Some mechanical and thermal manifestations of the 1908 Tunguska event near its epicenter

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Dedicated to the blessed memory of my grandmother (Tuzlukova Anna Ivanovna) and my mother (Ol'khovatova Olga Leonidovna)

Abstract. This paper is a continuation of a series of works, devoted to various aspects of the 1908 Tunguska event. It is devoted to some manifestations near the epicenter of the event. Many of the manifestations were established back in the 1960s. Recently a couple of works have appeared that reveal previously undetected phenomena, namely, traces of exposure to high temperatures and high pressure. A mechanism of their formation was proposed in the same works. The proposed mechanism is considered in this paper using the method of comparison with other known manifestations of the Tunguska event. Some other aspects of the Tunguska event are considered also.

1. Introduction

This paper is a continuation of a series of works in English, devoted to various aspects of the 1908 Tunguska event [Ol'khovatov, 2003; 2020a; 2020b; 2021; 2022; 2023a; 2023b; 2025]. The works can help researchers to verify the consistency of the various Tunguska interpretations with actual data.

Until recently, such manifestations of the Tunguska event on the surrounding area as mechanical and thermal effects were mainly established during numerous expeditions. However at the American Geophysical Union meeting AGU24 in 2024 a poster [Abbott et al., 2024] was presented with new info. In 2025 a new article appeared [Kletetschka et al., 2025] which presents more detailed info with interpretation. The presented paper considers how new data and their interpretation are consistent with already firmly established facts.

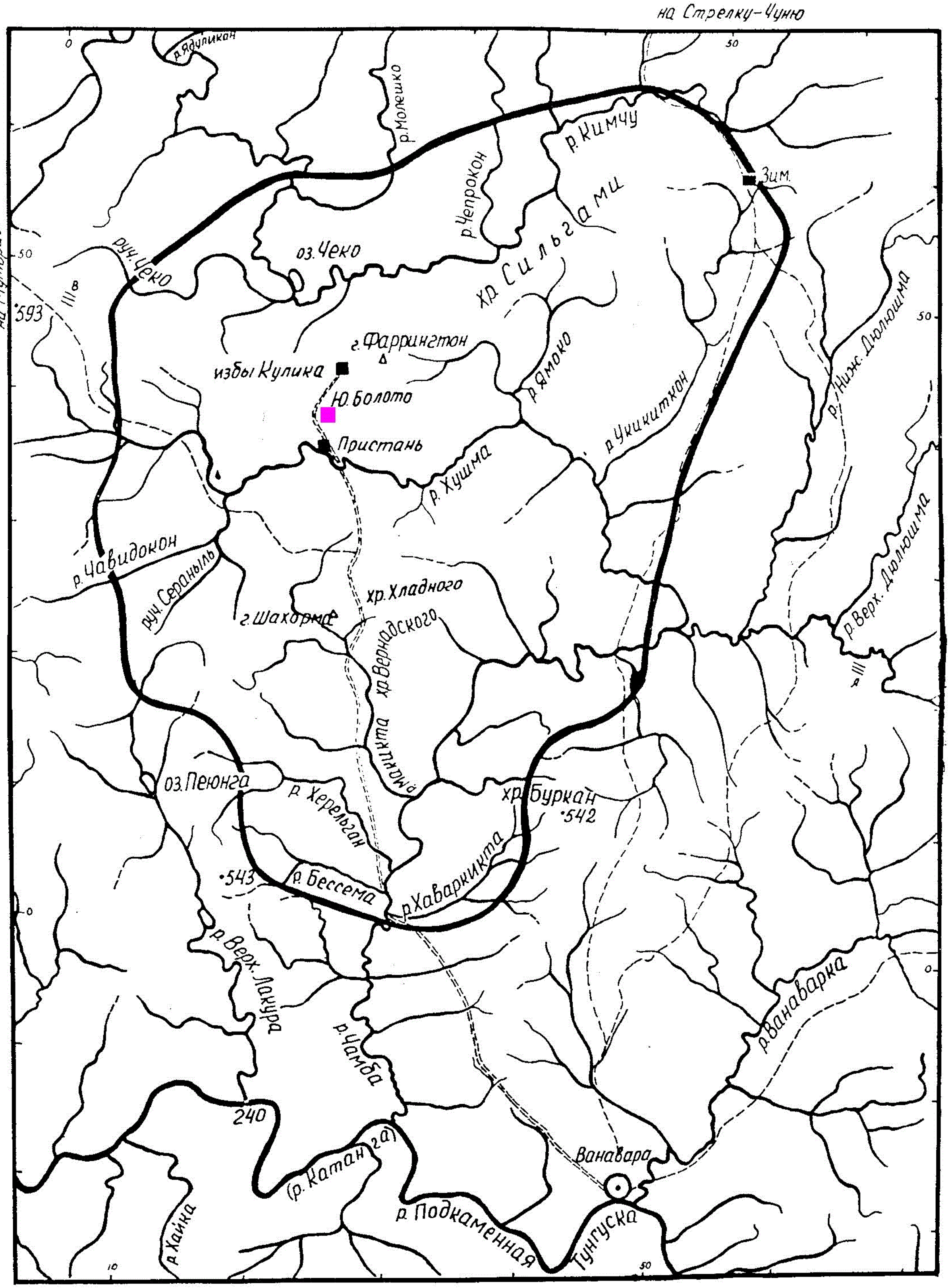
Let's start with a very brief historical introduction to the Tunguska event. In the morning of June 30, 1908, thunderous sounds were heard by population north and northwest of Lake Baikal in Central Siberia, In some places also the ground trembled. Reports of a flying glowing body came from various points of the region. Soon a newspaper story appeared about a fall of a large meteorite near the town of Kansk, but then it was recognized as wrong. Some years later a large forestfall of radial character was attributed to a probable result of the event in the area about 61° N, 102° E. Nowadays the forestfall is named (Kulikovskii) after the first scientist who researched it – Leonid Kulik. He discovered inside the forest-fall burnt trees, bushes, and other manifestations of thermal effects. The Committee on Meteorites of the USSR Academy of Sciences (KMET) continued research the area of the Tunguska event in 1950s and early 1960s. Later amateurs most of whom united under the name Kompleksnaya Samodeyatel'naya Ekspeditsiya (KSE) continued research. Since the late 1980s foreign scientists take part in research too.

