THE TUNGUSKA METEORITE PROBLEM TODAY

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I. INTRODUCTION

Today the Tunguska Meteorite problem can be considered as an important part of the larger problem of the possible collision of Earth with those cosmic bodies called Near Earth Objects (NEO). To estimate the scale of collision danger threatening our planet, one should base research not only on the calculations of collisions probability, but also on the investigative results of such events in the history of the Earth.

Information about the Tunguska Event obtained during approximately 90 years of investigations is enormous. However, most of it derives from work done after 1945 and is published in Russian science literature in the Russian language and, therefore, has not not been available to scientists of the West. We consider it important to present a brief overview of the exsisting Tunguska information and to discuss its more important aspects, which may play a key role in a final solution to the problem.

The term "Tunguska Event" refers to the cosmic phenomenon that was observed on June 30, 1908 in Central Siberia over the Krasnoyarsk Territory, Irkutsk Region, and Yakutiya (Kulik, L.A., 1933, 1939; Krinov, E.L., 1979). The most remarkable feature of the event was the explosion of a space object of unknown origin. The event had been observed in many settlements of the region (Astapovich, I.S., 1951; Vasilyev N.V. et al., 1981; Vasilyev, N.V., 1984, 1986, 1988). The flight of the object was accompanied by sound, seismic, and electrophonic effects, which covered a vast territory. The scale of these effects indicates the size of a bolide from - 22 to -17 magnitude. Its brighthness was comparable to that of the Sun. Many eyewitnesses observed a trail of iridescent bands resembling a rainbow.

When the body reached an altitude of 2.5 to 9.0 km over the area (60ø 53' N, 101ø 54' E), there occurred an explosion-like energy release. The TNT equivalent of the effect is estimated at 10 to 20 (possibly up to 40) megatons, the estimated energy being 4.2x1023 to 1.7x1024 ergs (Stanyukovich, K.P., Bronshten V.A., 1961; Maslov, E.V., 1963; Boyarkina, A.P., Bronshten, V.A., 1975; Bronshten, V.A., Boyarkina, A.P., 1975; Ben-Menahem A. 1975, Pasechnik, I.P., 1976, Zolotov, A.V., 1969; Zotkin, I.T., Tsikulin, M.A., 1968; Korobeynikov, V.P., 1974; 1974 a; 1976; 1980; 1984, Goldin, V.D., 1986). There is some evidence suggesting that after the explosion-like energy release at least a part of the Tunguska Cosmic Body (TCB) continued to move in the "pre-explosion" direction upwards (Fast, V.G. et al., 1976, Plekhanov, G.F., in press).

The TCB "explosion" initiated a seismic wave that was recorded in the cities of Irkutsk, Tashkent, Tbilisi and Jena. There also were pressure disturbances (Astapovich, I.S., 1933; Whipple, F.W.,1934) 5.9 ??(0.9 minutes (or, according to another estimate, 6.6 ??(0.2 min.) after the explosion. Additionally, a local magnetic storm was registered and persisted for more than four hours and caused geomagnetic disturbances in the atmosphere similar to those that follow nuclear explosions (Pasechnik, I.P., 1976; Ivanov, K.G., 1961). In Antarctica near the volcano Erebus on June 30, 1908 they observed abnormal aurorae which may have been induced by the Tunguska Event (Steel D., Ferguson, R., 1993).

The shock wave of the Tunguska explosion devastated 2,150 ??(25 km2 of the taiga forest (Fast, V.G. et al., 1967; 1967 a; 1976; 1983), and the flash burned vegetation over an area of about 200 km2 (Zenkin, G.M., Ilyin, A.G., 1964; Ilyin, A.G., et al., 1963; 1966; Vorobyev, V.A., 1967; L'vov, Yu.A., Vasilyev, N.V., 1976) . The Tunguska explosion resulted in a major forest fire covering an area comparable to that of the devestated forest (Kulik, L.A., 1976; Kurbatsky, N.P., 1964; 1975). The abnormalities of paleomagnetic properties of soils in the region, likely to be related to this event, are described (Sydoras, S.D., Boyarkina, A.P., 1976).

The explosion on the Podkamennaya Tunguska River was the most striking event in the several anomalies that occurred during that summer of 1908. Starting on June 23, 1908 bright twilights were observed in some locations of Western Europe, the European part of Russia, and in Western Siberia. They increased in intensity until June 29, reaching their peak on the evening of June 30. These anomalies included unprecedental formation of mesospheric clouds, bright "volcanic" twilights, disturbances of atmospheric polarization, and intense solar halos. After July 1 these effects weakened exponentially; some after-effects were observed until late July (Zotkin, I.T., 1961; 1966; Vasilyev, N.V., Zhuravlev, V.K., Zhuravleva, R.K. et al., 1965; Vasilyev, N.V., Fast, N.P., 1972; 1976).

