ارزیابی دیرین‌آسیب‌شناسی مومیایی‌های نمکی ایران، شماره‌های ۱، ۷ و ۱۰ معدن نمک چهرآباد، دوزلاخ، ایران

لنا اورستروم، ناتاشا باقرپور کاشانی، راجر سیلر، به‌آتا بوده، ابوالفضل عالی، سارا خلیفه سلطانی، شاپور شیرانی، گابریلا روب-پوپا، توماس اشتولنر، فرانک رولی

چکیده

در این مقاله به ارزیابی دیرین‌آسیب‌شناسی بقایای انسانی به‌دست‌آمده از معدن نمک دوزلاخ که در موزه ملی ایران نگهداری می‌شود، پرداخته شده است. بقایای انسان باستانی به‌وسیله مقطع‌نگاری کامپیوتری (CT) و همچنین بافت‌شناسی مورد بررسی قرار گرفت. آنالیزهای مولکولی هنوز ادامه دارد. تجزیه و تحلیل‌ها نشان داد که بافت‌ها به خوبی در نمک طبیعی حفظ شده‌اند. ضایعات تروماتیک را می‌توان با مقطع‌نگاری کامپیوتری که نشان‌دهنده نیروی زیادی است که هنگام فروریختن معدن به افراد وارد شده است، شناسایی کرد.

واژگان کلیدی: مومیایی‌ها، معدن نمک باستانی، رادیولوژی، دیرین‌آسیب‌شناسی.

https://doi.org/10.22034/JINM.2023.544674.1050

Paleopathological assessment of the ancient Iranian salt mummies #1, #7 and #X, Chehrābād salt mine of Douzlākh, Iran

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Abstract

A paleopathological assessment of the ancient human remains from the Salt mine of Douzlakh, which are kept in the National museum in Tehran, Iran. The ancient human remains were investigated by Computed Tomography (CT) as well as by histology. Molecular analyses are still ongoing. The analyses showed that the tissues have been very well conserved in the natural salt. Traumatic lesions can be identified by CT, as a result of the massive force which was put on the individuals during the collapses of the mine.

Keywords: mummies, ancient salt mine, radiology, paleopathology.

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Introduction

In 1993, the mummified head of a bearded man wearing an ancient-style golden earring, a leather boot and other remains possibly belonging to this head were unexpectedly found in the Chehrābad – a salt mine still active at that time. All these remains were assigned to so called salt mummy #1 (SM1).

In 2004, further mummified bodies were discovered in the course of a rescue excavation. After that, mining activities in the salt mine were stopped by the Iranian Heritage Organisation and several archaeological excavation seasons were carried out. To date, eight individuals have been identified, named saltman or salt mummy (SM) 1, 2, 3, 4, 5, 6, 7 and 8 (Aali, *et al.* 2012; Stöllner and Aali 2015; Vahdati Nasab, *et al.* 2019). Apparently, they were salt workers and died in various mining accidents that occurred around 2,400 and 1,400 years ago, in Achaemenid and Sasanian times (Pollard, *et al.* 2008; Stöllner, *et al.* 2020.).

The salt mine of Chehrābad, also called Douzlākh (English: place of salt) in the local Azeri language, is a valuable site for further research and scientific discourse (Fig. 1), (Aali, *et al.*).

The mummies and organic finds, which have been sensationally well preserved in the salt mine and were recovered during the excavations, are important data sources with multi-layered technological, sociological and cultural information. They are now preserved and presented in the Zanjān Saltmen and Archaeological Museum, while the first finds of SM#1 are kept in the National Museum in Teheran.

The organic finds in particular require special conservation care, as they are susceptible to microbiological decay as well as pest infestation and are sensitive to climatic changes.

Long-term conservation is a challenge because there is a lack of sound experience and knowledge about the proper treatment of human remains preserved in salt, as these mummies are among the few of their kind in the world.

Fig. 1. Chehrābād salt mine; archaeological site, view from southeast. Copyright by NBK.

Therefore the mummies, the organic finds from the salt mine and the mine itself are part of a comprehensive program (7), that includes

- conservational concepts to keep the cultural heritage,
- their presentation that also includes discussion on ethical questions,
- special exhibitions in Germany and Iran,
- structural development around the mine and tourism.

