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Tunguska Phenomenon: Discharge Processes near the Earth's Surface

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Abstract—An investigation of the Tunguska cosmic body's epicenter showed that both dried trees and those that survived the catastrophe are marked with characteristic deteriorations. For the trees that survived near the epicenter (the distance is <4 km), cracks of up to 7 m in length are found on their stems. All the vegetation near the explosion epicenter has traces of uniform scorch that covered the trees even on the land parts isolated by water. On the background of this uniform scorch, a notable feature is carbonization that touched the tree tops and the earth-directed ends of broken branches. All tops of both living and dried trees in the central zone are burned and dead. Carbonization of tops and branch ends was observed up to a distance of 10–15 km from the epicenter; i.e., charge processes took place over an area of more than 500 km^2 in size. Carbonized branch ends have a characteristic "bird's nail" shape, which has no analogs on the Earth. Similar deterioration is typical for the crater shape that obtains an anode during arc discharge combustion. It is supposed that the duration of these charge processes could be ≥1 min.

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INTRODUCTION

Resulting from the Tunguska cosmic body (TCB) intrusion into the Earth's atmosphere, a field of silver clouds of more than 10 mln km^2 in size had formed. The appearance of this field could not be possible without the introduction of at least 10^{10} kg of water into the atmosphere (Gladysheva, 2011). The required water could only be provided by a comet; therefore, below we assume the comet nature of the TCB.

Destruction of the TCB started at an altitude of ~1000 km above the Earth's surface (Gladysheva, 2011). The object suffered intensive fragmentation during the flight and discharged the most part of its mass prior to its explosion above the Siberian taiga. The ultimate destruction of the TCB above the epicenter was of a complex character. Based on an analysis of eyewitness reports and an epicenter investigation, the conclusion was made that the TCB destruction took place in two stages. First, several explosions occurred and their blast waves stroke down the forest in a territory of more than 2000 km^2. Approximately one to two minutes later after the beginning of the explosive destruction, conditions favoring the appearance of a giant atmospheric charge emerged (Gladysheva, 2009).

Obviously, the appearance of an electric charge, connecting the near-surface layers with the ionosphere and being observed from a distance of 500 km, must have left traces above the epicenter. These traces are changes in the magnetic properties of rocks near the epicenter and deteriorations of trees and shrubs.

An investigation of the magnetic properties in loose deposits in the area of the epicenter has shown a deviation of the remanent magnetization vector from the direction of the modern geomagnetic field. This indicates the presence of two magnetization components in the rocks: one coincides with the geomagnetic field, while the other one is directed westward. According to experimental data, such a distortion of the magnetization vector in rocks appears when affected by an external magnetic field of 25–30 Oe in intensity (i.e., more than the terrestrial magnetic field by a factor of 50–60) (Boyarkina and Sidoras, 1974).

In the present work, based on the appearance of deteriorated trees in the vicinity of the explosion epicenter, the character of charge processes in the near-surface atmosphere is determined. In addition to this, the distance, to which the charge processes propagated, and the duration of the charges are estimated.

DETERIORATIONS OF TREES AND SHRUBS

According to the study results, the trees located in the vicinity of the TCB explosion epicenter have extremely characteristic deteriorations. As was noted by the investigators (Kulik, 1927; Vasil'ev et al., 1981), a forest in the Great Kettle was stroke down radially with tops directed from the center, but the radial orientation of the forest was at that reported at a certain distance from the center. In the central part of the epicenter zone, both survived and rooted dried trees were located; a gradual fall in the latter had shaped the zone of the so-called "chaotic fall."

In addition to the forest fall, destruction of tree canopies was reported: some trees lost all their branches, while others remained some broken branches. Some branchless trees had dried, while others survived, as well as trees with partially torn branches. New branches on survived trees began to grow directly from stems and shaped cypress-like canopies.

