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THE TUNGUSKA INCIDENT, JUNE 30, 1908:
A BLAST, A METEORITE, A COMET, OR A THREAT FROM SPACE

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Almost 115 years ago, the very powerful explosion occurred at 7:17 AM in the morning of June 30, 1908 in Central Siberia, 800 km NNW from Lake Baikal and Irkutsk near Podkamennaya Tunguska River. It devastated the forested area of 2150 km^2, flattening and scorching some thirty million trees. The object that flew that morning over Siberia is usually designated the Tunguska meteorite or – more cautiously – the Tunguska space body. Certainly, this body was dangerous: the taiga was levelled over an area twice as large as New York City. The whole number of explosion hypotheses reaches a hundred, or so. But few of them have been built according to the standards of science and with consideration of empirical data. The scientific interest stimulated by the Tunguska explosion of 1908 has produced enormous speculation and controversy as to its origin. The theories offered by those who have studied the event range from the realm of science (a meteorite, comet, or nuclear explosion) to the realm of science fiction (a black hole, anti-matter rock, or an alien spacecraft). Each theory has protagonists promoting and defending their point of view considering the evidence. However, because the scientific community did not view the actual event, but only observed the devastating results (it was 19 years after the explosion before the first scientist arrived on the scene), each theory contains speculation. Therefore, before delving into the specifics of each theory, it is important to review the facts of the event.

Keywords: Tunguska explosion, Tunguska meteorite, Lake Cheko, cosmic body, Tunguska incident, nuclear explosions, Tunguska space body, Podkamennaya Tunguska River, Leonid Kulik, Greenland, Iridium.

ТУНГУССКИЙ ИНЦИДЕНТ 30 ИЮНЯ 1908 ГОДА: ВЗРЫВ, МЕТЕОРИТ, КОМЕТА ИЛИ УГРОЗА ИЗ КОСМОСА

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Почти 115 лет назад, 30 июня 1908 г. в 7:17 утра в Центральной Сибири, в 800 км к северо-западу от озера Байкал и Иркутска, недалеко от реки Подкаменная Тунгуска произошел мощнейший взрыв. Он опустошил лес площадью 2150 км^2, сровняв с землей и опалив около тридцати миллионов деревьев. Объект, пролетевший в то утро над Сибирью, обычно называют Тунгусским метеоритом или, более осторожно, – Тунгусским космическим телом. Конечно, это тело было опасным: тайга была сровнена с землей на площади, вдвое превышающей площадь Нью-Йорка. Общее число гипотез взрыва достигает сотни или около того. Но лишь немногие из них были построены в соответствии со стандартами науки и с учетом эмпирических данных. Научный интерес, вызванный Тунгусским взрывом 1908 г., породил огромные спекуляции и споры относительно его происхождения. Теории, предлагаемые теми, кто изучал это событие, варьируются от научных (метеорит, комета или ядерный взрыв) до области научной фантастики (черная дыра, камень из антивещества или космический корабль пришельцев). У каждой теории есть протагонисты, продвигающие и защищающие свою точку зрения с учетом доказательств. Однако, поскольку научное сообщество не рассматривало фактическое событие, а только наблюдало его разрушительные результаты (прошло 19 лет после взрыва, прежде чем первый ученый прибыл на место происшествия), каждая теория содержит спекуляции. Поэтому, прежде чем углубляться в специфику каждого случая, важно ознакомиться с фактами события.

Ключевые слова: Тунгусский взрыв, Тунгусский метеорит, озеро Чеко, космическое тело, Тунгусский инцидент, ядерные взрывы, Тунгусское космическое тело, река Подкаменная Тунгуска, Леонид Кулик, Гренландия, иридий.

Prologue

For centuries, the appearance of a comet has been taken as a harbinger of death and misfortune. It is an old superstition whose origin it is difficult to trace. But a small grain of truth is probably still in the old superstition. The Earth has been hit by alien celestial bodies before, with rather large disasters as a result. We want to tell about such a cosmic collision that happened as recently as 1908 over the sparsely populated northern forestland above the Podkamennaya Tunguska River in what is present-day Krasnoyarsk Krai [1].