In this paper a position (of the Kulikovskii forestfall 'center') calculated by Wilhelm Fast [Vasil'ev, 2004] is called 'the epicenter' unless otherwise stated. Ithe

epicenter is assigned to ~60°53’ N, ~101°54’ E. The Evenki tent (chum) in this paper means a portable dwelling in the form of a conical tent covered with hides, bark, felt, etc. The author of this paper (i.e. A.O.) for brevity is named as “the Author”.

2. The Manifestations

On Fig.1 (based on a sketch by W. Fast) the epicenter of the Kulikovskii forestfall is marked by a red square, and a solid line is a smoothed border of the Kulikovskii forestfall.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Пристань
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хр. Вернадского
р. Нижн. Дюлюшма
р. Верх. Дюлюшма
оз. Пеюнга
р. Херельган
хр. Буркан
542
543
р. Бессема
р. Хаваркикта
р. Верх. Лакура
р. Чамба
р. Ванаварка
240
(р. Катанга)
Ванавара
р. Подкаменная Тунгуска
р. Хайка

Fig.1

On Fig.2 there is a simplified scheme of the area with strong thermal damage of tree's branches, and the border of the Kulikovskii forest-fall (adapted from [Bidyukov, 2008]). The red circle is the epicenter of the forest-fall (calculated by W. Fast). The coordinate system is by W. Fast, the x-axis is directed to the magnetic north, the y-axis to the east. 1 - boundaries of the Kulikovskii forest-fall, 2 - the area of thermal burn of branches (with a diameter of more than 10 mm) of trees.