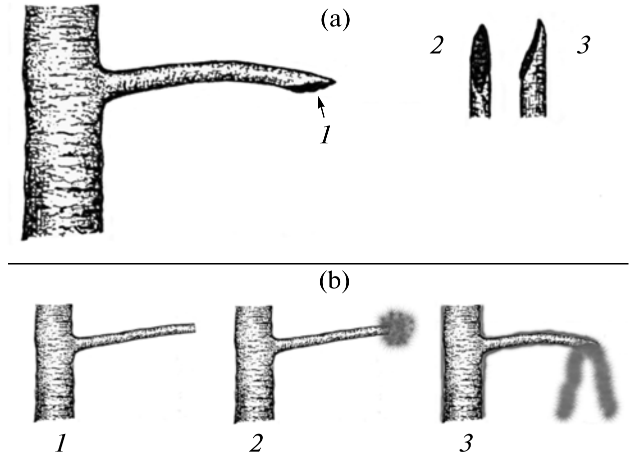
The characteristic effect of the catastrophe on the vegetation in the central zone of windbreak was scorch. The scorch was uniform and covered mountains, valleys, and trees in the land sites surrounded by water. In some cases, trees were scorched entirely (from tip to roots). The degree of scorch was exclusively uniform and did not depend on the location of trees (Kulik, 1927; Vasil'ev et al., 1981).

Kulik reported that in the central part of windbreak (10–15 km), all tops of both living and dried trees (both fallen and rooted) had been scorched and deadstanding. Even in the case when tops were broken, the break surface had traces of carbonization (fuming and scorch). Kulik also emphasized that fallen tops were not decayed but scorched (Vasil'ev et al., 1981).

Among the investigated 360 trees that survived the catastrophe within a zone of less than 4 km from the epicenter, stem deteriorations were found for 200 trees. These deteriorations are seen as cracks of 10–30 cm in length in the upper parts of stems or cracks of 2–7 m in length stretching upwards from the stem bottom, and the crack depth sometimes was about the stem radius (Zenkin et al., 1963). In some cases, crack edges also carried traces of scorch or carbonization.

Dead and scorched tops and cracked stems are characteristic features of the effect of thunderbolts. The area around the epicenter, where the tops of all trees carry heat shock traces, is 10–15 km; therefore, significant (most probably) multiple discharges affected trees over an area of more than 500 km^2.

Near the epicenter of the TCB explosion, another unprecedented zone of deteriorated vegetation was found. Both Kulik (1927) and Krinov (1949) reported the characteristic appearance of branch ends for trees and shrubs. Explosion waves torn off canopies of dead rooted trees, leaving only knots. It appeared that the broken branches of dried trees were arcwise bent downwards with the concave part oriented toward the top (see figure a). It was noted that a carbonized fragment was located at the ends of every broken branch of dried trees (i.e., bending accompanied scorching or vice versa). It is important to note that bends were always directed downwards and obliquely. The broken end of a branch with a carbonized fragment has a specific shape resembling a "bird's nail" (according to the term by Kulik). This phenomenon took place everywhere within the central zone of windbreak of ~15 km in radius (Vasil'ev et al., 1981).



Shape of deteriorations on trees in the area of the Tunguska catastrophe. (a) Deterioration of dead tree branches (Krinov, 1949) (*1*, carbonized end of a broken branch; *2*, carbonized break of a branch; and *3*, "bird's nail"); (b) reconstruction of the processes leading to the deterioration type shown in (a) (*1*, a branch broken by the explosion wave; *2*, corona discharge; and *3*, discharge between a branch end and the ground).

It should be emphasized that, according to Kulik, the vegetation near the explosion epicenter was only slightly scorched without any visible traces of carbonization. In Kulik's opinion (Vasil'ev et al., 1981), carbonization involved only those parts of trees which were poorly protected with bark or were not protected at all; i.e., these were the surfaces of branch breaks (see figure a), tree tops, etc. In other words, uniformly scorched trees had carbonized tops and branch ends. Similar tree deteriorations have not been reported elsewhere; hence, we can conclude that conditions took place when the Tunguska catastrophe was extremely different from usual terrestrial processes. The carbonization of branch ends and the arcwise bending of dried branches are most likely related to powerful discharging phenomena. The burned lower (directed to ground) ends of branches indicate that discharge currents flowed between branch ends and the ground surface.

