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BRONZE AGE IMPACT EVENTS IN LIGHT OF THE ALVAREZ AND AGREST HYPOTHESES

Research article

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Abstract

Recent archaeological discoveries in the Near East are again raising the question of the natural or artificial nature of impact events and their resulting consequences, and stimulating a competition between the hypotheses of M. M. Agrest and L. W. Alvarez. None of the hypotheses still does not look completely convincing, but new data indicate the need for further research and systematization of the phenomena of impact events, their causes and consequences for human civilization. The analysis indicates the need for further searches for traces of crater-forming impact events, including in the Sinai Peninsula, Gaza Strip, Dead Sea and Syria (Abu Hureyra) and for conducting expanded high-precision measurements of radioactivity in these areas, which will allow us to more accurately answer the question of the natural or artificial origin of the destructive consequences of the explosions and shed light on ancient, and possibly modern history.

Keywords: Abu Hureira, Tell al-Hammam, SETI, Alvarez hypothesis, Agrest hypothesis, impact event, radioactive contamination, Bronze Age, airburst, nuclear explosion.

ИМПАКТНЫЕ СОБЫТИЯ БРОНЗОВОГО ВЕКА В СВЕТЕ ГИПОТЕЗ АЛЬВАРЕСА И АГРЕСТА

Научная статья

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Аннотация

Недавние археологические открытия на Ближнем Востоке снова ставят вопрос о естественной или искусственной природе импактных событий и вызванных ими последствий, и стимулируют конкуренцию гипотез М. М. Агреста и Л. У. Альвареса. Ни одна из гипотез до сих пор не выглядит до конца убедительной, но новые данные говорят о необходимости дальнейшего исследования и систематизации феноменов импактных событий, их причин и последствий для человеческой цивилизации. Проведенный анализ указывает на необходимость дальнейших поисков следов кратерообразующих импактных событий, в том числе в районе Синайского полуострова, Сектора Газа, Мертвого моря и в Сирии (Абу Хурейра) и проведения расширенных высокоточных измерений радиоактивности в указанных областях, что позволит более точно ответить на вопрос о естественном или искусственном происхождении разрушительных последствий взрывов и пролить свет на древнюю, а возможно и на современную историю.

Ключевые слова: Абу Хурейра, Телль аль-Хаммам, SETI, гипотеза Альвареса, гипотеза Агреста, импактное событие, радиоактивное загрязнение, Бронзовый век, воздушный взрыв, ядерный взрыв.

Introduction

Big discoveries require bold hypotheses and, fortunately, modern science has plenty of them. The pressing issue of the safety of the planetary biosphere, and above all of human civilization, under the influence of cosmic or other natural phenomena, dictates the need to use any data to recognize and predict the corresponding risks. An important source of such data is archeology.

In the mid-20th century, mathematician, physicist, and participant in the Soviet nuclear program M. M. Agrest suggested that the so-called “gods” from ancient legends could be of extraterrestrial origin, and that the biblical episode telling of the destruction of Sodom could be connected with the use of weapons similar to nuclear weapons. Agrest insisted on conducting archaeological research in the Dead Sea area, and also pointed to the reports of the director of the UAR Institute of Atomic Energy about the discovery of traces of radioactive elements in the areas of Rashi, Darniat and the Sinai Peninsula [1]. Many decades later, work in these areas was carried out, and the results discovered are impressive.

Astrophysicists C. E. Sagan and I. S. Shklovsky addressed this exotic hypothesis back in 1966 in their work “Intelligent Life in the Universe” and assessed it as bold, reasonable, and in need of careful analysis, although it did not have sufficiently convincing material evidence [10, P. 454–464]. This is how the global project of searching for extraterrestrial intelligence SETI (Search for Extraterrestrial Intelligence) began, which may not have produced obvious results (actually, the discovery of this very intelligence), but it has performed and continues to perform a colossal stimulating function, forcing the unification of the efforts of specialists from the most diverse fields of knowledge at the global level, and in a direction different from solving short-term pressing problems of survival and civil strife.