The area where these phenomena were observed is bound by the Yenisey River in the East, by the latitude of Tashkent-Stavropol-Sevastopol-Bordeaux in the South, and by the Atlantic coast in the West. In August in the Western Hemisphere, the Mount Wilson Observatory reported a decrease in the air transparency, which could be explained by the circulation of Tunguska explosion products in the atmosphere (Fesenkov, V.G., 1978). Concurrent with the Tunguska aerosol cloud, there were products of another large bolide which entered the Earth's atmosphere in May 1908 (Kondratyev, K.Ya. et. al., 1988). It also has been suggested that the Tunguska Event influenced the ozone layer (Turco, et al., 1982; Kondratyev, K. Ya. et al., 1988). Soon after the Tunguska expolosion an effect similar to the well-known Bowen effect that follows meteor showers was registered (Fast, N.P., Zalevskaya, V.V., 1970).

It should also be noted that the summer of 1908 was quite rich in bright bolides (Vasilyev, N.V., Zhuravlev V.K. et al.,1965; Anfinogenov, D.F., Budaeva L.I., 1984).

Neither expeditions to the Tunguska site prior to World War II that were headed by L.A. Kulik, nor the post-war field work under supervision of Florensky, Plekhanov, Zolotov and Vassilyev, found any explosion or impact astroblems (??) or large fragments of the TCB (Florenskiy, K.P.et al.,1960; Plekhanov, G.F., 1963; L'vov, Yu.A. et al.,1963; 1963 a). Search for finely-dispersed cosmic matter in the soils and peat of the catastrophe area, over 10, 000 km2 (Kirova, O.A., 1961; Florensky, K.P., 1963; Florensky, K.P., Ivanov, A.V. et al., 1968; Glass, B.P., 1969; 1976; Vasilyev, N.V. et al., 1971; 1973; 1974; 1974 a; 1983; Vypadenie ... 1975; Boyarkina, A.P. et al., 1976; 1976 a , Alexeeva, K.N. et al., 1977; Kvasnitsa V.N. et al., 1979; Sobotovich, E.V. et al., 1980; 1983; Zbic, M., 1984; Doroshin I.K., 1988) did not result in discovery of material that could be reliably differentiated from fluctuations of the bacrground fall of extraterrestrial matter. However, biogeochemical element and isotopic anomalies that may be related to the event have been discovered in the area of the catastrophe (Kovalevsky, A.F. et al., 1963; Alexeeva K.N. et al., 1976; Zhuravlev, V.K et al., 1976; Golenetsky, S.P. et al., 1977; 1977 a; 1980; 1981; 1983; Kolesnikov, Kolesnikov, E.M., 1984; 1989; Kolesnikov, E.M. et al., 1979; Zhuravlev, V.K. et al., 1976).

Increased quantities of microparticles enriched by Cu, Au, Zn and certain other elements in the resin of the trees in the epicenter area that survived the 1908 catastrophe are very likely related to the Tunguska event. (Longo, G. et al., 1994).

The post-war expeditions revealed a complex range of ecological consequences of the Tunguska explosion, namely: 1) accelerated growth of new (post-catastrophe) trees and trees that survived the event (Nekrasov, V.I.; Emelyanov, Yu. M., 1964; Beregnoi, V.G., Drapkina, G.I., 1964; Shapovalova, R.D. et al., 1967; Emelyanov, Yu.M., Lukyanov, V.B. et al., 1967; Vasilyev, N.V. et al., 1976; 1980); 2) population-genetic effects, mainly at the epicenter area and along the TCB trajectory (Dragavtsev, V.A. et al.,1975).

This is a general outline of the Tunguska phenomenon which, proves to be different in principal from other impact phenomena. The many hypotheses that have been put forward in an attempt to explain the Tunguska event can be arranged in two groups. One includes those hypotheses that are based on the concept of conversion of the kinetic energy of the TCB into shock wave energy. The other group consists of hypotheses that emphasize a release of the internal energy of the body, whether chemical or nuclear.

The first group of hypotheses involves the concept of an asteroidal nature of the TCB (Kulik, L.A., 1933; 1939; 1939; Krinov E.L.,1949; Astapovich, I.S., 1933; Anfinogenov, D.F., 1966; Sekanina, Z; 1983; Chyba, C.F., 1993, Longo G. et al., 1994;), or a cometary nature (Astapovich, I.S., 1933; Whipple, F.I.W., 1934; Fessenkov, V.G., 1961; 1978; Grigoryan, S.S., 1976; 1979; Korobeynikov, V.P. et al., 1976; 1980) . These can be classified as hypotheses based on the classical concepts of the minor bodies of the Solar System.

