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*We study:
anomalous phenomena.
We consider:
any theories.
We accept:
normal proofs,
exact references.*

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EDITORIAL

TUNGUSKA: 90 YEARS AFTER

This summer coincides with the 90th anniversary of the fall of the famous Tunguska space body (TSB). Any anniversary in science is a good opportunity to review previous work, even if there are no other obvious reasons for that. In this case, however, such reasons do exist. During the last years and decades the TSB investigators have been accumulating a vast amount of information on some TSB-related effects that were not previously studied in detail. These effects include, in particular, anomalies of thermoluminescence of the rocks and soils of the Tunguska area, the regional geomagnetic storm that followed the TSB explosion, atmospheric fallout of strange composition (mainly rare earths), and some other TSB traces that cannot find a place in the framework of the "classical" meteorite (or comet) conception of this event.

Conceivably we are on the threshold of obtaining a comprehensive data set that will allow to build a well-grounded model of the phenomenon. Of course, you can never be sure that the data set is comprehensive indeed. When building such a model, one cannot help but conjecture some its elements. (In fact, this is not so blameworthy: to verify these conjectures means to substantiate the model as a whole.) What is, however, definitely unacceptable in serious scientific research, that is the rejection of well established facts just because they do not correspond to a theoretical model.

In physics there has been developed an effective method of describing mathematically a complicated process or phenomenon which cannot be grasped at first glance. Having taken such a phenomenon in its simplest form and built a rigorous mathematical model, the scientist tries to add new components to the model so as to bring it closer to reality. Whether or not this procedure results in a successful solution of the problem, depends first of all on whether or not the original model reflects the essence of the process under consideration. If it is not the case, no additions, however sophisticated, can bring us to the truth.

The Tunguska event was initially classified as a usual meteorite fall. Its main anomalous feature — the overground character of the explosion — could not be perceived with this assumption in mind. Even after A.P.Kazantsev made out this feature, the "meteorite establishment" tried to convince the scientific community and the reading public that the explosion had been in fact of impact nature. The "disciplinary" values and restrictions proved to be of more importance than the general scientific ones (if we assume that the quest for truth is the main value for science). Formation of an alternative research community, working gratis, from disinterested enthusiasm (that has found its concentrated expression in IITE — the Interdisciplinary Independent Tunguska Expedition — see RB. Vol. 1. No. 3-4, p. 2) has resulted in a much broader freedom of discussion. By the way, this suggests that the "disciplinary values" in science are not purely "ideological".

But if inside this community the problem is now considered with due allowance to its real intricacy, the situation outside it is very different. More often that not (especially for Western scientists), the Tunguska phenomenon serves just as a pretext to build various mathematical models of impact processes in the Solar System, than as a real object of study. This is not useless in itself, but does not open up the way to the solution of this problem. The "logical" rigour of such models sharply contradicts their "empirical looseness".

If we imagine the main alternative ideas of the TSB origin in the form of two "skeletons" (N — "natural": an iron meteorite — a stone meteorite — a comet; A — artificial: an ET spacecraft), then we'll have to admit: the A-skeleton is gradually being filled in with flesh and life, whereas the integrity of the N-skeleton is being maintained only at the cost of ignoring the existing facts. Yes, the N-conception is based on the experience of meteor astronomy, and the A-conception on vague ideas of the "multitude of inhabited worlds". Yes, the former one is logically self-consistent, and the latter rather ambiguous (who can say he has any concrete idea of "possible" parameters of an ET spacecraft?). But the logic of the N-model tends to run counter to the empirical data, accumulated by a few generations of Tunguska researchers, while the "vague" (at first) A-model successfully assimilates these data, assuming a more definite shape.

One of the principal questions, to which the N- and A-conceptions answer in different ways is the question of whether or not the Tunguska explosion was accompanied by nuclear reactions. Both V.K.Zhuravlev and B.F.Bidyukov, whose papers are published in this RB issue, have come to the same conclusion: it probably was. This result has been obtained independently and — what is very important — by different methods.

Strictly speaking, even if this conclusion proves to be correct, it will be just another argument in favor of the A-hypothesis, rather than its ultimate proof. Adherents of the N-hypothesis will certainly try to look for possible natural mechanisms of such a process. It is not improbable that they will succeed, at least to some extent.

But when one model predicts new facts, and the other just tries to explain these facts *post hoc*, the former one should certainly be preferred.

Just as much, the conclusions reached by G.F.Plekhanov and L.G.Plekhanova in their paper "On a Possible Ricochet of the Tunguska Meteorite" hint at the artificial nature of the Tunguska space body. Although the paper has been written in terms of the N-conception, its results seem to fit naturally into the A-conception. In this case the latter tends however to go beyond the bounds of its simplest form (the catastrophe of an ET spacecraft before its landing on the Earth).

And last but not least, the 90th anniversary Tunguska RB issue appears to be a proper place to pay tribute to the late Dr. Alexey V. Zolotov, whose contribution to the development of the A-hypothesis may be safely called crucially important. Having introduced this hypothesis into science, Zolotov was for a long time looking for traces of the Tunguska *nuclear* explosion. It is a pity he did not live to see these traces discovered. It is fortunate that his work was not in vain.

— Vladimir V. Rubtsov

THE GEOMAGNETIC EFFECT OF THE TUNGUSKA EXPLOSION AND THE TECHNOGENEOUS HYPOTHESIS OF THE TSB ORIGIN

V. K. Zhuravlev

1. Introduction

In 1946 the Moscow engineer and science-fiction writer Alexander Kazantsev proposed the hypothesis that the Tunguska event, formerly ascribed to a meteorite fall, had in fact been the catastrophe of a nuclear-powered extraterrestrial spaceship [1]. According to Kazantsev, the complete lack of material remnants of the "meteorite" in taiga, leveled by the tremendous blast over a huge territory, is due to the overground character of the explosion. The altitude of the latter was estimated by the author of the hypothesis as a few hundred of meters.

Since a meteorite can explode only when striking against the Earth's surface, the Tunguska space body (TSB) must have been artificial, or technogeneous. The huge scale of the taiga leveling could be explained by the colossal amount of energy that was released at the time of the explosion, probably of a nuclear nature.

These suppositions stemmed from the close similarity between the Tunguska explosion and the nuclear bombing of Hiroshima, that did not remain unnoticed by Alexander Kazantsev. Each of them could in principle be verified (proved or disproved) by scientific methods, and therefore the hypothesis as a whole is scientific [2].

It was apparently the first attempt in the history of astronomy to explain a phenomenon, related to the sphere of interest of meteoritics, on the assumption of a direct contact with an extraterrestrial civilization. Kazantsev conjectured that the amount of the nuclear fuel that had been carried by the spaceship must have been sufficient for it to return home. Therefore, it seemed possible to deduce from the magnitude of the explosion the distance to the spaceship home planet (even if crudely).

In the mid-twentieth century everyone used to think that technogeneous phenomena were produced by nothing but our own terrestrial civilization. Kazantsev's hypothesis sharply contradicted the general scientific paradigm of those days. It is not surprising therefore that the majority of scientists were more than skeptical about it.

Yet the first expedition sent to the Tunguska site by the Academy of Sciences of the USSR after World War II (in 1958) had to conclude: the TSB explosion did occur in the air [3]. One of the assertions of Kazantsev's, that had seemed ridiculous to specialists in meteoritics, was proven to be true. The altitude of the explosion was found to be even greater than it had been supposed by Kazantsev, namely, 6 ± 1 km. But taken alone, this fact did not fully validate the technogeneous hypothesis.

Proponents of conventional views on the nature of the Tunguska space body perceived the overground character of its explosion as an argument in favor of the TSB cometary origin. Experts in aerodynamics and meteor physics have considered in a number of works possible scenarios and mechanisms of the "explosion-like deceleration" of the Tunguska bolide [4; 5; 6]. At the same time, supporters of the "mad idea" of Kazantsev's began to look for traces of radioactivity in the area of the catastrophe. Soon some positive results were obtained: peat and trees in the Tunguska taiga had been contaminated in 1908 with caesium-137, chlorine-36, carbon-14. But the effect was weak and observed only in certain samples of peat and wood. Besides, the "fresh" radioactive fallout after nuclear tests made interpretation of the anomalies discovered more ambiguous. These investigations encountered both passive and active opposition from established science; by the mid-1970s they had practically came to a standstill [7; 8; 9].