On the other hand, there is an influential hypothesis of impact events of cosmic nature related to the fall of asteroids, proposed by the American physicist Luis Alvarez. These events supposedly led to at least one mass extinction of living

organisms on the planet as a result of the fall of a large asteroid in the area of the Yucatan Peninsula (the Chishkulub crater). Based on the available data, this hypothesis can also claim to explain the findings in the mentioned areas.

The reviewed abundant factual and analytical materials, published on the results of archaeological research in the Dead Sea region, Syria, the Sinai Peninsula and the Gaza Strip, currently speak both “for” and “against” both hypotheses, which will probably arouse the curiosity of researchers from various fields of science and lead to new scientific discoveries in the future.

Main results

2.1. Airburst in Tell al-Hammam

First of all, it is necessary to consider the results of 15 years of excavations and analysis in the northern Dead Sea, in the area of Tell al-Hammam (hereinafter — TeH). It was established that one of the largest settlements of the Bronze Age in this area was destroyed by an airburst (neither a crater in the epicenter nor fragments of the supposed meteorite were found), and the power of the explosion was estimated at more than a thousand bombs similar to the one that exploded in Hiroshima on August 9, 1945, i.e. over 20 megatons in TNT equivalent (the most powerful explosion in history refers to the test of the "Tsar Bomba" AN602, 58.6 megatons). Radiocarbon dating has determined the time of the event to be 1,650 BC. The authors of a collective article in the scientific journal "Nature" analyzed the area and the collected samples in detail and compared the results with the consequences of crater-forming events (meteorite falls), the airburst of the supposed Tunguska meteorite, and the airburst of the Trinity atomic bomb in New Mexico. A comparison of 17 parameters yielded a match of 17/17 with crater-forming events, 17/17 with an air burst in the area of the Podkamennaya Tunguska River, and 15/17 with an air nuclear explosion of the Trinity bomb in New Mexico (the first test of this type of weapon in history). The comparison with crater-forming events in this case has one significant drawback: the absence of a crater. There is also no information about nuclear tests in this area, so the authors chose the air explosion version by analogy with the supposed "Tunguska meteorite". But the meteorite version of the Tunguska event also has the same drawback: the absence of material evidence of the presence of a meteorite, which is why there is a paradoxical situation of a hypothesis based on another hypothesis. As for the "nuclear" version, the authors write the following: «atomic blast produces a wide range of melt products that are morphologically indistinguishable from the melted material found at TeH. These include shocked quartz; melted and decorated zircon grains; globules of melted material; meltglass containing large vesicles lined with Fe-rich crystals likely deposited by vapor deposition; spherules embedded in a meltglass matrix» [6, P. 54].

Despite the striking similarities, there are differences between the TeH and New Mexico airbursts. The first is the elevated concentration of iridium, platinum, and palladium at the suspected epicenter of the TeH blast. The authors did not provide comparative data from the Trinity test site, so it is not possible to verify the correctness of the conclusion. At the same time, iridium, platinum and palladium can be both signs of meteorite impact and have an artificial origin: it is known that they are currently used in the nuclear industry. The second difference concerns the low level of residual magnetism in the ceramic samples from TeH. In this case, again, no data on Trinity is presented and no studies have been found that would allow a correct comparison.

An interesting remark also concerns the elevated concentration of molybdenum in the iron found in TeH: such a concentration is not found in natural terrestrial material, but it is more than 35 times higher than in known samples of iron meteorites [6, P. 38]. However, it is also tens of times lower than in the artificial material ferromolybdenum, widely used in the space industry, so it is premature to claim that the ferromolybdenum found in TeH is artificial. Molybdenum is also widely used in the modern nuclear industry.

The authors of the article on TeH provide a detailed analysis of the so-called shock quartz, as well as the following conclusion: «Our evidence suggests that the lamellae observed in TeH quartz formed during a cosmic airburst under conditions similar to those during the Tunguska airburst and the aerial atomic detonations» [6, P. 27]. Shock quartz is found in large quantities in the Middle East and North Africa (so-called"Libyan glass"), and was also found at the site of the Abu Hureyra airburst, Syria [8]. Some authors [7] disputed the presence of shock quartz in TeH, insisting that the method of examining the samples was not perfect enough. In response to the criticism, another group of researchers tested the samples in ten different ways (including the one proposed by the opponents) and reconfirmed the presence of shock quartz, noting, however, that the structural deformation occurred under the influence of lower temperatures than was initially calculated [11].

