are used in the mechanical preparation of vertebrates, the preparation of invertebrates requires extremely delicate equipment and handling skills, patience, and dedication (Feldmann & Schweitzer 2017). This process is conducted exclusively with the aid of a stereoscopic microscope, which provides the necessary precision to prepare the delicate anatomical structures of the samples.

However, the preparation is not limited to the mere removal of the rock matrix. Rather, it involves a detailed investigation of the preservation history and considers the diagenetic and taphonomic events that shaped the sample over the years; this includes a careful analysis of the processes that occurred from the organism's death to its discovery and encompasses diagenetic and taphonomic events that influenced the preservation of the fossil remains.

Holz & Schultz (1998) analyzed bone mineralogy to explain diagenetic alterations, such as swelling and carbonate concretion formation. They identified calcite and hematite filling cavities and Haversian canals in the bones. Bone deformation was attributed to expansion caused by the displacive growth of calcite, invalidating some species proposed solely based on distinct bone proportions.

Diagenesis refers to the physical and chemical changes that the fossil undergoes after death, and during its burial and subsequent transformation including mineralization and compaction. These processes can alter an organism's original morphology, increasing its resistance to decomposition and facilitating its preservation in rocks. Taphonomic apparatuses, including processes such as bioerosion, the action of decomposer organisms, and transport effects, are fundamental to the integrity of the fossil. The interaction of these factors generates characteristics that must be observed during preparation as they provide information about the living environment of the organism and processes that occur over time.

During fossil preparation, observing diagenesis is crucial, as the physical and chemical alterations undergone by the fossilized material can affect both its integrity and its taxonomic and paleoenvironmental interpretation. Thus, understanding diagenesis aids in selecting appropriate preparation methods and achieving a more accurate reconstruction of the studied material.

In this context, Silva & Kellner (2006) highlighted that the scarcity of publications on fossil preparation techniques has led to the application of empirical methods based on trial and error due to the absence of comparative parameters to guide the methodology.

Given this empirical method and considering this gap, the present study proposes comparative parameters for the preparation of fossil shrimp from the Araripe Basin, Crato Formation, via mechanical and chemical methods and including the use of vinegar as a preparatory agent.

For chemical preparations, practices based on experimental experience are recommended, such as strict control of acid concentrations, continuous monitoring of exposure time, and proper neutralization of residues, which are essential measures to avoid damage to the fossil material. Similarly, in mechanical preparation, the careful selection of tools, precise adjustment of pressure and working speed, and the use of a stereo microscope ensure the controlled and efficient removal of the rock matrix.

The use of ultraviolet (UV) light has proven to be a valuable tool in paleontology for fossil analysis and documentation, as highlighted by Junger & Bergqvist (2007). This technique is based on the interaction between ultraviolet (UV) radiation and the organic and inorganic materials present in fossils, which permit the identification of details that are often imperceptible under visible light. These integrated strategies contribute to the efficiency of observing the fossilization process and assist in the preparation of fossils.

This study evaluates the effectiveness of chemical and mechanical techniques in fossil preparation to optimize processes to preserve structural integrity and improve the visual quality of samples. The focus is on using accessible and low-cost methods and tools, including the adaptation of conventional instruments and the creation of simple and effective devices tailored to the specific demands of paleontological preparation, as well as the application of ultraviolet light and scientific illustration techniques using a camera lucida and Adobe Photoshop.

2 Materials and Methods

The prepared sample corresponds to a specimen from the Crato Formation (UFC 2466/CRT), which is deposited in the Paleontology Laboratory of the Federal University of Ceará (UFC) on the Pici *campus* in Fortaleza. The specimen was previously described by Barros *et al.* (2021) and identified as *Beurlenia araripensis* Martins-Neto & Mezzalira (1991). The preparation methodology is thoroughly detailed in this work.

This study focused on the fossil preparation process, emphasizing specific techniques aimed at preserving and enhancing the specimen's observable morphological features, without addressing its taxonomic identification.

The process includes the application of methods based on technical recommendations and previous experiences in mechanical and chemical preparation, which ensures effective and safe results. The sample was analyzed with all required licenses in compliance with current ethical and regulatory standards.

2.1 Effective Equipment for Mechanical Preparation

For the development of mechanical preparation instruments (Figure 1A-H), various distinct tips were crafted using accessible and easy-to-handle materials. The first tip was made from 1 mm thick iron rods from bicycle rims, acquired from stores specializing in cycling equipment. These rods were shaped and sharpened using a grinder, resulting in three specific formats: cane, half-cane, and chisel (Figure 1E).