A catastrophe may be defined as a natural event of large magnitude (energy), short duration, wide extent and low frequency. The Tunguska explosion of 1908 can be considered the epitome of a cosmic impact catastrophe. An understanding of this unique event and its origin could provide insight into large ancient asteroids or comets collisions with the Earth and possible global catastrophic effects (e.g., from flooding, tectonism, volcanism, glaciation and air blast waves). Catastrophism, a doctrine spurned by uniformitarian scientists in the twentieth century, is now being confirmed by events, which have occurred in this century [13, p. 36-37].

Cosmic material is constantly falling to Earth's surface. It happens partly as more or less violent meteor falls, partly as a quiet rain of cosmic dust. In total, the Earth is hit by around 10,000 tonnes of space rocks and gravel per year. Hundreds of large meteor craters are known around the globe. Although most of them are so old that there are no records of fallout events, there is usually no doubt that it really is a meteorite fall, because pieces of the fallen meteorite are found in and around the crater. In the Tunguska event on the hot summer day of 1908 in Eastern Siberia, however, one was in the exact opposite situation. There were reliable eyewitness accounts and thousands of square meters of overturned forest, but meteorites or comets – not even a little cosmic dust, and it was a bit of an enigma to both contemporaries and scientists today.

The Tunguska blast in 1908

The Tunguska blast took place at 7:17 am on June 30, 1908. Then in China a celestial body was seen moving with great speed to the northwest. Before this, a luminous body flew overhead in the cloudless sky. The air waves from the explosion were recorded as far as in London. It made a luminous trail and left behind a dark tail of dust and gas. A few seconds later, the celestial body reached so far into the atmosphere that the friction developed into a regular explosion. Its epicentre was in an almost desolate area of the Siberian taiga, covered with ancient conifers. The dust trail in the atmosphere could be seen 500 km away, and the angle of the trail with the horizontal was approximately 16 degrees [2, s. 14].

This warm summer night was not really night in Europe and in Western Siberia. An enormous amount of cosmic dust had entered the atmosphere and was constantly illuminating the night sky. Even in places further north in Siberia, where the transition between night and day is very abrupt, bright nights were experienced. Light, transparent, and unusual luminous silver clouds, mostly visible only in glimpses, could be observed over an area of several million square kilometres. All because of the explosion near the Yenisei tributary Podkamennaya Tunguska River. Despite the desolate location of the impact site, there were several eyewitnesses to the explosion, including a reindeer herder who was quite close to the epicentre. The light from the celestial object was so strong that the shepherd had to turn around to avoid hurting his eyes. He also suffered burns on his back from the explosion that followed a few seconds later [6, s. 15].

The first report of the explosion was in the Irkutsk paper dated July 2, 1908, published two days after the explosion. The readers could know that the peasants saw a body shining very brightly (too bright for the naked eye) with a bluish-white light. The body was in the form of “a pipe”, i.e., cylindrical. The sky was cloudless, except that low down on the horizon, in the direction in which this glowing body was observed, a small dark cloud was noticed. It was hot and dry and when the shining body approached the ground (which was covered with forest at this point) it seemed to be pulverized, and in its place a loud crash, not like thunder, but as if from the fall of large stones or from gunfire was heard. All the buildings shook and at the same time, a forked tongue of flames broke through the cloud. All the inhabitants of the village ran out into the street in panic. The old women wept, everyone thought that the end of the world was approaching [4].

Several eyewitness accounts were at the nearest trading post in Vadecara about 60 km south of the explosion site. The Russian tradesman Semedec, an eyewitness in the village of Vadecara, provided excellent information. He told the authorities that he was sitting in the porch of the house at the trading station of Vadecara at breakfast time, when suddenly in the north, the sky was split in two and high above the forest the whole northern part of the sky appeared to be covered with fire. At that moment he felt great heat as if my shirt had caught fire; this heat came from the north side. He wanted to pull off my shirt and throw it away, but there was a bang in the sky, and a mighty crash was heard. The tradesman was thrown to the ground about seven meters away from the porch and for a moment he lost his consciousness. The crash was followed by noise like stones falling from the sky, or guns firing. The earth trembled, and when Semedec lay on the ground. He covered his head because he was afraid that stones might hit it [4].

