

The Role of Physical and Chemical Factors in Natural Mummification

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Authors identify, analyze and systematize the basic physical and chemical factors that caused natural mummification of preserved ancient mummies. They group and write up in tables the best preserved and famous natural mummies all over the world.

Key words: Mummy, Mummification, Bog, Glacier, Desert.

Introduction

According to *Aufderheide* [4] “mummification” is a method of protection of soft tissues, at which they become resistant to the enzymes opening up and after-death decay. This term is issued at the cases when mummification was made under influence of natural factors with or without human intervention (spontaneous, natural mummification) as well as when mummification is the result of the intentional human intervention (artificial mummification).

Modern paleontologists [2, 5, 19] found thousands of mummies in different parts of the world – Melanesia, North and South America, Egypt, Scythia, Europe, Asia etc.

Purpose and aims

The purpose of the present scientific research is using literature data, the basic physical and chemical factors that caused natural mummification of preserved ancient mummies to be identified, analyzed and systematized.

General information

Spontaneous mummification most frequently occurs after fast intentional or incidental drying of the dead body in the hot or cold but dry deserts [25] or in the places with microclimate suitable for mummification and preservation of many years [9] of corpse material. Recently, these natural mummies are valuable source, from which the modern medicine can get information for diseases in the ancient human societies and their development till nowadays. The most frequent places where one can find sandy mummies are shown in Table 1.

Atacama Desert. American paleopathologists [1, 13] studied intestinal parasites diseases and spinal diseases of ancient inhabitants of South America of more than 30 well-preserved mummies aged between 500 and 1000 years, most of them are from the Atacama Desert in the north of Chile. Recently, they are kept at the *Museo Arqueologico de San Pedro de Atacama*. Although the long historical period, now mummies are in a good condition.

A mine of natural human mummies, the desert Atacama is situated at a height of 3000-3200 m above sea level. It is a waterless plateau with tropical and trade-wind climate and it is 140000 km² big, situated between the Pacific Ocean and the Andes. This is one of the driest places in the world - the average annual quantity of rainfall is 15-20 mm, but it may not rain for decades [37]. Huge deposits of sodium nitrate from which they extracted the famous "Chile silicate" were found in the desert covered with sandy and volcanic stones. Atacama is a "cold" desert – maximum summer temperatures barely reach 19°C [15].

Sahara Desert. A large quantity of natural sandy mummies was found in the Sahara Desert [12]. Some of them are buried in the sand covered only in leathers, others are put in wooden coffins, and the rest are put in bigger or smaller tombs, most frequently built by stones [16]. Egyptologists from Manchester University implemented the modern techniques when they studied ancient tissues to found what parasitoids Egyptians, whose mummies are found in the Sahara desert, suffered 5000 years ago [10]. They also reported about the condition of different parts of the mummified bodies - skeleton, muscles, skin. Some of these mummies are kept at the *Museum of Manchester University*.

A well-preserved mummy from Egypt, called *Ginger*, is kept at the British Museum [11]. It lies on its left side with strongly bended legs and arms put under the face. The hair is preserved, but here and there the skin is dry and chapped, by reason of this the tissues can be seen (Fig. 1.).

Table 1. The most typical place in the world where "sandy mummies" were found

Location	Age	Condition	Factors	Where are they kept
The Atacama Desert	500-8000 years	Good	Dry and clean air, permanent winds alkaline react of the soil	Museo Arqueologico de San Pedro de Atacama
The Sahara Desert	5 000 years	Good	Dry hot air, strong sun radiation	British Museum, Manchester Uni. Museum
The Taclamakan Desert and a basin of the river Tarim in West China, around the towns of Cherchen and Loulan	4 000 years	Excellent	Primary low temperatures, salty sandy soil, dry air with permanent streaming; high summer mummifying temperatures	Provincial Museum of Urumchi, West China, Uigur autonomous region
Catacombs in Palermo	Variable	Very good	Dry air, permanent air draught	Palermo
Central Italy	600 years	Good	Dry air, permanent air dra	Missing data



Fig. 1. Ginger – a Sandy Mummy from Sahara

The Sahara Desert covers the area of 8 million km² and 80 % of it is sandy valleys with above sea-level between 200 and 500 m. The climate is desert, tropical, dry and hot. Maximum temperatures reach up to 56°C, and the rainfall-up to 200 mm [38].