Scientific research on the mummified remains therefore is not only a basis for archaeological, historical and medical findings, but also partly for the knowledge on how to keep this cultural heritage for the future.

The head and lower leg of SM #1 have been the subject of several investigations since they were found. Scientists from the National Museum Iran and the Institute of Evolutionary Medicine in Zurich had the opportunity to study a torso discovered with SM #1, which is referred to as SM #X (Öhrström, *et al.* 2021).

Here, we report the findings of SM #1, SM #7 and SM #X.

Material and Methods

The ancient human remains around salt mummy #1 (SM1) from the Chehrābād Salt mine in Douzlakh, Zanjan, Iran, which are kept at the Iranian National museum in Tehran, were paleopathologically investigated. Furthermore the leather boot was analysed by a leather specialist (G.-R-P.).

The head of SM1 was found in 1993 during mining operations in the still active salt mine of Chehrābād in Zanjan, northwest Iran (1350 meters above sea level, latitude N 36°54'52", longitude E 47°51'25"). It was a fully mummified head with long hair and beard. However, it was not until the subsequent rescue excavations that a mummified lower leg in a still very well preserved leather boot was found near where the head was found, possibly belonging to the same individual. The age determination of the head by means of C-14 analyses showed that it was a person from the Sassanid period (220-390 AD) (Pollard, *et al.* 2008). Other mummified remains, including cervical vertebrae and a second upper jaw, were discovered in the same area. However, these must be at least two individuals. As these investigations were carried out later, these remains are referred to as salt mummy #7 (SM7) (Vahdati Nasab, *et al.* 2019). Other mummified remains also associated with the excavations around SM1, but for which it is unclear how they were found, include part of a rib cage, a humerus and ulna, and some loose ribs (here named salt mummy #X). In the case of these remains, it is also unclear to which individual they belong; possibly SM1, SM7, or another individual. These remains have not yet been dated.

All remains were radiologically investigated by using Computed Tomography (CT) at the Tehran Heart Center on a clinical Siemens Somatom Definition Flash CT-Scanner. The following imaging parameters were used: 512x512 matrix size, between 0,6 -1mm slice thickness, 0,496-0,89 um pixel spacing, between 35-160mA tube current, and between 80-140kv tube voltage. DICOM reading software (OsiriX MD v.8.0.1, Pixmeo, Switzerland) and Horos (v3.3.6, www.horosproject.org) were used for image analysis.

Small samples have been collected for histological and molecular analyses. The histological analyses were carried out at the Institute of Pathology and Molecular Pathology of the University Hospital, Zurich, Switzerland. After rehydration the samples were fixed by immersion in buffered 4% formalin. Bone-containing samples were decalcified in EDTA. Then the samples were embedded in paraffin and cut in 2 µm thick sections. All samples were finally stained with hematoxylin and eosin (HE), elastica Van Gieson (EVG) and PAS, Grocott and Gram staining were performed on some of the samples.

Molecular analyses are complicated and are still ongoing and will not be reported here.

Results

Salt mummy #1 (SM1):

Macroscopy: A mummified head, including the left clavicular bone and cervical vertebrae 1-4 are preserved. The mummy wears an earring on the left ear and has long hair and a beard, which indicates a male sex (Fig 2a).

