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The Parthian Battery: Electric Current 2,000 Years Ago?

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Introduction

Archeological excavations carried out at Ctesiphon by various expedition teams during 1930 and 1936 brought to light curious objects such as earthenware jars, copper cylinders, and iron rods.

In 1936, a clay jar, a copper cylinder and an iron rod were found at Khujut Rabbou'a near Ctesiphon. Since the region was known to have been settled by the Parthians, the finds were attributed to the Parthian Empire.

The clay jar, the opening of which was sealed with an asphalt plug, turned out to be hollow. The copper cylinder was capped at the bottom with a copper disc that was held in place and covered by asphalt. The iron rod seemed to be attacked by corrosion. The real purpose of the objects was unknown.

The Austrian archeologist Wilhelm König, who first described them, claimed that they were parts an electric battery. Later, he suggested that several such devices connected together would supply sufficient electric power, and could have been used by Parthian goldsmiths to deposit gold layers onto base metal artworks to improve their appearance and enhance their apparent values.

However, not all scientists accepted the idea that the find of Khujut Rabbou'a had been used by Parthian goldsmiths as an electric power source to plate gold coatings. Some of them believed that perhaps the "battery"

was used as a ready source of analgesic electricity, or for similar therapeutic purposes such as imparting electric shocks to patients. Others thought it was more likely that the clay jar and its contents were used in magical rituals. There were also researchers who refused the power source hypothesis categorically and argued that such clay jars may have been containers for blessings or incantations, which were written on organic materials and placed inside them.

Ever since the discovery scientists from all over the world have performed extensive experiments using replicas of the findings to conform or to refute König's theory [1].

The Discovery

In the course of earth-moving operations carried out on June 14th, 1936, at Khujut Rabbou'a the archaeologists came across an ancient site. They proceeded routinely with their excavation work until something quite unexpected occurred. The excavators found strange objects of unknown nature. They considered the findings at first as just another ordinary discovery and did not become very excited about them. However, it did not take them too long to realize that they were actually digging out peculiar objects of unknown purposes.

W. König studied the "curious aggregate", as he put it, and published his observations in an article, which appeared on January 1st, 1938, [2]. In his paper, he presented a photograph (Fig. 1) of the objects and gave a detailed description of the different parts.

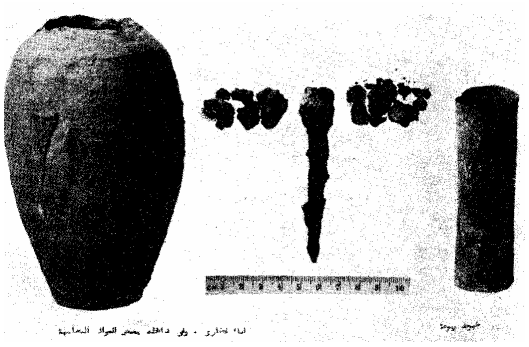

Fig. 1: Objects discovered in 1936 at Khujut Rabbou'a [2]
From left to right: clay jar, iron rod between fragments of asphalt for spacing, copper cylinder (The scale is 10 centimeters long.)

The question, which kept König occupied at this stage, was whether anything like these objects had been discovered before. The answer he found to his question was positive. Three different excavations had been carried out at Seleucia in the 1930's by an excavation team from the University of Michigan under the directorship of Professor L. Waterman and had yielded small devices with iron and copper parts. In further excavations undertaken in 1931/32 jointly by the Islamic Art Section of the Staatliches Museum, Berlin, and the Metropolitan Museum of Art, New York, led by Professor E. Kühnel, six sealed unglazed earthenware jars were found, each containing little rolls of metal or metal nails.

König's Hypotheses

König found himself confronted with the tantalizing question of what purpose the mysterious objects might have had? He decided to deal with this question systematically and continued searching for any further details that could help him to establish the real use of them in antiquity.

On August 29th, 1936, he sent a complete set of the device to the University of Vienna to be examined by Professor O. Menghin and Dr. W. Gangl. Unfortunately, there are no records available on the results of these investigations.

Looking for an answer to his question regarding the possible use of the findings in antiquity, König finally hit upon the idea to put them together. What came out of his idea was an assembly that looked like a galvanic element. The hand-made drawing, which he included in his paper is reproduced in Fig. 2. It is a cutaway model of the assembly.

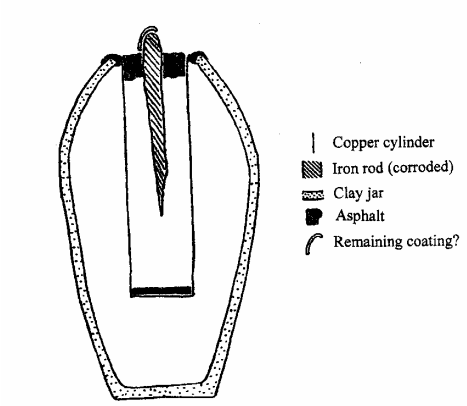

Fig. 2: König's hand-made drawing of the Parthian Battery [2]

From this schematic representation one can see that the copper cylinder is placed centrally into the clay jar, and the iron rod, held in place by a bung made of asphalt, is pushed through the upper asphalt plug and hangs down into the copper cylinder without touching any part of it. The upper end of the iron rod protrudes above the asphalt stopper; its sharp end does not

come into contact with the bottom of the copper cylinder, which is covered with a thin asphalt layer.

König speculated that such an arrangement could have served as a galvanic element or battery. He was the first to suggest that such a device could have been employed by Parthian goldsmiths to generate electric power arguing that all the materials used were common and the manufacture was well within the ability of the people of that time.

Having said that, König put forward the daring theory according to which the Parthians might have used such batteries as electric power source for electroplating gold onto the surfaces of base metal objects.