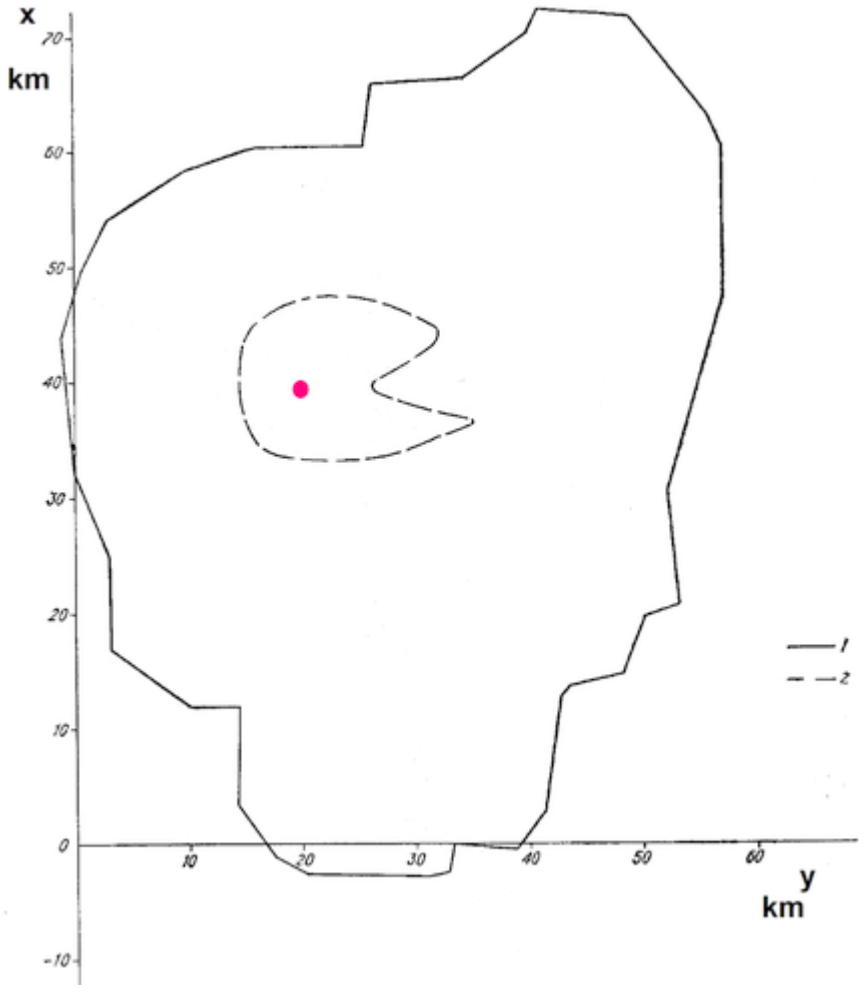

Fig.2

On Fig.3 detailed scheme of the area near the epicenter is shown (adapted from [Zhuravlev and Zigel, 1998]). The Fast's epicenter is marked by a red square.

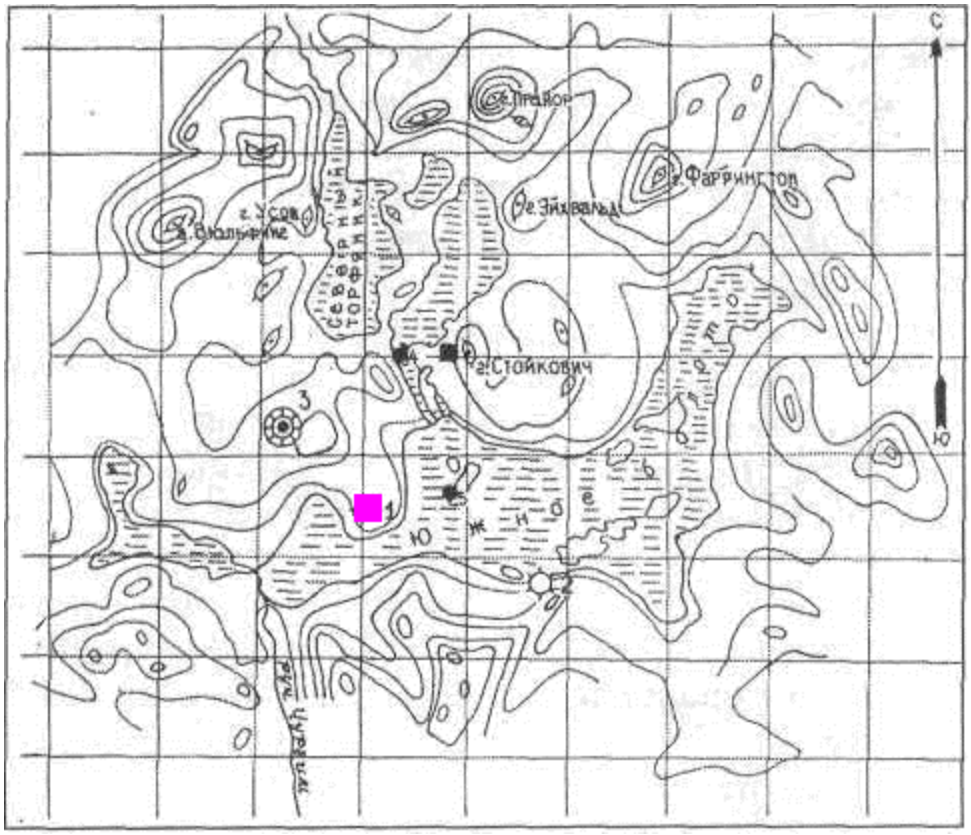

Fig.3

In 2019 a brief info appeared [Kletetschka et al., 2019] (TE is Tunguska event): “Paleomagnetic data revealed presence of plasma during the TE near rock surfaces”. More detailed info appeared at the American Geophysical Union meeting AGU24 in 2024 in a poster [Abbott et al., 2024]. Here are some fragments of its abstract and plain-language summary:

“Abstract

The 1908 Tunguska event remains one of the most enigmatic cosmic impacts in Earth's recent history. We present new microscopic evidence from samples collected at the Tunguska epicenter, providing unprecedented insights into the event's nature and intensity. Using advanced analytical techniques including SEM,TEM, EBSD, and CL, we characterized a diverse array of microspherules, melted particles, and shock-fractured minerals.

Our findings reveal a complex, heterogeneous field of high temperatures and pressures, with evidence indicating localized

temperatures exceeding 1700°C and shock pressures reaching 5-10 GPa.
<...>

Plain-language Summary

The Tunguska airburst was accompanied by extremely hot particles that burrowed into the Earth. They were stopped by the top of the permafrost layer about 2 feet down. This helps to explain why the decades long search for the Tunguska "meteorite" was not successful. By sampling at the top of the permafrost layer, we have found new evidence for extremely high temperatures and other unusual features generated by the Tunguska airburst."