The last witness was a farmer in the Kezhma area (about 200 km south of the impact site) and he related the following: "At that time I was ploughing my land at Narodima (6 km to the west of Kezhma). When I sat down to have my breakfast beside my plough, I heard sudden bangs, as if from gunfire. My horse fell on its knees. From the north side above the forest a flame shot up. I thought the enemy was firing, since at that time there was talk of war. Then I saw that the fir forest had been bent over by the wind and I thought of a hurricane. I seized a wall of water up the Angara [a seiche perhaps]. I saw it all quite clearly, because my land was on a hillside hold of my plough with both hands, so that it would not be carried off. The wind was so strong that it carried off some of the soil from the surface of the ground, and then the hurricane drove" [cit. ex: 4].

Several eyewitnesses had seen a fireball crash into the tundra. Others could tell of terrible bangs very reminiscent of thunder and very powerful lightning. Weather stations in large parts of Siberia recorded a blast wave across the globe. In a radius of 10 kilometres from the centre of the explosion, the trees were burnt. The thing that had caused the explosion, however, left no direct clue as to its nature and origin, but disappeared without a trace in the fire it had itself ignited in the area.

The explosion was so powerful that the sound wave travelled twice around the earth and was recorded by seismographs everywhere. Later data processing of the seismograph recordings showed that the energy in the explosion corresponded to 13 megatons of TNT, or 650 Hiroshima bombs. The energy released was what was left of the celestial body's kinetic energy, which was converted into frictional heat within a fraction of a second. Seen from a distance of a few kilometres, there is no difference between the effect of a nuclear bomb and a collision with a celestial body, except of course for the lack of radioactive radiation in the latter. In both cases, it is the enormous and sudden release of energy that determines the development of the explosion. If we assume that the speed before the final explosion was 10 kilometres per second, the mass of the celestial body can be calculated from the measured seismic energy to one million tons [13, p. 17].

The earthquake that resulted from the Tunguska explosion was 5.0 on the Richter scale. And based on the very first readings of the seismographs, researchers were later able to confirm that the celestial body did indeed enter the Tunguska area from the south-east. The explosion itself happened at a height of 8 kilometres, and the explosion broke and toppled huge pine trees to 52 kilometres from the epicentre. All trees from which the explosion could be seen were knocked down to 25 kilometres from the epicentre. Areas of destruction and fallen trees were large. This corresponded to an area of 7,500 square kilometres. It is thought provoking that if this celestial body, which has been moving around the solar system for 4.5 billion years, had collided with the Earth just a few hours later, it could have hit St. Petersburg or Oslo with enormous destruction as a result. Just like the giant earthquake in Lisbon in 1755. But by chance it hit one of the most deserted areas on the planet instead.

Through comparison of old seismograms of the Tunguska event and seismograms of the decay Zemlya and Lop-Nor nuclear-weapon tests, researchers determined that the Tunguska projectile had the effects of an Extra-terrestrial Nuclear

Missile of yield 12.5±2.5 megatons. This is approximately three orders of magnitude greater than the Hiroshima A-bomb and about one-fifth the energy of the largest hydrogen bomb explosion. The height at which the explosion occurred was estimated to be approximately 7.5 kilometres, with a total energy release of approximately 3×1023 ergs, 5×1018 ergs of which was changed into seismic energy [12].

More energy went into the air blast than the earthquake. It was estimated the energy of the air blast wave to be 3.2×1020 ergs. The seismic activity measured on the Richter scale was 5.0; and the air compression wave went twice around the Earth, according to recordings at meteorological stations. The projectile travelled in a southeast to northwest direction with a 60º azimuth, according to Russian researchers who made use of eyewitness accounts and an inspection of the radial symmetry of the trees at the explosion site. This direction was probably immediately prior to the explosion; however, there are conflicting reports as to the actual line of flight [13, p. 15-16].