The increased iridium content in rocks, conventionally related to the conventional Cretaceous-Paleogene period, at one time allowed Luis and Walter Alvarez to put forward a hypothesis of the mass extinction of dinosaurs and other creatures during this period as a result of the fall of a large asteroid. A trace of such a fall was discovered in the area of the Yucatan Peninsula. The estimated power of the explosion in Yucatan [5] is approximately 5 million times greater than the force of an air blast in the TeH. At present, the impact crater-forming event in Yucatan has been studied quite well and is largely confirmed. This and similar events are everywhere marked by an abundance of shock quartz in the areas of maximum damage.

For several decades, researchers of the Alvarez hypothesis have linked the sizes of shock quartz with the power of the impact event [4], [9], which even leads some of them to the conclusion that shock quartz all over the planet is a derivative of the Yucatan explosion, since the sizes of shock quartz samples seem to decrease with distance from the epicenter [9]. Thus, the maximum size of a fragment of Yucatan shock quartz is indicated as 0.58 mm, and for samples from Eurasia and New Zealand — 0.18 mm [9, P. 268–269]. At the same time, TeH researchers indicate the maximum size of shock quartz samples as 0.85 mm [6, P. 57], i.e. 46% larger than in Yucatan, and in Abu Hubeira the grain size reaches 1.2 cm [8, P. 2], i.e. more than twice as large as in Yucatan, which, given the difference in the estimated explosion force of millions of times, either makes the assumption about the direct dependence of the shock quartz size on the explosion force not entirely valid, or speaks of an even more powerful explosion or even a series of ancient explosions in the Middle East, traces of which in this case have yet to be found, and of an incorrect periodization of events in Yucatan, TeH and Abu Hubeira with a difference of tens of millions of years, since another explosion that led to mass extinction on the planet, based on the current scientific consensus, could not have occurred in the Bronze Age.

At the same time, it still makes sense to consider the version of the explosion in the TeH as a crater-forming impact event, and in this case the trace (or part of the trace) of the crater may be the Dead Sea itself. It is known that this area is at the lowest point in the world on the planet in relation to sea level. The second "record holder" is Lake Assal in Djibouti, and this lake is just a crater, and its salinity reaches 400 ppm. It is known that the Dead Sea is also one of the saltiest on the planet (300–350 ppm). If the Dead Sea also turns out to be a crater, the Alvarez hypothesis can be expanded to several epicenters of the explosion that led to mass extinctions, and the dating of the explosions in the Middle East and Yucatan will need to be rechecked and clarified.

2.2. Shocked quartz and the Alvarez hypothesis

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2.3. The precision of the explosions in Tell al-Hammam and Abu Hureyra.

In thousands of years of history, there is not a single documented case of a human settlement being destroyed by a meteorite or asteroid, and today NASA estimates the probability of such an event at only a few thousandths of a percent [12]. At the same time, Sumerian-Akkadian, Indian, and biblical texts of the Bronze Age report similar events, describing them as the result of the use of "divine weapons."

For example, the Sumerian legend of Ninurta reports the suppression of a rebellion in the mountainous regions where the Tigris and Euphrates rivers originate (apparently the Zagros and Eastern Taurus ranges) using powerful weapons. Geographically, Tell Abu Hureyra is located on a mountain plateau several hundred kilometers from these ranges. It is believed that the settlement in Abu Hureyra was destroyed by an impact event 12,800 years ago [8]. In turn, the air explosion in TeH, as has already been said, is, by a number of indications, quite firmly associated with the biblical story of the destruction of Sodom and is dated to 1,650 BC. Leaving aside all discussions about the exceptional fantastic nature of ancient legends, and also taking into account the population size and density at present and in the Bronze Age, we should note that the probability of such a precise defeat of settlements in TeH and Abu Hureyra by meteorites looks no less fantastic, even despite the conditional time difference between the events of more than 10,000 years.