Soon a new article appeared [Kletetschka et al., 2025](published open access under License CC BY 4.0). Here is its abstract.

"Abstract

We report diverse shock-metamorphosed and melted grains from the 1908 airburst site in Russia, one of history's most significant and enigmatic cosmic events. Analysis of samples from a rimmed crater-like feature near the epicenter using scanning electron microscopy (SEM), transmission electron microscopy (TEM), electron backscatter diffraction (EBSD), and cathodoluminescence (CL) revealed evidence of extreme conditions. Our findings indicate heterogeneous shock pressures (~≥2 GPa) and temperatures (~≥1710°C) produced various microparticles, including FeO and aluminosilicate glass microspherules, melted quartz microspherules, carbon spherules, glass-like carbon, and melted minerals. Notably, quartz grains exhibit high-temperature melting and shock metamorphism, including planar deformation features (PDFs) and planar fractures (PFs), with some showing glass-lined internal fractures and melted silica coatings. Similarly, some feldspar grains display melted feldspar coatings. While multiple origins for these materials are possible – including an older crater and volcanism – the evidence best supports the 1908 Tunguska airburst hypothesis. The abundance of melted, shocked materials in the biomass-burning layer aligns with proposals that airburst fragments struck the Earth's surface at velocities sufficient to produce shocked quartz. The coexistence of melted particles, shock-metamorphosed minerals, and unaltered grains suggests a heterogeneous energy distribution that created shallow craters and melted surface materials. These findings advance our understanding of airburst/impact mechanics, but few people have ever observed a dangerous airburst like Tunguska, so very little is known about them. Lacking sufficient real-world data, scientists should continue modeling these dangerous low-altitude airbursts to understand them better.

The Tunguska event is a valuable case study demonstrating the urgent need to improve our planetary defense strategies."

In the body of the article the authors wrote that the observed effects indicate moderate shock pressures of 2-10 GPa.

The authors presented their computer simulation of the Tunguska airburst which will be discussed below.

Let's look at some manifestations of the Tunguska event near the epicenter which are firmly established.

Remarkably that many trees near the epicenter survived. Here is what was written in 1964 regarding individual trees near the epicenter [Boyarkina, et al., 1964] (translated by A. O.):

"Individual trees are distributed everywhere in the northern, western and eastern directions.

Despite careful attempts, no old trees were found to be confined to the relief. They are also on the inner and outer slopes. It is impossible to talk about shielding them. The preservation of old trees is probably due to biological reasons: strong roots, good, moist soil, the long absence of fire, i.e. the strength of the forest.

In the northern direction, the old forest generally comes close to the epicenter."

It is important to note that there were even many survived groves of trees near the epicenter. Here are some details [Boyarkina, et. al., 1964] (translated by A.O.):

"Of considerable interest is the presence and distribution of living old trees. The epicentral zone contains a significant number of individual old trees and entire groves, which was discovered back in 1959-1960 [4, 12].

In the diagram [8, FIG. 6] all notable groves of old trees are marked. The largest of them are: on the slope of the Wulfing (500 X 700 m), on the southern shore of the Southern Swamp (200 X 700 m), an array on the Western peat bog, a 200 X 300 m, groves to the east of the swamp, etc."

Here is what I.K. Doroshin wrote about the Wulfing grove [Doroshin, 2005] (translated by A. O.):

"...at least one grove consisting of larch, spruce and cedar (near the Wulfing mountain). In such places, the trees either did not lose their crowns at all, or the loss was minimal. There are either no traces of the 1908 fire here at all

(a grove near the Wulfing mountain), or there are traces of a grass-roots fire of varying intensity;... "

The Wulfing grove is situated about 3 km to the north-west from the epicenter.

And here is more about the whole groves of trees - from [Kharuk, et al., 2006] (translated by A.O.):

"As source data in the work aerial photography materials were used ... made in July 1938, as well as aerial photography materials on the same territory conducted on July 26, 1999 .... <...>

Two areas were selected in order to reduce temporary and resource costs processing of the images. The choice of these areas was due to that only they had overlap of large-scale (1:10 000) photos of 1938 and 1999. Analysis of these areas in the photographs of 1938 revealed the following anomaly: in the area-2 almost completely absent forestfall, also not noticed "telegraph forest" (trunks of trees, completely devoid of branches, but not fallen by the shock wave). There are also no visible marks of foresfire.