Much to the surprise of the scientists who were convinced of the TSB's natural origin, there were found in 1959 magnetograms of the Irkutsk

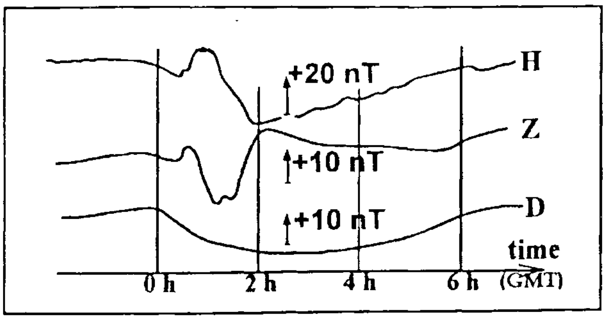

Fig. 1. The geomagnetic storm, dated June 30, 1908, as recorded in Irkutsk. The magnetograms have been corrected for the sun-related daily variation of the geomagnetic field by K.G.Ivanov and V.I.Afanasieva [13].

H — horizontal component of the vector of the geomagnetic field;

Z — vertical component of the vector of the geomagnetic field;

D — magnetic declination.

Arrows with figures show the scale of every magnetogram in gammas (nanoteslas).

Magnetographic and Meteorological Observatory (see Fig. 1) that had recorded a magnetic storm of an unusually short duration (about four hours) that had started 6.6 ± 0.2 min after the moment of the Tunguska explosion. (The latter was calculated from the seismograms of the same observatory, as well as from the barograms of Siberian and European meteorological stations, see Ref. 10.)

The magnetic disturbance, recorded by the three magnetographs of the Irkutsk Magnetographic and Meteorological Observatory on June 30, 1908, had absolutely nothing in common with those induced by invasions of meteor bodies into the atmosphere. It had however all the distinctive features of the disturbances of the geomagnetic field that are generated when nuclear bombs with the TNT equivalent of a few megatons are exploding at heights from 10 to 70 km (Fig. 2, Refs. 11–17).

The geomagnetic effect of the Tunguska explosion is a highly unusual aspect of the phenomenon. To grasp its meaning, one should know not only all the related factual material, but the history of its examination as well. The Irkutsk magnetograms were discovered and analyzed by several researchers independently of one another. What follows is a list of the main stages of the investigation of this most important effect of the Tunguska catastrophe that has remained, strangely enough, rather little-known to the scientific community.

2. The History of the Question

1) In the spring of 1959 two leaders of IITE — the Interdisciplinary Independent Tunguska Expedition, G.F.Plekhanov and N.V.Vasilyev (Tomsk, then the USSR), when compiling a data

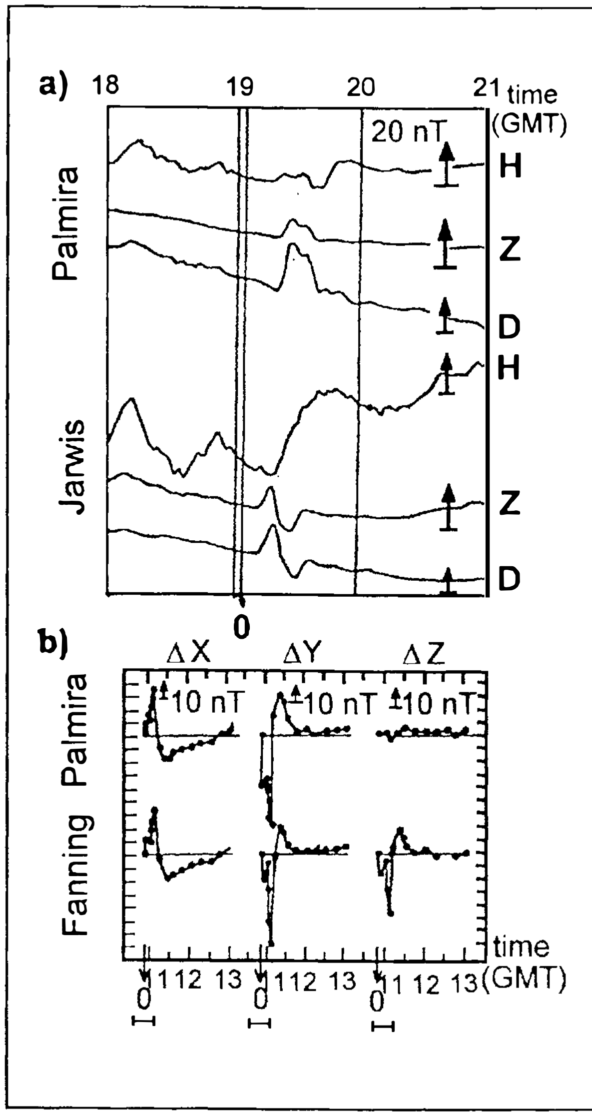

Fig. 2. Geomagnetic storms generated by thermonuclear explosions.

a) Magnetographic records obtained by the stations Palmyra and Jarwis on April 28, 1958, after an explosion over Christmas Island [31]. Designations are the same as in Fig. 1.

b) Magnetographic records obtained by the stations Palmira and Fanning on August 1, 1958, after an explosion over Johnston Island [32].

Δ X — northern component of the vector of the geomagnetic field;

Δ Y — eastern component of the vector of the geomagnetic field.

Δ Z — vertical component of the vector of the geomagnetic field;

Horizontal line segments under the axis of abscissas show duration of the "artificial aurora" accompanying the "artificial geomagnetic storm".

bank on the anomalous atmospheric and geophysical phenomena of 1908 that had preceded the coming of the Tunguska bolide uncovered a short paper published in the journal *Astronomische Nachrichten*. According to it, from June 27 till June 30, Professor Weber, working at a laboratory of Kiel University, observed an unusual geomagnetic effect, namely periodic changes of declination of the magnetic needle [18, p. 63; 19, p. 239]. This date coincides with the beginning of the large-scale optical anomalies in the sky over Europe. These variations lasted from 6 PM (June 27) till 1:30 AM (June 28), then exactly at the same time interval on June 28–29, whereas on June 29 they started at 8:30 PM and stopped forever on June 30, at 1:30 AM again. Since the Tunguska explosion occurred at 0 h 13.59 ± 0.08 min GMT (which corresponds to 1 h 13.59 ± 0.08 min middle European time, that was most probably used by Weber), this means that the variations of the magnetic needle in Kiel stopped 16 minutes after the moment of the explosion. The peak value of the variations reached 2 angular minutes, and their period was equal to 180 seconds.

In 1958 and 1959 there also appeared in some scientific journals first data on the geomagnetic effects, caused by nuclear explosions. Both these data and the discovery of the Weber report gave the IITE researchers impetus to an accumulation of information about geomagnetic conditions in 1908. In 1959 they sent out inquiries to the observatories that were functioning in 1908 in various countries, asking for copies of their magnetograms and other geophysical records.

2) In February of 1960 G.F.Plekhanov received a reply from the Irkutsk Magnetographic Observatory. K.G.Ivanov, a scientist at the Siberian Research Institute of the Terrestrial Magnetism and Propagation of Radio Waves, informed that he had found a strange geomagnetic effect recorded by the Irkutsk magnetometers on June 30, 1908.

Ivanov associated the newly-found anomaly of the variable terrestrial magnetic field with the Tunguska explosion without any reservation. A photocopy of the magnetograms, sent to Tomsk, was critically examined by A.F.Kovalevskiy, V.K.Zhuravlev, G.F.Plekhanov, and N.V.Vasilyev. The IITE investigators came to the same conclusions: on the Irkutsk magnetograms has been recorded a new — this time, geophysical — trace of the Tunguska phenomenon. By then these investigators had at their disposal materials obtained from 18 geophysical observatories of the world. These materials demonstrated that the geomagnetic effect, recorded at the Irkutsk Magnetographic Observatory, was confined to a relatively small region. Even in Ekaterinburg (some 2400 km from the explosion site) the geomagnetic field remained quiescent during the Tunguska catastrophe.

