

Gold Extraction from Sakdrisi Deposit (Georgia) at turn of the 4th and the 3rd Millennia BC? Discussion Based on Geological and Mining Arguments

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Abstract: On the analysis of the geological and mining data, discusses the question whether it was possible to extract gold from Sakdrisi hydrothermal ore deposit (Caucasus, Georgia) at turn of the 4th and the 3rd Millennia BC, as some recent publications claim. In order to establish the validity of their assertions, the author has studied and researched the oldest metallurgical centers in Caucasus, history of archaeological studies of Sakdrisi mine, method of radiocarbon (^{14}C) dating, geological type of Sakdrisi deposit, types of gold mineralization, methods of gold extraction from ore deposits and their history. The obtained results are analyzed in two main directions: 1) whether at this stage of human history (at turn of the 4th-3rd millennium BC) there existed sufficiently developed technology for extracting gold from the hydrothermal ores, and 2) how reliable are the Sakdrisi mine dating results by radiocarbon method (^{14}C). The paper argues that the above mentioned publications have not dealt on a sufficiently strict professional level with the question of gold extraction from the Sakdrisi deposit. It explains in detail that gold mining from the Sakdrisi type deposits is possible only by chemical or biological methods, which were discovered at considerably later period, and therefore, could not have been used earlier. The paper points out that the charcoal found in the Sakdrisi mine has been already contaminated due to many factors, and consequently all the results of the radiocarbon dating have to be wrong in any case. Taking into account the study of geological and mining data and established unreliability of radiocarbon dating, the paper considers the possibility of gold extraction from Sakdrisi hydrothermal ore deposit as early as the turn of the 4th and the 3rd Millennia BC to be unrealistic.

Key words: Sakdrisi mine, hydrothermal deposit, gold extraction, radiocarbon method (^{14}C)

1. Introduction

The ancient mine of Sakdrisi, developed in the polymetallic hydrothermal ore deposit of the same name, is located in the central Caucasus, 90 km south from Tbilisi, the capital of Georgia. A number of publications on the topic of archeology that appeared lately claimed that Sakdrisi was the oldest gold mine in the world and extracting of this noble metal from the main ores was carrying out at the turn of 4th and 3rd

millennia BC. The idea was expressed by the Georgian-German archaeological group on the basis of the archaeological studies of the Sakdrisi mine [1-4] that had ignored the genetic type of the Sakdrisi deposit and a mechanism of gold extraction from this type deposit.

According to the modern archaeological research, on the territory of Georgia and the entire Caucasus, extraction of iron, non-ferrous metals and gold was carried out in the 6th and 3rd millennia BC [3, 5, 6]. Unfortunately, archaeological information on mining operations of a later period is insignificant enough, which, naturally, raises serious questions. In author's opinion, there is a tendency of "ageing" the palaeometallurgical history for various reasons, among

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them overdependence on the methods of radiocarbon dating.

Got familiarized in detail with the above-mentioned publications, as a geologist and researcher working on radiometric dating methods, the author considers his duty to express own position on the matter based on scientific confirmations and not on historical emotions.

2. Territory of Georgia as the Oldest Metallurgical Center

Ancient Georgian Kingdoms, Colchis and Iberia have been regarded as one of the most notable places of the world for the early mining and processing of precious metals. Many scientists consider the area that had been settled by the Georgian tribes such as Khaldes, Tubales and Mosnikes, was the original homeland of metallurgy [7-9]. H. Richardson [7] believed that the method of iron mining and steel making technology was discovered in the 14th century BC by the Khaldes, who lived in the Halyse River Canyon (vicinity of modern Trabzon, Turkey).