A somewhat different picture is observed in the area-1, where there are fallen trees, and tree trunks without crown. <...>

As noted earlier, the analysis of the studied areas in 1938-photos shows anomaly in the forestfall. Considering the scale of phenomenon as a whole, and small, about 600 meters, the distance between the areas, this anomaly cannot be explained by weakening shock wave with retreating from the center of the explosion, if to take the epicenter of the explosion center, calculated by the Fast's catalog of the forestfall. <...>

When analyzing the relief, on the topographic map of 1: 100000 is seen that the area-1 is located in the southeast, gentle (3-4°) slope, while the area-2 on the north, more steep (7-8°) slope. The northern slope can partly explain the lack of fires in the area-2 and associated damage of the forest, because higher humidity level at this time of the year. It could be an obstacle for the spread of the lower fire, as well as for inflammation of the litter from the thermal radiation of the explosion, which undoubtedly had place in the catastrophe area.

As for the direction of the shock wave, then considering that the majority of researchers give an estimate of the height of the explosion in 5-7 km, then minor, not more than 50 m, elements the relief could not play a significant role in the case of one, central or volumetric, air explosion. But if to allow a lower explosion option, then the relief could be partial or fully supress the shock wave."

Here is the Vasil’ev opinion [Vasil’ev, 2003] translated by AO.:

"This is certainly enough to singe the needles of cedar, which is extremely sensitive to temperature effects. Meanwhile, a group of cedars that survived the Tunguska disaster is on edge of the Southern swamp is only 2.5 km away from the projection of the center of the light flash of the Tunguska explosion, and fir trees grow directly in it, which also survived the disaster."

Here are several points from [Plekhanov, 2009]:

"d) On the whole territory of the fire, including the centre, there are some areas where the surviving trees do not reveal any traces of the 1908 fire.

e) The ends of branches of the dry trees are scorched and resemble bird claws (Kulik's term).

f) Every zone of the fire area 1908 including the centre contains standing and felled trees burned to the core along with the trees still having small branches. <...>

h) Peat bogs have areas where the surface layer, dated to 1908 according to the outgrowth of the moss, covers a 5–10 cm thick layer of ash (L.A. Kulik also claimed that there are peat bog spots with the layer of ash up to 30 cm thick).

i) There are also peat bog spots with a 5–10 cm thick layer of ash next to the areas with no signs of the fire."

So one of the peculiarities of the Tunguska event near the epicenter is the spotty nature of the manifestations when areas with a high degree of damage are adjacent to almost intact ones.

Here is a fragment of a record in the Vronskii diary (http://prozhito.org/person/386) of June 28, 1961 (Vronskii was near the epicenter), translated by A.O.:

"Not far from Zaimka {i.e. the Kulik hut – A.O.}, 6-7 kilometers away, a section of standing dead/dry wood/trees was discovered as a result of an old fire before 1908. As a result of the 1908 disaster, no burn marks are observed on this deadwood. In general, the phenomenon remains very mysterious, without traces/signs of a glimmer {of hope – A.O.}."

Remarkably that Vronskii started to research the Tunguska epicenter in 1958. At first he was a strong supporter of "a meteorite". Since about 1960 in his diary he rather often wrote about the Tunguska event as of a "mystery". Indeed he even finished his book about the Tunguska event with this phrase [Vronskii, 1984] (translated by A.O.):

> “Unfortunately, so far we can only make more or less probable assumptions about the nature of this exceptional phenomenon.”

A remarkable peculiarities of the mechanical effects of the Tunguska event also can be demonstrated on the fact that some eyewitnesses were close to the epicenter and were affected just a little! In 1974 Vasil’ev with a journalist visited Andrei Ivanovich Jenkoul (Evenk). Here is a fragment from the Vasil’ev diary of July 28, 1974 (from tunguska.tsc.ru) translated by A.O.:

> “According to I.D. {probably A.D.- A.O.}, at the time of the fall, his father was standing on Cheko, they were thrown into the air, the tents were thrown away, but that was the end of the matter. Before that, the sky turned red, and then there was a terrible blow. When I asked if they had seen a body fly by on the Cheko, he answered not quite definitively that they had seen a red sharik {meaning a small ball in Russian – A.O.} (in my opinion, he came up with this during the conversation).
>
> Currently, he hunts at Tatare, Jelindukon and Yu. Chunya. Claims that on the ridges in the area Paiga, Jelindukon and Segochamba have fallen forests caused by the meteorite. He considers meteoric and the Chuvar forest-fall, claiming, however, that there are no meteorite falls further to Mutorai.”

As for Andrei Ivanovich Jenkoul, the film director Mikhail Alexandrovich Zaplatin (a member of the KMET expedition in 1958) gives him the most positive characteristic in his book "V chertogakh Podkamennoi Tunguski" (1966). In his book, he also quotes the words of the future academician of the VASKHNIL (now RAN/RAS), Yevgeny Evgenyevich Syroechkovskii, that he considers A.I. Jenkoul (with whom Syroechkovskii travelled through the taiga) to be his great friend. In 1939 Jenkoul wanted to be imprisoned because of his father, who was a prince of a kind of Kurkogira, but the chairman of the village council stood up for him, and he was left alone. After the war, he became a famous hunter, a leader in production, was awarded the Order of the Red Banner of Labor, and was a deputy of the village Council. It is reasonable to add that his data on the boundary of the forest-fall showed good agreement with the results of the 1958 KMET expedition [Florensky et al., 1960]. Andrei Ivanovich Jenkoul died in December 1992 and was buried in Surinda village.