During the sharpening process, the tip was moistened with water to ensure greater precision. This procedure produced a functional and precise tip suitable for paleontological preparation. To provide manual protection during tool use, a heat-shrink insulating tube was applied to the iron rod using a heat gun. This coating prevented friction and oxidation from hand sweat and helped avoid the formation of calluses (Figure 1C-E).

The second tip was crafted from a barbecue skewer, cut to a comfortable size for manual handling. Its end was coated with Durepox glue (epoxy putty) to secure a 0.25 mm stainless-steel orthodontic wire, commonly used in dental braces. The wire was lightly sharpened with a grinder for enhanced precision.

The third tip was made from a 0.45 mm insulin needle, which was directly fixed onto a syringe or a barbecue skewer, also using Durepox glue (epoxy putty) (Figures 1F-H).

The fourth tip was developed using acupuncture needles with thicknesses ranging from 0.18 mm to 0.30 mm, attached to a wooden stick in a manner similar to the previous method, utilizing Durepox glue. Due to the malleability of the needle, its end was gradually cut until it achieved the ideal precision when force was applied to the rock. The resulting tip is highly precise due to the thinness of the needle. Additionally, the stick was coated with varnish to increase its durability. All tips, including needles, were lightly sharpened on a grinder to enhance their functionality (Figure 1F).

The tips can be attached to a manual chuck to provide greater operational control. It is also possible to integrate wood drill bits with diameters ranging from 0.5 mm to 1 mm, which are sharpened on a grinder for improved precision and performance (Figure 1H). Each tip was designed and tested with a focus on strength and precision, efficiently meeting different mechanical requirements. Due to the cutting and perforating properties of the materials, the individual use of the equipment is recommended, along with the monitoring for oxidation and proper disposal when necessary.