2.4. Radioactive contamination

There are no known nuclear tests in the Sinai Peninsula area, and the first reports of increased radiation in this area arose, as previously mentioned, in the middle of the last century. Modern studies in the south of the peninsula, within a radius of 150 km. in the Sharm el-Sheikh area, have found levels of radioactive elements above the world average. In order to protect the health and life of the population, it is recommended not to use minerals from this area for construction and other purposes and not to settle in these areas [3]. It is noteworthy that, due to the imperfection of measuring instruments, to determine the uranium content, the authors of the study proceeded from the assumption that they were dealing with natural radiation, and thus used a calculation method through radium-226 using the known proportion of isotopes in the composition of natural uranium — 0.0055% uranium-234, 99.27% uranium-238 and 0.75% uranium-235 [3, P. 78]. Apparently, it makes sense to repeat the measurements using more sophisticated equipment and more reliably determine the natural or artificial nature of the

radioactive substances, especially taking into account the results of another study conducted in the north of the Sinai Peninsula and in the Gaza Strip, where an unnatural ratio of uranium isotopes 238 and 235 was discovered [2]. Of particular interest is the fact that the soil and buildings in the aforementioned areas also contained the isotope americium-241 (a decay product of plutonium), a synthetic isotope used in nuclear weapons and energy. The authors suggested that americium could have been brought to the Gaza Strip with sand from the Algerian nuclear test site (which is 3,200 km from the Gaza Strip), but they generally refuse to explain such an unusual find [2, P. 9]. In turn, the researchers of the air explosions in TeH and Abu Hureyra do not report signs of radioactive contamination of any kind in the radius of the explosions, but another noteworthy detail is noted in the TeH area: according to archaeological data, the ancient city of Jericho, which was affected by the blast wave, repeatedly suffered from military actions, earthquakes and other disasters, but was always rebuilt and populated again, and after the explosion in TeH it was abandoned for centuries [6, P. 50]. A similar fate also later befell many cities during the Bronze Age catastrophe, the causes of which have not yet been reliably established, which forces us to assume that the abandonment of the cities could be associated with radiation contamination due to natural or artificial impact events. It seems that expanded studies of the radioactivity of the areas will confirm or refute this assumption.

Conclusion

Based on the available research materials, a paradoxical situation has emerged. The explosions in TeH and Abu Hureyra, considered to be the result of meteorite impacts during the Bronze Age, are not accompanied by the findings of meteorite craters and fragmentation material and have a high degree of similarity with airborne nuclear explosions. At the same time, no radioactive contamination of the indicated areas is reported. The anomalous proportions of iron and molybdenum found in TeH also cannot be unambiguously attributed to the artificial nature of the explosion. On the other hand, the confirmed extensive radioactive contamination of the Sinai Peninsula and Gaza Strip, including by the synthetic isotope americium-241, is not accompanied by the findings of epicenters of powerful airborne explosions similar to those that took place in TeH and Abu Hureyra. Indirect and still not very reliable evidence of radioactive contamination in the Bronze Age are the results of archaeological research of the ancient city of Jericho, which was hit by the explosion in TeH and abandoned for centuries, and similar examples of abandoned cities during the so-called Bronze Age catastrophe. The high accuracy of the destruction of the ancient settlements of TeH and Abu Hureyra by supposed undiscovered meteorites, the probability of which is vanishingly small, also remains unanswered.

In turn, the Alvarez hypothesis had for a long time the same significant drawback as in TeH and Abu Hureyra — the absence of obvious traces of the fall of a celestial body, presumably leading to mass extinction. At present, this problem has apparently been solved, since a large and deep crater has been discovered in the area of the Yucatan Peninsula. At the same time, it remains unclear why the maximum size of shock quartz samples from TeH and Abu Hureyra is 46–100% larger than in Yucatan, while researchers tend to associate the size of molten quartz with the power of the explosion, which in this case differs, according to estimates, by a factor of millions. Within the framework of the Alvarez hypothesis, it makes sense to consider the possibility that an impact event (most likely another and more ancient than those considered) took place in the Dead Sea area, comparable in strength to the Yucatan event. Considering that this area is located at the lowest point relative to sea level on the planet, and also that the Dead Sea is endorheic and has high salinity, which, by all the above signs, brings it closer to Lake Assal in Djibouti, which is a crater — it can be assumed that the crater cannot be detected primarily because of its colossal size (as was the case with Yucatan, where the diameter of the crater is 180 km).