Taclamakan Desert. Paleontologists [3, 6] announced about more than 500 mummies aged between 3000 and 4000 years found in 1970 in Chinese Turkistan in the most salty east part of the Taclamakan Desert wedged between Russian and Mongolia near the towns of *Cherchen* and *Loulan*. They are of European people from the Caucasus little race and many of them are perfectly preserved, better than the most famous Egyptian mummies. They were buried in winter and they had been dehydrated by the salty sand before the summer temperatures damaged them. Found coffins in which the mummies were put and that allowed intensified circulation of the air streaming the bodies, also contributed to the mummification. From the summer funerals only skeletons are preserved [22]. The most preserved mummies are: *the Man* and *the Woman from Cherchen*, the *Woman with the child from Cherchen* and the *Beauty from Loulan*. Now, the find is kept at *Provincial Museum of Urumchi* – the capital of Uigur autonomous region (Xinjiang Uigur), also famous as Chinese Turkistan [17].

The desert Taclamakan has the area of 337 600 km², 800 and 1664 m height above sea level and has rarely continental climate, almost without any rainfall. The soil is sandy and with high percentage of NaCl in it. Winters are cold – the average winter temperature is –15°C, and summer is hot- +30°C [39].

Natural mummies can also be found in **bogs** or in alpine and **arctic glaciers**. Natural mummification is very often due to combined effect of a few natural factors. Sometimes artificial mummies that subsequently got in glaciation can be found and this is the reason they were preserved in excellent condition.

The famous discoveries of **bog mummies** are shown in Table 2. A bog is a marshy ecosystem that is characterized with humidity and porous black-brown peat soil [15]. Bog mummies are only found in North-west Europe – in the marshes formed when the drainage of rain water is violated, but there are no bog mummies in the countryside Fen in the east of England, where the marshes are supported from waters rich of mineral subsoil [8]. The main vegetation in the north marshes is peat moss, their pH is lower than 5.0 and mineral substances are in an insignificant quantity. The peat moss, *Sphagnum* (family *Sphagnaceae*) covers vast areas that alternate with open hollows filled with water. The moss soaked with water (90-95 %) violates air metathesis so there is no oxygen only a few centimeters under the surface of the peat [15, 39]. According to *Stucker* [35] the low level of pH has mummifying effect over the bodies, so the characteristic feature of peat mummies is brown color of the skin combined with vital-like appearance (Fig. 2). Well-preserved hair of dead bodies is often colored in vermilion or orange under the influence of active factors from the environment after the death [31]