The temperature at the centre of the fireball was estimated by one source to be up to 30 million degrees Fahrenheit. Some storage huts in the nearby vicinity of the focus were found devastated by fire and the silverware and tin utensils within were deformed by intense heat. “Preceding the front of the shock wave there arises a heated zone whose radiating surface area is far larger than that of the shock wave itself”. This is substantiated by Semedec who first felt the heat wave, then was thrown to the ground by the air shock wave. The inhabitants of Central Siberia saw the fall and explosion of the meteorite over an area with a radius of 600-1000 kilometres. Eighty million trees in the taiga (coniferous forest) were uprooted and blown down for a radius of 30-40 kilometres. Some trees on the leeward side of hills were somewhat protected, yet still had their branches broken off and bark stripped to leave them standing naked, resembling telegraph poles [13, p. 120].

The Tunguska event as it was perceived in 1908

In 1908 it was not clear where the sudden pulse of pressure came from on the then recently installed microbarographs (pressure gauges) in Great Britain. The barographs recorded the pressure wave from the explosion both the first and second time it rolled around the Earth. You had practically nothing to compare the barograph measurements with, so you were not surprised by the sudden pressure increases. It was simply believed that it was either the order of nature, or perhaps a small fault with the many new instruments. In 1908 the meaning of the seismic signal, which was picked up on seismometers around the Earth, was also not understood. Only many years later did it become clear that the seismic signal originated from the Tunguska explosion. When the explosion occurred, it was thought that it was simply an unreported earthquake somewhere on the Earth [3, s. 44; 10, s. 14-15].

What people wondered about in 1908, and even wrote about in many countries' newspapers, were the extraordinarily bright nights that everyone in Northwest Europe could see and experience. The Danish newspaper "Politiken" wrote on 2 July 1908 that people had noticed with astonishment on the nights around 30 June that it would not get dark at all. Even at 11 PM on the night of July 1, it had been full daylight throughout Denmark. And even at 0.30 PM it was still like the sun was up in the sky. Similar accounts were noted in newspapers in Stockholm, Oslo, Helsinki, Berlin and Konigsberg (now Kaliningrad). Also in many places in Russia and neighbouring Asian countries the strange sky phenomenon was observed. Contemporary explanations ranged from gigantic fires above luminous night clouds to secret experiments carried out by the English navy. After all, the world was in an unstable state when World War I loomed a handful of years later [6, s. 16].

The most reasonable theories of the Tunguska blast

The Tunguska event has formed the framework for several theories, hypothesis, and conspiracy theories. Today, 115 years after the event, science has not yet pointed to a certain theory. In this paper only realist theories will be focused on. The UFO theories will not be dealt with. Therefore, here the following three theories and two hypotheses will be briefly described: the meteorite theory, the comet theory, the nuclear theory and the black hole and anti-matter hypothesis [12].

The meteorite theory

A meteor airburst is a type of air burst in which a meteor explodes after entering a planetary body's atmosphere. This fate leads them to be called fireballs or bolides, with the brightest airbursts known as super bolides. Such meteoroids were originally asteroids and comets of a few to several tens of meters in diameter. This separates them from the much smaller and far more common "shooting stars", that usually burn up quickly upon atmospheric entry. Meteoroids enter the Earth's atmosphere from outer space traveling at speeds of at least 11 km/s (7 mi/s) and often much faster. Despite moving through the rarefied upper reaches of Earth's atmosphere the immense speed at which a meteor travels nevertheless rapidly compresses the air in its path. The meteoroid then experiences what is known as ram pressure. As the air in front of the meteoroid is compressed its temperature quickly rises. This is not due to friction, rather it is simply a consequence of many molecules and atoms being made to occupy a smaller space than formerly. Ram pressure and the very high temperatures it causes are the reasons few meteors make it all the way to the ground. Most simply burn up or are ablated into tiny fragments. Larger or more solid meteorites may explode instead [5, p. 33].

During Leonid Kulik's three succeeding expeditions to determine the cause of the Tunguska event, his meteorite theory received no substantiating evidence. Despite tremendous hardships caused by the searing heat of summer, the coldness of winter and insufficient funds for supplies and equipment, Kulik and his party persevered to obtain evidence relating to the Tunguska explosion. Throughout his investigations and those of others covering a total of fifty years, there was no evidence of impacting iron, no impact craters, no meteorite remnant, and no strewn field of particles. The only evidence left by the Tunguska bolide was toppled and burned trees. The holes that Kulik thought to be from meteorites proved to be natural depressions. Furthermore, the meteorite theory is problematic because of the lack of evidence of different minerals known from other meteorite impacts [7, s. 53].