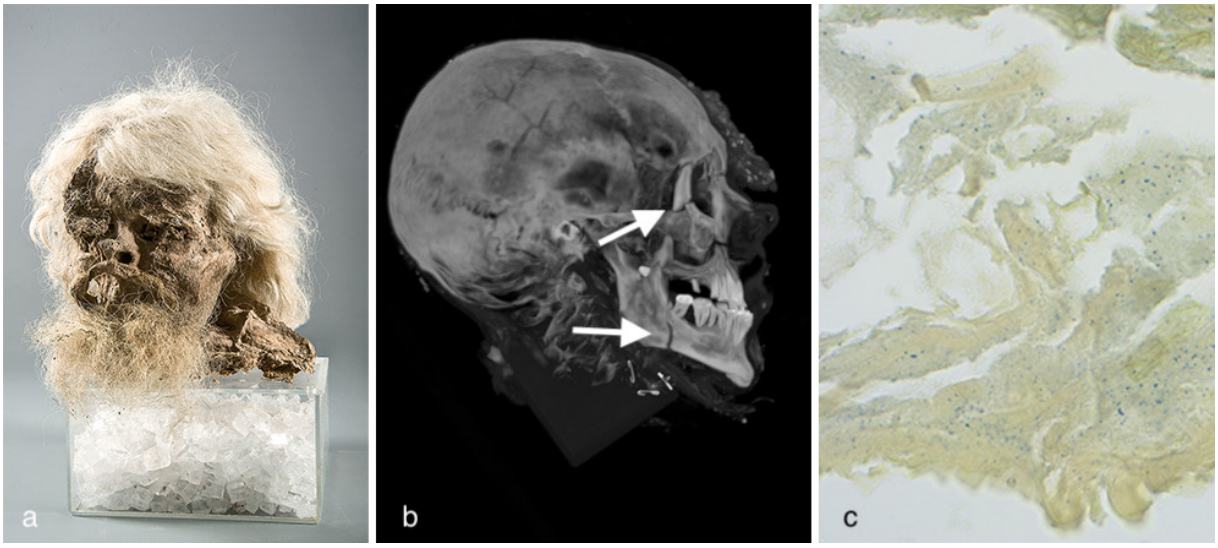

Fig. 2. Salt mummy #1; a) photo co by Baloot Noghrei inst. (Nima Fakoorzadeh), b) MIP (Multi intensity projection), note the fractured mandible and orbit (arrows), c) histology, gram stain, showing the bacterial colonisation (black points).

Radiology: Radiological findings showed fractures of SM1's facial skull. The right maxillary bone and orbit are fractured, as is the right mandibular bone. Dental analyses showed no caries, but massive dental wear. Some dried brain remnants as well as dura rest are preserved. (Fig 2b).

Histology: Histological analyses of samples from the throat and neck as well as hair showed very well preserved tissues in all samples. Samples from the throat showed a lot of bacteria and also fungi (Fig 2c).

Salt mummy #7 (SM 7)

Macroscopy: Three thoracal vertebrae and part of the upper jaw are preserved. While the vertebrae have some preserved soft tissues the remains of the facial skull are mostly skeletonized. These remains are well described in Vahdati (Vahdati Nasab, *et al.* 2019).

Radiology: The CT scan of these mummy parts showed some perimortem fractures, no specific pathologies are visible.

Dentition: In the preserved bone fragment of the left maxilla, a total of eight teeth are preserved. Of these, the front teeth are deeply fractured, and the palatal cusp is missing from the first premolar. The wisdom tooth has erupted completely and is aligned in the tooth row. The periodontal conditions are good, the teeth show only moderate dental wear. The first molar shows a deep carious cavity on the distal side. The palatal is fractured to bone level, and the opening of the pulp has led to infections in the bone around the root apices. Thus, the palatal root shows a poorly defined, approx. 7 mm large defect at its apex (Fig.3a, left arrow), while the defect at the mesiobuccal root has perforated the buccal bone surface (Fig.3a, right arrow, Fig.3b, circle). The adjacent mesial surface of the second molar opposite the large cavity of the first molar shows a small carious defect at the enamel-cement junction.

Histology: Analyses of a sample from the maxilla showed necrotic bone with preserved structures and colonisation with a few fungi.

Salt mummy #X (SMX):

Macroscopy: The partial mummy includes a fragmented lateral aspect of the right scapula (including the glenoid fossa, the lateral border, and fragments of the subscapular fossa), a complete left humerus, several thoracic vertebrae (likely T5-T12), 5 right ribs (rib head, neck, and the costal groove), 4 left ribs (rib head, neck, and the costal groove, (1) costal angle), one probable lumbar vertebrae (L1; fragmented), a complete left ulna, and a right ischium (acetabular notch, ischial tuberosity, and a partial distal obturator foramen), (Fig 4).