Later, K.G.Ivanov asserted that his search for geomagnetic traces of the Tunguska meteorite had been due to the paper "The Mystery Remains" by F.Y.Zigel [2], and not to the inquiry from Tomsk. In this paper its author emphasized that after proving the overground character of the Tunguska explosion (by the expedition, sent to the site by the USSR Academy of Sciences in 1958) scientists must pay serious attention to the hypothesis of Kazantsev's.

3) In February of 1960 a short paper entitled "On the Geomagnetic Effect of the Tunguska Meteorite Explosion" was published in the journal *Fizika* ("Physics") that was being issued in Tomsk. The paper was signed by Plekhanov, Kovalevskiy, Zhuravlev, and Vasilyev. Referring to K.G.Ivanov, the authors informed the scientific community of the discovery of the unusual geomagnetic disturbance that had proceeded simultaneously with the explosion-induced earthquake. The effect was defined as a regional magnetic storm of an unusually short duration. But the most important feature of the paper was a correlation between this geomagnetic disturbance and the "artificial magnetic storms" that had followed thermonuclear explosions over Pacific atolls in the summer of 1958. The "geomagnetic signatures" of these storms resembled the Irkutsk disturbance of 1908 in every detail. The former were also regional magnetic storms of an unusually short duration (less than one hour).

A.F.Kovalevskiy, having analyzed the Irkutsk and Pacific magnetograms, came in his publication [16] to a very substantial conclusion: "As for the general run of the H and Z [components of the geomagnetic field], this effect does not in fact exceed the differences between the data obtained by different recording stations when monitoring the nuclear explosions."

4) Paper "The Geomagnetic Effects, Observed at the Irkutsk Magnetographic Observatory Immediately After the Tunguska Explosion", written by K.G.Ivanov and sent to *Astronomicheskiy Zhurnal* ("Astronomical Journal", Moscow) was, unfortunately, rejected by the editorial board of the journal and did not appear in the press until 1961 [13]. Its author did hesitate, however, to draw the analogy between the newly-found effect and the artificial magnetic storms induced by thermonuclear explosions. Twenty five years later, in 1986, when having a talk with the author of the present paper, K.G.Ivanov stated that he had recognized this analogy at once, as well as its far-reaching implications. According to Ivanov, A.P.Kazantsev and F.Y.Zigel tried to persuade him to make a public statement on the true significance of the geomagnetic effect of the Tunguska explosion. They believed that the scientific community would listen to the expert opinion of such a competent geophysicist. Yet Ivanov declined the proposal, being certain that this new evidence in favor of the technogeneous hypothesis would not be accepted by official science and could even hamper the Tunguska studies.

5) In 1961 there also appeared in the annual *Meteoritika* ("Meteoritics", Moscow) a survey writ-

ten by G.M.Idlis and Z.V.Karyagina [20]. The authors tried to explain the geomagnetic effect of the Tunguska explosion in the context of the cometary hypothesis. However their own reasoning showed that the effect had had to be global, which sharply contradicted the evidence available. This work was critically reviewed by V.G.Fast, A.F.Kovalevskiy, and G.F.Plekhanov in 1963 [21], after which the geomagnetic effect was never taken into account in cometary models of the Tunguska event.

6) In 1960 O.I.Leypunsky was the first to point to the fact that the nature of the geomagnetic disturbances produced by nuclear explosions and that of the "usual" magnetic storms (induced, as it has been conclusively established, by corpuscular streams of the solar plasma) is essentially the same [22]. These effects must have much in common, giving at the same time somewhat different "signatures" on recording instruments.

7) Both A.F.Kovalevskiy and K.G.Ivanov developed their models of the Tunguska geomagnetic effect, ignoring possible radiation and plasma generation. Even considering different "schemes" of the effect, they agreed with each other that the disturbance had started when the shock wave had reached the ionosphere. This had to give rise to unbalanced processes in the ionosphere (a lasting dynamo-effect, according to Kovalevskiy; formation of an unusual bipolar system of currents over Irkutsk, according to Ivanov). Kovalevskiy believed that the "meteorite" disturbance of the ionosphere was (unlike the "nuclear" one) characterized by a time lag between the moment of explosion and that of the beginning of the first phase of the geomagnetic storm. From this time lag one could determine the altitude of the Tunguska explosion, the result being within reasonable limits.

Why, however, did the "shock mechanism", triggering the geomagnetic disturbance, work only in the "meteorite" case, and not in the "nuclear" one? Even though the energy of the shock wave of a thermonuclear explosion is comparable to that of the Tunguska one, the mechanism of the subsequent geomagnetic storm is fundamentally different: it is triggered by hard radiation of the explosion. The authors of these models blinked at this logical contradiction, trying to remain in the framework of "natural" (i.e. not technogeneous) explanations of the Tunguska phenomenon.

8) Simultaneously with the first paper by K.G.Ivanov, there appeared a short paper [23] written by S.O.Obashev and explaining the Tunguska geomagnetic effect, starting from the model of a plasma cloud containing the explosion products and expanding in the magnetic field of the Earth. Obashev considered the TSB as the icy core of a comet. K.G.Ivanov conclusively showed, however, that this model was unable to explain the duration of the effect.

In my paper [24], published in 1963, it was admitted that comparing the magnetograms of 1908 with those of 1958 did not reveal any principal differences between these explosions. To put it bluntly, the Tunguska explosion could be nuclear.

9) This idea was substantiated by a calculation made by V.K.Zhuravlev, D.V.Demin, and L.N.Demina, and published in 1967 [25]. By that time there appeared in international geophysical journals a number of papers containing rather detailed information on the consequences of high-altitude nuclear explosions. The authors showed that the model of the "shock wave trigger" contradicted the data available and therefore could not explain the Tunguska geomagnetic effect. It was carefully stated that the nuclear nature of the Tunguska explosion could not be ruled out.

10) In 1969 A.V.Zolotov expressed (and motivated) in the monograph [26] his opinion that the geomagnetic effect was a proof of the nuclear nature of the Tunguska explosion. Taking into account the whole set of publications on geomagnetic effects of nuclear explosions, Zolotov developed a semi-quantitative theory of artificial magnetic storm. Based on this theory, he considered in detail the Tunguska geomagnetic effect and demonstrated clearly that attempts to explain the effect by the action of shock waves on the ionosphere were flimsy. According to Zolotov, the Tunguska explosion mush have been accompanied by nuclear reactions. This follows from analysis of the curves of dissipation of shock waves and radiation of nuclear explosions in the atmosphere. When the altitude of the explosion is less than 20 km, the geomagnetic disturbance (a regional magnetic storm) may arise *only* provided that the explosion is accompanied by gamma rays and/or a neutron flux. Other types of radiation are swiftly absorbed by the atmosphere and cannot produce a sufficient amount of electrons that could feed a quasi-stable system of currents existing for hours or even tens of minutes.

11) In 1983, V.K.Zhuravlev and A.N.Dmitriev put forward a new — heliophysical — hypothesis of the TSB origin. According to it, the event should be considered as a link in the chain of the Sun–Earth interactions. The plasma cloud (required by any model of the regional geomagnetic effect) did not originate at the moment of the explosion, but came to the troposphere of the Earth as a "plasmoid", generated by the Sun. When recombining, the plasma emitted hard radiation that gave rise both to the regional magnetic storm and various anomalies on the ground (mutations, thermoluminescence peaks of minerals, etc.) The latter cannot have been explained by the cometary hypothesis and were therefore generally ignored. The new hypothesis has made

it possible to find in the world's geophysical archives important data indicating that the heliophysical and geomagnetic conditions in 1908 were highly abnormal [27; 28].