The comet theory

The comet theory due to a lack of evidence for the meteorite theory proposed by Kulik, other theories were proposed to explain the Tunguska event. This model consists of a large dirty snowball composed of dust and rock interspersed with water, methane, and ammonia ices. But also a high level of iridium should legitimate this theory. It appears unlikely, therefore, that the Tunguska explosion was produced by a bona fide active comet a hundred or so meters in dimension, more likely, however, the Tunguska object was an inactive, low density, friable body. There is no reason to suspect that it was interstellar. It is an understatement to suggest that the origin of the Tunguska explosion is controversial. There are various elements of the commentary hypothesis that explain the eyewitness accounts and the associated physical data. Probably the most important concept supporting the comet hypothesis is the nature of flight of the Tunguska fireball. Usually, the meteorite overtakes the Earth from behind on the evening side. However, comets have a wide range of orbits and velocities and could collide with the earth on the morning side. "These properties of the [dust] distribution can be explained if the cloud of cosmic particles was associated directly with the nucleus of the Tunguska comet and pointed in a direction away from the sun" [cit. ex: 4]. This is a plausible explanation regarding the brilliant nights observed in Europe. No other theory offered adequately explains this anomaly. More evidence supporting a comet came to light in 1962 when technicians discovered microscopic pellets of magnetite and silicate globules, thought to be extra-terrestrial, in soil samples from the Tunguska explosion site. A double spherule consisting of a magnetite pellet inside a larger silicate shell is unique to this event and thought to be the result of "rapid condensation of incandescent gas upon cooling" [cit. ex: 4]. There appear to have been three radiant centers made by fallen trees, according to several Russian researchers, which would indicate multiple explosions. It was noted that the air wave recorded on the microbarographs appears to indicate two types of waves: one generated by penetration of the object into the atmosphere, and the other generated by the explosion or explosions [5, p. 78-80; 15, p. 67].

The nuclear theory / UFO theory

The similarity between the Hiroshima A-bomb devastation and the mysterious Tunguska effects gave rise to the notion that the 1908 event was caused by a man-made nuclear bomb. The fictional writings of the Soviet author Alexander Kazantsev in 1946 were the first to pick up the idea which scientists later considered. A prominent Soviet scientist Alexei Zolotov after a 17-year investigation, expanded the nuclear explosion theory by supposing it was caused by the visit of an alien spacecraft (TASS news release, mid-October 1976). "According to Zolotov, a spaceship controlled by "beings from other worlds" may have caused the 1908 explosion. He imagined a nuclear propelled craft that exploded accidentally due to a malfunction. Zolotov also admits to problems with the theory, realizing that safety devices would probably prevent such a mishap, and observing that the actual area of destruction was an amazing demonstration of pinpoint accuracy and humanitarianism" [4].

"The body approached from the south, but when about 140 miles from the explosion point, while over Kezhma, it abruptly changed course to the east. Two hundred and fifty miles later, while above Preobrazhenka, it reversed its heading toward the west. It exploded above the taiga at 60º55' N, 101º57' E." [cit. ex: 4]. Scientists who have reviewed eyewitness reports are not convinced of any course changes as the brilliant object traversed the sky.

The anti-matter theory

This theory proposes that an anti-rock composed of anti-matter was annihilated in the atmosphere above the Tunguska explosion site and caused the observed damage. Cowan et al. postulated that such an explosion would cause an increase in atmospheric radiocarbon. Upon analysis of C-14 content in a 300-year-old Douglas fir from Arizona, they believe that they obtained increased radiocarbon for the time of the event. However, the data presented in their paper appear to lack statistical significance for support of their conclusions. Furthermore, careful C-14 measurements of a tree nearer the blast fail to show an increase in 1909 [4; 5, p. 150].