Higher level of mining activities in the ancient Georgia is also implied by the ancient Greek mythology (Mycenyan myth) about Argonauts' trip in their quest to find the Golden Fleece in the ancient Colchis. Some scholars of the antiquity believed the trip to have taken place in reality. For example, Greek poet Homer (8th c. BC) describes this voyage as a real event in his poem "Odyssey". Roman historian Appian of Alexandria (95-165 AD) also considered Argonauts' trip to the ancient Colchis to be real, and believed the

main purpose of this mission was learning the technique of extracting gold from river placer. Based on the contemporary geological and archaeological studies, the paper's author shares this opinion and consider that they must have traveled to the province Suania, in the northwestern part of Georgia (modern Svaneti), because only in that part of the ancient Colchis it was possible to pan gold from river placer [10]. It is noteworthy that even today the population of Svaneti extracts gold from rivers using sheepskins and they still make for this very purpose special wooden vessels that are unique in their form and functional characteristics. However, in spite of the fact that there is a large number of main gold deposits in this region, and local tradition of gold extraction from placers has a long history, there is no information documenting gold extraction from the main ore deposit as well.

3. Brief description of Sakdrisi Ore Deposit

The Sakdrisi hydrothermal ore deposit [11] presents a part of Bolnisi ore region located in 90 km to the south-east from Tbilisi (Fig. 1). Washing placer gold and smelting metals from ores were carried out since the earliest times that is evidenced by mining remains of smelters [12]. Written recordings on the processing of the ores have been in existence since the middle ages. The recordings from 17th-18th centuries described in detail the mineral deposits of the south-eastern Georgia. They show that in the second half of the 18th century, during the reign of Erekle II, copper and iron were mined intensively.



Fig. 1 Geographic map of the modern Caucasus showing the study object—Sakdrisi hydrothermal ore deposit.

At the beginning of the 19th century, some gold placers were discovered in Bolnisi ore region. This information was given in the report on the economic matters for the government of Tsarist Russia [13]. The report underlined that gold mining was carried out from the alluvial placers in the gorge of the Kazreti River, but nothing is mentioned on gold mining from the main ores. Later in the second half of the 20th century, gold-bearing copper-barite-polymetallic deposits were discovered in some places of the Bolnisi ore region: Madneuli, David-Gareji, Tsiteli Sopeli and Sakdrisi.

Sakdrisi hydrothermal copper-polymetallic and low-sulfide gold-quartz deposit is located on the left bank of the Mashavera River and was formed in the Late Cretaceous period. The copper-polymetallic mineralization is found in lower layers while the gold-quartz slightly sulfide mineralization (secondary

quartzites) in upper exposed part of the deposit.

In the exposed part of the Sakdrisi deposit there are old mines called by the locals Kachaghiani (a den of robbers) (Fig. 2). The mine shaft is dug in secondary quartzite layers where fine inclusions of gold (0.1-0.2 mm) are concentrated in pyrite and chalcopyrite. Gold content in secondary quartzites of the Sakdrisi hydrothermal deposit varies within 0.3-1.2 g/t [11]. It is well known that gold extraction from such deposits is possible only by chemical or biological methods. Although the main mineralization of Sakdrisi hold its own gold containing placers, from which the metal has simply being washed in the past. It is noteworthy that German archaeologists themselves reported that they could not extract gold for analysis from the main deposit, after which they were obliged to obtain gold samples by washing the alluvium [14].



Fig. 2 Sakdrisi deposit hill, where the so-called Kachagiani mines are dug.

4. History of Archeological Study of Sakdrisi Deposit

The deposit of Sakdrisi (historical Abulmugi) gets exposed at the left ridge of the Mashavera River gorge. At this place one can still see the remains of a village that, Vakhushti Bagrationi, a Georgian royal prince (batonishvili), a known Georgian geographer, has mentioned as Abulmugi. He notes that the inhabitants of the village “mine copper, iron and azurite from the ore hill” [15].

The first archaeological researches in the region were carried out by an archaeologist Ioseb Grdzlishvili in 1950's [12]. He was the first who discovered mining adits in Kvemo Bolnisi, Tsiteli Sopeli and Abulmugi. Among the ejected dead rocks

he found and listed coal, ash and tens of stone hammers made of cobblestones. The researcher dated all these mines as the Middle Ages.

In 1980's, the Geological department of Georgia excavated an exploratory gallery in Sakdrisi, which cut through the old mining adit of Kachagiani mines (Fig. 3). The adit was described in detail and measured by geologist T. Mujiri [16], who gave to Abulmugi deposit the name Sakdrisi in his report and expressed an opinion that it may have been functioning since ancient times. Mujiri considered it was necessary to continue archaeological studies of these mines believing that gold mining in the ancient Georgia was possibly carried out not only from placers but from the bedrocks as well [16].