Unfortunately, the place of events is unclear from the diary entry - by a lake or a stream, although both places are close to each other. There is another account that probably clarifies the location. From [Vasil'ev et al., 1981] here is an account by L.V. Jenkoul, born in 1904, who was interviewed in 1960 and told from the words of his father and uncle (who had died long ago by 1960), translated by A.O.:

"At that place, 7 rich Jenkoul brothers grazed a herd of 600-700 deer heads at that time. The brothers were rich. That day, my father went to meet the deer on Ilimpo (to the north). The herd was grazing between the Kimchu River and the Polnoty River (Churgim). There was one labaz {a warehouse elevated on tall pillars – A.O.} in the upper reaches of the Polnoty river. There was a second labaz at the mouth of the Cheko. Where the first labaz was (on Polnoty - Churgim), everything burned down there. There's only ashes left from this labaz. At the mouth of the Cheko, the labaz was thrown away (carried away) by a whirlwind. At the top {probably "in the upper reaches" – A.O.} of the Khushma, their herd burned, the deer burned, only ashes remained. At the mouth of the Cheko, the deer lay in lumps, but did not burn (they were stunned and died).

My uncle said: Ogdy has come down to earth. There was a lot of thunder. The weather was absolutely clean {see below – A.O.}, even there wasn't any rain. Early in the morning, thunder started, there were two blows: one short, strong, the second long. Sparks flew. A whirlwind swept in the direction from NW to SE. Such a strong whirlwind was that the forest collapsed. The ground was shaking. From the top of the river Polnoty, the forest was scattered in different directions. The chums/tents blew up in the air, people fell unconscious, then consciousness returned."

Besides hinting that the place of events told by Andrei Ivanovich Jenkoul was the mouth of the Cheko stream/creek (7.3 km from the epicenter at azimuth 348°), there are also several interesting points. Now about 2 of them – about the weather and sparks. Please pay attention that the criterion for clean weather was not the absence of clouds, but the absence of rain (and it rained in some places in the vicinity - see [Ol'khovatov, 2023b]). What were these sparks? Since it was not far from the epicenter, one could assume that it was, for example, flying burning forest litter/debris. However sparks also were reported much farther from the epicenter - 126 km and azimuth 256 degrees (see English translation of an account by Masmoro in [Ol'khovatov, 2023b]. Couldn't it be ball-lightnings? Who knows…

Anyway, eyewitnesses located ~7 km from the epicenter saw neither the alleged super-bolide nor even its trail. It can be said rather surely that they saw reddening of the sky followed by the explosion and strong wind. Remarkably, this applies not only to eyewitnesses near the epicenter. Here is from [Demin et al., 1984] where analysis of all known accounts was conducted (translated by A.O.):

"The relative frequency of visual observations as a function of distance from the epicenter is also quite interesting. Most observations are grouped at distances of 400-500 and 800-1000 km, and in a circle with a radius of 200 km, with 35 accounts related to other aspects of the

phenomenon, there are practically no visual observations of the flight.”

It is important to add that eyewitnesses many kilometers away from the epicenter reported about similar sky reddening – see [Ol'khovatov, 2023b].

Also from the accounts it follows that the eyewitnesses at Cheko did not get burn or any similar manifestations. On a sampling tree N 802 located about 1 km away (and about a half kilometer closer to the epicenter), burn of branches was noted (see Fig. 3 in this paper). No burn was found on more distant trees along this azimuth - see Fig. 3.

Here is on Fig.3 a map of the trees with the branch’s burn (by Vorobyov, V.A., Il'in, A.G., Doroshin, I.K. from http://www-th.bo.infn.it/tunguska/99-catalogue.zip, the author of this paper only translated the mark ‘The Kulik huts’). Trees with branches/limbs without detected burn are shown as black dots/spots. Trees with branches/limbs with detected burn are shown as black dots/spots encircled by fiery circles.