3. Description and Interpretation of the Geomagnetic Effect

The Irkutsk magnetograms, fixing the geomagnetic effect of the Tunguska explosion (Fig. 1), are described in detail in works [13–15] by K.G.Ivanov and [16; 17] by A.F.Kovalevskiy.

On June 29, 1908, the geomagnetic field was, judging from records of the Irkutsk Magnetographic and Meteorological Observatory, slightly disturbed, but seven hours before the explosion of the Tunguska bolide, it practically calmed down. According to I.P.Pasechnik [29], who determined the moment of the explosion from seismic data, it occurred at 0 h 13.59 ± 0.08 min GMT, on June 30, 1908.

In the populated localities of the Irkutsk province, on the Angara, Podkamennaya Tunguska, and Nizhnaya Tunguska, in the upper reaches of the Lena, where hundreds of eyewitnesses saw a huge bolide flying in the cloudless sky, it was 7:14 AM local time. The TSB exploded at the altitude of 6 ± 1 km (this figure has been calculated by different researchers on the basis of various explosion traces: the size of the standing trees area at the epicenter; parameters of the tree burns; barographic data; eyewitnesses' reports). I.G.Pasechnik believes that it took some 10 seconds for the blast wave to reach the Earth surface (the estimates vary from 2 s to 10 s). The TNT equivalent of the explosion was about 25 megatons, or some 10^{17} Joules.

At 0 h 20.2 ± 0.2 min GMT the horizontal component of the geomagnetic field (H) increased abruptly at 3.5 nanoteslas (nT) and remained at this level for 2.3 minutes. This was the first phase of the disturbance. Its second phase started with a new increase in the H magnitude. In the course of 18 minutes its value reached 23.5 nT (in relation to the magnitude of the undisturbed field). Then the H component did not change for 14 minutes, after which it fell by 67 nT during 1 h 41 min. Its gradual return to the initial level lasted some three hours.

The vertical component of the geomagnetic field (Z) did also change. After a slight increase, coinciding with the first phase of the H-disturbance, the Z component began to fall. There appeared the so-called "negative bay" that is characteristic of usual magnetic storms. At 1 h 5.5 min GMT its peak value reached –25.5 nT (in relation to the "undisturbed level"). Some 25 minutes later the Z component of the geomagnetic field began to increase. It reached its maximum value at 2 h 8 min. At 3 h 20 min the magnitude of the Z component did not differ from its "undisturbed value".

Having introduced a correction for the sun-related daily variation of the geomagnetic field, K.G.Ivanov and V.I.Afanasieva discovered alterations in the magnetic declination D as well. The plane of the magnetic meridian in Irkutsk deviated from its undisturbed position by 10 angular minutes to the west. This deviation persisted during 5–6 hours. On the tapes of the magnetograph this effect has been hidden by the sun-related daily variation of the field.

According to K.G.Ivanov, the Tunguska geomagnetic disturbance passed through the following three stages which are characteristic of usual magnetic storms: a brief initial increase of the field, a longer fall of the H component, and a relaxation towards its original level. Comparing the Irkutsk records with those of "nuclear" magnetic storms, A.V.Zolotov differentiated on both of these types of magnetograms the following four "entries" corresponding to various processes in the atmosphere. The "first entry" (an initial phase of the disturbance) is induced by the front of the magnetohydrodynamic wave that is formed as the plasma fireball expands. Parameters of this phase carry information on the size and temperature of the plasma cloud that will give rise, a few seconds later, to the blast wave.

When a flow of charged particles (ionizing radiation) traverses the ionosphere, there arises a second magnetohydrodynamic wave that is reflected on magnetograms as the "second entry". Its amplitude depends on the radiation flux. The "third entry" (corresponding to the main phase of the geomagnetic effect) is generated by the motion of electrons inside a magnetic trap. The electrons move from the center of the explosion towards a magnetic conjugate point, traversing the geomagnetic equator. The magnetograms enable the speed of the electrons to be determined. Both for the nuclear explosions and for the Tunguska one, it proved to be close to 4 km/s. The time lag of the main phase of the geomagnetic disturbance depends on the magnitude and altitude of the explosion, as well as on its distance from the recording stations.

The "fourth entry" arises when the electron flow comes to the magnetic conjugate point (the end of the magnetic trap), reflects from it and generates another magnetohydrodynamic wave.

Magnetographic data can in principle allow not only the altitude, magnitude and temperature of the explosion to be determined, but also for the type to be established of the ionizing radiation that gave rise to the magnetic storm.

Although the blast wave of a powerful explosion does produce an excess ionization, it remains too low to maintain the system of currents in the ionosphere over a course of several hours. If an explosion occurs below 20 km, then only gamma rays and neutrons can reach the altitudes of the order of 80 km and form there a flow of secondary electrons, sufficient to induce a geomagnetic disturbance.

From Zolotov's theory it follows that the flow of secondary electrons, generated by the Tunguska explosion, must have traversed the geomagnetic equator and reached the regions situated to the south of 60° S. Studying the diaries of R.Shackleton's expedition to Antarctica, N.V.Vasilyev found a record of their observation of an impressive aurora australis not far from Mount Erebus on June 30, 1908. Thermonuclear explosions over the Pacific atolls were accompanied by "artificial aurorae". They appeared simultaneously with the first and second phases of the "artificial geomagnetic storms" (see: Fig. 2b).

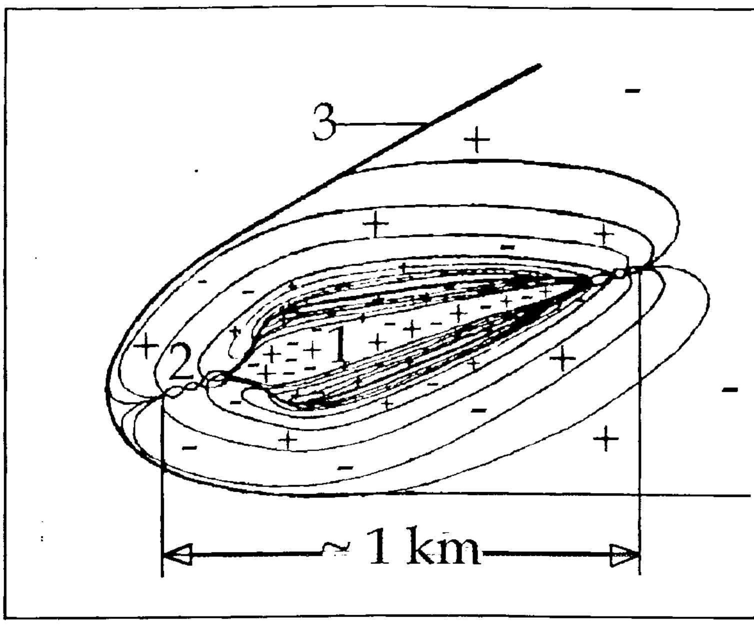

Fig. 3. A model of the solar plasmoid entering the Earth atmosphere [28, p. 123].
1 — plasmoid's body; 2 — plasmoid's magnetosphere; 3 — the ballistic shock wave compressing the plasmoid. Positive and negative signs show the charge distribution. The frame of the plasmoid is formed by the lines of force of the magnetic field frozen in the plasma.

However, Australian researchers D.Steel and R.Ferguson examined archives of the Shackleton expedition and showed this observation to have occurred a few hours *before* the moment of the Tunguska meteorite fall. It would be very desirable to establish the time zone to which the expedition watches were set.

4. The Heliophysical Hypothesis.

TSB investigators used to consider reports of those peasants who had seen the Tunguska bolide "to part from the sun" as an obvious error of "uneducated aborigines". The more so, since one of the educated eyewitnesses noticed that the TSB trail had traversed the sun rays. For some reason or other, the Evenks called, nevertheless, this bolide *dyliachady* — "a solar one". Maybe it was due to its brightness: they used to tell about "the second sun" that had appeared in the sky on June 30, 1908.