These latter hypotheses assume a special nature of the TCB, one different from asteroids or comets. These include the hypotheses of an antimatter nature of the TCB (La Paz, L., 1948; Cowen, C. et al., 1965); of the Tunguska object being a miniature black hole (Jackson, IV A.A., Ryan, M.P.,1973), or of its being a "solar energophore" (Dmitriev, A.N., Zhuravlev, V.K., 1984), or even being of technogeneous origin (Zolotov, A.V., 1961; 1961 a; 1967; 1969; Zigel, F.Yu ., 1983).

It is both timely and appropriate that we examine the most serious difficulties which one has to deal with in any attempt to construct an integrated concept of the Tunguska phenomenon.

II. ON THE DIRECTION OF THE TCB FLIGHT

The first investigators of the TCB (L.A.Kulik, 1939; E.L.Krinov,1949; and I.S.Astapovich,1951) who analyzed evidence of the object's flight in the area of the Angara River had no doubts that it had been moving generally from the south to the north. However, there were three options for a more precise trajectory: a southern trajectory, proposed by L.A.Kulik, a southeastern one proposed by E.L. Krinov, and the southwestern path proposed by I.S.Astapovich. (See Sytinskaya, N.N., 1955, and Levin, B.Yu., 1954 as well). By the early 1960s it was Krinov's trajectory, namely 135ø, that was considered most realistic.

Later, however, a "corridor" of axis symmetrical deviation of the vectors of the felled forest from the dominating radial pattern was revealed. This deviation was interpreted as the track of the ballistic wave (Boyarkina, A.P.et al., 1964; Fast V.G., 1967; Zotkin, I.T., 1966; Zolotov, A.V., 1969). The direction of the "corridor," wich was initially estimated as 111ø,E from N (114ø, east of the true meridian) (Fast, V.G., 1967), was later found to be 95ø, E from N (99ø, east of the true meridian) (Fast,V.G. et al., 1976). During this period of time a number of elderly residents of the area who had lived in the upper reaches of the Nizhnaya Tunguska in 1908 were questioned. No eyewitnesses from this area had been questioned in the 1920s and 1930s. This resulted in the conclusion that the object had moved from the ESE to the WNW (Konenkin, V.G., 1967), i.e. by the path coinciding with that of the trajectory of the TCB. This coincidence caused revision of the notion of the TCB trajectory, so since the year 1965 the ESE-WNW option has cominated the literature. For several years it was assumed to be a final result.

But later the publicaton of a catalog of eyewitness accounts made analysis of the whole event possible. (Vasilyev, N.V. et al., 1981) Two fundamental facts were established:

1. "Images" of the bolide observed in the area of the Angara Rriver and observed in the area of the Nizhnyaya Tunguska River are quite different, and the evidence seems to indicate that they belong to different objects (Demin, D.V. et al., 1984).

2. The trajectory, calculated on the basis of Angara eyewitness accounts, differs considerably from that determined by analyzing the vector structure of the felled forest area and the radiant burn area. Indeed, evidence of the Angara eyewitheness, including the report of a district officer, suggests that the bolide flew "high in the sky," which is hardly consistent with the path 99ø east of the true meridian. On the contrary, the data obtained on the Nizhnaya Tunguska River, even though agreeing with the shape the area of devestation, is in contradiction with the Angara observations.

Another complication is that the Nizhnaya Tunguska data suggest, virtually unambiguously, that the bolide's flight occurred in the afternoon, whereas the data from the Angara River identify it as an early morning flight. Attempts to resolve the conflict between both sets of data present considerable problems.

In the search for an exit from this maze, more then one approach has been tried. Some researchers practically ignored eyewitness accounts as unreliable subjective material. This approach could be agreed with to a certain extent if only it were a matter of a few inconsistent accounts, whereas there were many hundreds of independent accounts.

Other investigators have tried their best to combine the Angara evidence, the Nizhnyaya Tunguska data, and the geometry of the devastated area (Zotkin I.T., a. Chigorin, A.N., 1988; Yavnel, A.A., 1988). The results seem to be rather dubious.

Then the idea of a non-ballistic trajectory of the TCB was introduced (Zigel F.Yu., 1983), based on the assumption that it had been moving initially along a trajectory close to that calculated by Krinov. The object then moved along a sloped curve trajectory and entered the space above the joining of the Nizhnyaya and Podkamennay Tunguska rivers, after which it continued its flight in an eastern direction and finally to the place where it exploded.

The cause of the incompatibility of the bolide path projection with the data of the Angara eyewitnesses remains unclear. Yet, it should be borne in mind that the identity of the axis of symmetry of the observed forest destruction pattern with the projection of the bolide path is only an assumption of high probability rather than an established fact. The axially symmetric "corridor" is the trace of the ballistic wave, where it touched Earth's surface. It remains essentially an open question--what its initial space position was and whether it could have changed for some reason or other.