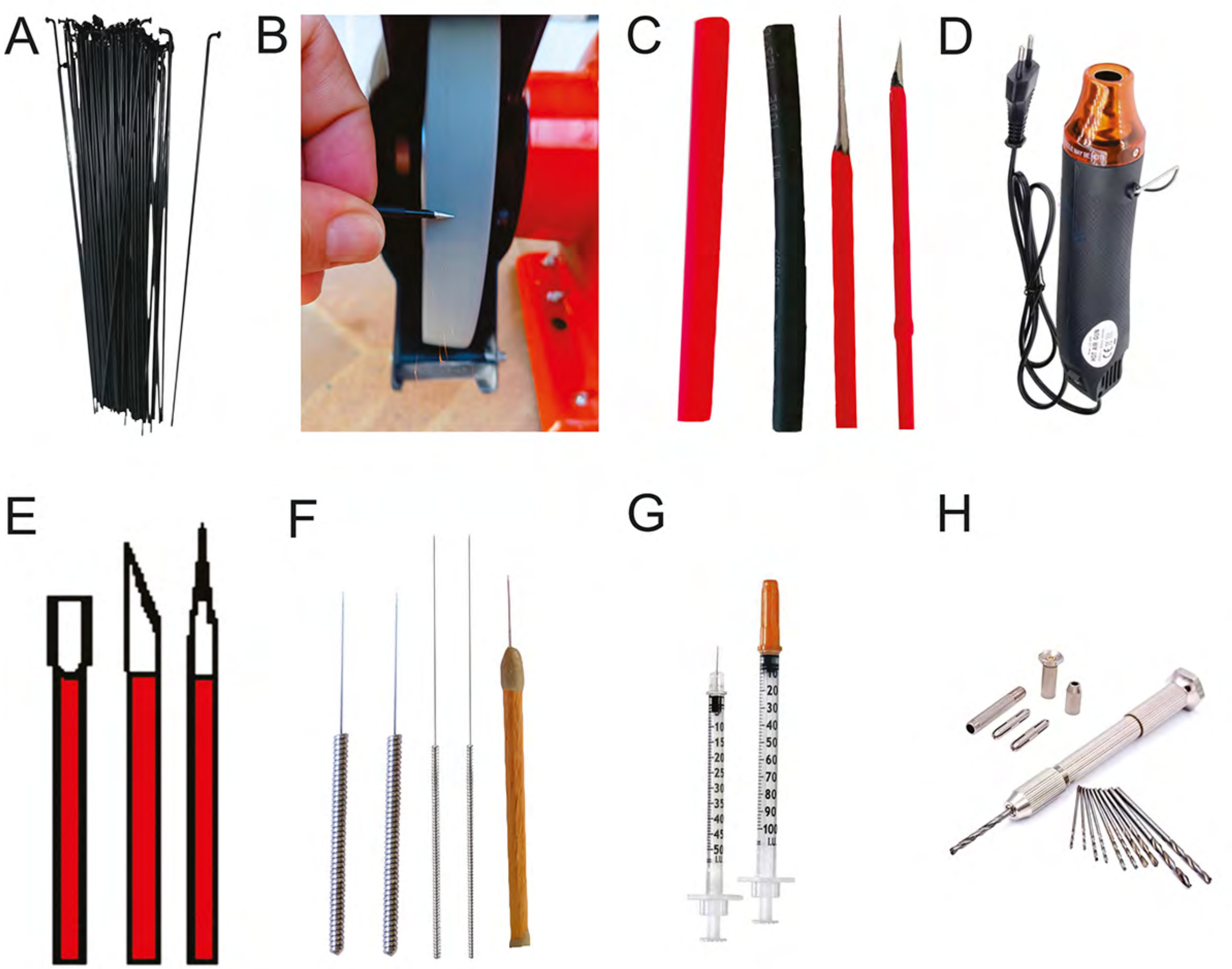

Figure 1 A. Iron rods from bicycle rims; B. Fabrication of the tip on a grinder; C. Heat shrink insulation tube; D. Heat gun; E. Tip shapes as follows: chisel, half-cane, and cane; F. Example of how to place acupuncture needles fixed on a stick with epoxy glue; G. Example of an insulin syringe; H. A hand drill with fine wood drill bits.

2.2 Morphological Study of the Specimen under a Stereoscopic Microscope and Photographs

Before the fossil was prepared, a detailed study of their morphology was conducted to assess the position and preservation state of the structures. This initial survey guided the preparation process, prioritizing the preservation, orientation, and integrity of the exposed parts. An initial photograph was taken to record the original state of the sample, allowing for the monitoring of changes and adjustments to the methodology. During preparation, the gradual removal of the rock matrix was carried out considering structural fragility and anatomical relevance, ensuring the preservation of paleontological information. All stages were documented using a high-resolution ocular camera mounted on a Nikon SMZ-445 stereoscopic microscope, capturing detailed images of appendages, carapaces, and other morphological features.

2.3 Chemical Preparation of Sample 2466/CRT (UFC)

The procedure utilized 4% and 6% alcohol vinegar, with water as a control. The vinegar was pretested on a non-significant area of rock to evaluate its interaction with the material. Application was conducted using ultrafine Atlas AT950/000 brushes with rounded, delicate bristles moistened in the acidic solution.

Each application lasted an average of 30 seconds, followed by the addition of a drop of water to neutralize the acid. Excess liquid was carefully removed using toilet paper or cotton swabs. If the swab left a cotton residue, it was gently removed with tweezers. The entire process was closely monitored to ensure that the acid's action remained limited to the matrix, preserving the fossil structures.

The procedure began with 6% vinegar to dissolve the thicker layers of rock covering fossil. As the rock matrix thinned, 4% vinegar was used to allow for more precise control of exposure.

2.4 Mechanical Preparation of Sample 2466/CRT (UFC)

Fossil preparation requires refined technique, time, and experience. The use of cutting and drilling instruments demands patience and precision, prioritizing quality over speed. of Sample preparation was conducted on specific parts of the fossil using different tips. As the rock thinned, the tip size was gradually reduced, starting from 1 mm and reaching 0.18 mm.

For mechanical preparation, the applied force was sufficient to scrape, not pierce, the rock. Scraping was performed from the center outward to preserve the structure, as suggested by Feldmann & Schweitzer (2017). This controlled and precise approach minimizes the risk of damaging the fossil. Reversing the scraping direction increases the risk of scratching or piercing the rock surface, compromising the fossil's integrity and hindering successful preparation. Therefore, careful application of force is crucial to ensure the preservation of paleontological material without causing irreparable damage.

2.5 Use of Paraloid

Paraloid B72, a stable thermoplastic resin, is commonly used for the conservation of fragile fossils. It is diluted to 5% in acetone or ethanol (5 g/100 mL) for impregnation and to 20% (20 g/100 mL) for adhesion. The solution requires agitation in a closed container, and its application protects fossils from moisture, dust, and degradation.

Due to the high cost of Paraloid, especially in budget- limited projects, clear nail polish (base coat) serves as a viable alternative for fossil fixation in less demanding contexts. Although less durable and chemically different, it provides good adhesion and stability. The choice of adhesive should consider both the material's characteristics and the usage context.

In acetic acid preparation, pure clear nail polish is applied to fragile fossils to ensure adhesion. For more resistant fossils, a 60% nail polish and 40% acetone solution are used, with thickness adjusted according to the rock type and acid concentration. Before application, a preliminary test on the matrix rock is recommended. Furthermore. the excess can be reused in future preparations.