The Tunguska problem developed however so unpredictably that in 1983 this naive "model" was reborn as a scientific hypothesis. It was conjectured by A.N.Dmitriev and myself that the TSB was in fact a "plasmoid" ejected from the sun — a sort of the spindle-like "magnetic bottle" containing a considerable amount of plasma and surrounded by an external magnetosphere. When recombining at an altitude of some 6 km over the Earth's surface, protons and electrons of the plasma object generated hard radiation that induced in the ionosphere a space charge. The latter gave rise to a system of currents that produced the regional geophysical effect. The amount of plasma was sufficient to maintain this system of currents for a period of five hours, or so.

Let's try to assess the value of magnetic intensity that is sufficient to maintain plasma capable of releasing energy of the order of 10^{17} Joules (the energy of the Tunguska explosion). The law of conservation of energy for the hypothetical Tunguska plasmoid may be written (possible losses are here ignored) as:

$$w = \frac{U}{V} \qquad (1),$$

where w is the density of magnetic energy of the plasmoid; U is the energy of the Tunguska explosion; V is the volume of the plasmoid.

On the other hand,

$$w = \frac{B^2}{2\mu_0\mu} \qquad (2),$$

where B is magnetic flux density (T); μ_0 is the permeability of vacuum ($1.26 \cdot 10^{-6}$ H/m); μ is relative magnetic permeability of the plasmoid ($\mu \approx 1$).

Since $B = \mu_0\mu H$, where H is magnetic intensity (A/m), then

$$w = \frac{(\mu_0\mu H)^2}{2\mu_0\mu} = \frac{\mu_0\mu H^2}{2} \qquad (3)$$

Inserting Eq. (3) into Eq. (1), we obtain:

$$\frac{\mu_0\mu H^2}{2} = \frac{U}{V} \qquad (4),$$

or

$$H = \sqrt{\frac{2U}{\mu_0 \mu V}} \qquad (5)$$

Strictly speaking, $V = \frac{4}{3}\pi R^3$, where R is the effective radius of the plasmoid, but aiming only at a rough estimate of the figures, we can set $V \approx R^3$. Then

$$H = \sqrt{\frac{2U}{\mu_0 \mu R^3}} \qquad (6)$$

Assuming $U = 10^{17}$ J, and $R \approx 1000$ m, we obtain $H \approx 1.26 \cdot 10^7$ A/m. $B \approx 16$ T.

Such powerful fields have not been detected on the sun as yet. (The maximum recorded intesity of the solar magnetic field does not exceed 2000 Oe, which formally corresponds to the magnetic flux density of the order of 0.2 T only.) True, they exist both in space (on the so-called magnetic stars and white dwarfs) and in terrestrial laboratories (in superconducting solenoids). Thus, trying to explain the Tunguska explosion on the base of the conception of a purely natural solar plasmoid, we came again to a scheme of an object, whose parameters are close to those of some man-made devices.

5. Conclusion

The superpowerful explosion of a space object of unknown origin over the Tunguska taiga produced global disturbances that remained on the tapes of automatic geophysical recording instruments. The seismic, barographic, and actinometric disturbances were discovered as early as the 1930's. However important these effects were, they did not arouse much surprise and were easily interpreted. As for the Tunguska geomagnetic effect, it was not discovered until 1960. Attempts to explain it in the belief that the TSB was just an icy meteoroid entering the Earth atmosphere at a high velocity, have completely failed. Its sole analog proved to be artificial magnetic storms, produced by high-altitude nuclear explosions, only when hard radiation reaches the ionosphere. If it is not the case, there originates no magnetic storm, even if the explosion shock wave is very strong.

Thus, uncovering the Tunguska geomagnetic effect is a discovery of fundamental importance not only for the Tunguska studies, but for science as a whole. A disturbance of the magnetosphere that proceeds according to the "scenario" of a geomagnetic storm, was never observed by astronomers studying meteor phenomena. No isolated individual can be given credit for this discovery, nor even K.G.Ivanov, who found these magnetograms in the archives of the observatory. The discovery resulted from the research work of several scientists whose analytical and computing work did certainly influence each other.

Serious investigations were conducted in the 1960's which enabled the Tunguska geomagnetic effect to be considered as evidence in favor of (if not as a proof of) the technogeneous hypothesis. It can also be regarded as another corroboration of the overground character of the Tunguska explosion. Both the high-altitude explosion and its geomagnetic effect are consistent with the nuclear nature of the explosion, resp., the technogeneous nature of the TSB. But from the "cometary" standpoint, the geomagnetic effect proved to be unnecessary: no serious model of the comet core destruction took this effect into account, just ignoring the very fact of its reality.

This strange situation can be explained rather simply: the effect was difficult to reconcile with the paradigm of modern astronomy, according to which there exist in the Solar System only the following minor bodies: meteoroids (after reaching the Earth surface they are called meteorites), asteroids, comets, and their fragments. If the Tunguska space body was neither a meteoroid, nor an asteroid, it could have been only a comet; no other class of space bodies exists in the Solar System (except, of course, for space dust and solar wind which cannot be considered space *bodies*).

Both the plasmoid hypothesis and the technogeneous one attempted on this paradigm, even though the former tried to remain in the framework of natural sciences. But in principle, it can turn out another version of the technogeneous approach to the Tunguska problem, since this model requires "too high" values of the explosion density of energy, as well as of the intensity of the magnetic field inside the TSB.

At present — when the "cold war" has ended, the military industry is in the process of conversion, and an interest is arising to the problem of defense of our planet against dangerous space objects — there comes a time to revive investigations of this unique effect, discovered in 1960. This revival does not require too much: it would be necessary to collect and reprint publications dealing with the Tunguska geomagnetic effect that are dispersed in hard-to-access books and journals, to open to the scientific community the complete information about the effects of high-altitude nuclear and chemical explosions, as well as to publish the data existent on the geophysical consequences of the catastrophe of "Challenger" and geomagnetic effects of other technogeneous explosions.

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THE THERMOLUMINESCENT IMPRINT OF THE TUNGUSKA EVENT

B. F. Bidyukov

A specter is haunting Tunguska — the specter of radiation. More than once has it been exorcized from the region of the catastrophe and proclaimed non-existent — just to return under the mask of the so-called secondary effects and "background fluctuations". Mutations in the pines, the regional geomagnetic effect, the strange paleomagnetic traces — all these phenomena suggest that the Tunguska explosion was in fact accompanied by nuclear reactions. Unfortunately, no direct traces of these reactions have been discovered as yet.

Of course, if a net of radiation monitors had been positioned at the area before the explosion, the problem would have been solved easily. Is this a mere dream and nothing else? Strange to say, but it seems to be not quite so...

Some 45 years ago American and Japanese scientists attempted to reconstruct the picture of the radiation effects caused by the nuclear explosion in Hiroshima. For this purpose, they used ceramic tiles that had covered roofs of Hiroshima buildings. Tile is a radiation monitor of a sort. It consists of some minerals (in particular, feldspar) that, being exposed to hard radiation, store in their crystal lattice the energy of the radiation, keep it for a long time and release it, when heated up to 400°C, in the form of light. This is the effect of thermoluminescence (TL).

When tile is being made from clay, it is subjected to annealing. As this takes place, the whole energy that was stored in the minerals due to various forms of external radiation, is released. Thereafter the tile "works" as a TL radiation monitor. In Hiroshima this effect helped both to reveal weak radiation traces some ten years after the explosion and to reconstruct the distribution pattern of the radiation effects around the epicenter.

There are however no tile roofs in the Tunguska taiga, and therefore the method does not directly apply in this case. Admittedly one can hope to find some ceramic objects that survived the Tunguska explosion when at a close distance to its epicenter. These might be pots and pans, ornaments, ritual accessories, etc — that is, any article that was annealed when being manufactured.

Unfortunately, up to this time almost no attempts have been made to discover and examine such relics. This work is still to be done (maybe, with the help of ethnographers and archaeologists). True, in 1996 Vitaliy Romeyko gave to the present author a piece of a ceramic pot, which he had found at an old nomad camp some 40 km to the NW from the epicenter of the Tunguska explosion. This piece remains however to be investigated. So far, Tunguska investigators concentrated their efforts on natural TL indicators. These are, first of all, quartz and feldspars, incorporated into bedrock and sedimentary rock in the Tunguska explosion area. If the explosion was accompanied by hard radiation, this fact had to be fixed in the structure of these minerals. In principle, this information can be retrieved from them by some well-known methods.