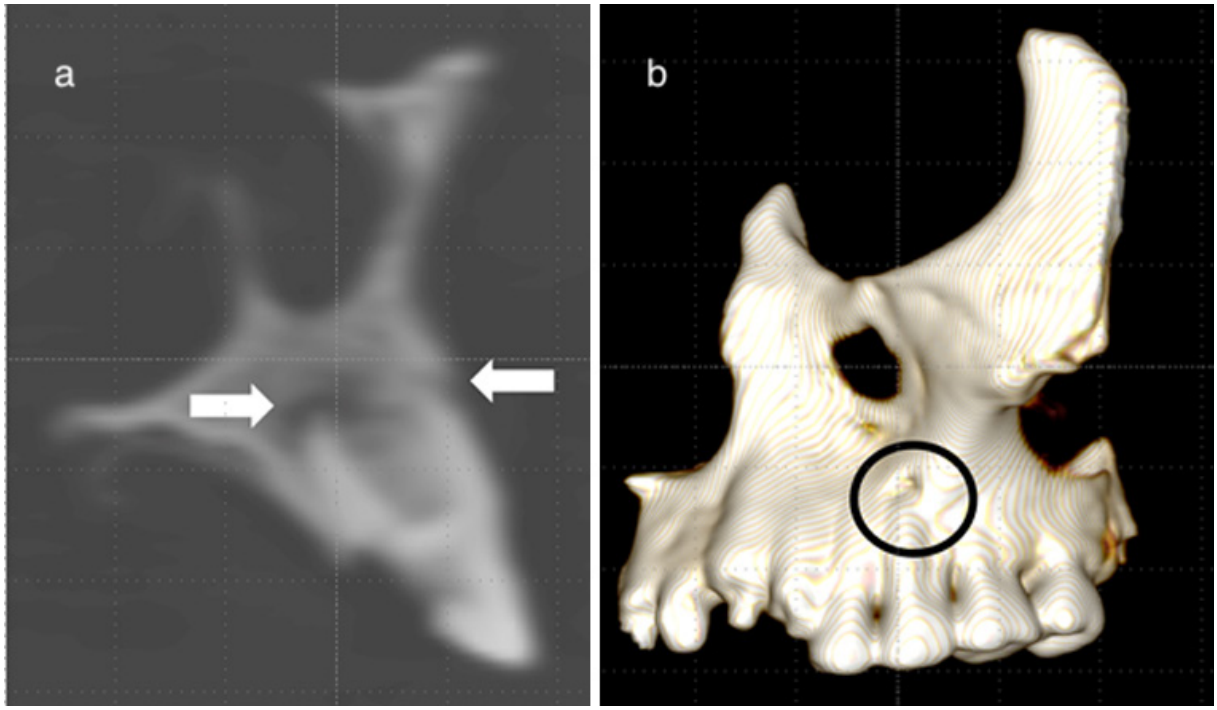

Fig. 3. Salt mummy #7; a) CT image and b) 3D reconstruction showing both the bone defects.

The epidermis is very well preserved on the posterior aspect of the mummy, but the anterior side contains little to no tissue, aside from the fibrous tissue surrounding the spinal column. To note, the neural arches of the vertebrae currently house the dried remains of the spinal cord. The skin mass extends from the superior aspect of the humeral head and continues inferior-medially to the left side. The skin gives a leathered texture and contains a large postmortem rip in the mass, near the location of the inferior scapular angle, which tears lateral-medially on the right side. There are soft tissue and skin remnants on the humeral head, surgical neck, and the deltoid tuberosity, while the rest of the bone is skeletonized. The ulna is completely skeletonized, as is the ischium, aside from a few organic tissue fibers. Brief measurements were conducted on the ischiopubic ramus (2.3 cm), maximum ulnar length (approximately 23.9 cm, though re-measuring is recommended), and the maximum humeral length (31.8cm).

Radiology: Radiological analyses showed an intact part of the vertebral column with good alignment and without fractures or degenerative changes. Some dura remnants can be recognized. Some rib fractures are present, as well as a partially preserved fractured right scapula and a slightly displaced distal clavicula fracture (Fig 4b and c). No intravitem pathologies are detected.

Histology: Histological investigation of the ribs showed intact necrotic bone structure, whereas histology of the thorax-sample showed collagen fibers only (Fig 4f). No analyses for bacteria or fungi have been performed for these samples.

Leather boot

Macroscopy: The footwear (Fig. 5) is made of leather and the left foot and the lower leg of the wearer are still in his knee-high boots (EU-size 42) (Goubitz, *et al.* 2001). The material is of a coarse-grained, strong structure (Fig. 5a) and a greenish-brown colour. The velvet-like appearance of the boot (Fig. 5c) is due to the fact that the flesh side of the leather is on the outside and the smooth grain side (Fig. 5a) faces inwards. The uppers are made of the same flexible material. It must derive from a soft leather which allowed putting on the shoes. The sole seems to be made from a thicker material.