Fig 3 Entrance of the central part of the Kachagiani mine.

Later, in 2004-2007 the Kachagiani mines of Sakdrisi deposit has been closely studied by a German-Georgian archaeological group. As a result they published sensational articles [1-4]. In these publications they basically report the following: “As known at the early periods of Copper and Bronze Ages extraction of gold was carried out by washing only. At present we can confidently say that at turn of 4th and 3rd millennia BC gold was extracted from mines as well [3]. By mines the authors meant the so-called Kachagiani mines of Sakdrisi deposit. This was indeed a bold statement from historical and technological perspective. Let us now consider whether it is consistent with reality.

5. Analysis of the Publications of the German-Georgian Archaeological Group

First of all, it should be noted that in their papers there is less archaeological information than mining and geological data that cannot withstand professional scrutiny. The authors describe “staged mineralizations”, suggest their own version of “ore enriching pits”, etc. Then, they give scanty information on archaeological artifacts and jump into an important conclusion that “it

is therefore evident that the mines in this territory began functioning at the Kura-Araxes period and later the works were resumed although it remains unknown what type of works miners conducted here at the end of 1th millennium BC and at the first half of 1th millennium AC, since there are no clear traces of their activity” [3]. In addition to many uncertainties an important question arises: how did the authors determine at what period the first settlers appeared and what type of work were they conducting. But one thing is clear, the authors wish to believe that mainly the people of Kura-Araxes culture worked there but they “find it hard to explain” what kind of works did the unknown “miners” do who arrived later. However, they answered the question themselves by calling them “miners”.

After this extraordinary declaration the authors describe mining adits and specifically emphasis on presence of stone crushing “hammers”, by means of which, they believe, people mined gold ore in prehistoric times. They assert that the mines were dug with such hammers and list about 10,000 crushing “hammers” (Fig. 4). The presence of such a large amount of hammers they explain by stating that “it was

the matter of working with very hard rocky layers,” mining specialist would only smile at such statement. The author considers this a matter for separate

discussion. However, it is interesting to know whether the archaeologists gave it a serious thought what purpose such huge amount of “hammers” must have served.



Fig. 4 The so-called stone crushing hammers from the Kachagiani mine (Shtolner et al., 2014).

After having finished with “the question of ore mining”, the authors consider “a question of ore enrichment”. They are certain that it was possible to extract gold from crushed secondary quartzite. In addition, they believe the ore was crushed into small pitted stones (Fig.5), which is absolutely unrealistic. At the same time archaeologists do not take into consideration that in gold mining process it is one thing

to enrich ore (i.e. remove barren rock), and quite another to extract gold from the enriched ore. It should be pointed out that enrichment process is one of the most important stage in mining and each mineralization has its own individual scheme of enrichment. However, the authors do devote a short paragraph to this problem: “There are some places in the mine where the ore must have been dissected. This

is confirmed by the discovery of large crushers and broken stones”. Absolutely confident in their assumptions, they note: “At the depth of 5 m” the ore was roughly processed and then “as seen on the ground level the ore was crushed into finer particles”. After dealing with the problem in this vein, the authors come to the final enrichment process: “As for final enrichment of the ore and washing out gold, we assume that a suitable place for this activity must have been Balichi-Dzedzvebi settlement which was in all probability situated between the rivers Mashavera and Ukanagora” [3]. However, they fail to explain the main

thing, namely, by what means or methods did the “prospectors” extract gold from the enriched ores. The researchers refer to the process of gold extraction simply as “this work” and with that they abandon further discussion of this most important question. It should be pointed out that when the researcher archaeologists talk about “gold ores and methods of their enrichment”, nowhere in their publications do they describe mineral content of ores, which is the most important geological component of “this work”. How can one speak about ore enrichment, if it is unknown which mineral gold is associated with.

