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Near-Earth Orbit of the Tunguska Cosmic Body

Alexander Yastrebov

Krypton Ltd., Bryansk, Russia

Correspondence to: Alexander Yastrebov, astrokrypt@mail.ru
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ABSTRACT

Previous studies substantiated the fact that Tunguska Cosmic Body was in a near-Earth orbit prior to falling. This paper considers the events preceding the June 30 catastrophe. Identified are the Tunguska Cosmic Body orbital parameters and the factors resulting in the falling. The information from the Mount Wilson Observatory is provided, which confirms the fact that Tunguska Cosmic Body was in near-Earth orbit. The circumstances surrounding Tunguska Cosmic Body entry into near-Earth orbit are reviewed, and the event timing is identified. Substantiation is proposed of the relationship between Tunguska Cosmic Body and Comet Schwassmann-Wachmann. As to the Tunguska Cosmic Body breakup circumstances, the structure and the properties of its materials are proposed.

1. INTRODUCTION

The discovery of fan-shaped reliefs in 1996 [1] gave a fresh look at the problems of the Tunguska catastrophe. The article [2] was intended to provide information and to remind those interested in the catastrophe of this discovery. The article [3] substantiates the relationship between Siberian Fan reliefs (SFR) and Tunguska Cosmic Body (TCB), suggests the possibility of TCB falling from the intermediate near-Earth orbit and defines the comet nucleus ice strength parameters. In the article [4], the TCB falling path is considered in detail.

The hypothesis is proposed stating that the fall occurred from the near-Earth orbit, while the TCB fell accompanied by numerous other falling smaller bodies. The TCB falling trajectory indicated a very flat entry into the atmosphere, which allows us to conclude that a near-Earth orbit is possible. However, it must be verified that such an orbit is possible and does not contradict the laws of celestial mechanics. It is also necessary to consider the circumstances of TCB orbit capture.

This article develops the ideas outlined in previous papers. It gives a complete picture of the 1908 catastrophe and allows us to remove all the contradictions encountered by the alternative hypotheses.

2. TCB FLIGHT PATH

Article [4] proposes the TCB flight path substantiation based on a number of witness statements and objective data obtained in the field. The path is plotted using seven points. Testimony of witnesses from Khvorostyanka and Sulomaya provide evidence of the passage of an extremely powerful bolide. The western path is traced for 3500 km from the Volga to the Nizhnyaya Tunguska. The TCB path coincides well with the Western and Eastern forest falls, which has been puzzling and even frustrating many researchers for many years. It is in good agreement with the objective data obtained at the Kulikovsky forest fall.

Emphasis should be laid on the Eastern forest fall. This forest fall was often mentioned in the literature, but it did not fit into most of the existing hypotheses. For this reason, it was not actively sought for and was considered mythical. There were attempts to suppose that the 1911 expedition passed through the Kulikovsky forest fall, but this is completely inconsistent with the Eastern forest fall nature description.

In addition to the information on the Eastern forest fall in the article [4], it is advisable to quote a more complete testimony of P.N. Liepai, a participant in the 1911 expedition [5].

The road was cleared by the Tungus walking ahead of us. It was dry autumn and there was no snow yet. Early in October, the caravan following the ridges, *i.e.* watersheds with "pure" woods, entered the windsnap zone striking us with its large scale, uniform direction of the fallen tree trunks and continuous burning-out. Only the largest trees were standing on the roots at the windsnap border, but they were without limbs, which should not happen in a normal wildfire, as it results in dead-standing trees retaining even small twigs. There were no dead-standing trees here. All the participants in the expedition were so amazed at the windsnap intensity and its extraordinary appearance, that they addressed the Tunguses. They answered that "the dragon flew and brought down"; "the snake came from the sky"; they were horrified and reluctant to speak about it; despite their general sociability, they said that it "made everything dead" for 200 - 300 kilometers.

The range estimation by nomadic peoples can be trusted, notwithstanding that their measurements are not in kilometers, but in marches. The Eastern forest fall may extend over at least 200 kilometers. This forest fall may be 2 - 3 times as great as the Tunguska forest fall. The Tunguska catastrophe picture cannot be considered complete without the Eastern forest fall. Should the proposed hypothesis be accepted, the attitude toward the Eastern forest fall must be reconsidered, and efforts must be made to study it to the extent feasible taking into account the elapsed time.