The black-hole theory

The last theory as to the cause of the Tunguska event is proffered by Jackson and Ryan in 1973. They suggest that a black hole with a mass of 10^{22} to 10^{23} g would have the necessary energy about 1023 ergs to have caused the Tunguska destruction. The researchers maintain that the black hole would cause the destruction as it pierced through the earth with the ease of cutting soft butter, exiting the Earth through the Atlantic Ocean. Beasley and Tinsley in 1974 refute the black-hole theory because the microbarographs that recorded the air waves of the explosion did not record air waves of an exit point in the Atlantic Ocean. This is vital to the black hole theory because the exit of the black hole from the earth would be expected to exhibit devastating effects like those at its entrance. The black-hole concept also does not explain the magnetite and silicate globules found in the explosion region, nor does it account for the anomalously bright night sky observed over Europe [q.v.: 4; 5, p. 139-140; 15, p. 123].

In the following, these theories (especially the two first mentioned theories) will be further explained.

The Tunguska event and scientific research

However, a full twenty years had to pass before a scientific expedition was sent to the disaster site, but it returned home completely empty-handed. No trace of any foreign object was found at the impact site. Nor later scientific expeditions had luck with them in their quest. Science was in a classic, that is, in a classic situation, where the lack of evidence provided fertile ground for the most diverse and fantastic hypotheses. Around 1927, two hypotheses gradually gained a foothold. Either it was a nuclear explosion, or it was a comet impact. However, only a few scientists dared to present theories about the impact at scientific conferences or in political congresses. Indeed, not even when researchers specializing in meteorite impacts met, did they dare present theories.

Russia's turbulent history and World War prevented a real scientific visit to the impact site until the year 1927. Here, the Russian meteorite researcher Leonid Kulik from Moscow equipped an expedition to the desolate and difficult to access area. Kulik devoted most of his life to the Tunguska blast. He died on the Eastern Front during World War II. Kulik and his assistant started the long journey in February 1927 and after many problems and hardships, they reached the Vanavara trading station a month later. Here they met Tungus nomads who had seen and experienced the explosion. The Tungus people told of forest fires that had lasted up to a week and killed thousands of reindeer.

No one was apparently injured or killed in the blast. Moreover, it was not difficult for Kulik and his assistants to find the central impact site, the epicentre, where all the large pine trees lay fallen like matches with the broken end pointing towards the epicentre. So, it was just a matter of following the direction of the trees. The outline of the area with felled trees resembled in shape a butterfly with its tail pointing to the northwest. This was later shown to be consistent with the pattern of destruction from a spherical explosion superimposed by a pressure wave traveling at about 40 kilometres per second from the southeast.

What surprised Leonid Kulik at first was that exactly in the epicentre there were several square kilometres of forest, where the trees did not fall, only ribbed for branches and badly charred. This phenomenon, which today is called telegraph pole forest, was observed later in 1945, when an atomic bomb was detonated just above the headquarters of the Japanese 5th Army in Hiroshima. Here, charred but upright trees without lateral branches were also found just below the detonation site. At the Tunguska impact site, however, no crater was found, not even the smallest piece of meteorite. All subsequent expeditions after 1930, which gradually brought more and more advanced equipment for the detection of meteorites, have searched in vain for traces of meteorites in the area.

As time passed, the discussion of the phenomenon ebbed, but the investigations of the impact site were still carried out. Every year, expeditions were made to the Tomsk area 1,200 kilometres east of the impact site. The scientific expeditions, however, had the focus on biological phenomena in the area and on possible changes due to the Tunguska explosion. But none of the most important questions; had mutations occurred? What effect had the explosion had on the plant life at all? Was there any increased radioactivity accumulated in the plants? Where was the radioactive zone? Could be answered based on a scientific basis.

During the 1960s and 1970s Russian scientists researched whether it was possible to find larger amounts of radioactive carbon in trees and plants throughout the greater area. The only concrete result was some researchers who found some tiny spheres in the soil at the impact site, spheres of silicate and metal. Silicate particles originate from meteorites from space. Russian measurements in the 1980s on a core of peat from the central impact site showed a very small amount of iridium, a precious metal like gold and platinum that is the best marker for cosmic material. However, the iridium content of the peat was very low, and it almost looks as if the Russians themselves considered the sampling or the measurements to be tainted by some error.