Apart from his power source and gold plating hypotheses, König came up with another interesting idea suggesting that the Parthians might have used such devices for medical purposes as well.

To summarize, König was of the opinion that the Parthians might have used such devices for three purposes:

- To generate electric current (Power supply hypothesis)
- To gold plate base metal objects (Gold plating hypothesis)
- To heal diseases by electric shocks (Medical application hypothesis)

König's interpretations have often been cited and are still a matter of discussion. In the following an attempt will be made to evaluate König's hypotheses.

Power supply hypothesis

To examine König's power supply hypothesis, it is necessary to consider the action of a galvanic cell or element.

A galvanic cell is a device for producing a voltage and delivering an electric current as a result of electrochemical reactions. It consists of two dissimilar metals, generally referred to as electrodes, or more specifically, as anode (A) and cathode (C), which are connected together by means of an external wire and immersed in an electrically conductive solution, called electrolyte. Due to the potential difference between the two electrodes, the electrons will flow from the anode towards the cathode. The flow of electron constitutes an electric current that can be measured by means of an ammeter. This arrangement is depicted in Fig. 3.

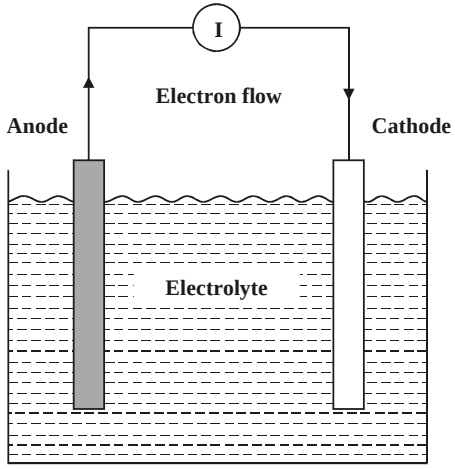

Fig. 3: Measurement of the electric current I flowing from a galvanic cell by means of an ammeter

On close inspection, one realizes that the arrangement of the iron rod and copper cylinder in the clay jar according to König's sketch (Fig. 1) establishes a galvanic cell, in which the iron rod is the anode and the copper cylinder the cathode. Such an assembly is capable of supplying an

electric current, provided the two electrodes are connected together and the copper cylinder is filled with a suitable electrolyte, as indicated in Fig. 4.

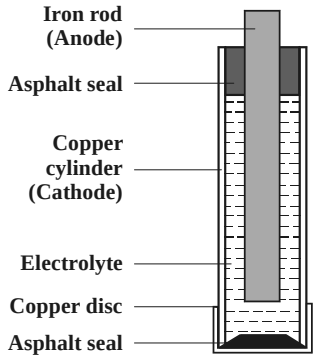

Fig. 4: Arrangement of the iron rod (anode) and the copper cylinder (cathode) in the unit found at Khujut Rabbou'a

Three questions must be answered in this connection:

- Firstly, how did the Parthian goldsmiths connect the iron rod with the copper cylinder?
- Secondly, what kind of electrolyte did they use?
- Thirdly, what voltage and electric current can such a battery supply?

To answer the first question, one needs to remember that thin wire-like bronze or iron rods were found next to the urns, as reported by the archeologists. As a point of departure, one may assume that Parthian goldsmiths might have used them as connecting means between the iron rod and the copper cylinder.

As far as the second question is concerned, the simple answer is that any electrically conductive fluid may be used as an electrolyte. In the course of

time researchers and commentators have suggested various possibilities. Given the fact that acetic acid and citric acid were known to the Parthians, one may assume that they probably made use of them as electrolytes.

To answer the third question, one has to consider that the voltage, which develops in a galvanic cell is determined by the difference between the normal potentials of the electrodes employed. In theory, the voltage of the Parthian Battery amounts to +0.79 V. Experiments carried out by scientists using replicas of the Parthian Battery and different electrolytes have shown, however, that such a cell is capable of generating a voltage of only 0.5 V. The electric current, which flows from such a cell, amounts to a few milliamps [mA].

The electrochemical reactions leading to the build-up of the potential difference between the iron rod and the copper cylinder and the flow of electric current comprise of the anodic dissolution of iron according to reaction <1> and a cathodic reaction of unknown nature, which takes place simultaneously at the copper cylinder.

$$Fe \rightarrow Fe^{2+} + 2e^{-} \qquad <1>$$

Reaction <1> indicates that the iron atoms enter the electrolyte as iron ions (Fe^{2+}) leaving behind electrons (e^{-}), which flow through the external connecting wire towards the copper cylinder to be consumed by the cathodic reaction.

The electric current generated in the cell continues to flow as long as electrons are released at the anode and consumed simultaneously at the cathode. The voltage decreases in the course of time because of the internal

resistance of the cell and the slowness of the electrochemical processes at the electrodes. That is why any electrochemical cell has a limited energy content. Such a battery is rather weak and one has to use several of them in conjunction to produce sufficient voltage and electric current.

Gold plating hypothesis

In order to electrodeposit gold, an anode of gold and the item to be gold plated must be connected through a conductor with the terminals of the electric power source and immersed in a gold salt solution in the plating tank as shown in Fig. 5.