The path length indicates a very flat TCB entry into the Earth's atmosphere at a speed of about 10 - 12 kilometers per second.

3. TM NEAR-EARTH ORBIT

We can assume that TCB entered the atmosphere accidentally at a speed of about 12 km/s at the required angle and fell along the proposed path. But such a scenario cannot explain the totality of the observed phenomena. Everything points to the fact that TCB was orbiting the Earth for some time.

This orbit must satisfy a number of conditions. The fact that the light phenomena occurred within a limited area indicates the requirement for geosynchronous orbit, *i.e.*, one having a period of about 24 hours. The orbit must be potentially unstable, and a fall from it must be probable under certain conditions.

These conditions are satisfied by an orbit with an apogee altitude of 77,850 km and a perigee altitude of 150 - 200 km. This is a highly elliptical orbit. Such orbits are subject to rotation unless their inclination angle is $i = 63.4^{\circ}$. The assumed orbit inclination is about 62°, which is very close to the required angle. Combined with the high apogee altitude, the orbit can be exactly located at a specific longitude. A perigee point drift is probable due to the period duration not being exactly 24 hours. With the drift not exceeding one degree per day, this would be of no great consequence due to the relatively short TCB orbiting time.

The light phenomena indicating the existence of a near-Earth orbit began to show up especially clearly in the last 7 days before fall. If the drift occurred at a rate of approximately one degree per day, it could not be identified based on the nature of the light phenomena. We can tentatively consider the TCB orbit as a conditionally geosynchronous one.

Such orbits are well-known and used as an alternative to the geostationary orbit in some cases. The orbit ground path as of June 30 is shown in **Figure 1**.

Figure 1. TCB orbit ground path.

The comet body had a diameter of 220 - 250 meters. The question may arise why no one observed it until the fall. This is due to the orbit peculiarities. In such an orbit, in the daytime, TCB quickly passed the perigee zone located near the Sulomaya village at 92˚E, 62˚N, entered the Pacific Ocean zone near the Kuril Islands, crossed the equator and departed to the southern hemisphere. The TCB flew over Australia in the daytime. Then it hovered in the apogee zone at an altitude of 77,850 km above the point with coordinates 92˚E, 62˚S.

The TCB albedo is not known precisely, but the comet nuclei are among the darkest bodies reflecting 4% of the incident light only. According to calculations, at the apogee point, TCB could be observed as an object with magnitude of 7.5 - 8, *i.e.*, with optical instruments only. This was practicable from Australia and South Africa. Then it entered the Earth's shadow zone and became invisible. Over Africa and Turkey, TCB was in the shadow and came out of it already in the sunrise zone over the territory of Russia. Within a small path portion, TCB could be briefly observed as a first-magnitude star. Information about the periodic appearance of a moving celestial object is unavailable.

4. FALLING

Highly elliptical near-Earth orbits are potentially unstable. The perigee altitude can change due to effect of the Moon. P. Ya. Elyasberg addresses this issue in the study "Introduction to the Principles of Flight of Artificial Earth Satellites" [6], Chapter 16: "The effect of the Sun and the Moon on the motion of artificial Earth satellites". The results of calculation of orbital change due to effect of the Moon are summarized in **Table 1**. According to the source, perigee is also affected by the Sun, but this effect is 2.2 times as little.

According to **Table 1**, the perigee change per revolution with an initial height of 200 km and an apogee height of 77,850 km can make up to 20 kilometers. The perigee changes cyclically depending on the Moon position; it lowers and then recovers. When a body enters the drag-producing atmosphere during the perigee lowering, a fall will occur. The altitude of 90 - 120 kilometers can be considered critical. For example, when the total perigee lowering was 60 kilometers, the original orbit height was 150 - 180 kilometers. The fact that anomalous phenomena were recorded implies that this altitude was such that a certain interaction with the atmosphere occurred at each perigee passage.

The perigee altitude lowering may also be due to atmospheric braking. The lowering was started due to the Moon and the Sun effects, while at the last revolutions, atmospheric braking could be significant. Thus, TCB was a "meteoroid": it entered and exited the Earth's atmosphere.