Table 2. The most famous "bog mummies" in Europe

Name (nickname)	When was found?	Where was found?	Age	Condition	Where is kept?
Lindow Man	1984	Great Britain	50 B.C.	Excellent	British Museum
Rendswuhren Man	1871	Germany	Unevidential	Excellent	Landesmuseum - Schleswig
Yde Girl	1897	Netherlands	200 B.C.	Very good	Drents Museum - Assen
Tollund Man	1950	Denmark	300 B.C.	Very Good	Drents Museum - Assen
Grauballe Man	1952	Denmark	170 B.C.	Very Good	Forhistorisk Museum - Højbjerg
Huldremose Woman	1879	Denmark	350 B.C.	Very good	National Museum of Denmark
Windeby Girl II	1952	Germany	50 B.C.	Good	Landesmuseum - Schleswig
Husbake Man	1936	Germany	Roman age	Good	Landesmuseum - Oldenburg
New England Man	1941	Germany	Roman age	Good	Landesmuseum - Oldenburg
Neu Versen Man	1900	Germany	Unevidential	Not good	Landesmuseum - Hannover
Borremose Woman	Missing data	Denmark	Unevidential	Not good	Drents Museum - Assen
Bockhornfeld Man	1934	Germany	Unevidential	Not good	Landesmuseum - Oldenburg
Elling Woman	1938	Denmark	200 B.C.	Not good	Silkeborg Museum
Weerdinge Men	1904	Netherlands	Roman age	Bad	Drents Museum - Assen
Damendorf Man	1964	Germany	300 B.C.	Bad	Landesmuseum - Schleswig
Emmer-Erfscheidenvee Man	1938	Netherlands	1200 B.C.	Bad	Drents Museum - Assen
Kayhausen Boy	Missing data	Germany	150 B.C.	Bad	Staatliches Museum - Oldenburg

(for example, "*Red-haired Franz*" and the *Bourtangermoor Girl* - Netherlands and 20-year-old *Husbake Man* - Germany).

"The glacial mummies" are a few in numbers, but due to their excellent preservation, they are a valuable source for scientific data about the life and diseases of the ancient people. The most frequent localization of glacial mummies is shown in Table 3 and the best of them are:

Ötzi - the glacier man from the Alps (3350 B.C.) was found in 1991 in a glacier near *Hauslabjoch* on the border between Austria and Italy, on 3200 m above the sea-level [30]. It was studied in details by international teams of scientists and three-dimensional anthropological virtual reconstructive methods were implemented [26]. Using radioactive carbon they proved that this is the oldest very well-preserved glacier mummy in the world and through forensic-medical analysis they found the reasons for the death of the ancient man [34]. Other scientists used gas chromatography [23] and spectroscopy, and electronic microscopy [36] for identifying the molecular structure of the skin from the glacier mummy.

Now the mummy is kept at the *South Tyrolese Archeological Museum* in the town of *Bolzano*, Italy in special chambers at temperature -6°C and relative humidity of the air between 96 and 98 %.

Alpine mummies from the Andes. *Ampato*, *Misti* and *Hualca Hualca* in the Andes were the sacred mountains of the Incas where they offered sacrifices to their Gods. Between 1954 and 2000 on more than 30 mountains peaks, between Central Chile and North Peru, 115 glacier mummies were found [27, 33]. With the little exceptions, most of them are aged about 500 years and for every one of them the basic protective factor is the low temperature, but in some cases additional features that increased influence of the cold, are presented.

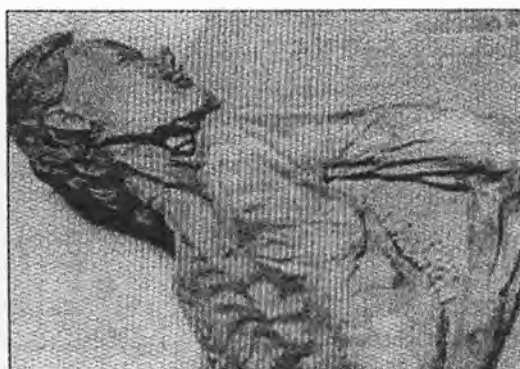


Fig. 2. A Bog Mummy from Grauballe - Denmark (Red-haired Franz)