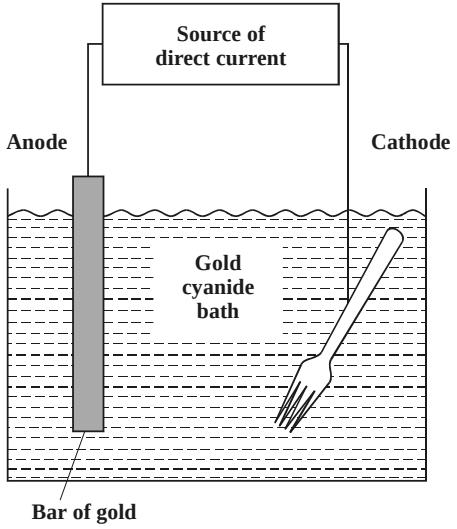

Fig. 5: Apparatus for gold electroplating

In theory, the reduction of gold ions (Au^+) can be described by the following reaction:

$$Au^+ + e^- \rightarrow Au \qquad <2>$$

This reduction reaction requires, however, a potential of 1.71 V, which is remarkably high. For this reason, solutions of gold complex compounds are needed whose deposition potentials are considerably less than that of pure gold. Gold cyanide ions such as $[Au(CN)_2]^-$ are most suitable, since they dissolve easily in water and can be reduced to gold metal according to reaction <3> at a potential of only -0.61 V, which is much lower than that of Au^+.

$$[Au(CN)_2]^- + e^- \rightarrow Au + 2CN^- \qquad <3>$$

The gold cyanide ions are reduced at the cathode where they are deposited as a gold layer on the object to be gold plated. The gold anode replenishes the supply of the gold ions in the electrolyte solution.
The crucial issues at this stage are:

- How did Parthian goldsmiths produce gold cyanide[1] in the first place?
- What type of container did Parthian goldsmiths use to carry out gold plating.

Since there was no solvent for gold in the Parthian era, chemists have come up with various assumptions to demonstrate how Parthian goldsmiths might have obtained gold cyanide. Investigations have shown that gold cyanide can be formed while preparing gold leaf through hammering gold sheets

[1] Gold cyanides were discovered in 18th century and were applied in 1839 by John Wright to plate gold electrolytically.

between leather flaps. Badly tanned, rotten leather causes gold to oxidize and change into a complex gold cyanide compound. Another approach would be to treat gold with crushed fruit stones in aerated liquids. Due to such treatment, one of the components of the fruit stone called amygdalin separates the cyanide ions hydrolytically. Thus, gold interacting with air will oxidize and build a gold cyanide compound.

As far as the gold plating container is concerned, one has to remember that Parthian goldsmiths were highly secretive about their art and never allowed anyone to associate their battery with gold plating. Therefore, vessels found on different excavation sites might have served as plating tank, their real usage, however, went unnoticed by the archeologists.

Medical application hypothesis

König postulated that devices such as those discovered at Khujut Rabbou'a may have also been used by Parthian doctors and magicians to heal patients with electric shocks. The fact that such cells are capable of generating electric currents and such currents are generally of positive clinical effect, confirms König's assumption.

Experts who tend to believe that such devices may have been used for purposes other than gold plating have taken up König's idea. They point to the Mesopotamian medical practice, which included a number of elements conducive to the reception of an electrotherapeutic device of this sort. These researchers believe that Parthian magicians stimulated and excited the nerves of their patients by means of their batteries, and to this end, they used such units connected in series to obtain higher voltages.

Pros and Cons

König's article and book [1, 3], in which he reported on the curious objects found at Khujut Rabbou'a and their possible uses, were published during World War II and did not received much attention. After the war the news of the find aroused much curiosity in the scientific community and engendered many publications [1, 4-36], in which the discovery was outlined and the Parthian Battery was dealt with in great detail. Some authors were in favor of König's views and offered additional arguments to prove his case; others, being highly critical of his gold plating hypothesis, tried their best to prove him wrong.

In the following, the major events which took place after the discovery are reviewed chronologically and some of the scientific activities are outlined in detail.

1938 The German newspaper "The New Leipzig Journal" broke the news of the discovery in greater details and suggested that Parthian goldsmiths were obviously able to employ such apparatuses to produce electric power and electrodeposit gold onto base metal objects. The newspaper pointed out that the existence of such devices was kept strictly secret by these artisans so that only a small circle of initiates knew about it.

1939 By the end of 1938, nothing of the discovery had been published in any language other than German. W. Ley did so in the form of two short reports with the same wording carrying the title "An Electric Battery 2,000 Years Ago". One of the papers was published in America in "Astounding"

[4], the other in England in "Discovery" [5], both by coincidence, in the March issues of 1939.

1940 George Gamow (1904-1968), the famous Russian-American physicist, published a book entitled "The Birth and Death of the Sun", in which he wrote:

»The first practical use of electricity and electric current takes us back to the distant past. In recent excavations at Khujut-Rabua, not far from the city of Baghdad, a very strange type of vessel has been found among the relics that probably belong to the first century B.C. It consists of a vase, made of clay, inside of which is fastened a cylinder of pure copper. Through a thick asphalt cover on its top is driven a solid iron rod, the lower part of which has been eaten away, probably by the action of some acid. This assembly could hardly have been used for any other purpose than that of generating a weak electric current, and was most probably used by Arabian silversmiths, long before the reign of the fabulous Harun al Rashid, for electrogilding their wares. In the backs of little shops in colorful oriental bazaars, electric currents were depositing uniform layers of gold and silver on earrings and bracelets almost thousand years before the phenomenon of electrolysis was rediscovered by the Italian Dottore Galvani and made widely known to humanity.«[1] [6]

Gamow included a hand-drawn sketch of the Parthian Battery in his book, which is reproduced in Fig. 6.