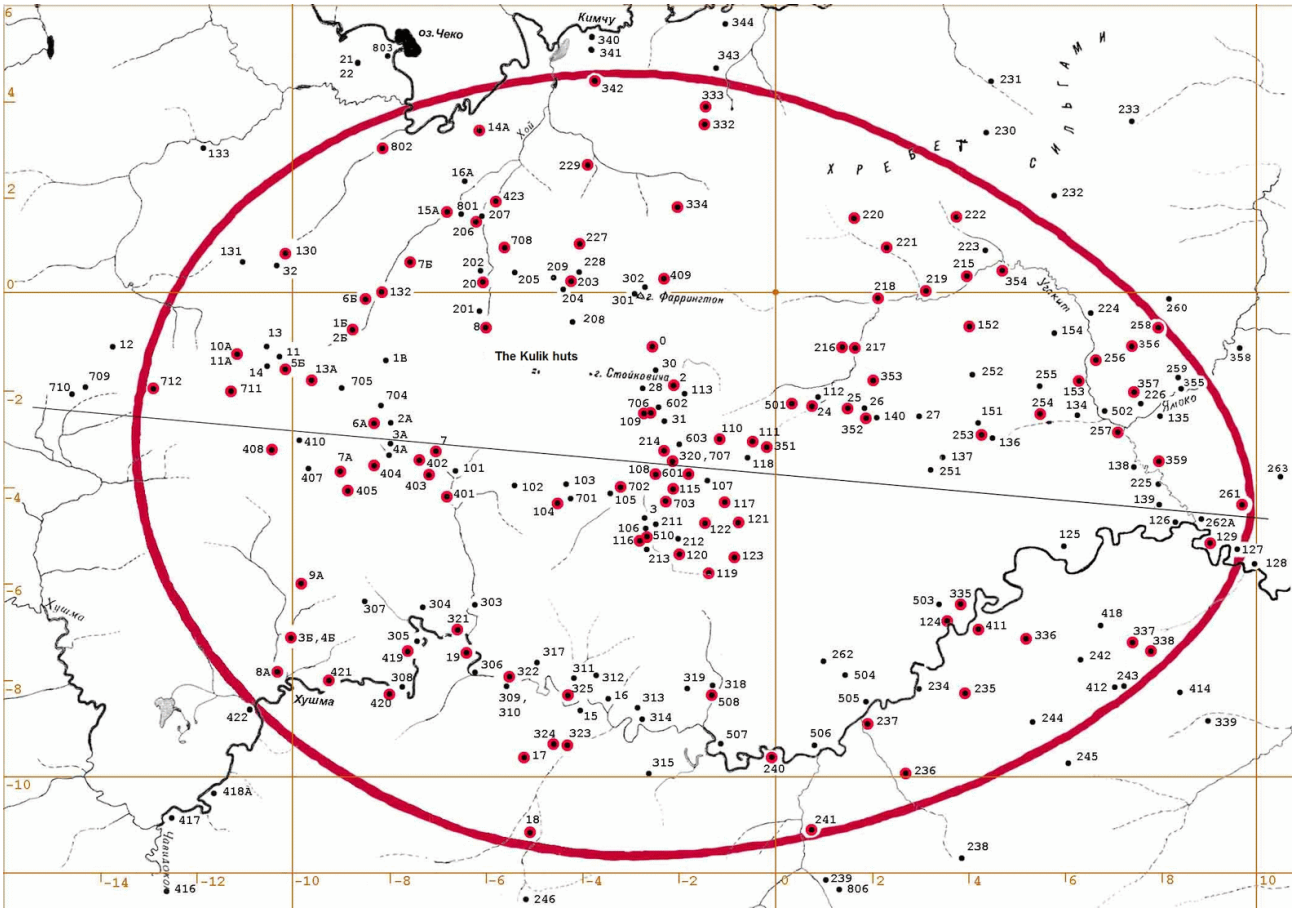

Fig.3

As follows from Fig.3, the burn effect is spotty in almost the entire area. There are

trees without burnt branches even near the epicenter.

Such behavior of the burn made some Tunguska researchers skeptical regarding the radiant/light burn from a single source.

Any interpretation of the 1908 Tunguska event should explain these peculiarities of the Tunguska event.

The presented factual data is already sufficient to verify the reality of the mechanism proposed in [Abbott et al., 2024] and [Kletetschka et al., 2025].

3. Discussion

The question of the reality of the proposed interpretation in [Abbott et al., 2024] and [Kletetschka et al., 2025] can be viewed from different angles. In the presented paper compliance of the proposed interpretation with the above facts will be considered.

Results of the computer simulation in [Kletetschka et al., 2025] are shown on 2 pictures (Figure 19 and 20) in there. Here is a signature of Fig.19:

> **Hydrocode model of the Tunguska airburst.** Pressure representation. The model's assumptions from Marcus et al. [41, 44] are that a 60-m-wide stony asteroid entered Earth's atmosphere at 20 km/s with an entry angle of 45° (yellow dashed line). Friction caused it to break up in an airburst at an altitude of 5.74 km with an energy of 14.6 megatons and temperatures >4000 K. These are within the range of accepted conditions cited by multiple studies of the Tunguska event [65]. A) At 0.4 s, the plume of hot vapor and small fragments (#1) was ~2 km wide. B) At 2.6 s, the plume was ~7 km wide (#2) and continued to expand. The shockwave carrying small bolide fragments struck Earth's surface (#3) at ~2.3 km/s. The fragments generated pressures >2 GPa, sufficient to produce shock metamorphism in quartz. C) By 4.77 s, the plume had rebounded off Earth's surface in an upward-moving reflection wave (#4), as additional bolide fragments continued to strike the Earth at >2 km/s (#5), creating more small craters. D) After 6.00 s, the plume's shockwave was >10 km wide (#6), and bolide fragments damaged Earth's surface across ~6 km (#7). Images created with Autodyn-2D, versions 2023 R1 and 2023 R1 Student (Ansys, Inc.).