In the present study, 2% Paraloid was applied as a thin layer on sample 2466/CRT (UFC) only after all images were captured, ensuring discreet fossil fixation without interfering with the photographic sheen. Application was performed at the end of the process, after confirming the absence of damage or fracture risks. Once completed, the sample was wrapped in white tissue paper for safe storage.

2.6 Use of Ultraviolet Light in Fossil Preparation and Visualization

The fossil was carefully cleaned with soft brushes to remove dust particles and residues that could interfere with fluorescence. It was then exposed to ultraviolet radiation lamps, following safety protocols such as wearing UV protection goggles. Images were captured using cameras adjusted for color balance and luminosity.

The camera was set to manual mode with a low ISO (100–400) to minimize noise and adapt to fluorescence intensity. To ensure stability and prevent vibrations, the camera was securely positioned and triggered remotely. This procedure was performed to visually document the fossil's condition before and after preparation.

2.7 Illustration Using a Camera Lucida

A camera lucida was used, which, by means of a prism, allows for simultaneous visualization of the object and drawing on paper; ensuring morphological accuracy, fidelity, and perspective (Figure 2A-B). In both the traditional configuration (Figure 2A) and when attached to a stereoscopic microscope (Figure 2B), the camera lucida proved highly effective in capturing details and geometric precision.

In this technique, the initial drawing was manually created using a camera lucida to ensure accurate proportions and alignment with the fossil image at scale. An HB pencil was used for the drawings, providing clear lines and suitable pressure control, allowing for the precise representation of observed morphological structures.

The final sketch was scanned at high resolution and digitally refined using a Parblo A610 tablet and Adobe Photoshop 2021. Adjustments were made for contrast, sharpness, and imperfection correction, combining manual precision with digital tools to create high-quality scientific illustrations.

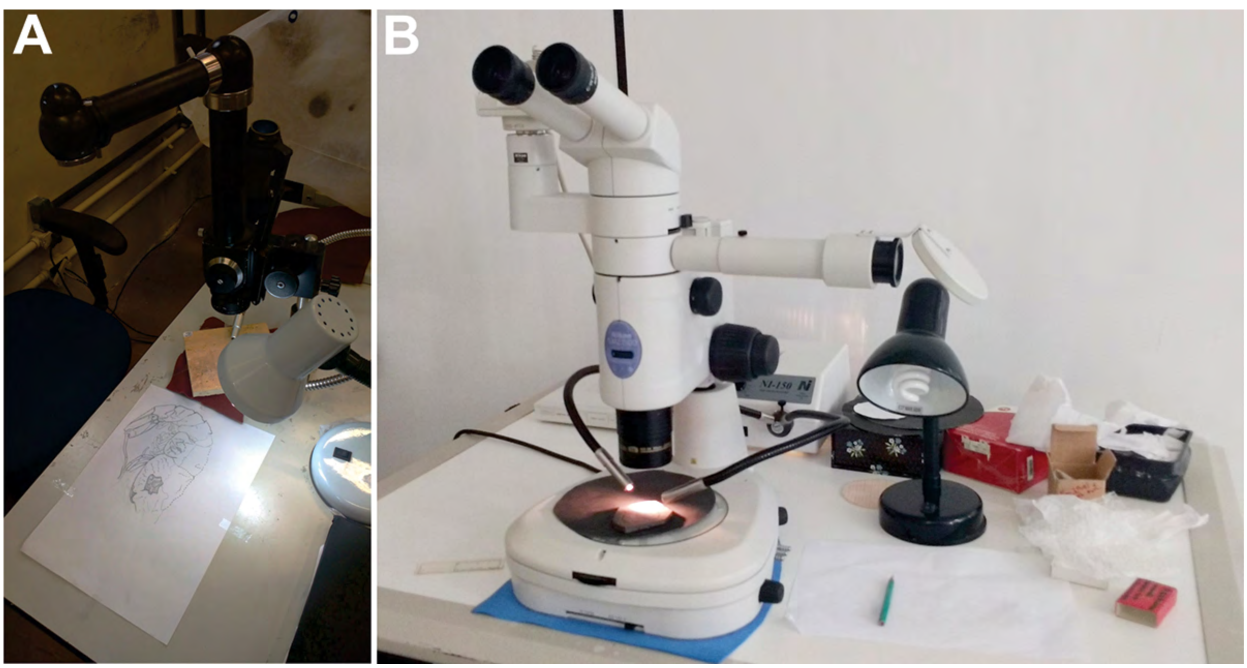

Figure 2 Illustration process of sample 2466/CRT (UFC): A. An older model of Camera lucida used for drawing on paper; B. Demonstration of the camera lucida attached to the stereoscopic microscope. Photos: O.A. Barros.