[1] In the first edition of his book published in 1940, Gamow spoke of an "Ancient Arabian Electrogilding", in the 1952 edition, however, he made mention of an "Ancient Persian Electrogilding"

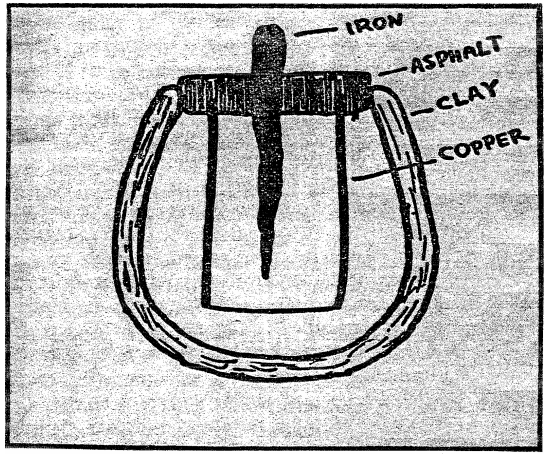

Fig. 6: Gamow's hand-made sketch of the Parthian Battery [6]

One thing König had not tried to do was to find out whether a replica of his battery would work. This was done in 1940 by W. F. M. Gray, an electrical engineer at the General Electric's High Voltage Laboratory in Pittsfield, Massachusetts. Gray volunteered to test König's power source hypothesis by duplicating the Parthian Battery and observing whether it worked. König had given the dimensions of the battery and established the composition of the metals involved analytically. Based on his analytical results, the compositions of the iron rod and the copper cylinder were very close to those commercially available. So there were no difficulties as far as materials for building a replica were concerned. The only unknown factor was the nature of the electrolyte used by the goldsmiths of the Parthian kingdom. However, the choice was somewhat narrowed down to substances that could have been in the use then. Acetic or citric acid was definitely known to the Parthians. Nevertheless, Gray decided to use a

solution of copper sulfate as a likely electrolyte. As solder he applied a 60/40 tin-lead alloy. Fig. 7 shows Gray holding his replica of the Parthian Battery.

Fig. 7: W. F. M. Gray holding the first working replica of the Parthian Battery he built in 1940 [7]

Obtaining electric current from the replica of the Parthian Battery constructed by Gray was considered by many to be one strong proof of the functionality of such a cell.

1957 M. Schwalb published a paper, in which he included the cutaway of W. F. M. Gray's working model of the Parthian Battery to be exhibited at the Berkshire Museum in Pittsfield, Massachusetts. Concluding his paper, he stated:

»Up-and-coming Baghdad silversmiths were goldplating jewelry – using electric batteries….Cleopatra didn't have electric lights in her palace, but some Parthian admirer could easily have sent her a bracelet electroplated with gold.« [8]

1959 In a German technical magazine [9] appeared an article by an anonymous author reporting on the return of an American archeological expedition form Syriac-Persian sites, which had brought along various finds of special interest to the historians of technology and electrical engineers. According to this article the expedition members had performed extensive excavations near the ancient city of Seleucia on the river of Tigris and discovered a number of unglazed small vases. Some of them were empty; others contained iron rods and copper cylinders. The excavators had also found copper discs, short thin metal wires, and pieces of bitumen. Fig. 8 shows the sketch of a replica of one these vases, which was included in this report.

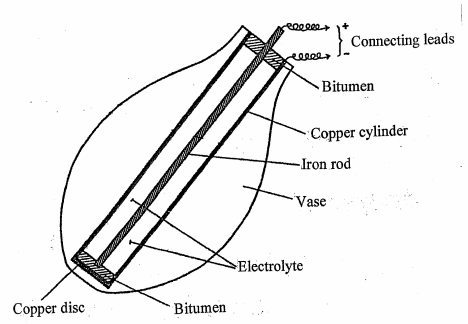

Fig. 8: Schematic representation of the replica of a battery found in Mesopotamia [9]

The vase was, the report stated, 12 cm high and contained a copper cylinder of 7 cm height, in which an iron rod was placed. The electrolyte used to generate electric current was according to this report copper sulfate. The iron rod and the copper cylinder were connected together by means of connecting leads as indicated in Fig. 8.

Also in 1959, a paper was published by E. K. Hornauer [10] who opened his account by telling an interesting story. Referring to an unknown Roman historian he stated that once Julius Caesar took along a golden object as a special present for his beloved Cleopatra. The object, however, was not made of pure gold, but from silver coated by a thin gold layer. The author went on to say that the art of gold electroplating was completely unknown to the Romans and concluded that the gold-plated object in question was from Parthia, where Parthian goldsmiths were true masters of the fine art of electrodeposition of gold.

1960 W. Winkler published a paper [11], in which he reported that he had built a replica of the Parthian Battery. Fig. 9 represents the cross-section of his replica.

As one can see from the sketch in Fig. 9, a metal strip resting over the neck of the vase (on the left side) was Winkler's suggestion for making a connection to the adjacent element to obtain a higher voltage for gold plating purposes. Winkler went so far as to suggest that the elements found in Seleucia would have been used for stationary operations, since the electrolyte had to be replenished or even substituted for, whereas the

galvanic cell discovered at Khujut Rabbou'a was used as a portable power station.