All of the above points to the need for further searches for traces of crater-forming impact events, including in the Sinai Peninsula, Gaza Strip, Dead Sea and Syria (Abu Hureyra) and conducting expanded high-precision measurements of radioactivity in these areas, which will allow us to more accurately answer the question of the natural or artificial origin of the destructive consequences of the explosions and shed light on ancient, and possibly modern history.

Конфликт интересов

Не указан.

Рецензия

Все статьи проходят рецензирование. Но рецензент или автор статьи предпочли не публиковать рецензию к этой статье в открытом доступе. Рецензия может быть предоставлена компетентным органам по запросу.

Conflict of Interest

None declared.

Review

All articles are peer-reviewed. But the reviewer or the author of the article chose not to publish a review of this article in the public domain. The review can be provided to the competent authorities upon request.

Список литературы / References

1. Агрест М. Космонавты древности / М. Агрест // На суше и на море. — Москва: Географгиз, 1961. — С. 528–542.

2. Abd Elkader M.M. Radiological hazard assessments of radionuclides in building materials, soils, and sand from the Gaza Strip and the north of Sinai Peninsula / M.M. Abd Elkader [et al.] // Scientific Reports. — 2021. — Vol. 11, № 1. — P. 23251. — DOI: 10.1038/s41598-021-02735-9

3. Al-Sharkawy A. Environmental assessment of gamma-radiation levels in stream sediments around Sharm El-Sheikh, South Sinai, Egypt / A. Al-Sharkawy [et al.] // Journal of Environmental Radioactivity. — 2012. — Vol. 112. — P. 76–82. — DOI: 10.1016/j.jenvrad.2012.03.014

4. Bohor B.F. Worldwide Size Distribution of Shocked Quartz at the K/t Boundary: Evidence for a North American Impact Site / B.F. Bohor, G.A. Izett // Lunar and Planetary Institute. — 1986. — P. 1–4.

5. Bralower T.J. The Cretaceous-Tertiary boundary cocktail: Chicxulub impact triggers margin collapse and extensive sediment gravity flows / T.J. Bralower [et al.] // Geology. — 1998. — Vol. 26. — P. 331–334. — DOI: 10.1130/0091-7613(1998)026<0331:TCTBCC>2.3.CO;2

6. Bunch T.E. A Tunguska sized airburst destroyed Tall el-Hammam a Middle Bronze Age city in the Jordan Valley near the Dead Sea / T.E. Bunch [et al.] // Scientific Reports. — 2021. — Vol. 11, № 1. — P. 18632. — DOI: 10.1038/s41598-021-97778-3

7. Jaret S.J. No Mineralogic or Geochemical Evidence of Impact at Tall el-Hammam, a Middle Bronze Age city in the Jordan Valley near the Dead Sea / S.J. Jaret, R. Scott Harris // Scientific Reports. — 2022. — Vol. 12, № 1. — P. 5189–5193. — DOI: 10.1038/s41598-022-08216-x

8. Moore A.M.T. Evidence of cosmic impact at Abu Hureyra, Syria at the younger Dryas Onset (~12.8 ka): High-temperature melting at > 2200 °C / A.M.T. Moore [et al.] // Scientific Reports. — 2020. — Vol. 10. — P. 4185. — DOI: 10.1038/s41598-020-60867-w

9. Morgan J.V. Analyses of shocked quartz at the global K-P boundary indicate an origin from a single, high-angle, oblique impact at Chicxulub / J.V. Morgan [et al.] // Earth and Planetary Science Letters. — 2006. — Vol. 251, № 3–4. — P. 264–279. — DOI: 10.1016/j.epsl.2006.09.009

10. Shklovskii I.S. Intelligent Life in the Universe / I.S. Shklovskii, C.E. Sagan. — Holden-Day, 1966. — 509 p.

11. Silvia P.J. Modeling how a Powerful Airburst destroyed Tall el-Hammam, a Middle Bronze Age city near the Dead Sea / P.J. Silvia [et al.] // Airbursts and Cratering Impacts. — 2024. — Vol. 2, № 1. — P. 1–52. — DOI: 10.14293/ACI.2024.0001

12. Earth Impact Monitoring // NASA Center for Near Earth Object Studies. — URL: https://cneos.jpl.nasa.gov/sentry/ (accessed: 01.10.2024).