However, there are still other problems associated with the TCB path parameters. Most authors who have studied this issue conclude that the angle of the TCB trajectory was relatively small (Zotkin, I.T., Tsikulin, M.A., 1966; 1966 a; Tsikulin M.A., 1969; Bronshten, V.A., Boyarkina, A.P., 1975). Still, modeling experiments, as well as the results of mathematical simulation of the Tunguska explosion parameters (Korobeynikov, V.P. et al., 1976; 1980; 1983, 1984) testify that the final part of the trajectory was most probably 40ø. The transition of the TCB flight path from a comparatively flat trajectory to a steep one seems to have taken place when the bolide approached the point where it exploded; it might be due to an avalanche fracturing of the object and enlargement of its frontal surface.

Especially suspicious is the fact that the "corridor"--the impression of the ballistic wave on the forest--is observed, as has been recently shown, to extend beyond the epicenter of the explosion. It is as if the object continued its flight path after exploding. (Fast, V.G. et al., 1976; Plekhanov, G.F.a. Plekhanova L.G., in press). The most reasonable explanation is that part of the TCB survived the explosion and continued its flight, maintaining the same trajectory to some degree.

It is important to relate certain features of forest devastation at the epicenter of the Tunguska explosion area.

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III. Some specific features of the forest devastation at the epicenter of the Tunguska explosion.

It has been stated that the main cause of the forest devastation in the area of the Tunguska catastrophe was a powerful energy release that occurred at an altitude of 2.5 to 9.0 km (Goldin, V.D., 1986). It must have been a huge explosion in the air which initiated a spherical shock wave. The front of the shock wave was parallel to the earth's surface in general at the epicenter of the explosion, and inclined to it away from the epicenter. So the vertical component of the shock wave was the most active component, whereas the horizontal component away from the epicenter was increasingly dominant and most pronounced in the area of interference of the incident and reflected waves (Demin, D.V., 1963; Boyarkina, A.P. a. Demin, D.V. et al., 1964; Fast, V.G. et al., 1967; 1976;). As a first approximation, this can be interpreted as such. Around the epicenter there is a vast area of dead forest (about 8 km across), scorched and devoid of branches, but with trees standing upright. This is the zone of the vertical component impact of the blast wave. Outside this area the forest is felled radially at a distance from 12 to 40 km away from the epicenter. This is the area of impact of the horizontal component of the blast wave. If the above model is valid, then at the explosion epicenter there must be no radially felled forest. The actual situation is, however, essentially different. First, the forest was not destroyed completely at the epicenter. Within 5 to 7 km away many groups of trees survived. (Zenkin, G.M. et al., 1963). The trees have attracted much attention of investigators, and attempts to explain their existance, based on the relief features, have not yielded unambiguous results. With the area's highest altitude above sea level being 593 m, and the height of the explosion at 2.5 km (more likely 5.5 km), we can approximate the whole area to a plane.

The structure of the felled forest area in the immediate vincinity from the epicenter also proves to be strange.

First, the assumption that no trees within this zone were felled in a radial pattern is not true. Surface observations have shown that there are some leveled trees in this area as well, and the general radial character of the felled forest is seen up to a "special point," viz. the geometric center of the fallen forest area, as calculated by V.G. Fast (1963).

Second, Kulik's interpretation of the felled forest area on the basis of a large-scale photographic air survey of 1938 (L.A. Kulik, 1939) not only corroborated the complex vector structure of the epicenter area, but also suggested at least two or three subepicenters.

Third, the vector structures of the felled forest on hillsides facing the epicenter, and on the the opposite hillsides, are essentially different. This is in poor agreement with the assumption that the blast wave center was generated high above earth's surface.

Thus, we may tentatively conclude that along with a great energy release from 5 to 5.8 km above the earth, there were a number of low-altitude (maybe even right above the surface) explosions that contributed to the total picture of destruction (Kulik, L.A., 1939; Golenetsky, S.P. a. Stepanok, V.V., 1984). This seems to be sustained by data concerning the deposition of aerosols immediately after the explosion (Serra, R. et al., 1994).

Thus, the features of destruction at the epicenter suggest inhomogeneity of the physical parameters of the Tunguska explosion field and complexity of the physical processes underlying it.

It should be emphasized that though the patchine ss (????) of the effects associated with the Tunguska explosion has been noted in literature more than once, its origin has not been discussed. This seems to be due to serious difficulties of its interpretation in terms of the existing TCB models.

IV. On the geophysical effects of the Tunguska explosion

One of the most striking geophysical effects associated with the Tunguska explosion is the local geomagnetic disturbance detected shortly after the explosion in Irkutsk, although not recorded by any other geophysical observatory in the world existing at that time (Plekhanov, G.F. et al., 1960; 1961; Ivanov, K.G., 1961; 1961 a; 1962; 1964; Obashev, S.O., 1961; Zhuravlev, V.K., 1963; Kovalevsky, A.F., 1963;). This disturbance was similar to some effects following middle- and high-altitude nuclear explosions in the atmosphere, but unlike the latter, it exhibited a kind of lag; i.e. it occurred some time after the explosion. This has provided the main argument to account for the geomagnetic effect of the Tunguska object as being due to the shock wave and the period of time required for the wave to cross the distance from the explosion point to the lower ionosphere boundary.