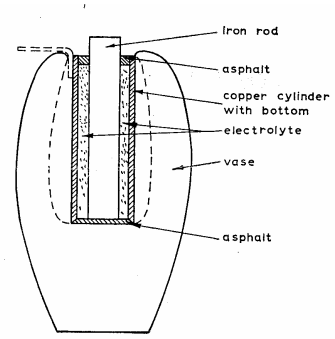

Fig. 9: Schematic representation of the Parthian Battery built by. W. Winkler [11]

In 1960, according to A. Al-Haik's report, evidence was delivered in favor of König's hypotheses by an American scientist. The passage dealing with this event read as follows:

»It is interesting to mention here the extensive research made in March 1960 by Mr. John B. Pierczynski of the University of North Carolina on this intriguing discovery. Mr. Pierczynski conducted laboratory experiments with replicas of this unit and obtained very favorable results. When he used a 5 per cent solution of vinegar or wine as electrolyte, one-half volt of current was gained from each cell for a period of eighteen days. This, he says, is sufficient enough to electroplate silver onto copper. He further expresses the notion that this object may represent the antique forerunner of the electroplating process used by local silversmiths.« [15]

However, in an article published in 1960 by C. MacKechnie Jarvis, strong criticism was expressed with regard to König's hypotheses. Looking for an

alternative explanation for the objects found at Khujut Rabbou'a, the author suggested:

»The object found is a cell of modern origin and its presence in the desert in the neighborhood of Baghdad can be explained by the activity of telegraph enterprise during the second half of the 19th century, when overland telegraphs were erected by the pioneer companies. Alternatively, it is possibly more recent and may be attributed to the desert campaign in Mesopotamia during the 1914-18 War.« [12]

1962 During the summer and fall of 1962, W. Winton from the Science Museum in London had a chance to examine closely the Parthian Battery when he was on mission in Iraq for the reorganization of the Iraq National Museum in Baghdad. He examined the cell and found that "It was in fact as described". In his paper published in 1962 [13], he summarized his observations as follows:

»Perhaps the incredibility is in the mind of the unbelievers and that arrogant pride in our modern scientific achievements makes us unwilling to believe that effects of current electricity could be known to our Mesopotamian ancestors 2000 years ago.« [13]

Winton was, however, dubious about the real usage of this object and concluded his report by a cautionary remark stating that despite all indications, the Baghdad Battery should remain in the realm of conjecture until further and absolutely conclusive evidence was found.

1963 The Christian Science Monitor brought a detailed report on the discovery of the Parthian Battery and its reconstruction by. W. F. M. Gray including the picture shown in Fig. 10.

Fig. 10: Sketch in connection with the report on the Parthian Battery [14]

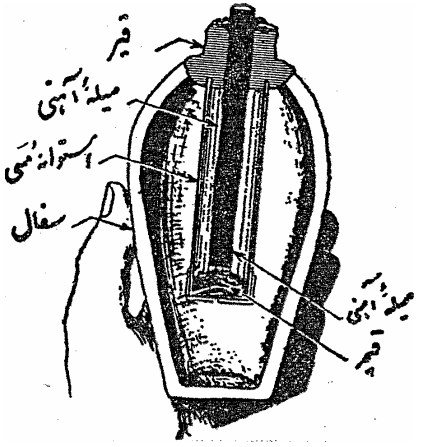

Fig. 11: Cutaway model of the Parthian Battery with explanations in Persian [16]

1967 For the first time mention was made of the Parthian Battery in a Persian book entitled “Iran’s Contribution to the World Civilization” [16] by H. Nayyer-Nouri. Referring to an article published in “Science Digest” in 1957, the author gave a short report on the discovery by König and included the cutaway model built by W. F. M. Gray (Fig. 11).

1972 J. O’M. Bockris and K. K. N. Reddy, the authors of a textbook entitled “Modern Electrochemistry - An Introduction to an Interdisciplinary Area” made mention of the Parthian Battery and stated their views as follows:

»Very remarkable discoveries have been made more recently concerning the apparent existence of a type of crude electrical storage device at least 1400 years before the time Volta (1800). The first discovery was made during excavations in Khjut Rabuah, near Baghdad, by König in 1936. The apparatus (estimated to have originated between 300 B. C. and 300 A. D.) was essentially an iron-copper element. There is evidence that gold plating was carried out in 2500 B. C. Thus, it appears that flowing electricity was only *re*discovered in the 18th century.« [17]

1978 From June 23 to September 24, the Roemer- und Pelizaeus-Museum in Hildesheim, Germany, presented an exhibition under the title “7,000 Years of Art and Culture Between Euphrates and Tigris”. On display were more than 200 objects from the Iraq National Museum in Baghdad giving. Scientists took a keen interest in this exhibition, since among others the Parthian era was presented in great detail. In the exhibition catalogue under the position 182 a photograph of the discovery at Khujut Rabbou’a was reproduced together with a detailed report on its origin and possible usage. “Unbelievable as it sounds, some 1,800 years before Galvani…the

Parthians knew an electrical cell.”, was the description of the display. In the exhibition catalogue, it was pointed out that the Parthian Battery would provide a voltage of about 0.5 V if a 5 per cent tartaric acid solution were used as an electrolyte. A. Eggebrecht, the director of the museum, demonstrated that it was possible to obtain a voltage of about 0.5 V from a replica of such battery using a solution of freshly pressed grapefruit juice. In the exhibition catalogue it was also mentioned that Parthian magicians might have used such devices for medical purposes such as electric shocks and electrotherapy.

Also in 1978, the German journalist G. Kirchner gave an extensive account on Parthian culture and civilization. An extract from his reportage is given below:

»The Parthians must have been a very capable and resourceful people. Unbelievable as it sounds, they did work with electric current almost 2,000 years ago! How do we know that? This can be easily explained on a sensational find, and with the help of an experiment performed by Rolf Schulte, a chemist from Hildesheim.« [18]

Kirchner included in his reportage three photographs to document the gold plating experiment of a small silver figurine.

1979 The exhibition of Art and Culture of Mesopotamia was on display at the Museum für Vor- und Frühgeschichte (Museum for Prehistory and Early History) in Berlin. The exhibition was considered to be most interesting from a scientific point of view, because one more time the Parthian Battery was exhibited. In the description of the display was

mentioned that the copper cylinder and the iron rod were used by Parthian goldsmiths to gold plate silver artworks.