The Italian researcher Giuseppe Longo to have traced an impact crater. Today it is the 50-metre-deep Lake Cheko, which lies 7.5 kilometres north of the presumed centre of the area. The Italian researcher claims to have made measurements, which show the reflection of seismic waves from something on the bottom of the lake. He points out that the shape of the lake suggests that it is an impact crater from a low-velocity body. He estimates that the body has a diameter of 10 meters and weighs 1,700 tons.

In the 1960s expeditions to Tunguska otherwise concluded that the lake was not an impact crater, but Giuseppe Longo confidently points out that the researchers then only had limited technological aids available. The Italians are also undeterred by the fact that samples they have taken of the mud on the lakebed show no signs of the structure they believe they have traced on the lakebed. Instead, next year they will take a drill sample from the lake, preferably from a depth of ten metres. Such a test can determine whether the seismic reflection is an error or whether there are the remains of a meteor at the bottom of the lake. However, the theory is not confirmed.

Iridium, Tunguska, Denmark and Greenland

If you are ever going to find out what kind of celestial body it was that hit the Earth in 1908, then it is a good idea to locate some of the celestial body and analyse it chemically. The chemical composition of the celestial body could reveal whether it was a comet, a rocky mantle from an asteroid (a possible Achondritic meteorite), or perhaps a fragment of one of Jupiter’s moons.

As we said, the explosion happened at an altitude of over 8 kilometres. Normally, the tropopause, the boundary layer between the troposphere and the overlying stratosphere, is approximately 5 kilometres above the poles and about 15 kilometres above the equator. The explosion therefore occurred in, or at least very close to, the stratosphere. That was the reason why a Danish-American research team chose to go to a completely different part of the world around the year 2000 to try to solve the Tunguska riddle. The reasoning was as follows: an explosion so close to the stratosphere, and incidentally also the dust trail in the upper atmosphere over China, must logically have pumped large amounts of material up into the stratosphere. It is realistic to imagine that up to half of the celestial body could be scattered as fine dust in the atmosphere [14].

It is known from nuclear weapons experiments that once fine dust is brought up into the stratosphere, it spreads over the entire northern hemisphere. But not to the southern hemisphere, due to the circulation pattern of the atmosphere, and then falls back down in a few years. Therefore, theoretically, it should have been possible to trace the Tunguska blast in the Greenland ice sheet. The ice sheet is more than 3 kilometres thick and together with over 1000 kilometres to the ice edge, this means that the air over central Greenland has a very low content of ordinary terrestrial dust. There should therefore be ideal opportunities to find an iridium signal from the Tunguska blast in an ice core from central Greenland [11, s. 133].

However, conducting this experiment some 90 years after the event was fraught with many problems. First, the glaciologists had to drill an ice core in Central Greenland. Next, with the help of oxygen isotope measurements on the ice, the year layers 1905 to 1914 had to be found, and then each year layer was cut out separately. Then the ice had to be cleaned, melted, and filtered in a completely dust-free laboratory. Finally, the small filters were rolled up using two tweezers and plugged into small ultra-pure quartz tubes. The quartz tubes were heated quite slowly until the filters and any other organic compounds first evaporated, then charred and finally disappeared completely.

The quartz ampoules were then irradiated for 20 days in the US's most powerful experimental nuclear reactor at the University of Missouri. After this, the broken ampoules were transported on the outer edge of the wing on the trip between St. Louis and Los Angeles. The material was then collected and then analysed. The results of the analyses were very surprising. No extra iridium was found in the strata after 1908. On the other hand, you could easily see the normal fallout of meteoric dust that falls to the ground every year. The experiment was one of the first ever measurements of the annual amount of cosmic dust that lands on Earth [11, s. 136].

But there was no extra iridium either in 1908, 1909 or 1910. If only half of the Tunguska material of carbon compounds, and of that 80%, reached the stratosphere, then you would have seen 15 times more iridium than the total annual background fallout. But the studies did not show that.

Danish and Russian research at the Tunguska area in 1999

In 1999 a Danish-Russian research group succeeded in determining the amount of cosmic iridium and carbon from the celestial body in a drill core of the peat from the impact site. The study found that the Tunguska body is likely to have been an icy object of very pure ice, purer than comets usually are. The body has vaporized explosively due to friction in the atmosphere, and the impact has therefore not left a crater. To try to investigate whether the material should have fallen locally in Siberia, the Danish expedition brought home a peat core, which then remained in laboratories in Copenhagen. The measurements showed that the amount of iridium in the peat in the 1908 layer was very low [9, s. 29].