Список литературы на английском языке / References in English

1. Agrest M. Kosmonavty drevnosti [Astronauts of antiquity] / M. Agrest // Na sushe i na more [On Land and at Sea]. — Moscow: Geografgiz, 1961. — P. 528–542. [in Russian]

2. Abd Elkader M.M. Radiological hazard assessments of radionuclides in building materials, soils, and sand from the Gaza Strip and the north of Sinai Peninsula / M.M. Abd Elkader [et al.] // Scientific Reports. — 2021. — Vol. 11, № 1. — P. 23251. — DOI: 10.1038/s41598-021-02735-9

3. Al-Sharkawy A. Environmental assessment of gamma-radiation levels in stream sediments around Sharm El-Sheikh, South Sinai, Egypt / A. Al-Sharkawy [et al.] // Journal of Environmental Radioactivity. — 2012. — Vol. 112. — P. 76–82. — DOI: 10.1016/j.jenvrad.2012.03.014

4. Bohor B.F. Worldwide Size Distribution of Shocked Quartz at the K/t Boundary: Evidence for a North American Impact Site / B.F. Bohor, G.A. Izett // Lunar and Planetary Institute. — 1986. — P. 1–4.

5. Bralower T.J. The Cretaceous-Tertiary boundary cocktail: Chicxulub impact triggers margin collapse and extensive sediment gravity flows / T.J. Bralower [et al.] // Geology. — 1998. — Vol. 26. — P. 331–334. — DOI: 10.1130/0091-7613(1998)026<0331:TCTBCC>2.3.CO;2

6. Bunch T.E. A Tunguska sized airburst destroyed Tall el-Hammam a Middle Bronze Age city in the Jordan Valley near the Dead Sea / T.E. Bunch [et al.] // Scientific Reports. — 2021. — Vol. 11, № 1. — P. 18632. — DOI: 10.1038/s41598-021-97778-3

7. Jaret S.J. No Mineralogic or Geochemical Evidence of Impact at Tall el-Hammam, a Middle Bronze Age city in the Jordan Valley near the Dead Sea / S.J. Jaret, R. Scott Harris // Scientific Reports. — 2022. — Vol. 12, № 1. — P. 5189–5193. — DOI: 10.1038/s41598-022-08216-x

8. Moore A.M.T. Evidence of cosmic impact at Abu Hureyra, Syria at the younger Dryas Onset (~12.8 ka): High-temperature melting at > 2200 °C / A.M.T. Moore [et al.] // Scientific Reports. — 2020. — Vol. 10. — P. 4185. — DOI: 10.1038/s41598-020-60867-w

9. Morgan J.V. Analyses of shocked quartz at the global K-P boundary indicate an origin from a single, high-angle, oblique impact at Chicxulub / J.V. Morgan [et al.] // Earth and Planetary Science Letters. — 2006. — Vol. 251, № 3–4. — P. 264–279. — DOI: 10.1016/j.epsl.2006.09.009

10. Shklovskii I.S. Intelligent Life in the Universe / I.S. Shklovskii, C.E. Sagan. — Holden-Day, 1966. — 509 p.

11. Silvia P.J. Modeling how a Powerful Airburst destroyed Tall el-Hammam, a Middle Bronze Age city near the Dead Sea / P.J. Silvia [et al.] // Airbursts and Cratering Impacts. — 2024. — Vol. 2, № 1. — P. 1–52. — DOI: 10.14293/ACI.2024.0001

12. Earth Impact Monitoring // NASA Center for Near Earth Object Studies. — URL: https://cneos.jpl.nasa.gov/sentry/ (accessed: 01.10.2024).