The atmosphere has no sharp boundaries. It can be assumed that the hard atmospheric impact with separation of individual fragments occurred already at two next-to-last revolutions. The existence of two groups of fans allows us to suggest that the fragments forming the Eastern Group were separated two revolutions before the fall, while those forming the Western Group were separated one revolution before the fall. The Eastern Group passed through the atmosphere twice and deviated farther on from the TCB impact site. But such separation could occur at the last revolution. According to the objective information, the secondary falls occurred before the TCB explosion and several hours after it.

At the last revolutions, the passage was accompanied by a large amount of matter entering into the atmosphere and probably by sound. This could explain the anomalously bright sky recorded in Sulomaya and the fidget behavior of dogs on the eve of the catastrophe.

5. OBSERVATIONS AT MOUNT WILSON

K. Ya. Kondratyev, G. A. Nikolsky, E. O. Schultz in the article "Tunguska Cosmic Body Is a Comet Nucleus" published in the collection "Topical Issues of Meteoritics in Siberia" [7] attempted to find traces of the Tunguska catastrophe in the results of changes in spectral transparency of the atmosphere during the 1908 season. These changes were recorded in studies performed under the direction of Charles Abbot by the staff of the Smithsonian Astrophysical Observatory (SAO) at Mount Wilson, California [8].

In doing so, it was found that the recorded atmosphere turbidity was not due to the passage of TCB-generated products, but to a dust cloud formed in the stratosphere by another space object. The fact

Table 1. Changes in the height of the orbit per revolution depending on the perigee and apogee of the orbit.

h_p, km / h_a, km	200	2000	10,000	20,000	50,000
2000	2.5 m	0	-	-	-
10,000	34 m	37	0	-	-
20,000	181 m	206 m	243 m	0	-
50,000	2.4 km	2.8 km	4.1 km	5.1 km	0
100,000	21.5 km	24.6 km	36.2	47.7 km	65.5 km

is that the turbidity was observed on June 4, 1908 for the first time. See **Figure 2**. This cloud also passed Mount Wilson on August 4 and October 4.

Observations in 1980 showed that the St. Helens volcanic eruption products ejected to a height of 21 - 27 kilometers circled the globe with a period of 60 days. Thus, multi-year westbound steady dust transport exists.

The authors of the article came to the following conclusion:

"Thus, the dust cloud passing over Mount Wilson on June 4, 1908 for the first time is formed and propagated within the high-speed bolide stopping zone and, in our view, represents the products of the large bolide destruction. By extrapolating the cloud erosion vs. time and its propagation velocity, we can assume that the bolide explosion occurred over the Pacific Ocean north-east of the Kuril Islands. We estimate the approximate bolide weight as equal to 0.1 Mt".

The indicated zone corresponds to the eastern part of the Bering Sea. With the cloud circulation period of 60 days, the movement rate is 6˚ per day. Mount Wilson is located at 118˚W, the Kuril Islands – at 150˚E, and we consider east of the Kuril Islands as 160˚. The cloud traveled the distance from the explosion site to Mount Wilson at 278˚W in 46 days. Subject to the dust cloud appearance on June 4, this corresponds to April 23.

But there is another, more likely possibility for formation of the dust cloud passing over Mount Wilson on June 4. The TCB perigee change is related to the Moon motion, so the perigee lowers according to the lunar month period. Hence, the critical lowering could also occur on April 30 and May 30. In case the contact with the atmosphere occurred on April 30, it could take 35 days for the cloud to reach Mount Wilson. This corresponds to $35 \times 6^\circ = 210^\circ$. The contact point longitude would be $210^\circ - 118^\circ = 92^\circ$.

But this coincides with the perigee location in the area of Sulomaya! Thus, TCB really was in the Earth's orbit at the time. The exact coincidence of the perigee point as of June 30 and April 30 indicates