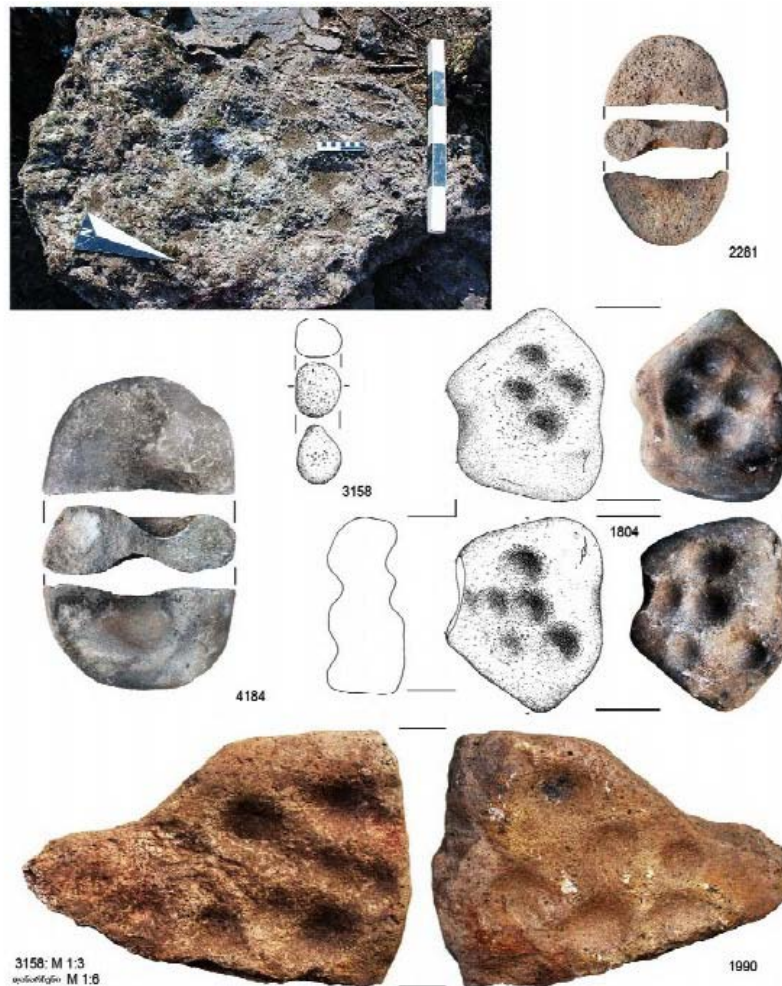


Fig. 5 “Stone tools for ore enrichment” from the Kachagiani mines of Sakdrisi deposit (Gambashidze et al., 2010).

Obviously, here the authors speak about some virtual enrichment schemes without any geological arguments. It should be noted that in these publications the researchers gave their imagination a free reign. For example, they describe "*Balichi-Dzedzvebi settlement*" and state that these settlements "must have been there," i.e. they assume the fact without having any proof of it.

It should be noted that having described the ore "enriching scheme" the group considers all the problems to be solved, although they admit that "*the problem as to where Sakdrisi gold has disappeared is unsolved so far*" [3], at which, naturally, professional geologists cannot help but smile.

After having described the gold mining method, the authors move to the dating of the mine but do it rather superficially; instead they dwell on the subject of the gold's chemical composition that, in my opinion, gives researchers nothing of importance since they make fairly trivial conclusions which have long been known in geology. The group considers even this question in a perfunctory manner and declares that "*the mine has been dated by means of radiocarbon analysis*" that according to the 10 calibrated data varies significantly, namely, from 3100 BC to 2800 BC [1,3].

It should be pointed out that in their brief interpretation of the results the authors describe a noteworthy fact but easily explain away this anomaly: "*The obtained ceramic material belongs to the later period. As it was mentioned, drainage of dead rocks is very long process and, probably, this material must have been mixed in the early layers in the same way. Hence the pottery discovered here must be used cautiously while defining the question of of mining date. One thing is clear, all the well preserved layers analyzed by now contains ceramics characteristic only for Kura-Araxes culture (Table 2)*" [3]. Such an interpretation by the authors is hardly believable since for the purpose of defining the ceramics of Kura-Araxes culture they describe not ceramics themselves but the results of carbon dating referring to

the data of Table 2, so that say nothing about dating by means of the ^{14}C method, about its positive and negative sides, its errors and causes of these errors, etc. It seems they consider the results obtained by dating polluted carbon taken from the bottom of the mine as foolproof.