The most epoch-making thing about the new studies, however, was that they also measured the amount of the natural radioactive isotope, carbon 14, in the peat core. This analysis revealed that significant amounts of carbon 14 were missing from the 1908 layer. Normally, carbon 14 is formed in the Earth’s upper atmosphere by cosmic radiation from the Sun and the Milky Way hitting the air molecules of the Earth’s atmosphere. Finding a missing amount of carbon 14 in the layers affected by the Tunguska blast suggests that the material made up the Tunguska celestial body contained a lot of carbon that was poor in the carbon 14 isotope. This is completely understandable because the Tunguska celestial body is of course millions or perhaps even billions of years old and all the carbon 14 in the Tunguska celestial body will have disappeared by radioactive decay [11, s. 137].

It was therefore possible for the first time to determine the ratio between carbon and iridium in the Tunguska celestial body. This ratio was abnormally large, about 10,000 times larger than known from any type of meteorite. There are no direct measurements of the ratio between carbon and iridium for comets, but there is no doubt that the ratio here is greater than for meteorites and asteroids. Whether it can really be 10,000 times larger than in the meteorites is unknown.

Conclusion

"The Tunguska explosion is indeed unique and mysterious. Of the possible causes it appears that the present consensus favours the comet hypothesis. However, suggesting a consensus is quite tenuous. Though the other theories have plausibility, they have difficulty explaining the observed event and the resulting physical evidence. Making use of the cometary hypothesis allows for the following probable scenario" [4]

The most likely explanation for the Tunguska blast is that it was a comet that hit the Earth. It fit well with the fact that no meteorites have been found in the area, and it may also fit with the distinctive observations of the bright nights before and after the Tunguska event. The situation is that a comet's tail always points away from the sun, and right around sunrise in Siberia, where it is still midnight in Western Europe, the tail will therefore point to the northwest. The reason for the light phenomena the night before the Tunguska blast may therefore be that the Earth, a few hours before the collision with the comet itself, was hit by the comet's tail. Likewise, the measurements of iridium and carbon 14 on the peat cores in Siberia fit better with a comet than with any of the meteorite groups.

The problem with the comet hypothesis, however, is that most planetary scientists agree that this small Solar System body can have at most 50% ice. The other 50% must consist of primitive carbon chondritic material (carbon 14) that is relatively rich in iridium. As we said, the measurements in the Greenland ice sheet show no extra iridium at all from the Tunguska blast and the measurements on the peat cores at the actual impact site only very small amounts of iridium. Both parts are a bit of a mystery that has not yet been solved [9, s. 29].

The lack of iridium after the Tunguska event is therefore global. Two possibilities seem to emerge. Either we are dealing with a celestial body of a different and hitherto unknown composition, or comets really have a different composition than is known today. A comet has not yet been directly examined at close range, so it could theoretically be thought that, despite our expectations, comets still contain 95% ice and less than 5% dust of carbon 14 and iridium. This will explain the measurements both from the Greenland ice sheet and from the taiga in Siberia. On the other hand, it cannot be completely ruled out that it could be a lump of ice from one of the outer moons in the solar system, or perhaps even further outside.

So, no definite answer to what kind of celestial body it was that hit the Earth on the morning of June 30, 1908, can be given yet. It is, at least for now, a mystery. Speculation will continue as to the origin of this catastrophe, yet no certain conclusions can be attained unless man has the dubious opportunity to observe and monitor such an event in the future. The Tunguska explosion directs our attention to catastrophic forces, which have helped form the Earth and causes us to ask questions about the nature of much larger cosmic events. What were the global effects of enormous impact events, which formed the 1-km-diameter Meteor Crater in Arizona, the 100 kilometres in diameter Popigay crater of Siberia, and the 140 kilometres in diameter Sudbury impact structure of Ontario? What changes in the earth's crust, atmosphere, ocean, and life were caused by the release of a million times more energy than the Tunguska explosion? The Tunguska event provides a faint glimpse [8].

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