Here is a signature of Fig.20 in [Kletetschka et al., 2025]:

> **Hydrocode model of the Tunguska airburst.** Temperature representation. A) At 0.4 s, the plume of hot vapor and small fragments was ~2 km wide. B) At 2.6 s, the plume was ~7 km wide (#2). The shockwave

containing small bolide fragments struck Earth's surface (#3) at ~2.3 km/s. The impacting fragments generated highly transient temperatures of >4000 K, sufficient to partially melt quartz and feldspar. However, most of the ground surface was exposed to temperatures of <1200 K below the melting point of feldspar. C) By 4.77 s, the plume had rebounded off Earth's surface in a reflection wave (#4), as additional bolide fragments continued to strike the Earth at >2 km/s (#5), creating more small craters. D) After 6.00 s, the plume's shockwave was >10 km wide (#6), and bolide fragments damaged Earth's surface across ~6 km (#7). Images created with Autodyn-2D, versions 2023 R1 and 2023 R1 Student (Ansys, Inc.).

Thus, judging by the text, the interpretation looks like this. A jet of hot gas (probably partially ionized plasma) with a temperature of several thousand degrees and fragments of a hypothetical Tunguska spacebody contained in it hit the ground at a speed of ~2.3 km/s. The fragment's hits generated pressures >2 GPa, sufficient to produce shock metamorphism in quartz (and additional fragments continued to strike the Earth at >2 km/s, creating more small craters). The impacting fragments also generated highly transient temperatures of >4000 K, sufficient to partially melt quartz and feldspar (however, most of the ground surface was exposed to temperatures of <1200 K).

Many questions immediately arise about this interpretation, but for now it is sufficient to note that the interpretation does not conform with the above facts of the presence of a large number of surviving trees in the epicenter area (moreover as some of them were only slightly affected).

Indeed, in order to knock down 90% of the trees in Tunguska, the wind speed behind the shock wave must be about 50 m/s [Robertson and Mathias, 2019]. The wind speed (behind the shock wave) in the case of this interpretation depends on distance from the epicenter, but as (according to the interpretation) the jet is several km wide, then it means that the area near the epicenter would be completely wiped out.

So if the reported discoveries of diverse shock-metamorphosed and melted grains are correct then this will demand different interpretation.

Remarkably that the discoveries don't contradict the geophysical interpretation of Tunguska (see, for example, [Ol'khovatov, 2023b]). The Author inclines to think that electromagnetic phenomena played a large role in the Tunguska event [Ol'khovatov, 2023b]. In the Author's opinion endogenic gas outbursts (followed by ignitions) could play some moderate role also. Indeed, here is from [Alekseev et al., 2010]:

"During the expedition, hydrogen flows were measured on the routes to the Farington and Stoikovich mountains and around the Suslov crater. In some areas, the hydrogen flows related to degassing of breakage

structures of the paleovolcano are anomalously high. This fact also confirms a possible endogenous origin of the geochemical anomalies (elevated concentration of microelements in the 1908 moss layers). Anomalous hydrogen flows suppress plant growth as identified in satellite photographs."

Authors of [Skublov, et al., 2011] also wrote about discovery of 2 hydrogen degassing anomalies.

In [Ol'khovatov, 1997] the Author drew attention to increased volcanic activity on the eve of the Tunguska event (eruptions of Etna, Matavanu, Erebus), and raised the question of whether the increased degassing of the Earth's interior played any role in the sky optical anomalies? Indeed, according to [Lazarev et al.,1987] most of the observations of noctilucent clouds made by cosmonauts V. V. Kovalenok and V. P. Savinykh at low latitudes from the Soviet spacestation were carried out over areas with active volcanism (the western coast of the Pacific Ocean, the Javanese Arc, etc.). The Author mentioned this fact in [Ol'khovatov, 1997], but unfortunately till now there is no clear answer. Further research is needed.

4. Conclusion

The interpretation proposed in [Kletetschka et al., 2025] does not conform with the facts of the presence of a large number of surviving trees in the epicenter area. The discoveries of diverse shock-metamorphosed and melted grains don't contradict the geophysical interpretation. The general conclusion is that the Tunguska event was a very complex phenomenon. A reader is welcome to make his own conclusions regarding various manifestations of Tunguska.

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