Table 3. The most preserved "glacial mummies" in the world

Name (nickname)	Where was found?	When was found?	Age	Condition	Where is kept?
The iceman from the Alps - Otzi	1991	Austria	3350 B.C.	Excellent	South Tyrol Museum of Archaeology - Bolzano, Italy
The Children from Llullaillaco	Missing data	Argentina	1500 A.D.	Excellent	Missing data
The baby from the Andes	1999	Argentina	0-500 B.C.	Excellent	Tucuman University, Argentina
The boy from Plomo	1954	Chile	1400 A.D.	Excellent	Arch. Museum in Santiago
Juanita	1995	Peru	1500 A.D.	Excellent	Catholic University of Arequipa
The Canadian ice hunter - Kwaday Dan Sinchi	1999	British Columbia	500 A.D.	Very good	Cremated and buried
The mummies from "Greenland group"	1972	Greenland	1475 A.D.	Excellent - 4 Not good - 4	Nuuk Museum - Greenland
The Newly-married from Ampato	1952.	Peru	1500 A.D.	Good	Catholic University of Arequipa
Sarita	1996	Peru	Missing data	Bad	Catholic University of Arequipa

The Prince from Plomo Peak. The first glacier alpine mummy from the sacrifices of the Incas was found in Chile in 1954 in the highest part of El Plomo Peak in the Andes at a height of 6090 m and it was called "*La Momia del Cerro El Plomo*" [18]. It is a boy aged about 8-9 years who was offered as a sacrifice to the Gods of Incas around 500 years ago. It is excellently preserved and looks as if he fell asleep.

Juanita. In 1995 was found a frozen body of a young girl at the age of 13-14 in the *Ampato Mountains* in Peruvian Andes at an height of 6094 above the sea-level [32]. According to Reinhardt [28] the mummy, named Juanita, is the best preserved human body since the Incas era, found till nowadays including-skin, internal organs, blood, intestinal content etc., that have not dried up, but only frozen [14].

Now, the mummy is kept at the temperature of -7°C and the air humidity about 80% at the *Catholic University in Arequipa* in a fridge with glass walls that allow permanent monitoring and control (Fig. 3).

The Baby from the Andes. In 1999 in a volcanic cave at a height of 3 600 m above the sea level in *Antofagasta*, on the slope of the Cerro Galan Peak in the Andes, in the



Fig. 3. Juanita – the Ice Maiden from Ampato

north-west part of Catamarca Province, Argentina in the conditions of very cold and dry wind mummified body of a child on visible age of about 4 months was found. The mummy, named the baby from the Andes, is dressed in beautiful leather article of clothing, enveloped in straw and it is preserved excellently. The mummy is 1500-2000 years old. [29]

Children from Llullaillaco. Two girls and a boy offered as sacrifices to the Gods about 500 years ago were found on a volcano peak in the Andes, in the *Llullaillaco* Mountains at a height of 6700 m above the sea-level in the north-west of Argentina near the border with Peru. According to Reinhardt [29] these are the highest excavations and the best preserved glacier mummies in the world. It is due to the fact that they had not been unfrozen since they were put on the peak by the Incas. The limbs and hair of children are in excellent condition, and the girl is wrapped in a beautiful decorated golden cover put on the mantle that additionally preserved her from the unfavorable outer conditions. After the computer tomography, they found completely preserved internal organs [29].

Kwaday Dan Sinchi – the frozen hunter from Canada (1415-1445). His remains were found on 14 August 1999 in the *Tatshenshini* – Alsek Park in the northwest part of British Columbia, near the borders with Yukon and Alaska about 200 km in the north from Vancouver and at a height of 1982 m. All tissues including skin and muscles are well-preserved [20]. In the course of three years, the mummy was kept at the low temperature at the *Royal B.C. Museum – Whitehorse*, when different tests were implemented – DNA test, radiographic monitoring of the skeleton, trace-element analysis etc. [24]. By means of radioactive carbon ¹⁴ it was found that this mummy is only 550 years old. So in 2001, on the insistence of Indian's leaders, she was cremated and buried near the place where it was found [20].

The mummies from “Greenland Group”. Lynnerup [21] describes eight mummies found by hunters in 1972 near the village of *Qilakitsoq* in Greenland. They are comparatively young - they died in 1475 and they are one of the best naturally preserved human bodies. The group includes 6 months old baby, 4 years-old boy and six women at different age who are closed in two stone caves and they were naturally mummified from the low temperature and drying glacial wind. According to *Buell J.* [7] the child who probably was buried alive and three of the women are in excellent condition, and

the other four bodies have been damaged to different extent. Now, the mummies are kept at the *Nuuk Museum in Greenland*.