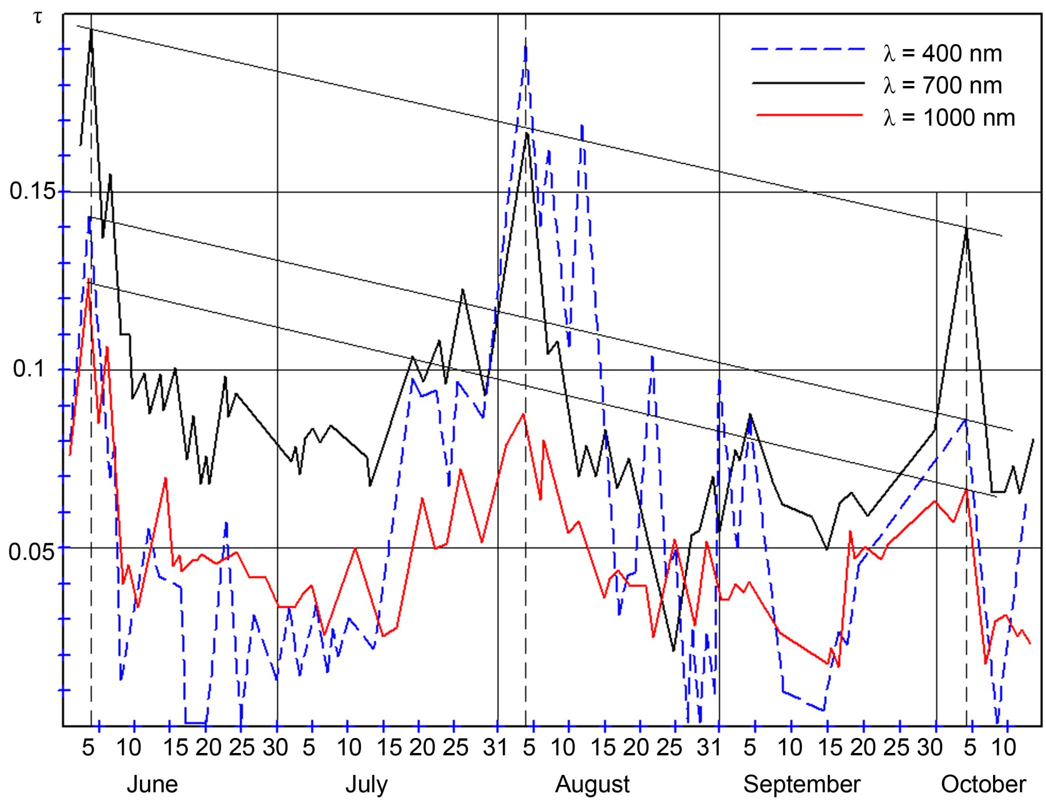

Figure 2. Changes in the optical density of the atmosphere over Mount Wilson in the article "Tunguska Cosmic Body Is a Comet Nucleus" [7].

that the daily perigee drift was insignificant, and the orbit was geosynchronous.

The authors of the article identified the fall zone based on the cloud scattering pattern for asteroid explosion at a high altitude and at a large entry angle. But in the case of atmosphere contact due to the perigee lowering, TCB passes the atmosphere in the west-east direction, and the contact spot is extended in longitudinal direction. Hence, the point of contact could indeed be much to the west of the point proposed by the authors. During the first contact, a large amount of dust blown off the TCB surface entered the stratosphere, so only the dust trace was recorded at Mount Wilson.

6. SOUTHEN GROUP

Falls occurred in the area of the Sayan Mountains show some peculiarities. It is reasonable to distinguish these as a separate Southern Group (**Figure 3**).

The falls here occurred very compactly. The point coordinates are S10 54˚53'N 97˚08'E. In an area spanning 120 km west to east and 80 km north to south, at least 20 large falls and hundreds of smaller ones filling the space between the large ones occurred (**Figure 4**). V. Burmakin is the discoverer of swarm falls. There are several spots without a fan pattern in this image, but there are indications that these are associated with damages occurring during the catastrophe. There are undamaged spots on some of the eastern slopes of these areas.

Apparently, individual body approximately of 60 - 70 m in diameter weighting 0.1×10^9 kg was separated from TCB. The fallout power is estimated at 0.1 - 0.2 Mt in TNT equivalent.

The Southern Group should pass as a swarm of bodies. There is rather unclear testimony confirming the swarm passage from the Chesnokovsk village near Barnaul. The testimony was recorded by L. E. Epiktetova in 1972 [9]. E. A. Yurieva born in 1898 reported as follows:

"When I was about 10 years old, balls flew from east to west. Coming like water-waves. A lot of balls like a cloud. Multicolored, red and green, shiny. As high as clouds. From the house, we looked out the windows. It was in spring, it seemed. There was no snow. In the morning, I think. The children woke up. The window to the east, a cloud was flying. Moving slowly. At the same altitude."