3 Results and Discussion

The sample from the Crato Formation (2466/CRT, UFC) was prepared using both mechanical and chemical methods, demonstrating high efficiency in the gradual and safe removal of the matrix rock without damaging the preserved fossil. The combination of these techniques proved particularly effective when applied complementarily, allowing the preparation to be completed in five days, including rest periods.

This approach allowed for the exposure of anatomical details essential for taxonomic studies, including appendages, antennae, pleopods, pereopods, uropods, and telsons. These structures were revealed with clarity and minimal morphological alteration, ensuring a robust comparative analysis (Figure 3A-B).

The results observed in the application of these techniques are consistent with those reported by Barros, Oliveira & Saraiva (2025), who highlighted the importance of careful preparation in preserving anatomical details in shrimp fossils. In our results, mechanical methods proved effective in removing the outer matrix layers without compromising more robust structures, allowing for the exposure of fine details without causing breakage. The initial preparation enabled the efficient removal of the dense matrix surrounding the fossil, revealing parts of the pereopods and antennae. The use of fine tips, such as acupuncture needles, was effective for cleaning areas close to the appendages, preserving delicate structures, and preventing wear. However, the fine-tip approach had limitations in areas with a harder matrix, requiring alternation between different tips to overcome this difficulty.

Chemical preparation using vinegar effectively removed the calcareous matrix, exposing the appendage joints, rostral spines, and fine carapace markings (Figure 3A-B). The process highlighted four rostral spines, with a fifth spine observed in a fragmented terminal portion, totaling five rostral spines. Additionally, three serrated sub-rostral spines were identified, ratifying the description provided by Barros *et al.* (2021). Exposure time was rigorously monitored to prevent wear in fragile areas of the shrimp's body (Figure 4A-B). The dissolution revealed details of the abdominal somites and appendicular structures, including pleopods, uropods, and telson, enabling precise morphological analysis.

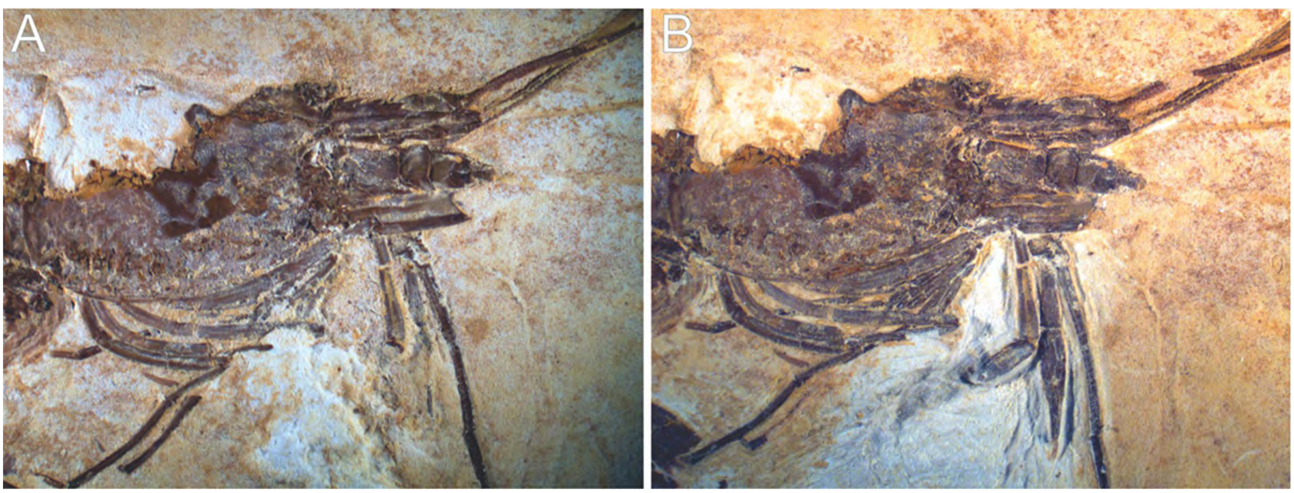

Figure 3 Specimen 2466/CRT (UFC): A. Initial state of the fossil before mechanical preparation with fine tips; B. Results after mechanical preparation with fine tips and showing the shrimp antennae and pereopods. Photo: O.A. Barros.