1981 In his paper [19], H. Grossmann strongly supported König's views. He stated that the Parthians were definitely capable of gold plating silver objects and mentioned that a few findings from the Parthian era were in fact made of silver, but plated with an extremely thin gold layer. He also gave a short report on the experiments performed by the scientists of the Battery Development Department of the Robert Bosch GmbH in Stuttgart to solve the enigma of the Parthian Battery.

1982 The German weekly magazine *Die Zeit* announced in its issue No. 45 of November 5th, 1982, under the heading "E as in Electricity" [20] that electricity was used by the Parthians 2,000 years ago. Describing the Parthian Battery in details and representing a sketch of the "Ur-Batterie" (Original Battery), it reported on experiments, which were performed successfully at General Electric's High Voltage Laboratory in Pittsfield, Massachusetts, in 1940, and later confirmed by A. Eggebrecht in 1978. The magazine came to the conclusion that these results were strong proof that the apparatus found at Khujut Rabbou'a was nothing but a battery. It could not help but jump to the conclusion:

»Now there is evidence beyond any doubt that the Parthians, who conquered Mesopotamia in 141 B. C., knew of the electric battery already in the time of Caesar and Cleopatra.« [20]

1984 M. Farshad's book entitled *The History of Engineering in Iran* was published in Tehran [21]. In his short account of the event leading to the discovery of the Parthian Battery, the author gave his own schematic representation of the find without further specifications. His sketch of the Parthian Battery is reproduced in Fig. 12.

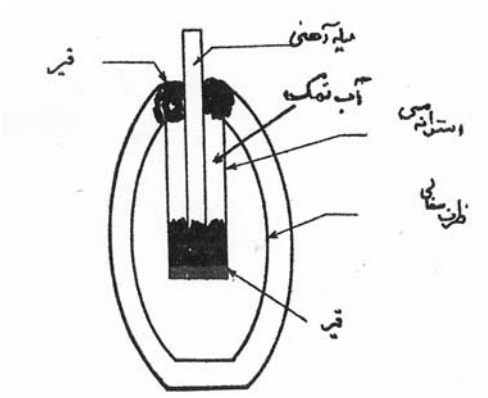

Fig. 12: Cutaway model of the Parthian Battery with explanation in Persian [21]

1985 E. Paszthory published a prolonged article [22], in which he strongly opposed the idea that the so-called Parthian Battery could have been used as a power source to gold plate base metal objects. Referring to the exhibition of Art and Culture of Mesopotamia organized by the Museum for Prehistory and Early History in Berlin in 1978/79 he went on to express his deep skepticism about the experiments carried out then.

Discussing the magical meaning of metals in antiquity, Paszthory argued that objects found at Seleucia and Ctesiphon were only containers for blessings or incantations written on organic materials.

1986 W. Thumshirn published a paper [23] claiming that "The Old Battery", as he put it, "was only to ward off the demons". Following the reasoning and theory put forward by E. Paszthory, he strongly denied that the Parthians could have used batteries to produce electric power. In his view such devices were containers for conjurations, blessings and the like, written on papyrus and deposited to exercise a protective magic spell.

W. Jansen form the University of Oldenburg, Germany, and his colleagues published a paper [24], in which they expressed their views on the Parthian art of gold plating in the following way:

»The Parthians, who conquered Mesopotamia in 141 B.C. and ruled over that region for many centuries, were true masters of gold plating. Their gold coatings are extremely pure and bright similar to those deposited in our times by means of modern electroplating.« [24]

Based on their results, the authors concluded that the assumed reconstruction of the "Ur-Batterie" could not be justified, since it would not allow oxygen to enter the electrolyte contained in the closed-bottom copper cylinder after the already dissolved oxygen was consumed. They conjectured that the old Parthian goldsmiths had been clever enough as to use galvanic cells with open-bottom copper cylinders because they were more effective.

1992 The French author H. Broch published his book carrying the title "Au cœur de l'extra-ordinaire" (In the Heart of the Extraordinary), in which he presented his own version of the Parthian Battery shown in Fig. 13.

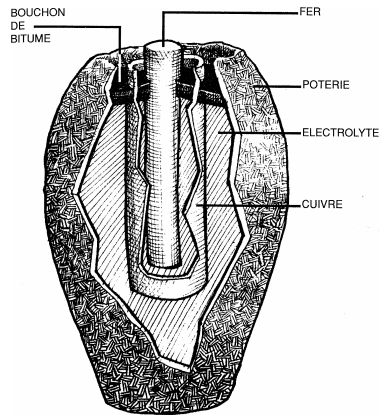

Fig. 13: Schematic representation of the Parthian Battery built by H. Broch [25]

1993 W. Jansen et al. published the 3rd part of their article [26]. They reported on their extensive laboratory experiments carried out under different conditions to study the performance of the Parthian Battery. Using experimental setups equipped with either closed or open-bottom copper cylinder, they could demonstrate the potential of such a device. They investigated the performance of the Parthian Battery as a function of oxygen concentration in the copper cylinder. Since the use of naturally occurring organic acids and sour fruit juices was found to be ineffective, Jansen and his colleagues had the idea of using benzoquinone as an electrolyte, which is known to be easily reduced to hydroquinone at the copper cylinder. A voltage of 0.55 V was obtained with 100 mg benoquinone in 200 mg dilute acetic acid as electrolyte.

Tests carried out in closed-bottom copper cylinders were successful but short-lived because the oxygen in the copper cylinder rapidly depleted, and

as a consequence the current quickly decreased to negligible levels. Experiments performed in open-bottom cylinders were more successful since oxygen could diffuse from the outside into the copper cylinder and maintain the cathodic reaction.
Based on these results, the researchers came to the conclusion that the Pathian Battery described by König was a faulty deviation from the real battery, which contained an open-bottom copper cylinder instead of a tightly sealed one. They postulated that in the case of the real battery, the entire clay jar was filled with electrolyte, and its porous walls would allow oxygen to diffuse into the cell leading to a continuous flow of current.