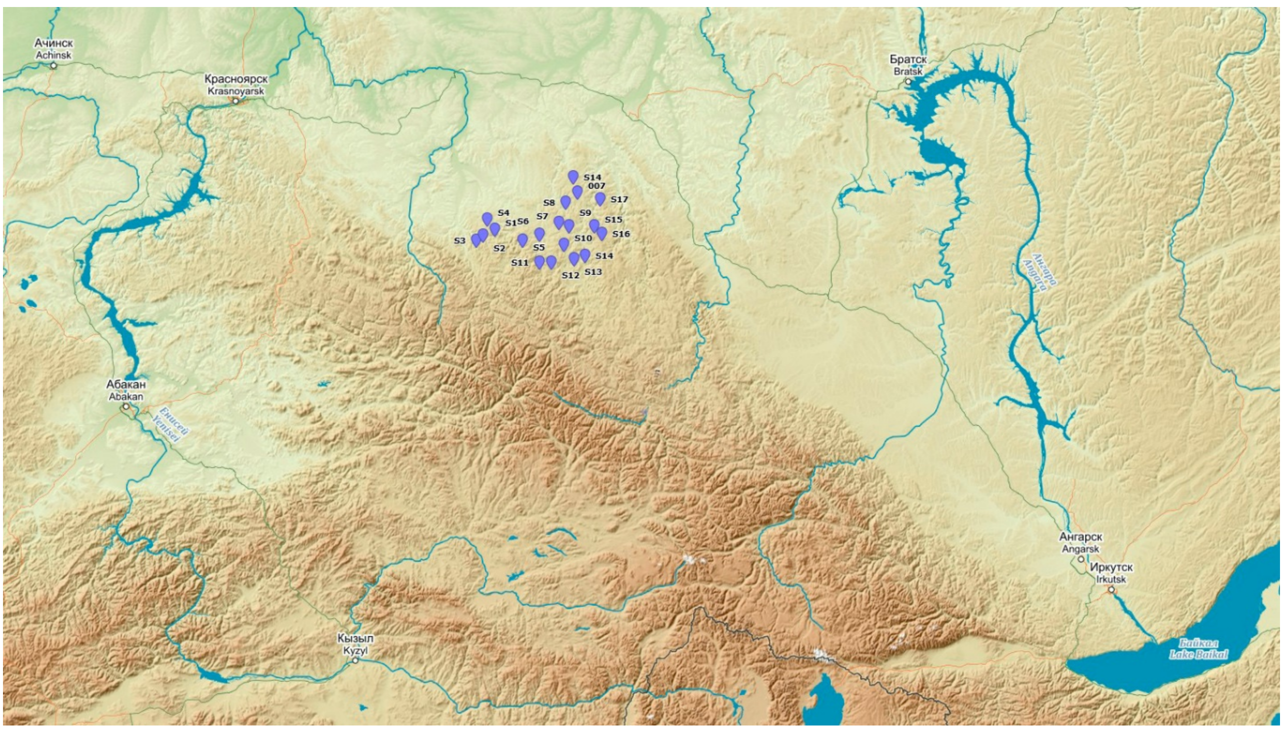

Figure 3. **Southern Group of Siberian fan reliefs.**

Figure 4. Central part of the Southern Group.

The opposite flight direction is indicated, but the other circumstances are the same. Barnaul is in the swarm flight path, and the swarm should look something like this. The windows overlooking east are mentioned, but should it flew from the east, the children would have to run outside to see where the "balls" would fly further. But should it flew east, everything should be clearly visible from the window until disappears. Thus, there is a good chance that the ten-year-old girl saw the swarm flight; the time and location coincide.

There is a high probability that the Southern Group fell on or around April 30. The dust cloud over Mount Wilson could be formed as a result of both TCB contact with the upper atmosphere and the falling of Southern Group bodies. Powerful falls occurred just 550 km from Irkutsk where the seismic station was located. But there are no obvious traces in the June 30 seismogram. The power of individual falls could make up to 20 kilotons of TNT equivalent. Unfortunately, seismograms for this period are probably lost. The fact that an individual fall in April or early May 1908 was not observed should not be surprising. The fall site is unpopulated and difficult to access even today.

The body forming the Southern Group was attached to the 200 - 250 meter TCB. We can be sure that it was not deeply embedded in TCB, and the connection was weak. Such a body could be separated at the very first contact with the atmosphere on April 30. The witness also indicates that the fall likely occurred in the spring, but this could not be considered accurate information.