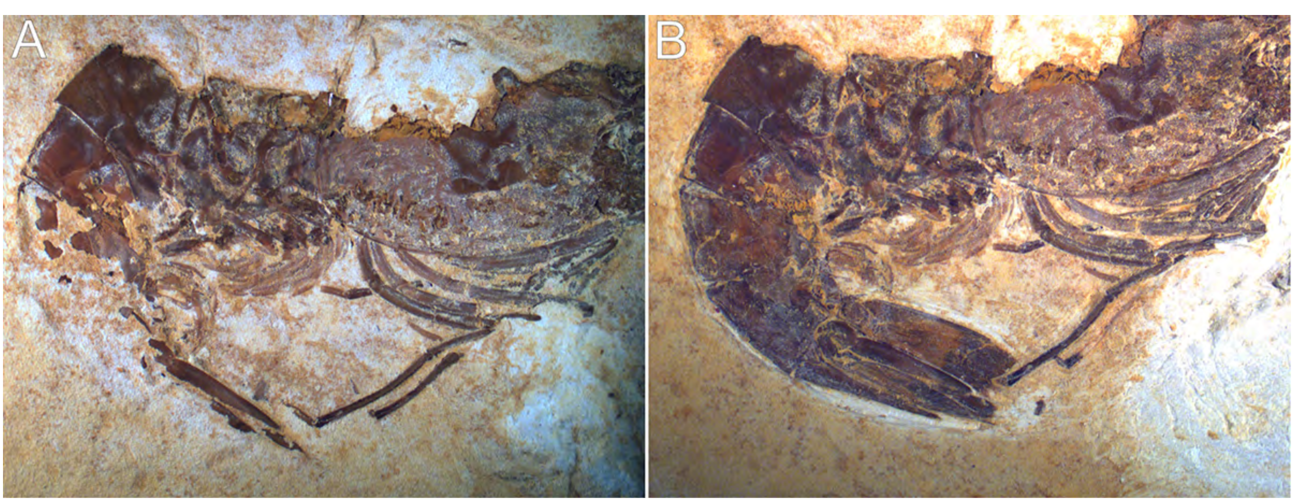

Figure 4 Preparation of sample 2466/CRT (UFC) using vinegar: A. Shrimp with parts covered by rock before preparation; B. Shrimp after preparation. Photo: O.A. Barros.

3.1 Ultraviolet Light in the Preparation and Visualization of Sample 2466/CRT (UFC)

The analysis under ultraviolet (UV) light revealed essential anatomical details, such as the preservation of soft tissues, microfractures, and boundaries between sedimentary layers. The fluorescence induced by UV light proved to be a highly effective tool for differentiating the fossil from the surrounding rock matrix, especially in cases where both exhibited similar coloration under visible light (Figure 5A). This fluorescence contrast allowed for a more precise observation of fossil structures and significantly contributed to the analysis and interpretation of the studied material.

Additionally, the technique enabled identification of rock areas examined before or after mechanical/chemical preparation. After preparation, previously scraped areas were observed (Figure 5B). This technique can also be applied to detect and investigate potential interventions or adulterations conducted by other researchers before or after preparation.

During preparation, the upper region of the shrimp initially appeared to be preserved, with the rock matrix covering the fossil. However, after detailed analysis and scraping attempts to reveal pleonal somites, no structures were observed. The application of UV light indicated that the upper regions of the pleonal somites and part of the cephalothorax were not preserved in the rock (Figure 5B). This degree of deterioration can be attributed to diagenetic processes, where factors such as pressure and temperature may have caused the dissolution or alteration of the most fragile parts of the organism, compromising the preservation of these structures.