In 1993 appeared another prolonged article, which dealt with the Parthian Battery at greater length. In this paper [27], the author, P. T. Keyser, stated that the real purpose of the device as well as its origin had remained an enigma. He announced that he would argue why the gold plating hypothesis put forward by König was impossible, and would rather prefer to review the device in the light of the ancient outlook and suggest a proposal more in keeping with the technological and scientific milieu of the time. In short, the author was convinced that Parthian physicians employed such electric cells as a substitute for the use of electric fish as a local analgesic.

1994 A different view was provided by P. Kurzmann [28]. He insisted that Parthian goldsmiths had no knowledge of batteries and pointed out that such vessels, some with bronze rods, others with iron rods, had been found in different locations. Describing the spiritual meanings that the ancients

ascribed to certain metals, Kurzmann suggested that the vessels were intended to provide some magic to the occupants of the graves.

1996 G. Eggert published an article in English [29], in which he took the trouble to check the experiments performed by scientists who were more or less in favor of König's gold plating hypothesis.

In 1996 appeared a detailed article by N. Kanani [30]. The author first provided a brief introduction to the civilization and cultural achievements of the Parthians. He then pointed out that the Parthians were also skilled winegrowers and resourceful wine-merchants. In this connection, he communicated the information that the discovery of a huge Parthian archive in the vicinity of the city of Nisa by Russian archaeologists had brought to light some 2,000 ostraca with 2,758 inscriptions. The majority of these potsherds contained official entries dealing with production and delivery of wine. The author went on to state that in view of magnificently crafted and richly decorated drinking horns from the Parthian period discovered in the course of the centuries, one could certainly assume that the Parthians themselves appreciated the drinking of wine. He pointed out that a copper vessel filled with wine and in direct contact with an iron scoop hanging in it constitutes a plating assembly. He then raised the question:

»Why should we not imagine that one fine day one of those Parthian winegrowers accidentally made an astonishing observation: His iron scoop hanging in the copper bowl filled with wine was covered, God knows why, with a thin layer of copper! Let us suppose just for one moment that this is the story of the Parthian discovery. What could then be the consequence?

As one can imagine, sooner or later some smart people, most probably Zoroastrian magi, happened to learn about this discovery and began to realize how important and far-reaching its practical implications could be. So they decided to do their best to keep this great secret to themselves and to prevent ordinary people from getting close to it. After all they did want to derive the greatest possible benefit from this discovery following the motto „Knowledge is Might!“« [30]

1997 L. E. Warren, the author of a short paper entitled “Did Ancient Cultures Know about Electricity?” [31] made the following remark:

»Modern civilizations tend to believe that they are superior to previous cultures and that these past great civilizations were primitive. We think many of technological wonders were revealed only to us and not to any prior cultures. However, archeological findings in the 20th century have shown this is not the case. Take for instance electricity, which is the source of all power in any modern society.« [31]

1999 D. Downes and A. Meyerhoff constructed in a model of the Parthian Battery and described the construction of their replica as follows:

»To recreate this “battery” we shaped clay into the form of a jar. In order to cut the jar in half, we omitted the firing process and instead shellacked the inside surface to make it non-porous [sic] to liquid. Using a band saw, we cut the jar in half to show the inner workings. We then proceeded to use the band saw to cut the copper cylinder, the steel rod (no iron available), and the rubber stopper (no asphalt available!). We also cut a piece of glass with a glasscutter to place one half of the jar. We epoxied the necessary pieces together. We then filled the jar with vinegar and lo and behold the jar produced 1.1 volts.« [32]

2000 M. Pezold published a new photograph of the Parthian Battery in his article entitled “The Find from Khujut Rabbou’a” [33] and claimed that

König himself had carried out experiments, too. The author failed, however, to be more specific about König’s experiments. Pezold also pointed out that by using other kinds of electrolytes, the battery would be capable of supplying a voltage of about 2 V, again without mentioning the source of his information. Furthermore, he claimed that in 1980 similar objects were discovered at Ctesiphon. He cited Rolf Schulte (cf. Kirchner’s reportage, 1978) as saying that in the mean time a few thousands of such devices have been found. [33]

2002 In his article *The Baghdad Battery - Myth or Reality?* [34], D. E. Von Handorf discussed extensively the possibilities whether the Parthian Battery could have been used for electrodeposition of gold millennia ago.

The Parthian Battery was again on display in 2002 on the occasion of an exhibition at the Museum in Stadtpark, in Grevenbroich, Germany.

2003 In an article entitled *Riddle of Baghdad batteries* [35] A. Frood investigated what could have been the very first batteries and whether these archaeological and technological artifacts were at risk from the impending war in Iraq. The author cited Dr. Paul Craddock, a metallurgy expert of the ancient Near East from the British Museum as saying:

»The batteries have always attracted interest as curios. They are a one-off. As far as we know, nobody else has found anything like these. They are odd things; they are one of life’s enigmas.« [35]

As to the origin and age of the findings, there was another citation in Frood's paper from Dr. St. John Simpson, of the department of the ancient Near East at the British Museum:

»Although this collection is usually dated as Parthian, the grounds for this are unclear. The pot itself is Sassanian. This discrepancy presumably lies either in a misidentification of the age or the ceramic vessel, or the site at which they were found.« [35]

A. Frood raised the question of "How could ancient Persian science have grasped the principle of electricity and arrived at this knowledge?" He then went on to deliver an answer by stating that many inventions are often conceived before the underlying principles are properly understood. As for the possible application of the objects found at Khujut Rabbou'a, he cited Mrs. Marjorie Senechal, a professor of history of science and technology, Smith College, US, as saying:

»I don't think anyone can say for sure what they were used for, but they may have been batteries because they do work. Replicas can produce voltages from 0.8 to nearly two volts.« [35]

In July of 2003 the popular German science magazine P. M. published an article by N. Schirawski entitled "7 Things that Should not Have Existed, or should they?" [36]. One of the these seven things, as expected, was the Parthian Battery. The author opened his account by the observation "Fill the 2,000-years-old clay jar with grapefruit juice, and it will deliver electric current." Including the picture of the Parthian Battery, he went on to describe the discovery by König and the experiments carried out by some researchers.