Reality is however not so simple. Natural minerals crystallized from a melt many millions of years ago. From that time on, they were subjected to perpetual influence of dispersed radioactive elements (uranium, thorium, radium, potassium-40). This increased the energy, stored in the crystal lattice of the minerals. At the same time, the joint action of water, wind, the interior heat of the Earth, and the solar ultraviolet radiation, reduced the energy. The resulting TL pattern is therefore very ambiguous, giving no way of deducing the real "radiation history" of the Earth's crust. Even if a natural mineral was exposed to an additional flow of hard radiation, this fact cannot be established with certainty. The "signal" is difficult to trace against a background of the "noise". Difficult, but not impossible...

In the 1960's – 1980's various minerals from the region of the Tunguska explosion were studied with this object in view (see, for example, Refs. 1–4). These were, in particular, plagioclases from the bedrock traps and a heavy concentrate of quartz and feldspars from the soil. The data obtained were processed with the help of a statistical computer program developed by D.V.Demin [5]. In result, there was revealed an anomaly of the TL field, characterized by two opposing effects: an increase in the TL level against the background one within 10–15 km from the epicenter (the zone of the increase is appreciably shifted to the east, being at the same time axially symmetric in respect to the projection of the eastern variant of the Tunguska space body trajectory), and a decrease in the TL level within a smaller zone (some 5–6 km in the radius) that is as if superimposed on the first [6].

The results are identical for various thermoluminescent materials — plagioclases, separated from the traps, the polymineral heavy concentrate (consisting mainly of quartz and feldspar), that was extracted from the soil, and pure quartz, sampled from this concentrate. The zone of the TL decrease fits well into the area of the radiant burn of the trees. Possibly, this effect was generated by the light flash.

Is this anomaly a sort of natural fluctuation of the background TL level, or is it directly related to the Tunguska explosion? Formerly it was common to assume that the effect of thermoluminescence did not depend on whether the

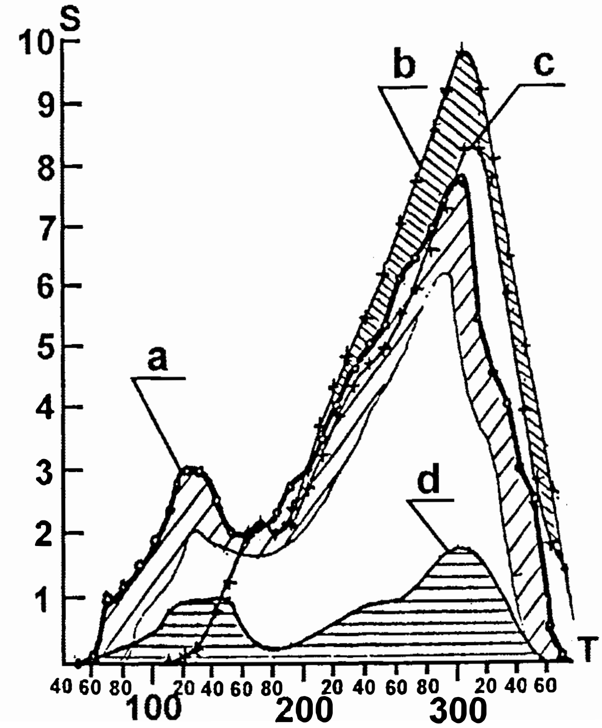

Fig. 1. These curves represent the results of tests on a set of samples of heavy concentrate (No. 409) taken at the foot of Mount Ostraya, Tunguska region.

S — intensity of thermoluminescence (in arbitrary units);

T — temperature in °C;

a — samples exposed to UV radiation;

b — samples not exposed to UV radiation (upper bound of variations);

c — samples not exposed to UV radiation (lower bound of variations);

d — a sample that was first annealed (for two hours) and then exposed to UV radiation.

energy had been stored gradually (which is typical of natural processes) or abruptly (which is typical, in particular, of nuclear explosions). In fact, it is not the case (see: [7]). If a mineral is exposed to a flow of ultraviolet radiation (solar, or artificial), then the naturally-induced TL effect (NTL) is reduced (reaching a minimal level that is characteristic of the mineral). On the contrary, the intensity of the artificially-induced TL effect (ATL) does not alter. This phenomenon provides a way to distinguish between these two types of thermoluminescence.

Figures 1 and 2 show the differences between TL properties of a Tunguska sample and a sample taken far away from the region of the catastrophe. As can be seen from the curves, the ultraviolet radiation does not affect the thermoluminescence of the Tunguska sample. This suggests that the Tunguska explosion was probably accompanied by a burst of hard radiation.

Of course, a closer look at the data is called for. Should the Tunguska TL anomalies be confirmed, this will make it possible to reveal and plot, point by point, a reliable radiation portrait of the event. This would be a big step towards the solution of the Tunguska problem.

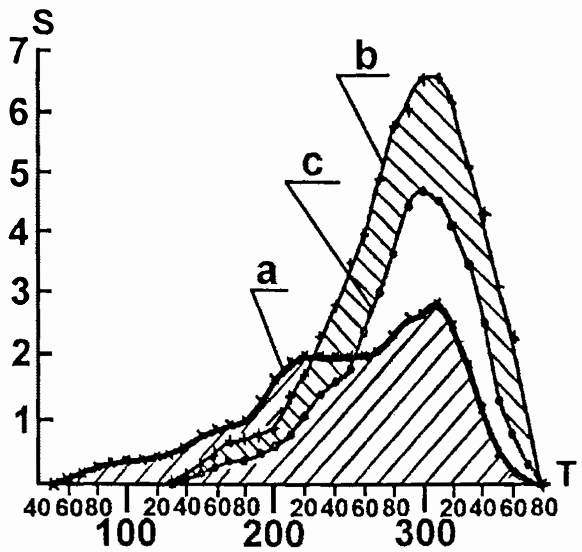

Fig. 2. A control sample of heavy concentrate, taken at the settlement of Belyaki, Krasnoyarsk Territory.

Designations are the same as in Fig. 1.

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ON A POSSIBLE RICOCHET OF THE TUNGUSKA METEORITE

G.F.Plekhanov, L.G.Plekhanova

Material remnants of the Tunguska meteorite (TM) have been looked for in vain during many years, both in the area of the Tunguska catastrophe and outside it. In 1927–1940 L.A.Kulik looked for large fragments of the meteorite, but nothing of this sort has been found. Small particles consisting of meteorite iron were found in 1957 by A.A.Yavnel in samples collected by Kulik and kept at the Committee on Meteorites of the USSR Academy of Sciences; but these had been, most likely, contaminated by the substance of the Sikhote Alin meteorite. True, some quantity of magnetite microspherules was selected from the Tunguska soils in 1961–1962 by the expeditions led by K.P.Florenskiy. In peat layers presumably dated 1908, the expeditions, led by N.V.Vasilyev between 1969 and 1991, discovered silicate spherules as well. But whether these substances should be attributed to the Tunguska meteorite remains vague. Even if it is so, their overall mass does not exceed a few hundreds of kilograms. This evidently does not correspond to the magnitude of the event. The same is true for the results obtained by S.P.Golenetskiy, N.N.Kovaliukh, E.V.Kolesnikov, E.V.Sobotovich, and other researchers who tried to find the TM substance by more sophisticated methods.