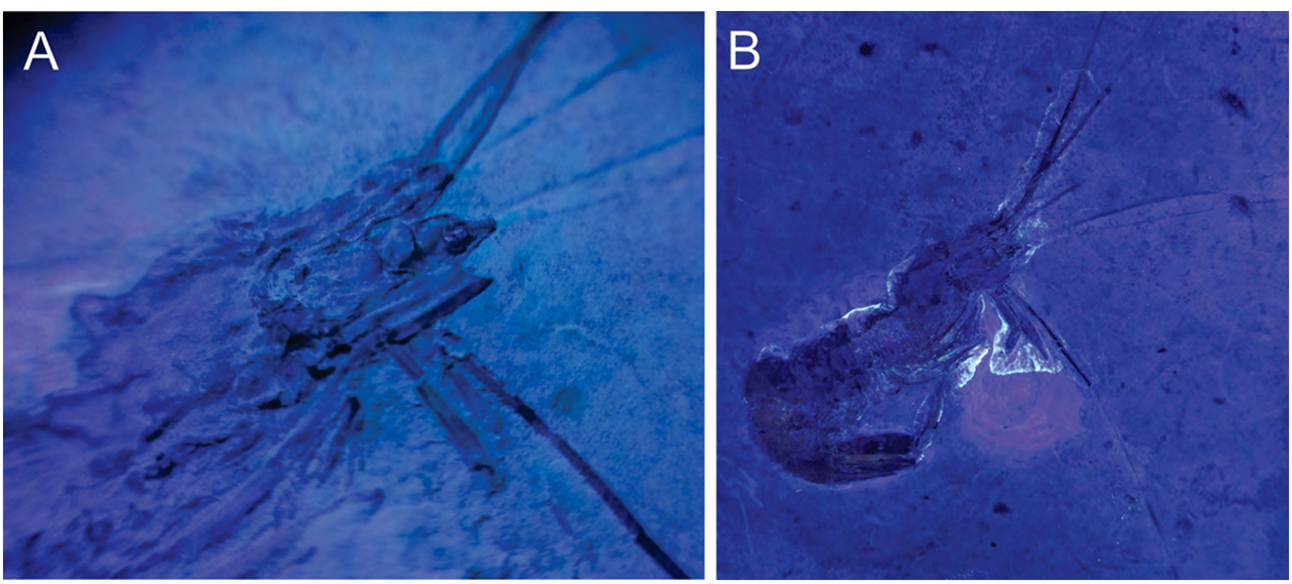

Figure 5 Sample 2466/CRT (UFC) under UV light: A. Shrimp before preparation; B. Shrimp after preparation, highlighting the clear area where the rock was scraped away. Photo: O.A. Barros.

3.2 Scientific Illustration Using the Camera Lucida and Photoshop

The camera lucida facilitated the production of detailed and geometrically precise illustrations, which are fundamental for fossil analysis and documentation. Regions of the sample that were not preserved are represented by dotted lines, ensuring a clear distinction between preserved and reconstructed structures. The illustration was initially drawn in pencil (Figure 6A) and later digitally enhanced in Adobe Photoshop, where the pointillism technique was applied to highlight preserved structures, further enhancing the fossil shrimp's details (Figure 6B).

Results of the digital drawing made directly in Photoshop revealed a precise and detailed illustration, faithfully representing the studied elements. The application of textures and shading added depth to the image and emphasized specific characteristics. The use of filters and color adjustments enhanced contrast, resulting in a visually impactful and informative image suitable for complementing scientific analysis (Figure 7).

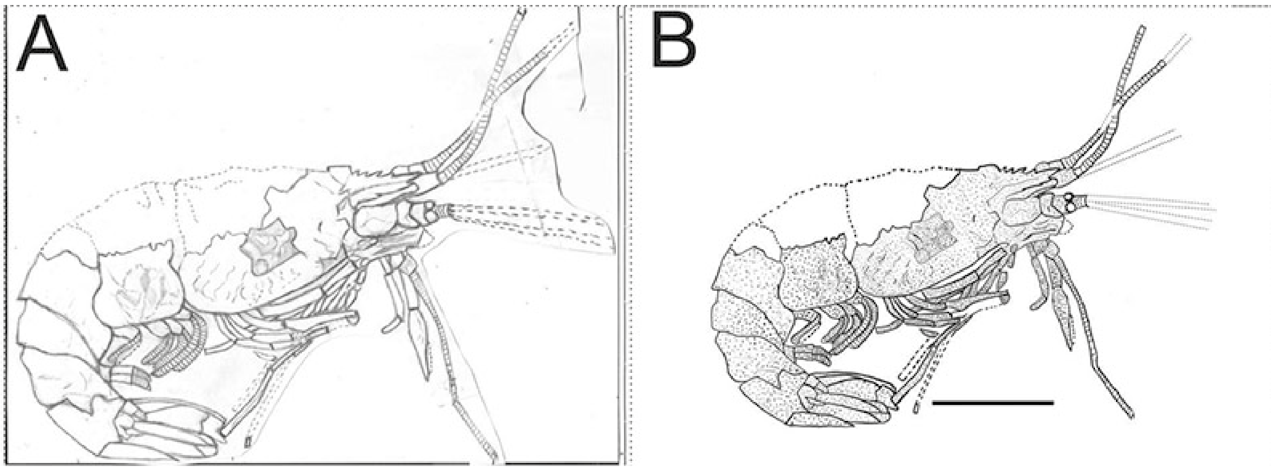

Figure 6 Illustration of sample 2466/CRT (UFC): A. Pencil drawing made with the aid of a camera lucida; B. Digitally enhanced version in Photoshop. Drawing: O. A. Barros.