POSITIONS OF EXPLOSIONS

The TCB destruction above the epicenter was accompanied by highly unusual acoustic phenomena. The most complete information, supported with eyewitness reports, was given for the Tunguska event in a newspaper publication dated July 13, 1908. The eyewitnesses, who lived in the settlement of Kezhma ($R \sim$ 200 km from the epicenter), reported that "... there was some noise that was similar to that from a strong wind. Immediately after this, a dramatic impact was heard and an underground earthquake was felt. The latter shook buildings as though they were strongly impacted with a big log or a heavy stone. The first impact was followed by a second one of the same power and by a third one... The time interval between the first and the third impacts was notable for an unusual underground rumble similar to the sound made by rails on which ten trains are running. Then, within a period of 5–6 min, a kind of artillery firing was heard: about 50–60 impacts at short and almost equal time intervals. By the end, these impacts became less intensive. After this, a calm period of 1.5–2.0 min took place, and then six impacts, which were distant but, nevertheless, distinct, and cannon shots were heard, accompanied by earth shaking... At attentive watching, something like an ash cloud was seen in the horizon in the north (i.e., from where impacts seemed to appear)... As was said by eyewitnesses, prior to the first explosions (impacts), a firelike celestial body flew in the sky from south to north with a deviation toward northeast ...” (Vasil’ev et al., 1981).

Multiple acoustic effects are common during the intrusion of cosmic bodies into the terrestrial atmosphere: in particular, they were reported during the fall of the Sikhote Alin meteorite. However, for this iron meteorite, it has been clearly founded that the first and the loudest sounds were caused by the collision of fragments, into which the object had split, with the ground, while the following weaker sounds were produced by the meteorite destruction during the flight, because the source of these weaker sounds “moved” upwards (Krinov, 1950). In the case of the Tunguska catastrophe, eyewitness reports one direction toward the source of sounds, and this direction agrees with that to the epicenter, where the body destructed.

Based on eyewitness reports, the “cannonade” that accompanied the TCB destruction $t \sim 5–15$ min. If the acoustic effect during the Tunguska catastrophe was determined by the sound source motion, as in the case of Sikhote Alin meteorite, then, with the space speed of the object ($\sim n$ km/s) taken into account, the sources of acoustic waves must have been spaced by at least $L \sim 100–300$ km. It is commonly accepted that the TCB moved from southeast to northwest; the only argued point is the angle of trajectory inclination to the meridian. In any version of the TCB trajectory, the settlement of Kezhma is located beyond it; hence, eyewitnesses could see the motion of the sound source from the distance $R \sim 200$ km from the epicenter. However, more than 20 eyewitnesses from the catalog compiled by Vasil’ev et al. (1981) stated that the “cannonade” was heard from one point and the direction to this point usually coincided with the direction to the epicenter.

Thus, TCB destruction during $t \sim 10 \pm 5$ min took place immediately above the epicenter. The most probable altitude of the explosion is believed to be $H \approx 6$ km above the Earth’s surface. Judging by the absence of any sound motion, the object had lost its space speed above the epicenter, but its fragmentation continued.

FRAGMENTATION

Based on the multiple explosions that occurred almost in the same place above the Earth’s surface, we can conclude that the destruction was gradual and multistage. At present, one viewpoint claims that comets consist of many clods of different sizes. Based on eyewitness observations of the TCB flight, the sizes of the large clods composing the space body can be derived. The eyewitnesses compared the flying body with a house, and the accompanying objects followed the body with barrels (Epiktetova, 1976). Based on all estimates, the TCB size was about 100 m; hence, the sizes of the large fragments (clods) were about 10 m. It is natural to suggest that every clod consisted of lesser blobs (up to spheres microns in size) analogous to the organic particles discovered during Halley’s comet investigation (Kissel and Krueger, 1987). Assuming such a structure, which can decompose into quite small initial components, we can explain the long-term fragmentation of the object above the epicenter.