Conclusions

There is some evidence that the ancient Parthian goldsmiths had inherited various gilding techniques from their ancestors, which enabled them to impart beautiful and permanent finishes to silver or copper artworks and, thus, enhance their apparent values.

W. A. Oddy[1], who has given a detailed account of different gilding techniques used in antiquity, has published the photograph of a Parthian silver bowl from the first century B.C. with bands of gilded decoration.

According to Oddy, the most important gilding techniques employed by the ancients were foil gilding, gold leaf, and fire gilding.

Foil gilding involved tucking a thin gold foil into the edges of the artwork. To secure the foil, grooves were cut into the surface of the artwork into which the edges of the gold foil could be inserted and held in position by hammering them closed.

The gold-leaf method involved pounding gold into the artwork. Compared to foil gilding, this technique had obvious economic advantages, since much less gold was required to cover a given area.

Fire gilding involved the use of gold in an amalgam with mercury. The artwork was cleaned and polished and then a very thin layer of mercury was rubbed into the polished surface. The gold leaf applied on top of this surface would adhere to the object by a process of partial amalgamation.

There were also other techniques available for gilding silver or copper objects. One method often practiced was the etching of baser gold alloys to

[1] W. A. Oddy: *Gilding – an outline of the technological history of the plating of gold on to silver or copper in the Old World*, Endeavor, New Series, Vol. 15, No. 1, 1991, p. 29-33

remove those portions of the surface composed of base metal and so leave a gold-enriched surface.

All these methods had their own specific disadvantages:

Foil gilding was unpopular because the thickness of the foil would obscure any fine detail, which was present on the surface of the artwork. Gold leaf was so fragile that it could hardly be wrapped around the object and had to be firmly attached to the surface of the base metal. Fire gilding was a time-consuming and demanding process.

Did the old Parthian goldsmiths invented the electrodeposition of gold to replace their old gilding techniques, which would leave much to be desired? Needless to say, the mere notion of such a systematical approach by Parthian goldsmiths towards inventing of a new technique would be ridiculous. But, what about making such a discovery by coincidence? W. Jansen and his colleagues remark:

»Presumably, an observation or a series of observations led the Parthians to the discovery of the "galvanic gold plating". The prerequisites for such a discovery were, of course, that the iron and copper electrodes were being immersed in the same solution, the gold bar and the silver object to be gold plated were electrically connected and immersed in a gold salt solution. Is this really believable?« [24]

Does the evidence presented in some of the publications provide convincing arguments that the puzzling find from Khujut Rabbou'a was in fact a galvanic cell, a battery, used for electrodepositing gold?

The question to be answered first is whether the materials needed to build such a battery were available at that time? The answer is that all the materials used to construct the battery were common products and the

manufacture was well within the ability of the "engineers" of that era. And what about the electrolyte? Acetic acid and citric acid were at hand to be used as an electrolyte, although wine and vinegar would have been good enough for that purpose. As for gold cyanide solution, we may believe that the ancient Parthian goldsmiths were well versed in the natural poisons available to them from a number of sources and could somehow concoct the solution they needed. But, what about the arrangement of the iron rod and the copper cylinder in the clay jar? Are we to believe that somebody figured out how to put them together in the right way to make a device capable of supplying a voltage and generating an electric current? Well, an iron nail and a piece of copper in vinegar or wine were all that was needed to experience something strange. After all, to find a source of electric current was the easy part of the story. And, no doubt has been expressed so far that the clay jar with its contents, as described by König, can produce electric current. The issue at stake is whether the battery was used the way he claimed. If only the bottom-sealed copper cylinder was filled with an electrolyte of some kind, then it would not take too long for it to stop functioning. The small amount of oxygen dissolved in the electrolyte would be rapidly consumed, and the electric current flowing from the battery would decrease to negligible levels.

One serious flaw with König's gold plating hypothesis is the lack of gold-plated items stemming from the excavation site at Khujut Rabbou'a. P. Craddock from the British Museums observes:

»The example we see from this region and era are conventional gold plating and mercury gilding. There's never been any untouchable evidence to support the electroplating theory.« [35]

To consider the case definitely proved and closed, one thing must happen. Either a two-thousand-year-old work of art must come to light, which is both gold plated electrolytically and well-preserved, or a remark must be found in some manuscript saying that Parthian artisans or magicians were capable of changing copper, bronze, or silver to gold.

One day, we may be able to answer all the questions raised above; nevertheless, we must accept that the true nature of the Parthian Battery remains for the time being a tantalizing enigma.

In conclusion, let us remember the remark made by W. Winton almost forty years ago:

»The incredibility is in the mind of the unbelievers and that arrogant pride in our modern scientific achievements makes us unwilling to believe that effects of current electricity could be known to our Mesopotamian ancestors 2000 years ago.«[13]

As far as the present fate of the findings is concerned, P. Craddock expresses his hope that they have survived the war in Iraq and states:

»These objects belong to the successors of the people who made them. Let's hope the world manages to resolve is present problems so people can go and see them.« [35]

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