Discussion and Conclusions

Natural preserved human bodies found in different place of the world, depending on mummifying and preserving physic-chemical factors, can be divided into a few groups:

1. Sandy mummies

Normally, sandy mummies are from deserts where there are natural factors forcing mummifying of the dead bodies. In the cold deserts, influence of *the negative winter temperatures* that do not allow fast macerating of the corps; the *air movement* that quickens dehydration and drying of the tissues and *alkaline react of sandy-stony soils* that on one side dehydrates the dead body, from the other side that does not allow growing of putrefactive bacteria and fungi. In the hot deserts, the *high temperatures* and the air movement are the main factors that dehydrate tissues and preserve corps throughout centuries.

2. Bog mummies

Natural conditions, which provoked mummification and preservation of human and animal crops, are *lack of oxygen* and *mineral substances*, *high acidity* and *low temperatures*. These are conditions in the North Europe that is why the main finds are in Great Britain, Ireland, Holland, Germany and Denmark. In peat-bogs situated in the South Seas, the dead tissues decayed for a few days.

3. Glacial mummies

These are not the real mummies, and they are rather frozen human bodies that preserved their entirety of the internal organs, but also thier alive-like appearance. These are alpine glaciers where the *low temperatures* are the main factors for preserving of the bodies.

4. Mummies made from combined effect of a few factors

These are the most frequent found mummies, since in nature “pure” laboratory conditions do not exists. In this sense, described above division is conditional and when we talk about for a type of mummies, it is based on predominant effect of one of the natural factors.

The principles of natural mummifying are used at some methods for embalming of dead people, as well as at modern conservation technologies for anatomic objects: through molecular substitution with polyethylene-glycol and the plastination with the products of Biodur, implemented in anatomic practice from Günter von Hagens in 1987.