Only the porous matter of a comet can create conditions for an explosion. Since comets are formed under space conditions, all gaps between major fragments and between particles composing major fragments are filled with vacuum ($P_{vol} \sim 0$). When an object is destroyed in the Earth’s atmosphere, a pressure difference emerges. At the altitude where the TCB was destroyed (~6 km), atmospheric pressure is $P_{atm} \sim 0.47P_0$, where P_0 is the pressure near the Earth’s surface. When the integrity of the TCB fragment envelope is disturbed, an shock wave emerges. Excessive pressure on the shock wave front is $P_{atm} - P_{vol} = 0.47P_0$. As was found during nuclear tests, such excessive pressure can destroy buildings with metallic skeletons (*Deistvie* ..., 1965); hence, it could lead to the destruction of the TCB fragment. The fragment splits up into components with smaller sizes.

It is known that the initial temperature of an extraterrestrial object’s interior is a space one ($\sim n \times 10$ K). When heating under the effect of high temperatures in the explosion zone, the release of gaseous components from TCB fragments is to be gradual. It is natural to think that the compounds releasing from the TCB fragments are explodable. According to (Tsynbal and Shnitke, 1988), it is the comet material where combustible organic compounds are contained in a quantity sufficient for explosion. Fragmentation during heating is also a feature of comet material. Thus, a cloud is formed that consists of combustible compounds, mixed with oxygen from the surrounding air, and the material of the TCB fragments.

The rate of cloud sinking down to the Earth’s surface is decreased by intensive convection flows, because the temperature in the explosion zone is about

2000–3000 K (Tsynbal and Shnitke, 1988). Inflammation of this mixture occurs owing to lightning that emerge owing to charge separation in the explosion zone. Charge separation can occur due to the following. It is supposed that positively charged large fragments of the TCB move to the ground under the effect of gravity force, while the negative charges in aerosols are carried upwards by intensive convection flows. It is important to note that the zone with dominating positive charges is separated from that of dominating negative ones by the permanently acting explosion zone.

DISCHARGES NEAR THE GROUND

The motion of a positive charge to the ground was to lead to field growth in the near-ground interval and the appearance of a corona charge at tree tops and ends of branches broken by the explosion wave (see figure b). For a corona charge to appear on trees, the electric field intensity near the ground should be 1000–5000 V/m (Chalmers, 1967). It is known that corona charges both lead to charge flows and cause air ionization favoring breakdown. The breakdown threshold field intensity in the air near the ground is about 3000 kV/m. In the case of the Tunguska catastrophe, the breakdown field intensity could be much lower, because the air ionization process was aggravated by factors, such as corona charges, explosion waves, and radiation from explosions.

In the case of the Tunguska catastrophe, the emerged electric field likely permanently grew owing to the approximation of positive charges to the ground under the effect of the gravity force. As the electric field intensity and air ionization level grew, conditions emerged for spark discharges to pass between branches and the ground. It is found that if there is a quite high-energy field intensity source and it does not allow intensity to drop, then a spark discharge transforms into an arc one. Thus, the end of a branch consecutively suffered the corona, spark, and arc discharges.

The carbonization of branch ends is most probably related to arc discharges. As an arc burned, the cathode electrode sharpened, while the anode electrode on the contrary became crater-shaped with a high temperature in the center of the crater. The "bird's nail" type carbonization, which was found in deteriorated branches (figure a), is a crater at a single branch. Even if an arc charge existed for a long time, this would have led to the burning (decrease in the length) of branched with a preserved shape of the crater in the form of a "bird's nail."

DISCUSSION

As was noted by the first investigators, there were no thin branches and knots on dead trees: only thick branches with carbonized ends remained. It is not necessary to prove that an shock wave, which destroys a tree canopy, would break thick branches first, while thin and flexible ones would sustain. Hence, a rough estimate of the duration of the discharging process (T) implies that the discharge lasted until the ends of thick branches became deformed and thin ones burned completely; i.e., $T \sim n \times 10$ s.