Later, however, I.P. Pasechnik, (1986) corrected the moment of the Tungunska explosion on the basis of direct experimental measurements of the velocity of the seismic wave between Vanavara and Irkutsk. It has been found that the "lag" was actually longer than 5.9 min. This fact is important inasmuch as the ensuing velocity of a shock wave in the atmosphere is too low. Hence the mechanism accounting for this effect as a consequencee of the arrival time of the shock wave in the ionosphe re appears dubious (Dmitriev, A.N., Zhuravlev V. K., 1984). The question thus remains open. The explanation of the "abnormal twilights" of late June and early July, 1908, being due to cometary particles in the upper atmosphere is not convincing.

Indeed, according to this assumption, particles of a comet's tail were to be decelerated at an altitude of 200 km or more, whereas most light anomalies formed at altitudes of 80 km (the zone of formation of mesospheric clouds), 50 to 60 km (diffraction effects that caused dawn and afterglow anomalies) and below that (atmospheric halos). >>I cannot understand the previous sentence.<< Besides, according to this assumption, the tail of the Tunguska "comet" should have been stretched over Canada, but this was not observed. Recently, there has been an attempt to ascribe the "abnormal twilights" of the summer of 1908 to transport of material from the site of the explosion by stratospheric winds. However, this assumption faces two contradictions:

1) At least 10 locations in Eurasia reported anomalous light effects on the night of June 29-30, 1908. The effects were practically simultaneous with, and even somewhat before, the Tunguska explosion. This makes it impossible to explain the optical effects of June 30 being due to mechanical transport of space aerosols from the site of the explosion.

2) There was a sharp exponential decrease in the intensity of the atmospheric anomalies after the Ist of July. This suggests that the major cause of the anomalies was due to photochmical reactions. If, alternatively, the main cause of the anomalies were the refraction and scattering of aerosol particles, it would be more reasonable to expect a gradual decrease in the effects, as in the case of volcano-induced optical anomalies. Neither explanation has been found adequate to account for the changes of the polarimetric properties of the twilight sky that appeared as deviations from the normal travel of the Arago and Babinet neutral points (Vasilyev, N.V. et al., 1965).

Thus, explanation of the geophysical effects of the Tunguska object faces serious problems.

V. Ecological consequences of the Tunguska catastrophe

Ecological consequences of the Tunguska event have been studied over the past 30 years. They can be divided into two main types.

First is the remarkably quick revival of the taiga after the explosion, as well as accelerated growth of young (Nekrasov, V.I., Emelyanov, Yu.M., 1964; Emelyanov Yu.M. et al., 1967; Shapovalova R.D. et al., 1967) trees and those which survived the event.

This effect covers a vast territory, it correlates wich the NSB trajectory. >>I do not understand the meaning of the words following the comma<< The effect is observed in all tree (??) species in the region, >>I cannot understand the rest of this paragraph except for the last sentence<< tending (for the 2nd post-catastrophic generation of pine) to concentrate toward the projection of the NSB path . There are two viewpoints on the nature of the effect:

1) The early revival and accelerated growth of the forest are due to some general results of the Tunguska explosion, such as better light and thermal conditions in the area after the leveling of so many trees, as well as enrichment of the soil with microelements as a result of the forest

fire . This point of view is not groundless, but it does not explain these two facts: an evident correlation of the effect with the projection of the NSB trajectory; and discrepancy between the zones of the acceletrated growth of saplings and the areas of the forest fall and forest fire. >>This second "fact" is not clear to me<<

Another possibility is that the stimulating effect of the Tunguska explosion was due to enrichment of the poor soil of the region with cosmogeneous microelements (Shapovalova, R.D., Lukyanov, V.B. et al., 1967., Emelyanov, Yu.M., Lukyanov, V.B. et al., 1967; Golenetsky, S.P., Stepanok, V.V., 1983). Modelling experiments provide evidence that extracts of the soils from the region enriched with rare-earth elements (RE) can in fact stimulate germination of pine seeds, as well as the seeds of certain other plants (Vasilyev, N.V., Kucharskaya, L.K. et al., 1980). But rare earths are outside the classsical set of cosmogeneous microelements.

The question has not been settled, and the effect probably cannot be explained by conventional factors.