The lack of any appreciable material remnants of the Tunguska meteorite brings some authors to set up very exotic hypotheses on the origin of the body and the mechanism of the shock wave formation. We mean such conceptions as an ET spaceship (A.P.Kazantsev and F.Y.Zigel), a nuclear explosion (A.V.Zolotov), an "icy meteorite" (K.P.Staniukovich), a "snowball" (G.I.Petrov), a "solar plasmoid" (A.N.Dmitriev and V.K.Zhuravlev), a "rheological shift" (T.Y.Gorazdovskiy), an "electrical meteorite" (V.F.Solianik), a "magnetic meteorite" (A.V.Zlobin), a "vacuum explosion" (M.N.Tsimbal and V.E.Shnitke), etc. Even if they explain some part of the Tunguska-related empirical data, all these hypotheses seem less convincing than the assumption that the TM was a natural minor body from the Solar System — that is, just a meteorite.

In this case its mass must have been of the order of a million tons. How could it disappear without trace? Let us re-analyze some data that can be found in the available literature, bringing together a few seemingly independent facts. These are: first, the information on a local earthquake at the Greater Pit river [1]; second, unpublished reports of some eyewitnesses who saw a bolide fly at Baykit (310 km to the WNW from the epicenter of the Tunguska explosion) in the morning of June 30, 1908; and third, the scheme of interpolation values of the field of deviations of the mean directions of the leveled trees from a radial pattern (see Fig. 1, borrowed from Ref. 2).

When analyzing this scheme, one can reveal a number of intriguing regularities. Positive deviations prevail in the upper left (NW) and lower right (SE) quadrants of the map; negative ones in the lower left (SW) and upper right (NE) quadrants. Demarcation lines between these zones run practically in the N–S and E–W directions, deviating from them only by 5°. The lines intersect at the point of epicenter, calculated by V.G.Fast [3] from the radial pattern of the fallen forest (with an accuracy of 2 km, being probably shifted up to 2 km eastwardly). The positive deviations in the NW and SE quadrants reach 18°–20°, whereas the negative ones in the NE and SW quadrants reach only 8°–12°.

Many researchers have pointed out that there existed in the eastern (NE and SE) quadrants of the map axially symmetric deviations of the vectors of the forest falling from a strictly radial pattern. A similar effect in the western (NW and SW) quadrants did not attract much attention and must therefore be further substantiated. A total of 346 points exists in the NW quadrants, where deviations from the radial pattern are given. From these deviations 11 ones are of negative sign and 335 of positive sign. In the SW quadrant there exist 567 points, from which 271 points are of negative sign and 296 of positive one. The maximum values of negative deviations (from 5° up to 12°) fall on 52 points, and those of negative ones (from 5° up to 7°) on 27 points. Statistical calculations allow to conclude that the probability of the existence of the axially symmetric deviations in the western part of the leveled forest area exceeds 0.999.

A second peculiarity of the scheme presented in Fig. 1 was indicated by V.G.Fast as early as 1967. It lies in the fact that the vector field of the tree leveling is as if twisted clockwise up to 3.3°. There is no definite explanation of this effect as yet. Attempts to associate it with the Coriolis acceleration, or with a change in the TM path of flight remain unproved. But this strange "vortex" does exist. If we take it into account and correct accordingly our figures (for 3.3° ± 3°), then the positive and negative deviations from the radial pattern will become even more distinct. In the NW quadrant there will be 188 positive deviations versus 11 negative ones; in the SW quadrant 271 negative deviations versus 13 positive ones. This result clearly demonstrates that the axially symmetric deviations are real.

Such deviations, located in the eastern part of the leveled forest area were more than once

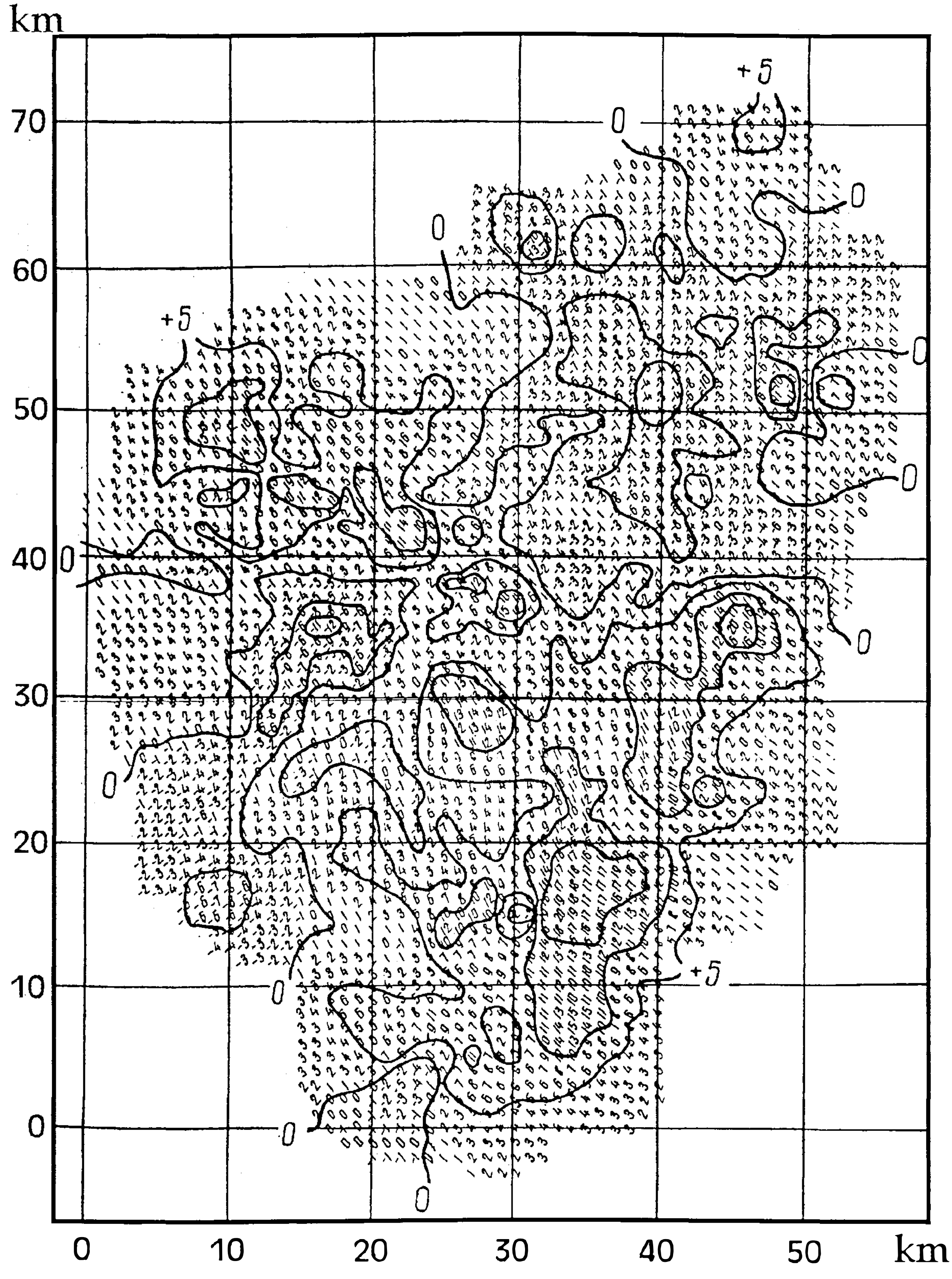

Fig. 1. Interpolation values α (in degrees) of the field of deviations of the mean directions of the leveled trees from a radial pattern. North is up.

interpreted as a trace of the joint action of the ballistic shock wave and the blast wave (or as a trace of the ballistic shock wave only, if the body moved in a steep path and the intensity of the wave increased at the final stage of its flight). Then the similar (even if less distinct) deviations from the strict radial pattern existing in the western part of the area can be explained in a similar way: as a trace of the ballistic shock wave. But from which body it came? The Tunguska meteorite itself is supposed to explode having not reached the western quadrants of the map. Therefore these might be either powerful air streams that had accompanied the TM in its motion through the atmosphere, or a part of the meteorite that had survived the explosion, or, at last, the meteorite itself (contrary to the popular belief). The air streams are not a compact body and they could hardly generate a ballistic shock wave that deflected falling trees at a distance of up to 20 km. Therefore the meteorite (or a piece of it) had, in addition to the falling branch of its trajectory (in the eastern part of the leveled forest area) the ascending one as well (in the western part of the area). This may be interpreted as a ricochet of the meteorite body.