If branches were anodes, then the ground and everything on it served as a cathode. With respect to this, the following eyewitness report is of high interest. Evenks told about their relatives, whose deers were near the epicenter of explosion, "Seven rich Dzhenkouli brothers pastured a herd of 600–700 deers at the place... At the source of the Khushma River, this herd burned, and only ash remained from deers. At the Cheko River mouth, deers laid dead, but they were not burned (they were stunned and then died)." The second report stated, "Parents stood at the Khushma River at that time; when the fall occurred, there was destruction, but there was no fire... At the place where the meteorite fell, 1000 deers were. All they ran away from the thunder and we did not find them later (even their bones). We searched for them in August. Searched for a month but did not find either bones or traces. We wondered where they had run. Then we stopped searching for them" (Vasil'ev et al., 1981). Thus, the following picture is shown: in the upper stream of the Khushma River (probably 4–5 km south of the epicenter), deers were burned to ashes; in the mouth of the Cheko River (about 8 km northwest of the epicenter), animals died but were not burned. It should be emphasized that the searching for the deers was extremely important for Evenkis, since the number of heads in a herd showed the degree of wealth. Moreover, the explosion epicenter is surrounded by peatbogs, where traces of ten people have been observed for a long time. With respect to this, absence of traces of a herd of several hundreds heads suggests that deers, which were not found later either dead or in the form of bones, had been burned to ashes as well; since the search for the runaway herd took place 1–1.5 months after the Tunguska event, this ash was washed out by rains.

If one assumes that several hundreds of deers were burned to ashes, in particular, due to high currents of arc discharges, then we can emphasize again the unordinary character of the conditions emerged as a result of the Tunguska catastrophe. Taking into consideration the size of a deer, we have to assume that the discharge processes near the epicenter lasted $T \geq 1$ min.

Two other pieces of evidence regarding the extraordinary conditions, which took place during the Tunguska catastrophe, are the mutation effects and the unique preservation of coniferous trees. Near the epicenter, anomalous deviations of morphometric features were reported for ants and the mutation effect was observed for pines (Vasil'ev et al., 1980). One of the causes of these mutations for vegetation and animals is hard rays (i.e., what took place as a result of the catastrophe).

In his first expeditions, Kulik noted that a larch forest fallen after the explosion completely decayed over 20 years, while dead coniferous trees were completely preserved (Vasil'ev et al., 1981). Academician Vernadsky (1941) also reported a long-term sustained forest and suggested that trees had "undergone a kind of petrification." However, analyses showed a normal quantity of ash in the samples. It is important to note that in some places the trees preserved after the catastrophe are still laid in regular rows and these sites can be found even at a distance of 20–30 km from the epicenter. A suggestion can be made that the ultraviolet radiation from the discharges caused the polymerization of resin that became amberlike. However, this hypothesis is required to be scrutinized.

CONCLUSIONS

Tree deteriorations expressed in the form of burning and dying of tree tops, as well as the characteristic carbonization of branch ends directed towards the ground, indicate the unordinary conditions that took place in the near-surface atmosphere during the Tunguska catastrophe.

Discharge processes within a zone of 10–15 km around the epicenter were represented by corona, spark, and arc discharges. The area covered by discharge processes could exceed 500 km^2, because, as was reported by eyewitnesses, multiple thunderstorm discharges were observed even at a distance of 40 km from the epicenter (Suslov, 1967). The action of discharge processes near the epicenter could last $T \geq 1$ min.

The crater-shaped deteriorations on tree branches in the epicenter of the Tunguska catastrophe unambiguously indicate that branches played the role of an anode in arc discharges. The cathode was the ground, and thus discharge electrons moved from the ground upwards to tree branches. This vindicates the above suggestion that it is the positively charged TCB fragments that moved to the ground (Gladysheva, 2009). In other words, during the TCB explosion, the body fragments retained a positive charge.

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