The second type of ecological consequences of the Tunguska event includes genetic impact. Linear increments of the Tunguska pine trees were processed with an algorithm discriminating the contributions of genotypic and phenotypic variations (Dragavtsev, V.A. et al., 1975) . This work revealed that the frequency of mutations in these pines has sharply increased. Again, as with many other effects of the Tunguska event, its genetic impact is of a patchy character, concentrating toward the epicenter area and the "corridor" of the TSB trajectory. The thermal influence of the forest fire could hardly be of any importance in this instance since the contours of the areas of the mutagenic effect, forest fire, and forest fall are quite different. The nature of the mutagenic factor remains unknown.

VI. On the substance of the Tunguska object

The diligent search for large fragments of the Tunguska cosmic object, which had begun in the late 1920's and ended in 1962, has shown totally negative results. There have been no traces of astroblemes. >>I don't know the word "astroblemes"<< The geomorphological formations around the epicenter once thought to be small meteorite craters proved to be of purely terrestrial origin (swamps, lakes, thermokarst holes, etc.). Attempts to find fragments of the meteorite through rough mineralogical analyses of soil, as well as with the help of magnetometers, metal detectors, etc., also failed (Plekhanov, G.F., 1963). As a result, beginning from the 1960's, through the initiative of K.P. Florensky, the search strategy for the TCB substance was radically altered. Since then efforts have been aimed at the search for and analysis of finely-dispersed space material.

During the subsequent 30 and more years of investigation a number of cosmochemical, geochemical, analytical and other techniques have been applied. The principal results of this work can be summarized as follows:

1. Small amounts of finely-dispersed silicate and magnetite space material are present in soils and peats in and around the region of the explosion (Florensky, K.P., 1963; Florensky, K.P., Ivanov, A.V.et al., 1968; Vasilyev, N.V. et al., 1973). However, there is no direct evidence that these materials have anything to do with the TCB. On the countrary, there is good reason to believe we are dealing with fluctuations of the background fall of space dust. 2. Information on the iridium anomaly in the Antarctic ice (Ganapathy,R., 1983) and Tunguska

peat (Korina M.I. et al., 1987) dated back to 1908 rests on isolated findings and requires further verification.

3. Traces of enhanced concentration of nitrates in the Greenland ice dated back to 1908 are absent (Rasmussen, K.L. et alll., 1984).

4. Increased concentration of microspherules enriched with copper, zinc, gold, and some other volatile and chalcophile elements is found in the 1908 layers of peat and wood resin at a number of locations in the region (Longo, G. et al., 1994; Kolesnikov, E.M. et al., 1977) . Cosmogeneous nature of these anomalies is probable but they should be differentiated from aerosols produced by the burning of peat (Doroshin, I.K., 1988) and (possibly) wood, as well as from volcanic ash .

5. There have been revealed in the 1908 layers of peat, both at the epicenter region and in the zone of the supposed dispersion train of explosion products, substantial shifts in isotopic compositions of carbon (toward its heavier isotopes), hydrogen (toward the lighter ones) and lead. According to Kolesnikov (Kolesnikov, E.M., 1988; Kolesnikov E.M., Shestakov, G.L., 1970) , these shifts are due to the dispersed substance of a space body of the approximate composition of carbonaceous chondrite.

6. A number of local geochemical anomalies were discovered at the Tunguska site, although their association with the TCB requires further investigation. This is, first of all, the rare earth (primarily ytterbium) anomaly. Concentration of that element in soil, as well as in the 1908 peat layers, is abnormally high (Zhuravlev, V.K., 1976; Levchnko M.A., Terentiiva A.S., 1976). The ytterbium content reaches its peak in the point of intersection of the extension of the TCB trajectory (provided that its slope was about 40 degrees) with the Earth's surface. Increased concentration of RE occurs mainly in the upper (i.e. recent) layers of soil, and not in deeper layers, close to the substratum . Along with the quantitative shifts, the affected zone shows a drastic change in the RE ratio (Dozmarov S.V., in press).

Thus, the key to the solution of the Tunguska problem--i.e., determination of the TCB's elemental as well as isotopic composition--is not yet at hand, and this line of inquiry must be continued.

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VII On radioactivity in the Tunguska catastrophe site

The hypothesis of a nuclear nature of the Tunguska sxplosion was tested by searching for radionuclides at the epicenter of the explosion area (Zolotov, A.V., 1961; 1967; 1969; Plekhanov, G.F., 1963; 1964; Kirichenko, L.V. a Grechushkina, M.P., 1963; Kirichenko, L.V., 1975; 1975 a; Mechedov, V.N, 1967; Kolesnikov, E.M, et al., 1975; Vasilyev, N.V. et al., 1976 ; Stadolko I, in press). The results of this research may be summarized as follows:

1. Radioactivity at the epicenter of the Tunguska explosion is within the range of fluctuations of the present background radiation. At the same time, however, its magnitude is somewhat higher at the epicenter than at the periphery of the region. Most radionuclides are concentrated in the upper horizons of the soil and peat and have been accumulated from global fallout after nuclear tests.