General conclusions of the above mentioned authors concerning the results of the completed works are even more surprising. For example: "*Ceramics typical for Kura-Araxes culture obtained in Sakdrisi and ^{14}C dates leave no doubt about its early age. Consequently, Sakdrisi is one of the oldest mines in the world. The adits of Sakdrisi precede the oldest gold mines known in the eastern desert of Egypt almost by half a millennium. It is the oldest site where it is possible to study details of mining prehistoric gold. As it is known, in the early periods of Copper and Bronze Ages gold was extracted by washing. Today we can say with confidence that at the end of 4th and beginning the 3rd millennia BC gold was obtained by mining as well*" [3]. According to this statement, gold was extracted from the Sakdrisi main ores not by washing but by another method, but the authors do not specify and neither will they be able to specify what method it might have been since no other method existed at that time. In addition, this text is unfortunately based on wrong data, specifically: 1) it was copper ore, not gold that was extracted from Egypt's oldest mines [17]; 2) in general, gold was known in Egypt 4000-3500 years ago but nobody affirms that it was obtained by processing main ores [18]. To all these statements they add unceremoniously that the Sakdrisi adits are older than Egypt mines almost by half a millennium. The authors should be reminded that according to all the historical sources available in the world, mining was originated in Egypt, and these people created those grandiose cultural masterpieces that fascinate visitors even today. If the inhabitants around the Sakdrisi mine area could extract gold from ores 5000 years ago, so they should have been on a higher stage of civilization than

Egyptians, and that in its turn would have been reflected in their cultural heritage.

Finally, the work by A. Hauptmann and S. Klein "Bronze Age Gold in Southern Georgia" [2], which deserves a special attention, is mentioned by the author. Paradoxically, in this work the authors admitted that in spite of considerable efforts, they could not extract gold from the Sakdrisi main ores and only after washing out the alluvial layers were they able to obtain 20 grains of gold. In fact, this was an acknowledgment that it was impossible to obtain gold from the main ores simply by crushing and washing.

6. Brief Review of the Radiocarbon Dating Method

Carbon dating is one of the radiometric dating methods used to determine the age of biological remains. The essence of the method is the following: it is determined what is the content of the radioactive carbon isotope ^{14}C in relation with the stable isotope ^{12}C in a sample. It is considered that in living organisms this relation is constant and equals to $1:10^{100}$, which in itself is an unstable parameter as the latest studies confirm.

This dating method was suggested by American researcher Willard Libby in 1946 [19] for which he was awarded Nobel Prize in Chemistry in 1960. In comparison with other isotope couples (Sm-Nd, U-Pb, Rb-Sr, Ar-Ar, and others) which exist as constant physical unit (neodymium is a product of radioactive decay of samarium, etc.) there is no genetic relation between radioactive and stable isotopes, which makes the method of carbon dating unreliable.

Carbon as the main component of biological organisms exists as stable isotopes ^{12}C (98.89%) and ^{13}C (1.11%), as well as radioactive ^{14}C (10^{-10} % of total carbons). The latter is continuously formed as a result of collision between the neutrons of cosmic rays and atmospheric nitrogen (^{14}N) in the upper layers of atmosphere at the height of 12-15 km. About 7.5 kg of ^{14}C is formed per year in the Earth's atmosphere and its

total amount equals about 75 tones. ^{14}C , half-life of which is 5730 years in average, undergoes permanent beta-decay. It is believed that the amount of radioactive carbon and stable isotopes in atmosphere and biosphere are approximately equal due to the active circulation in the atmosphere; however in closed spaces circulation is not intense and balance is disrupted in favor of stable carbon isotopes. After the organism's death stable isotope remains while radioactive isotope (^{14}C) begins to decay, hence its amount in the biomass decreases continuously.