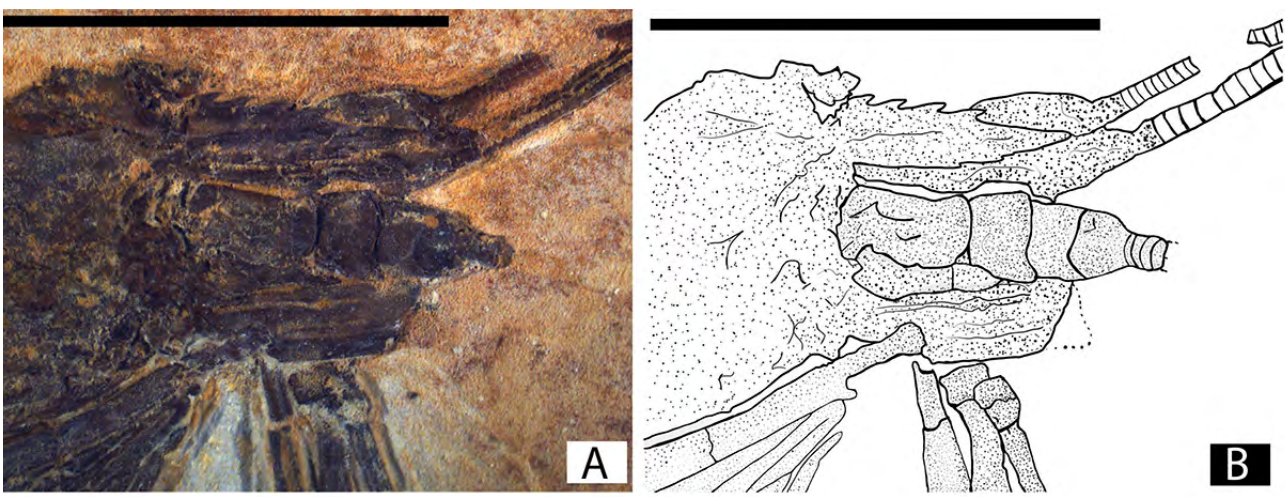

Figure 7 Sample 2466/CRT (UFC): A. Original photo used as the basis for the drawing; B. Illustration created directly in Photoshop.

4 Conclusion

Due to their structural fragility, the preparation of shrimp fossils requires highly specialized methods. This study demonstrated that combining mechanical and chemical techniques, such as using acetic acid in vinegar to reveal anatomical details and precision tools to remove the rock matrix, allows for the effective exposure of fossil structures. These approaches preserve the integrity of the samples, especially in fragile appendages and carapaces, ensuring efficient and accurate preparation for taxonomic analyses.

The vinegar concentration (4% or 6%) and application frequency were optimized based on the rock type and fossil preservation state to ensure controlled matrix corrosion while preserving fossil structures. Food-grade alcohol vinegar, as a corrosive agent, enables gradual matrix removal without compromising fossil integrity. However, its application must be rigorously controlled to prevent damage.

The fossil preparation, completed over five days with rest intervals, underscores the necessity of prioritizing quality over speed due to the delicate nature of invertebrates. Acid immersion is not recommended, as it risks destroying morphological details. Instead, controlled acid application should be gradual and monitored under a stereoscopic microscope to ensure fossil preservation and accurate results, which are essential for paleontological analysis.

Scientific illustration techniques, including freehand drawing, camera lucida, and high-resolution scanning, ensure the precise representation of morphological details that photographs may not capture. Digital illustration software enhances structural reconstruction and analysis, facilitating scientific communication and taxonomic comparisons. These approaches are essential for documenting anatomical and diagnostic features in paleontological studies of the Araripe Basin, where fossil diversity and preservation demand precise analytical methods.

This study improved paleontological preparation practices of invertebrates an underexplored area, contributing to enhanced sample quality and knowledge for future research. Meticulous and rigorous preparation is essential to avoid errors in paleontological analysis. Inaccuracies in preparation and taxonomic descriptions can lead to faulty diagnoses, requiring revisions or corrections, thereby compromising the integrity and reliability of scientific research. Therefore, attention to detail in fossil preparation and documentation is crucial to ensure robust and replicable discoveries, promote scientific advancements, and maintain accuracy and consistency in paleontological studies.

The selection of preparation methods must be carefully aligned with the research objectives, ensuring that both the integrity of the fossil and the scientific question under investigation are preserved. In certain cases, such as when the fossil exhibits exceptional preservation and lacks surrounding matrix, preparation may be deemed unnecessary. Similarly, when the fossil is represented solely as an impression in the rock matrix, mechanical or chemical preparation may be dispensed with, as it could risk damaging the delicate morphological details. Therefore, the decision to employ preparation techniques should be guided by the specific context and requirements of the study, balancing the need for detailed analysis with the preservation of the fossil's natural state.

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Author contributions

Olga A. Barros: writing – original draft; methodology; project administration; funding acquisition; supervision; review; editing; validation.

Conflict of interest

The author declares no conflict of interest.

Data availability statement

All data used in this study are publicly available in the existing literature.

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