The hypothesis that the Tunguska meteorite could have ricocheted from the lower atmosphere was advanced more than once — by A.A.Abramov, I.S.Astapovich, E.A.Iordanishvili, and V.A.Khokhryakov. Ricochets of some meteoroids have in fact been instrumentally detected. The results of the foregoing analysis can be considered as a factual proof of this assumption.

But if the "ricochet hypothesis" is true, then the Tunguska body, or a fragment of it, must have moved further. What was its final lot? Here two variants seem to be admissible. If the TM velocity was greater than 8 km/s, it left the atmosphere of the Earth and continued its motion in space. But if its velocity was not so great, it had to fall on the Earth surface at a point situated at an extension of its trajectory. Here seems to be of relevance a letter of P.L.Dravert, published by I.S.Astapovich. Its author reports about an earthquake that occurred in the Yenisey taiga on June 30, 1908. "The seism covered a region that lay approximately between 58°10′ and 59°20′ S, 93°00′ and 94°45′ E, probably extending further to the east. The magnitude of the earthquake reached VI on the Rossi–Forel scale." [1]

In relation to the epicenter of the Tunguska catastrophe this region lies at a distance of some 450 km to the west and 100–120 km to the south. If we suppose that the Tunguska meteorite ascended at an angle of 40°±5° and fell finally at this place, then its speed must have been in the order of 6 km/s. A deviation of 15° to the south seems to be acceptable, since the "vertical" ricochet may have been accompanied by a "horizontal" one. At the same time, it is not improbable that the "earthquake in the Yenisey taiga" was just another aftermath of the Tunguska catastrophe. Similar "earthquakes" were noticed by witnesses of the Tunguska event at comparable distances to the south from the epicenter. But were it a local earthquake indeed, it could result from the repeated fall of the TM or its part. In this case the few eyewitness testimonies describing the bolide as observed to the west from the epicenter and moving westward, should not be thought of as evidently erroneous.

P.L.Dravert supposed that the Tunguska meteorite might finally fall at another place — namely, in the upper reaches of the Ket' river (the Tomsk Region). However this assumption has been refuted when a group under N.V.Vasilyev's guidance explored the region in 1960, thoroughly questioning local inhabitants. Although there are large belts of leveled trees in this territory, their falls are dated to various years, being prevailingly directed to the east. This is the dominant wind direction in the region, and therefore these belts of leveled trees are, most likely, simple windfalls.

Thus, the axially symmetric deviations of the vectors of the forest falling from the dominating radial pattern that are observed in the western part of the leveled forest area lead us to the assumption of the TM ricochet. Information on a local earthquake that occurred in the upper reaches of the Greater Pit river gives grounds to believe that the meteorite, or its part, fell in this region, and some eyewitness accounts support this assumption.

To verify it, much work needs to be done. It would be necessary to question possible eyewitnesses of the event, or their immediate descendants, as well as to study carefully contemporary records. Detailed aerial photographs of the region must be scrutinized for any unusual (for example, crater-like) formations. If such traces are discovered, they are to be explored on the site.

This is a challenging task, however. An attempt to find eyewitnesses of the earthquake, carried out by A.G.Ilyin [4], has not been successful. There is in this region no native population: workers of gold mines went away as far back as before 1917 and the present-day inhabitants are all newcomers. Therefore there is very little hope of finding any eyewitnesses or their descendants. Whether or not any relevant information has been preserved in archives, remains unknown. A detailed exploration of the region from the air or on foot would be very time- and money-consuming. But in any case, we can conclude, based on the results of our analysis of the map of the forest leveling that the trajectory of the Tunguska meteorite had an ascending branch to the west of the epicenter of the explosion. This may be called a ricochet.

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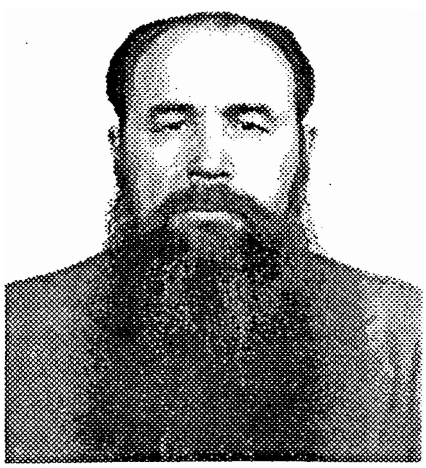
ALEXEY V. ZOLOTOV: IN MEMORIAM.

On October 6, 1995, ended in tragedy the life of the famous student of the Tunguska problem Alexey V. Zolotov.

Zolotov was born on March 16, 1929. After finishing at the radiophysical faculty of Gorki University, he worked first at the town of Oktiabrskiy (Bashkiria, Russia, then the USSR) and later, until his premature death, in Kalinin (now Tver). Dr. Zolotov was an eminent geophysicist, a specialist in radiation logging in boreholes and organizer of the Kalinin branch of the All-Union Institute of Geophysics.

He really burst, rather than just came, into the Tunguska problem in 1959, daring to openly support the technogeneous hypothesis of the Tunguska space body (TSB) origin. Even if the hypothesis as such had been put forward some 15 years before, by A.P.Kazantsev, it was Alexey Zolotov who ventured to scientifically substantiate this controversial assumption. This was a bold and even risky attempt for a professional scientist. But having taken Kulik's path in 1959, he did not leave it until his very last days. One cannot imagine Dr. Zolotov's life in science outside of the Tunguska problem; nor can the history of this problem be separated from his name.



Alexey V. Zolotov, 1929–1995

Many a scientist made a contribution to development of the Tunguska studies, but only a few may be named pioneers of this research field. Alexey Zolotov was among the latter; that's why he was heavily criticized more than once. Sometimes his critics were objective and well-disposed, but more often than not unfair and biased. Dr. Zolotov had enough courage, certitude of being in the right, and a high inner culture, to never traverse the verge of scholarly correctness and ethics in his objections to the opponents.

Alexey Zolotov was not a mere theoretician: starting with 1959, he conducted regular field investigations in the Tunguska region. Having his own scientific style, as well as profound intuition, Zolotov was one of few students of the Tunguska problem who tried to embrace it in all its complexity. It is no exaggeration to say that he did not leave unturned any stone in this field.

In 1970 there was published in Minsk, by the scientific publishing house "Nauka i Tekhnika" ("Science and Technology") Zolotov's monograph "The Tunguska Catastrophe of 1908" that became a very essential step forward in the Tunguska studies. The book came off the press, despite heavy opposition on the part of some authorities from the astronomical community. It was however none other than the then Vice-President of the USSR Academy of Sciences B.P.Konstantinov who backed up publication of this monograph. His high estimation of the book proved to be fully correct: even now, almost 30 years later, Zolotov's monograph is not just of historical interest. Many ideas, expressed in it, were certainly ahead of their time.

Alexey Zolotov was, so to speak, a long-distance runner in science and a strong partisan of scientific truth. He used to stand up for his ideas and to parry blows of his opponents. As is true of every genuine scientist, his life path was very thorny. Zolotov did not live to see the triumph of his scientific conceptions. The origin of the Tunguska space body still remains obscure, to say the least. But his approach to this problem, being very different from the classical meteorite one, turned out very productive. It played a crucial part in solving a great number of questions related to the Tunguska explosion. These are, in particular, determination of the most probable direction of the TSB flight, as well as the magnitude of its explosion, the relationship between the energies of the blast wave and ballistic shock wave, and many other parameters of this unique event.

Alexey Zolotov's life came to an end abruptly and tragically, but the life of his ideas in science will certainly last for a long time. He left a prominent and enviable trace after him, as well as good memories in the hearts of all his friends and colleagues.

— Nikolay V. Vasilyev, MD, member of the Russian Academy of Medical Sciences, member of the Russian Academy of Natural Sciences, Scientific Director of the Independent Interdisciplinary Tunguska Expedition

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