7. The Third Key

In February 1960 at the Betatron Laboratory, where the Commander of the Independent Tunguska Exploration Group (ITEG) Gennady Plekhanov worked, a thick packet arrived from Irkursk. It contained a letter from the Irkutsk Magnetographic and Meteorological Observatory, signed by the young geophysicist Kim Ivanov. This research organization had been renamed the Irkutsk Geophysical Observatory, but all the old records had been preserved in its archives. Among these materials, Ivanov had discovered a sheet of light-sensitive paper showing the disturbance of the geomagnetic field that had followed the Tunguska explosion. This was a great shock to Plekhanov and his colleagues. By that time the ITEG had been looking for about a year in vain for evidence of such an effect.

But why did the researchers believe that the Tunguska explosion had been accompanied by a magnetic disturbance? Let's look at the nature of the geomagnetic field and its interaction with the atmosphere. Although the Chinese invented the compass about 2,000 years ago, which was used by sailors and travelers for many centuries, the underlying science remained a mystery. It was the British physician and natural philosopher William Gilbert (1544–1603) who had the original thought that Earth was a gigantic magnet whose force makes the compass needle "look to the north."

Generally, magnetic fields arise around moving electrically charged particles. The magnetic field is what is called a "vector field," where not only its strength but also its direction matters. A magnetic field is measured in units called gauss and tesla, and one tesla is equal to 10,000 gauss. The strength of the geomagnetic field affecting the compass needle is only about half a gauss. So very weak magnetic fields and slight changes of their intensity are measured in nanoteslas. Geophysicists usually call one nanotesla a "gamma,"[1] so we will measure geomagnetic effects mainly in gammas.

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The magnetic field of Earth is constantly changing, these changes being periodic and non-periodic. As a rule, compasses are not sensitive enough to feel these alterations, but magnetometers are. The non-periodic variations, which occur suddenly, are called magnetic disturbances, the most intensive and long of these being geomagnetic storms. Their amplitudes usually reach tens or hundreds of gammas, and sometimes thousands of gammas. Geomagnetic storms usually start suddenly all over the globe, lasting up to several days. These disturbances of Earth's geomagnetic field result first of all from processes occurring in the ionosphere – the upper atmosphere of our planet, which is highly ionized by the solar radiation. It begins at an altitude of about 80 km.

A geomagnetic storm is due to a surge in the speed of the solar wind, which consists of protons and electrons that constantly travel from the Sun to Earth. When penetrating the ionosphere the solar wind boosts its level of ionization, and powerful electric currents begin to flow in the upper atmosphere, producing strong magnetic fields. This leads to the total or partial fade-out of transmitted radio waves over large territories and sometimes to serious malfunctions in the work of power lines (as happened on May 13, 1980, in the Canadian province of Quebec, when 6 million people remained without commercial electric power for nine hours). There also exist the so-called substorms – occurring practically every day, sometimes globally or near globally, but too weak to affect machinery in a noticeable way.

Surprisingly, human activities can also affect the ionosphere. In 1958 American geophysicists made an unexpected discovery. It turned out that nuclear explosions could produce local geomagnetic storms in the atmosphere lasting about an hour. The separate stages of such storms lasted 10–20 min, and the intensities of the geomagnetic field reached 50 gammas. These local geomagnetic storms were first recorded in August 1958, when thermonuclear charges of some 4 Mt in magnitude were detonated over Johnston Island at altitudes of 76 and 42 km.[2] Later it was found that such effects occur only if nuclear bombs explode in the atmosphere. Even the most powerful bomb detonating at ground level leaves the geomagnetic field unchanged. Very soon, scientists uncovered the cause of this effect. It was the fiery ball of the nuclear explosion consisting of high-temperature plasma and producing hard radiation – alpha, beta, and gamma rays, as well as an increase in neutron radiation.[3] Under the influence of this radiation, the number of charged particles in the rarified air soars, and there appear in the ionosphere electric currents and magnetic disturbances.

But such plasma in the atmosphere may be formed in other ways than by nuclear explosions. In the middle of the 1940s Academician Alexey Kalashnikov discovered the magnetic effect of meteors: disturbances of the geomagnetic field accompanying the flight of meteors through the ionosphere. True, this effect lasts a few seconds at best, being much weaker than any geomagnetic storm, with amplitudes of only a fraction of one gamma.[4] Nonetheless, the nature of this phenomenon is basically the same as the nature of the nuclear geomagnetic effect.