2. The vertical distribution of radionuclides in the soil and peat does not indicate the presence of radionuclides from test explosions before 1945. The only exception is a result of layer-by-layer radiometry of sphagnum peat in the region of Vanavara (1960) where a second maximum of radionuclide concentration was discovered at the depth of 35 cm. (Kirichenko, L.V., Grechushkina M.P., 1963). This effect was not studied in detail and it is not known which radionuclides were responsible for it.

3. Investigation of the isotopic composition of inert gases accumulated in rocks near the epicenter did not reveal any peculiarities that could be explained by the action of neutron irradiation on the natural environment at the epicenter (Kolesnikov, E.M. et al., 1975) .

4. Analysis of 514 0C (???) content in the rings of the trees that survived the 1908 explosion (Cowen, C., Atluri, C.R., Libby, W, 1965; Vinogradov, A.P. et al., 1966; Lehrman, I.C. et al., 1967; Nesvitaylo, V.D. a. Kovalyuch, N.N., 1983; Firsov, L.V. et al., 1984), revealed its reliable excess over background values for the ring of 1909, which could be expected if 514 0CO 42 0content was abnormally high in the summer of 1908. >>(I do not understand the previous sentence.<< The effect is of a global character and has been traced both in the region of the Tunguska explosion (Nesvetaylo, V.D., a. Kovalynkh, N.N., 1983) and outside (Cowen, C. et al., 1965; Vinogradov A.P. et.al.,1966). Usually it is explained by interference in the years 1908-1909 of two solar maxima, viz. the 11-year and 100-year cycles. However, such an interpretation does not explain the causes of the pathy character >>what is "pathy character"?<< of the effect at the epicenter of the Tunguska event (Firsov, L.V.,et. al., 1984;). The "solar" nature of the effect would be proved if it were detected for other similar periodsl. But such work, as far as we know, has yet to be perfomed.

Thus, the results of a search for radioactivity in the region of the Tunguska explosion negates a nuclear hypothesis. It should be noted, however, that a search for traces of radionuclide fallout half a century after a nuclear explosion in the atmosphere is a challenging task (especially taking into account comtamination from recent atmospheric nuclear tests.

Along with attempts to detect radionuclides retained from the 1908 event, some efforts were made to find their traces by indirect methods. First and foremost, variation of thermoluminecent properties of minerals in the explosion area were studied. It is well known that shifts in the intensity of thermoluminesence are a reliable, even if indirect, indication of the exposure of minerals to ionizing radiation. This method was successfully used to determine the level of radioactivity at the epicenter of the nuclear explosion over Hiroshima some years after the Tunguska event. Similar work was carried out in the epicenter area of the Tunguska explosion (Vasilenko, V.B. et al., 1967; Bidyukov, B.F., et al.; 1990). Results suggest that background characteristics of thermoluminescent minerals in this region were distorted by two opposing factors. The first reduced thermoluminescent properties of minerals in the immediate vicinity of the epicenter. Judging from the similarity between the contours of this zone and the area of the radiant burn of the trees, the effect was generated by the light flash. This seems plausible, since annealing of minerals leads to a decrease in their thermoluminescent properties and even to the loss of properties. But it remains unclear why this effect manifested itself only in the area of the light flash and not in the entire zone of the forest fire.

Working in parallel with the first factor, a second factor intensified thermoluminescence of the minerals. This factor was at its maximum in an area tending to the projection >>"tending to the projection" meaning not clear<

VIII. Discussion.

Beginning in the 1960's, there was a revival of the cometary hypothesis that had been put forward in the 1930's by I.S. AStapovich and F. Whipple, and later developed by V.G. Fesenkov. It was suggested that unlike the asteroidal version the cometary hypothesis could explain in a conclusive way the main peculiarities of the Tunguska event and distinguish it from other impact phenomena, namely: 1. the above ground character of the explosion; 2. the lack of an astrobleme, as well as any trace of large-scale fallout of meteorite matter; 3. atmospheric optical anomalies that accompanied the Tunguska explosion. The cometary hypothesis has had favorable effects on the progress of the Tunguska studies. In its framework there were attempts to calculate the main parameters of the TCB ; for example, its ity (???), mass, enegry, strength characteristics, the slope of the object's trajectory, as well as a description of the mechanism of the object's destruction (Fesenkov, V.G., 1961; Pokrobski, G.I., 1966; Tsikulin, M.A., 1969; Boyarkina, A.P., Bronshten, V.A., 1975; 1975 a; Petrov, G.I. a. Stulov, V.P ., 1975; Grigorian, S.S., 1976; 1979; Korobeynikov , V.P. et al., 1974; 1974 a; 1976; 1980; 1983; 1984; Kresak, L., 1978; Turco, R.P. et al., 1982; Zynball, M.N., Shnitke, V.E., 1986; 1988). Later, however, results of further studies have complicated the situation, which today seem to be at a critical point. Some obstacles which the cometary hypothesis ran into have been discussed above. It should be added that the authors of some theoretical models (Petrov, G.I., Stulov, V.P., 1975, Turco R.P. et al., 1982) proceeded from the assumption of a low (of the order of 10 5-2 0g cm 5-3 0, or even super-low 10 5-3 0g cm 5-3 0) density for the object. Direct investigation of Halley's comet has shown, however, that the real density of cometary ice is about 1 g cm 5-3 0. Conseqently, the models of the TCB as a "super-loose lump of cosmic snow" or a "gigantic cosmic snowball" should be rejected.