7. SECONDARY BOLIDES FALLING DIRECTIONS

We can judge the bolides flight direction based on two sources: the traces on the ground in the form of the Siberian fan reliefs and eyewitness testimony. The fan reliefs indicate two groups of falling directions: eastward for the Western Group and north-northeastward for the Eastern group.

After separation and braking in the atmosphere, the fragments moved to their own orbits; these orbits could not differ fundamentally from the TCB orbit. Therefore, the northward, northeastward, and eastward fall directions are due to the perigee lowering and shift to the east with the orbit touching the atmosphere with its other part.

However, many previous hypotheses provided other motion directions.

Over the Preobrazhenka village, a bolide was observed at the same time flying exactly along the TCB flight path continuation, but from the opposite direction. This cannot be a simple coincidence. This movement can be explained as follows. At the time of the TCB near-Earth orbit capture, another body was captured in the identical, but inversed orbit. The orbit projection is the same as in **Figure 1**, but the orbital motion direction is opposite. Since the orbits are completely identical and are subjected to the same impact of the Moon and the Sun, the fall at the same time can be considered not accidental coincidence. This body can be called TCB 2.

The passage circumstances indicate that TCB 2 was small in size compared to TCB 1. Witnesses did not notice any phenomena associated with its flight. The testimonies of witnesses from Preobrazhenka indicate the fall with an explosion and earthquake. Weight of evidence suggests that the explosion and earthquake were caused by TCB 1 with the formation of the Eastern forest fall.

Many hypotheses indicate the bolides flight direction northwestward. In principle, we can attribute the formation of this-direction bolides to TCB 2, which could also disintegrate at the last revolutions with such bolides formed.

But there is another likely option. All hypotheses were based on the single body fall, and each researcher had to solve an elementary problem. The coordinates of explosion location over the Tunguska are known, and a particular bolide observation point is available. From these two points, it is very easy to identify the desired direction. It is difficult to identify the exact direction from the testimonies, so where some direction is desired, unintentional fitting to the desired result is quite likely.

The Siberian fan reliefs of the Eastern Group indicate northward and northeastward directions and are located close to the locations where northwestern bolides were observed, of which direction was calculated based on the testimonies. Perhaps, the northeastern and northern bolides became the northwestern ones. Most likely, there were no northwestern bolides at all. Anyway, their existence must be confirmed by a rigorous analysis of the eyewitness testimony without fitting. The northwestward directions could exist, but solely in context of the alleged disintegration of TCB-2.

8. TCB AND COMET SCHWASSMANN-WACHMANN

On May 30-31, 2022, the Tau Herculids meteor storm associated with Comet Schwassmann-Wachmann was expected. This comet was discovered in 1930, but it has a longer history. For example, meteor showers in 1892 and 1897 associated with this comet tails are known.

Similarity is noted between this comet's calculated orbit as of 950 and the current orbit of the June Bootids. The June Bootids are the shower generated by the periodic Comet Pons-Winnecke. It is likely that the June Bootids and Comet Pons-Winnecke are in some way related to the Tau Herculids and Comet Schwassmann-Wachmann. Most likely, the original comet was broken down. In 1926, L. A. Kulik [10] was the first to notice possible association with Comet Pons-Winnecke. At the time, Comet Schwassmann-Wachmann had not yet been discovered.

In 1930, the orbital period was estimated to be 5.43 - 5.46 years. Therefore, the comet should have approached the Earth in the spring of 1908. The comet orbit may be changed due to effect of Jupiter, and it is difficult to judge the exact date of approach. Should the comet period be equal to 5.50 years, then the comet and the Earth orbits would have approached at the same distance as in 1930 for four 22-year cycles. Then the distance between them would be 0.06 AU (astronomical units).

If we take a period of 5.45 years, then we get $5.45 \times 4 = 21.8$ years for four cycles; the comet would arrive at a point 0.2 years earlier. This makes $0.2 \times 12 = 2.4$ months. Given that the 1930 approach occurred on May 30, the 1908 approach could have occurred in mid-March 1908. It is not directly about Comet Schwassmann-Wachmann, but about a swarm of fragments separated from the comet earlier. Thus, TCB could orbit in March-April 1908, but at latest on April 30. Weak Alpha Bootids meteor shower is known with a peak on April 30, which is likely related to the event.