References

1. Allison, MJ, T. Bergman, E. Gerszten. Further studies on fecal parasites in antiquity. – *American Journal of Clinical Pathology*, **112**, 1999, No 5, 605-609.
2. Andrew, T., C. Pearson, M. Pearson. *The History and Science of Preserved Human Bodies*. London, British Museum Press, 1999.
3. Anthony, D. Tracking the tarim mummies. A solution to the puzzle of Indo-European origins. – *Archaeology*, **54**, 2001, No 2, 36-40.
4. Aufderheide, A. Progress in soft tissue paleopathology. – *JAMA*, **284**, 2000, No 20, 2571-2573.
5. Aufderheide, A. *The Scientific Study of Mummies*. – Cambridge University Press, 2003, 277-286.
6. Barber, E. The mummies of Urumchi. – *Archaeology*, **1**, 1995, 28-35.
7. Buell, J. *The Greenland Mummies*. – Nuuk Museum Press, Nuuk, 1998, 1-35.
8. Buell, J. *Bog Bodies*. – Time Travelers, Philadelphia, 1998, 1-30.
9. Capasso, L., G. Di Tota. An unusual paleopathological finding: a possible 'ciclicium' in a XV century natural mummy from Italy. – *Paleopathology Newsletters*, **93**, 1996, 10-12.
10. David, R. Disease in Egyptian mummies: the contribution of new technologies. – *Lancet*, **349** (9067), 1997, 1760-1763.
11. Donleavy, J. *The Ginger Man*. Viking Penguin, 1986, 14.
12. Farouk, El-B. Gifts of the desert. – *Archaeology*, **54**, 2001, No 2, 41-43.
13. Gerszten, PC, E. Gerszten, M. Allison. Diseases of the spine in South American mummies. – *Neurosurgery*, **48**, 2001, 208-213.
14. Griek, S. *A Gift for Ampato*. – Greenwood Books, 1999, 5-36.
15. Guinness, P., N. Norton, P. Goetz. *New Encyclopaedia Britannica*. 15th Edition. – New Encyclopaedia Britannica Inc., 1, 1991, 660-661.
16. Harrington, P. From the sands of Sahara. – *Archaeology*, **5**, 1997, 34-37.
17. Harrington, S. The mummies' threads. – *Archaeology*, **49**, 1996, No 5, 29-31.
18. Horne, P. The prince of El Plomo. – *Paleopathology Newsletters*, **40**, 1982, 7-10.
19. Kleiss, E. Mummies. – *Anatomische Anzeiger*, **149**, 1981, No 5, 502-508.
20. Lundberg, M. Kwaday Dan Sinchi, The Yukon Iceman. – *Whitehorse Star*, 1998, 1-56.
21. Lynnerup, N. The mummies from Greenland. – *Ugeskr Laeger*, **160**, 1998, No 52, 7596-7600.
22. Mallory, J. P., V. Mair. *The Tarim mummies*. – Thames & Hudson book. 2000.
23. Mayer, B., C. Reiter, T. Beuter. Investigation of the triacylglycerol composition of iceman's mummified tissue by high-temperature gas chromatography. – *Journal of Chromatography Biomedical Sciences*, **692**, 1997, No 1, 1-6.
24. Monsalve, M., A. Stone, C. Lewis, A. Rempel, M. Richards, D. Straathof, D. Devine. Molecular analysis of the Kwaday Dan Chinchu ancient remains found in a glacier in Canada. – *American Journal of Physical Anthropology*, **119**, 2002, No 3, 288-291.
25. Post, P., D. Donner. Frostbite in a pre-Columbian mummy. – *American Journal of Physical Anthropology*, **37**, 1972, No 2, 187-191.
26. Recheis, W., G. Weber, K. Schafer, H. Prossinger, R. Knapp, H. Seidler, D. zur Nedden. New methods and techniques in anthropology. – *Col. Anthropology*, **23**, 1999, No 2, 495-509.
27. Reinhard, J. *Peruvian Mummies Revisited*. – National Geographic, **191**, 1997, 36-43.
28. Reinhard, J. *Discovering the Inca Ice Maiden*. – National Geographic Society, 1998, 1-48.
29. Reinhard, J. *My Biography*. – National Geographic society, 2000, 34-65.
30. Sjovold, T. The Tyrolean Iceman and excavated human remains as sources of information about the past. – *Int. J. Circumpolar Health*, **57**, 1998, Suppl 1, 49-54.
31. Smith, A. *Bodies of the Bogs*. – *Archaeology*, **12**, 1997, 39-42.
32. Schuster, A. *Andean Icewoman*. – *Archaeology*, **49**, 1996, No 1, 23-26.
33. Schuster, A. Highest dig yields Inca sacrificess. – *Archaeology*, **52**, No 4, 1999, 34-36.
34. Stone, R. *Paleoforensics. Ice Man warms up for European scientists*. – *Science*, **289** (5488), 2000, 2253-2254.
35. Stucker, M., F. Bexara, M. Bacharach-Buhles, P. Pieper, P. Altmeyer. What remains of the skin after 2000 years in a bog? – *Hautarzt*, **52**, 2001, No 4, 316-321.
36. Williams, A., H. Edwards, B. Barry. The 'Iceman': molecular structure of 5200-year-old skin characterised by Raman spectroscopy and electron microscopy. – *Biochim. Biophys. Acta*, **1246**, 1995, No 1, 98-105.
37. Георгиев, В. и др. Кратка българска енциклопедия. С., Том 1, БАН, 1963. 180 с.
38. Георгиев, В. и др. Кратка българска енциклопедия. С., Том 4, БАН, 1968. 470 с.
39. Георгиев, В. и др. Кратка българска енциклопедия. С., Том 5, БАН, 1969. 81 с.