However, these failures have not affected the "core" of the cometary hypothesis, since most of its supporters proceeded from more realistic estimates of the cometary ice density, assuming it to be equal to 1 g cm 5-3 0. But recently published material has cast doubt on the very fundamentals of this hypothesis. We mean, first of all, the detailed calculations, made by Z.Sekanina (1983) who came to the conclusion that, due to the strength characteristic of the comet nucleus, it would have had to disintegrate at a much higher altitude than is now accepted. Then, mathematical models have suggested that gigantic carbonaceous chondrites have to disintegrate at an altitude of 30 km, a circumstantial argument in favor of this inference being the explosion of the Revelstoke carbonaceous chondrite, as well as high-altitude explosions of meteoroides (Bronshten, V.A., 1981, Levin, B.Yu., Bronshten V.A., 1985), confirmed by aerospace methods. Since the chemical composition of the Tunguska object in its dominant conventional models is identical to that of a comet nucleus or to a carbonaceous chondrite, verification of this data would be of crucial importance to the Tunguska problem. Both Z. Sekanina (1983) and C. Chyba et al. (1993) arrived at the conclusion that the TCB should be classified as a stony asteroid. An iron meteorite as large as this would have reached the Earth's surface and formed an astrobleme. A comet nucleus or a carbonaceous chondrite would have disintergrated at a much higher altitude than the Tunguska body did. But if this it the case, then the question of the TCB substance reappears. A number of problems remain unsolved: isotopic anomalies in the 1908 layers of sphagnum bogs at the epicenter, as well as increased concentration of volatile and chalpophile elements in the sphagnum, to cite two such problems.

A return to the stony asteroid model would require an explanation of the 1908 atmospheric optical anomalies, which for a long time were assumed to be due to penetration of the "Tunguska comet" tail into the atmosphere.

At present the study of the problem has reached a phase in which it becomes possible to rigorously formulate the principal questions, which, if resolved, can restrict the spectrum of acceptable TCB models. Primarily, these are the following closely related questions:

1. Can the Tunguska explosion be explained as a result of destruction of comet's ice lumps or a meteoroid similar to carbonaceous chondrites at an altitude of 2,5-9 km? Are Sekanina and Chyba right in denying such a possibility? Or are Bronshten, V.A., a. Boyarkina, A.P., (1975, 1976) Korobeynikov, V.P. et al., (1983, 1984), Grigorian, S.S. (1976) and other investigators who advocate the cometary hypothesis? If the former are right, then it becomes imperative to revise a large number of calculations dealing with the mechanism of destruction of the Tunguska object that have been published since 1963. It is also necessary to re-explain the isotopic and elemental anomalies at the epicenter of the region, and to re-interpret the atmospheric optical anomalies of the summer of 1908.

2. What is the origin of the isotopic and elemental anomalies in 1908 peat and wood resin layers? Are they due to precipitation of remnants of the TCB or to some other processes? If indeed isotope shifts and increased concentrations of volatile and chalcophile elements dated to 1908 in these natural objects are due to some material of the TCB, then in this case the paradox of the absence of cosmic matter in the area of the explosion comparable with the scale of the phenomenon is eliminated. Thus, it appeares critical to make check investigations in control areas not associated with the Tunguska event.

3. Can the atmospheric optical anomalies of 1908 be due to transport from the explosion site by stratospheric winds of TCB matter--the material of a stony asteroid, in particular?

4. What is the nature of the WNW segment of the "corridor" of axially symmetric deviations of forest fall vectors from the dominating radial pattern? And can it be due to anything else than the trace of the ricochet of the part of the TCB that survived the explosion, in terms of the traditional models?

5. Is it possible to resolve the contradiction between the TCB trajectory as defined from evidence of the Angara eyewitnesses and the direction of flight of the body as suggested by the vector pattern of the forest fall? Unambiguous and comprehensive solutions to the above problems will lead to a choice between the opposing two hypotheses. It is now too early to predict the outcome. However, our present ability to pose the question is a significant achievement in the history of the development of the Tunguska problem.

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