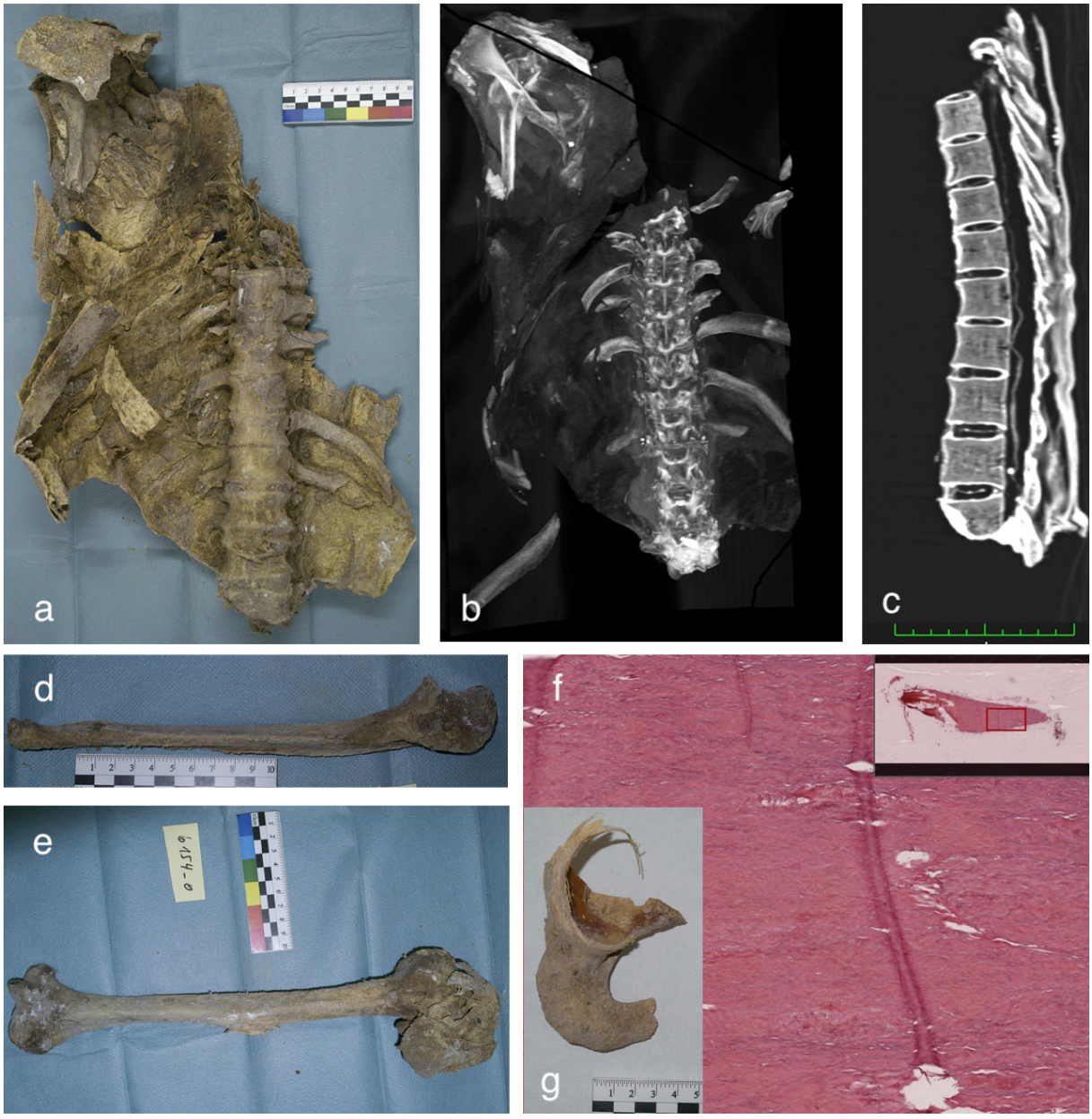

Fig. 4. Salt mummy #X; a) photo of the thorax remains, with corresponding MIP, multi intensity projection (b) and sagittal CT slice (c); photos of the humeral and ulnar bone and pelvis fragment (d, e and g); f) histology, EVG stain, showing collagen fibers. Photos co Lena Öhrström.