Based on this principle, when the initial content of carbon isotopes in organisms and its present ratio ($^{14}\text{C}/^{12}\text{C} = 1/10^{100}$), as well as the half-life of ^{14}C 's (5730 yrs) is known, one can determine the date of the organism's death. The theoretical basis of this method is simple and attractive, but there are a number of interfering factors in the nature because of which the method often gives wrong results [20]. The said method requires the sample (bone or wood) be burned but it must be thoroughly cleaned beforehand. Otherwise the analysis may show significant errors. The analyses for determining the carbon content for the purpose of dating is conducted upon burned samples. It should be noted that the upper limit of dating by radio-isotope method is 60 000 years by now, about 10 times of ^{14}C 's half-life. During this time ^{14}C decreases about 100 times.

It must be pointed out that carbon dating (and radiometric dating in general) makes sense only if natural ratio in isotope system is not off-balanced due to some external factors. For example: if it is not tainted with another matter, it has not undergone secondary changes or has not fallen into some powerful radiation or thermal fields, etc. Samples dating in 20th century is impossible exactly because of their substantial contamination and major errors occur. This clearly speaks for the fact that the carbon dating makes sense only if the sample is absolutely clean.

In addition to the problems related to sample preparation, carbon dating has other methodological

shortcomings as well [20]. I shall mention some of them which are directly connected with the subject under consideration: 1) the statement that the ratio $^{14}\text{C}/^{12}\text{C}$ is constant in the atmosphere is wrong. It depends on intensity of cosmic rays that has varied at different stages of the Earth's history; 2) in humid conditions, ^{14}C oxidizes better than ^{12}C thus unbalancing their ratio and consequently aging the results of dating; 3) in the past the content of ^{14}C in the atmosphere was greatly higher than it is at present, which naturally, leads to the error.

Because of the above listed interfering factors researchers of isotope geochronology consider that the carbon dating is not an exact science and therefore the results obtained with this method are mostly erroneous. In the scientific literature one can find a lot of examples proving falseness of this method [5, 21, 22].

7. Brief Description of Gold Deposits

Gold in the form of nuggets are found most infrequently in the Earth's crust; it is scattered in rocks and minerals as the thinnest intergrowths or inclusions. Its average normal content in the Earth's crust is 0.0031 g/t. The largest portion of gold is concentrated in primary bedrocks and relatively smaller portion is in secondary placers. By means of chemical or biological methods modern highly technological mining industry can obtain gold even if main ores comprise 0.3-1.0 g/t. Accordingly, this content of gold in rocks is considered today as gold deposits.

As a result of long geological transformation and break down of gold deposits, the secondary gold exogenous deposits are formed, the most parts of which are placers. Their formation is conditioned by decomposition of primary Au-containing ores and displacing by water flows. This process is long and complex, during which gold grains are released out of minerals containing them and drifted with water streams. However, due to the high density of gold (about 19 g/cm^3) the grains of size more than 0.5 mm are not carried to a long distance and are deposited at a

few hundred meters or kilometers from the main ore while smaller grains are transported farther.

It is precisely alluvial placer mineralization that are the most profitable gold deposits because gold particles are simply admixed there and they can be extracted simply by washing them out with water. Besides, due to the above described process purity of gold in such deposits is significantly higher than in main deposits. One can say that in this case the nature helps men and carries out a large part of his job. Historically it was precisely the placer gold that attracted man's attention and it is only natural that he began first extracting gold from the ores of this type. It should be noted that till the 20th century gold was mined from gold placers everywhere and "gold rush" in 19th century in United States was associated with gold mining from placers indeed [23].

8. History and Methods of Gold Extraction

There are several methods of gold extraction in the modern gold mining industry, namely: manual, amalgamation, cyanide, and biological method.

Manual method is used to isolate mechanical admixtures of gold placers. The method is facilitated by the high density and stable chemical properties of gold. It is to say, gold is 79 times heavier than water and 7 times heavier than containing placers. At the same time this element does not interact with any natural compounds under the temperature conditions existing on the Earth's surface. Since gold is concentrated in placers as mechanical admixture, it is washed manually with water out of placers. This is the oldest and simplest way to get gold available to men in ancient times and it is successfully used even today.