The Tau Herculids shower meteors had a velocity of 12 km/s. This velocity only slightly exceeds the second cosmic velocity, and under certain circumstances, the bodies from this shower could be in near-Earth orbit.

9. TUNGUSKA COMET STRUCTURE

TCB is a comet; this term was adopted at a time when its nature was doubtful, so it can be retained. The overall picture of the TCB fall and destruction is as follows:

Due to the gravitational attraction of the Moon, the perigee was lowered, and the comet started to pass through relatively dense atmospheric layers with fragments being separated from it.

Two revolutions before the fall, fragments were separated forming the Eastern Group of falls. At the next-to-last revolution, fragments of the Western and Southern Groups were separated. But this separation could as well occur at a single revolution.

During the fall, TCB was subjected to severe loads. This allows us to judge the material strength and structure. The TCB fall circumstances indicate that the base of the TCB and its fragments was solid ice. The ice strength was estimated at 16.5 MPa.

The fragments were separated at much lower loads. When passing through the atmosphere, some of the fragments were disintegrated forming swarms of debris. Several bodies were separated from TCB during descent. These fell behind the main body and exploded almost above the catastrophe site.

A powerful air explosion occurred near the Kulikovsky forest fall. The explosion was associated with the separation of several dozens of meters of shell. But the core of 150 - 170 m in diameter survived; it continued to fall along a flat path and was finally disintegrated near the point with coordinates 60˚20'N 106˚25'E approximately 100 km from Preobrazhenka on the Nizhnyaya Tunguska. The core ice strength could be 22 MPa.

The comet ice structure may differ from the terrestrial ice. Perhaps, it is characterized by porosity. With an overall high strength, such ice could lose its surface layer faster in a high-speed flow. The flight of such a bolide would involve an increased mass loss as compared with a solid ice body. Under certain conditions, such a bolide could "melt" in the atmosphere without local explosions. The bolide would generate higher power per kilometer of flight. Probably, the Eastern forest fall was formed due to such a destruction pattern.

Based on the destruction pattern, we can reconstruct the TCB structure and assume its formation sequence.

The ice formation process in space must have its own peculiarities, but some analogies can be drawn to the terrestrial processes. Initially, ice crystals being an analogue of terrestrial snow must be formed. Snow was accumulated into clumps of a wide size range; these clumps were in turn accumulated into larger ones. At some stage, processes were started in these bodies similar to the processes of ice formation from snow at Earth's glaciers. Whether ice or snow bodies were formed, but they had ice cores. These bodies were in turn merged. The result was the formation of the body that later became TCB. It had a monolithic core and perhaps several layers with strength decreasing inside out. The outer layer was much less strong. Other various-size ice bodies were embedded in it including the body forming the Southern Group. For some time, TCB was an independent space body.

100 - 500 meter ice bodies were merged into comets of kilometers in size under other conditions still interconnected just at the gravitational force level. Perhaps, a large amount of dust settled on the primary bodies thus preventing the formation of strong ice bonds.

Large comets are composed of many smaller nuclei. They continued to accumulate dust and gases for billions of years. Such a comet entered the inner regions of the Solar system and fell into the gravitational sphere of Jupiter. The comet became a short-period comet. More than a thousand years ago, it split into two parts forming comets Schwassmann-Wachmann and Pons-Winnecke. Shortly before the catastrophe, TCB was separated from Comet Schwassmann-Wachmann. This resulted in a swarm of fragments. Several fragments fell into the Earth's gravitational field and ended up in near-Earth orbits. TCB 1 and TCB 2 fell on June 30 with the other fragments probably falling for several more years. There is information that

1908 and subsequent years were rich in bright bolides.

Comets falling into the inner layers of the Solar system and breaking apart produce not only beautiful meteor showers, but numerous ice nuclei of considerable size. These nuclei are covered with a layer of charred organics contained in the ice and can exist for long periods of time. They are in cometary orbits, and it is difficult to detect such nuclei due to size of 100 - 500 meters and low albedo. TCB entered the atmosphere at a velocity of less than 11.2 km/s along a flat path, so it caused specific damages. With a steeper path, result could be an explosion at an altitude of 15 - 17 kilometers with a power of over 100 Mt.