The flat boot was made from multiple parts: the sole, the uppers with a round toe cap, heel and boot leg. This shoe is turn-sewn and here a left-right distinction can be seen. The edge of the boot leg is gathered and folded (Grömer, *et al.* 2020; Ruß-Popa 2020). The exceptional preservation of the boot can also be seen in the cross-section (Fig. 5b) of the leather. This is due to the highly saline environment but also to the optimal tanning.

Radiology: The CT shows a mummified foot and upper ankle, while the proximal part of the lower leg is skeletonized. No fractures and no other pathologies are visible. The boot is partially filled up with radiopaque material, probably sand and stones. It is an adult individual because the epiphyseal plates are closed. The boot was actually too small for its wearer; one can see that the clenched toes arrive directly at the toecap of the shoe (Fig. 6). Walking was probably causing pain because the foot usually slides forward when it rolls. In order not to abut against the toecap, there should be a space of about 1 cm between the toes and the tip

Fig. 5. The leather boot of salt mummy #1 (photos: G. Nayaflu, IBM); a) The grain surface of goatskin leather; b) The cross-section of goatskin leather; c) The flesh-side of the leather (a-c: microscopy pictures: G. Ruß-Popa; ÖAI)

of the shoe. The boot leather was permanently stretched and the toes of the wearer left a mark on the upper. The boot is made of goat leather, this shows us the characteristic grain pattern on the leather surface (Fig. 5a).

Discussion

Radiological analyses revealed multiple perimortem fractures and varying state of preservation. In the histological analyses no pathologies could be detected, however only very small sample sizes were analyzed to guarantee the integrity of the remains. So no final conclusion about possible pathologies can be made.

Age and sex estimation

SM 1: With only the head preserved age estimation is very inexact. However, the closed epiphyses and the dental status indicate an adult age. Also the sex cannot be determined with certainty without a pelvis. However with clear sex determinants such as the preserved beard, a male sex is ascertained.

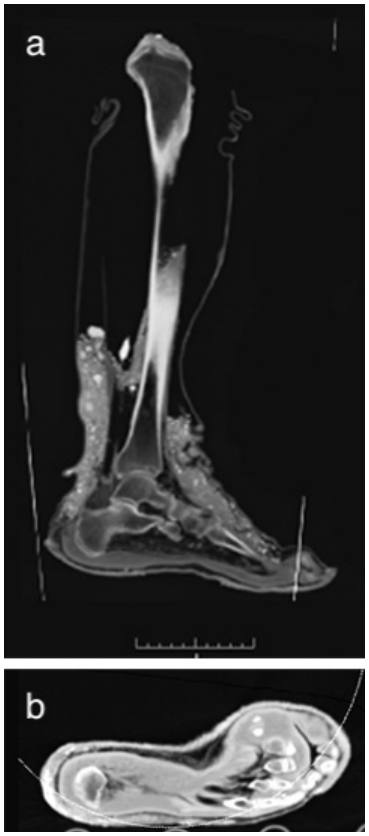

Fig. 6. CT images of the leather boot
a) sagittal slice b) axial slice

SM X: The pelvis is not complete enough for a sex determination, which is the standard method (Bruzek 2002). However, there are numerous hairs on the shoulder area of the skin, possibly representative of a male. There is slight lipping on a few lower thoracic vertebrae, but it does not indicate a significant age.

All present epiphyses are fused, indicative of an adult age. Due to the lack of pathological degeneration, the individual is likely a young adult.

In conclusion the remains show signs of massive pressure, which occurred when the ancient mine collapsed. Neither radiological nor histological evidence of intravitam pathological processes could be found. Molecular investigations, which may will reveal relationship between the different mummified parts, have not yet been completed, but are planned in near future.

Acknowledgement

Thanks to the Tehran Heart Center for preforming the CT Scans and to the National Museum of Iran for the access to the ancient remains. Thanks to the Miras Faranghi, The RCCR. Thanks to the DFG and the Mäxi foundation for financial support.

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