The first written information about gold extraction by manual methods is given in "History of Nature" by Pliny the Elder (77 AC) [24]. He describes in detail a process of extracting gold from "Las Medulas" (Spain) placers by Romans. The work was done by washing the gold with powerful water jets from the placer.

Amalgamation method. Amalgam is a compound of mercury and metals. Mercury possesses a property encase the finest grains of gold and other metals (except iron) at the room temperature and encapsulate them. However, it does not chemically interact with them. This is how silver, gold, zinc, lead and other metals are amalgamated. After this process is completed amalgam is extracted and the obtained compound heated up; highly volatile mercury (melting point 38.8 °C) evaporates and a pure metal remains. This method of extracting silver from placers was first used in Mexico in 1557. It became widespread production method in USA in 19th century and at present it is successfully used to obtain gold in many countries of the world.

Sodium cyanide (NaCN) Method. Solubility of gold in sodium cyanide was discovered in 1843 by a Georgian chemist, Petre Bagrationi who was at that time working in Petersburg, Russia. Gold extraction by using sodium cyanide in gold industry was first carried out in the USA at the end of 19th century. At present gold extraction using sodium cyanide is widely spread all over the world due to its low price. Essence of the method is simple: finely powdered auriferous enriched ore is sprinkled with sodium cyanide which dissolves gold and deposits it to the bottom. The bottom is covered with a special non-conducting surface where this mass is accumulated. Then the upper, leached mass is removed and gold is extracted from the enriched mass on the surface.

Biological method. This method was discovered in 1958 in USA. It is based on the ability of some microorganisms (bacteria, fungi) to generate cyanide thus providing means to leach gold. Microorganisms obtained in nature or by genetic engineering techniques are infused into ores containing precious metals. Afterwards the mine shaft is filled with water, precious metals float in it; some time later the shaft is drained. This method can be used to extract not only gold but other precious metals as well, such as copper, zinc, etc.

Disadvantage of the method is that the process is long - about 6 months in average.

9. Discussion

Having studied the publications under consideration in detail, the author came to a conclusion that the authors are not versed in ore geology and mining technologies. If we consider the gold concentration in the Sakdrisi deposit (0.3-1.2 g/t) and the methods listed earlier for gold separation: manual, by means of amalgamation, sodium cyanide and biological, as well as effectiveness of these methods, it will be evident that gold extraction from finely dispersed ores is impossible by mechanical method, i.e. by washing. According to the above data, it is possible to extract gold from the main ores of the Sakdrisi deposit by chemical methods only. Since these methods were not known at that time, accordingly, extracting gold by any other means was not possible. In my opinion, no explanation can counter the fact that it is impossible wash out gold by pounding main ore.

The second disputable question is the results of carbon dating of Sakdrisi deposit. In this case a number of questions arise: 1) malfunction of dating methods in general, 2) particularly, the question of purity of an examined sample, and to what extent it was protected from the impact of outside agents.

As the archaeologists claim, the charcoal burned in the Sakdrisi mines is about 5000 years old. However, there is no reliable information under what conditions was it burned, whether it was clean before burning, or anybody has stepped on it, if it was protected from contamination by various external factors, like humidity among them, etc. For this reason at the very first stage of the sample "preparation" a number of the factors arises that render doubtful the results of the Sakdrisi mine carbon dating. In addition, it is unknown whether the structure of dated charcoal taken from Sakdrisi mine was deteriorated. If so, the results will be erroneous in any event because in specimens with

deteriorated structure carbon isotopic ratio breaks down [25].

It is known that carbon is good absorbent and therefore with time it is enriched with chemical elements present in the air, with carbon among them. Because a mine is a closed system, understandably, coal presented there gradually gets enriched with stable carbon (^{12}C) while isotopic one (^{14}C) gets depleted because the latter is formed at higher layers of atmosphere and air circulation in the mine is restricted. Taking into consideration the principle of carbon dating method, the age of the sample declines significantly. In addition, as it was shown above, in the atmosphere of oxidation ^{14}C oxidizes more intensively than ^{12}C and consequently carbon dating in such areas show older data than it really is.