10. SIBIRIAN FAN RELIEFS IN SATELLITE IMAGES

The Siberian fan reliefs are the key to the proposed hypothesis and give everyone the opportunity to verify their existence. This is easy to do using the Internet. To do this, one must have access to satellite image archives. The archives allow viewing the images for several decades. Many people try to suggest their own SFR origin versions. There are two basic versions: windsnaps and wildfires. When viewing, it may appear that some of the fans are formed relatively recently, as these are not presented in the previous images. This is used as an argument that the SFRs are not related to 1908.

But such a conclusion would be hasty. We have to keep in mind that we are now dealing with damages that occurred over 110 years ago. The natural forest and soil layer was damaged. The damaged areas are restored following their own laws. First, deciduous trees grow, then conifers sprout under their shade. The damaged area differs in color from the undamaged taiga background. But the difference diminishes gradually, and the fan disappears. But this is where fires come in. The taiga burns approximately every 40 years. And the new forest grown at the damaged areas can be burnt to the ground. While age-old forests untouched by falls endure fires in a different way with only the undergrowth burnt. The bark protects the trunks from fire, and the crowns are far from the ground. Intermittent ground fires are actually beneficial.

Once again, the burned areas differ sharply from the background. Indeed, some of the fans may result from forest falling by a hurricane, from fire, or in some other way. One can only draw a correct conclusion on the relief origin in the field. The relation to 1908 is verified using the dendrochronology methods and space markers. The Southern Group fans were repeatedly visited by V. Burmakin. He was rafting on the rivers of Siberia for over 50 years and saw the forest falls in the west-to-east direction long before the discovery of SFR. The forest falls associated with the fans appeared very old already in the 1970's.

In the Sayan Mountains, vegetation is restored slowly. Elsewhere in Siberia, many fans have disappeared without a trace. There are testimonies about forest falls in specific places, but it is impossible to find these as they had disappeared before satellite images came to be. It is impossible to find even the traces in the images of the huge Eastern forest fall, which can be up to 6000 km^2 in area.

The first forest fall along the TCB fall path was witnessed in the area of Sulomaya. There is every reason to suppose that forest falls of various degree of intensity occurred from the Yenisei to the Nizhnyaya Tunguska.

11. CONCLUSIONS

Thus, the situation in 1908 is as follows. TCB was captured in Earth orbit in March-April, but at latest on April 30. It was probably associated with Comet Schwassmann-Wachmann. The orbit was geosynchronous with a period of about 24 hours, orbital inclination angle $i = 62˚$, perigee altitude 150 - 200 km, apogee altitude 77,850 km. The orbit perigee was lowered due to effect of the Moon and the Sun, and TCB entered the atmosphere. At the last revolutions prior to fall, dozens of fragments were separated from the comet forming the Siberian fan reliefs during the fall. The fragments formed 3 groups of falls. The bolides associated with these falls had directions ranging from northward to eastward. One of the bolides was in inversed orbit moving east to west.

TCB was falling along a path through Turkey, the Black Sea and the Kerch Strait. The flight was detected in the Khvorostyanka village near Samara and in Sulomaya near the Podkamennaya Tunguska influx into the Yenisei. In area of Fast epicenter, TCB has lost a part of its shell with an explosion forming

Kulikovsky forest fall in shape of Fast butterfly. At the moment of explosion, TCB was 210 m in diameter, weight 4.5 × 10^9 kg. The remaining core of 150 - 170 meters in diameter continued to fall in descent and formed the Eastern forest fall. The fall ended with air explosion or falling of core remnants at a distance of 100 kilometers to the west of Preobrazhenka village on the Nizhnyaya Tunguska.

The fall path was plotted based on witness testimonies and objective traces on the ground. The fact of TCB being in a near-Earth orbit on April 30 is confirmed by the data obtained at Mount Wilson Observatory.

The proposed hypothesis does not contradict the whole body of observations and objective information accumulated over the years of studying the problem. Some declared parameters of the event can be specified.

The ice strength calculated based on the comet destruction circumstances was 16 - 22 MPa. This information may be useful in case of ice asteroid approach risk. Additional information about the comet composition and the material properties can be obtained by studying the fragment falling sites.

CONFLICTS OF INTEREST

The author declares no conflicts of interest regarding the publication of this paper.

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