At the end of the discussion, the author would like to answer a question that may arise in the mind of the reader of this article. For what purpose was the Sakdrisi mine developed and what function did it have? The answer cannot be a straightforward one. In the scientific community two versions of the answer are considered. The first is that gold was mined here indeed (as it was considered above), and the second is that the mine had been, in fact, a natural joint that was gradually enlarged by erosion with time. However, in author's opinion, there is also the third version; namely, as Vakhushti Batonishvili tells us in his "Description of Kingdom of Georgia" [15], from the Abulmugi ore hill (to-day's Sakdrisi deposit) they mined copper, iron and azurite. There is no doubt that the great Georgian geographer has described a real fact.

But where exactly were these resources extracted on the Abulmugi hill?

As we know, massive copper-polymetallic ore veins are often found in hydrothermal secondary quartzite. Their width ranges from several centimeters to several meters and they form a complex system of mineralization [26]. Azurite [$\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$] is a secondary carbonate mineral of copper ore oxidation, which is often formed around copper mineralization,

frequently together with malachite [$\text{CuCO}_3(\text{OH})_2$] in water medium. As it seen, Vakhushti Batonishvili describes a really existing geological situation that makes his information more reliable. Thus, taking into account his description we have to concede that mining of copper, iron and azurite from Sakdrisi deposit took place at that time. It is possible that it was in the Kachagiani mine of the Sakdrisi deposit from where azurite was obtained. This version is also strengthened by the fact that the Kachagiani mines follow alongside the rock joint system. As we know, water runs along the joint system too, and azurite is a product of copper oxidation and formed in water-rich medium. Therefore, the mining adits probably moved along the azurite expansion that coincided with the direction of the joints. It should be noted here that azurite was used as a stone for art works and as the best pigment for blue dye in Europe and the Orient since the ancient times. At the Middle Ages azurite was brought to Europe mainly from Afghanistan. Looks like in the 18th century it was obtained in Georgia as well.

As for the function of a great number of boulders present in the Sakdrisi mines, I share the opinion of some experts that they were used for the purpose of defense rather than as hammers. From the toponymal meaning of the place (Kachagiani - a den of robbers) may have been used as a hiding spot for outlaws who used these stones served as weapons. It is possible that the Kachagiani hill had a military defense function at certain time.

As it has been known, such abandoned, closed places became a shelter for various kinds of people; maybe that's why the place is named Kachagiani mines. Naturally they built fire to warm themselves and have some light while hiding there. In author's opinion, this is why we find traces of fire there and not because fire was set for heating rocks, then cooling with water and crushing them, as the authors of reviewed publications assert. As for the tools used to dig a mine shaft in the secondary quartzite, they were, of course, iron tools. Iron was a valuable material at that time and nobody

would have left them in a mine shaft. However, several abandoned iron axes were found there.

10. Conclusion

Thus, based on our multifaceted research concerning gold mining from Sakdrisi deposit, it can be stated that it is impossible to extract gold from the primary main ores of this mine by crushing and then washing it by water. Extracting gold from the main ores of this deposit is possible only by applying chemical or biological methods or by amalgamation. Until these methods were discovered gold mining could not be carried out. The means of gold extraction by the process of amalgamation were discovered in the 16th century AC, chemical and biological methods were learned in the 19th and 20th centuries AC, respectively. If a man could extract gold not from placers but from main ores, he should have had at his disposal highly developed technology, and correspondingly, should have left its trace in history.

As for radiocarbon dating according to which the Sakdrisi mine has been in existence since 3100-2800 BC, it seems unrealistic due to a number of factors such as high probability of sample contamination, oxidizing medium in the mine and unreliability of the dating method itself.

Thus, on the author's firm opinion functioning of the Sakdrisi mine at the end of the 4th and beginning of the 3rd millennia BC and extraction of gold from the main ores at that time is scientifically groundless and unrealistic version. Such version suggested by the authors might point at insufficient professional level of knowledge in mining and radiometric geochronology, or by some other reasons, examination of which is beyond the framework of the current study.

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