Naturally, this brings up the question of whether a magnetic meteor effect occurred in 1908? If relatively small bolides and meteors do produce such an effect, then the enormous Tunguska space body (TSB) must have done so – in a big way. Judging from eyewitness accounts, published in Siberian newspapers, the space body approached Tunguska from the south. At a distance of about 970 km to the south-southeast from the Great Hollow lies Irkutsk and the Irkutsk Magnetographic and Meteorological Observatory, which is so important in this story, since it was separated from the TSB trajectory by a relatively short distance and could have recorded such an effect.

The idea to look for this effect occurred to Kim Ivanov in the summer of 1959. Ivanov was already aware of the artificial geomagnetic storms produced by high-altitude nuclear explosions, and he saw an opportunity to choose between the nuclear and meteoritic explanations for the Tunguska event.[5] If it were a nuclear explosion, it would have generated a geomagnetic disturbance similar to that which occurred in the Pacific in August 1958. No meteorite, however great, could produce such a local geomagnetic storm. According to the laws of physics, it could only be generated by ionizing radiation from the fiery ball of a high-altitude nuclear explosion. This fact has been established beyond doubt by American geophysicists who monitored the nuclear tests in the Pacific in 1958. But if the TSB were a huge piece of stone or iron from space, its flight would have been accompanied only by the usual magnetic meteor effect.

Luckily enough, at the Irkutsk Observatory, variations of the geomagnetic field had been recorded since 1905 on a 24-hour basis. So on the morning of June 30, 1908, the magnetometers did record a noticeable disturbance of the geomagnetic field. And this disturbance differed radically from a meteor magnetic effect. It started *after* the Tunguska explosion and lasted about five hours. Let's remember that a magnetic meteor effect occurs *during* a meteor's flight and lasts just several seconds. So, Kim Ivanov had discovered just that geomagnetic effect which had been recorded at the Irkutsk Magnetographic and Meteorological Observatory, but either missed or ignored by Dr. Arkady Voznesensky, the then Director of the Observatory. And what is no less unusual, there was on the magnetograms no sign of the "normal" magnetic meteor effect. For such a gigantic bolide this is very strange, and we can therefore suppose that the TSB flew at a low velocity not only over the Great Hollow but also through the ionosphere, its speed not being sufficient to have a vast plasma envelope form around it.

So, there was no disturbance of the geomagnetic field usually accompanying the flight of meteors. But what was there instead? The Irkutsk magnetogram is reproduced in Figure 7.1. During seven hours before the explosion of the TSB, the geomagnetic field was very

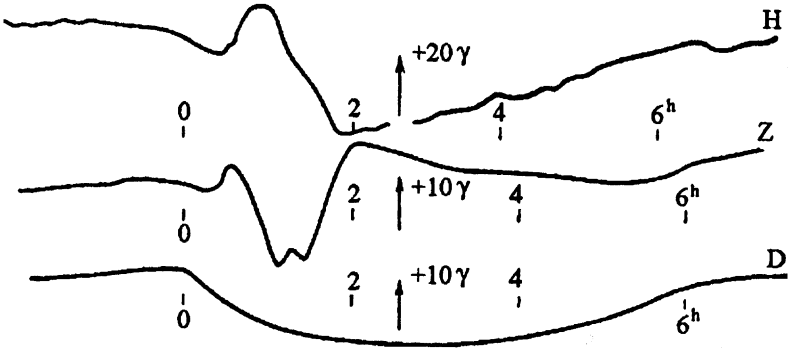

FIGURE 7.1. The geomagnetic storm, dated June 30, 1908, as recorded by instruments of the Magnetographic and Meteorological Observatory at Irkutsk. It started several minutes after the unknown space body exploded over central Siberia and was similar to the geomagnetic disturbances following nuclear explosions in the atmosphere (*Source*: Zhuravlev, V. K., Zigel, F. Y. *The Tunguska Miracle: History of Investigations of the Tunguska Meteorite.* Ekaterinburg: Basko, 1998, p. 82.).

calm. At 0 h 20 min GMT, that is, 6 min after this body exploded, the intensity of the geomagnetic field abruptly increased by several gammas and remained at that level for about 2 min. This was the initial phase of the local geomagnetic storm (or the so-called "first entry"). Then started a second phase – "the phase of rise." The geomagnetic field reached its maximum intensity at 0 h 40 min GMT and remained at the same level for the next 14 min. It then began to drop, the amplitude decreasing for some 70 gammas. It returned to its initial undisturbed level only five hours later.[6]

These four stages, the first entry, the phase of rise, the phase of fall, and the phase of relaxation, are also typical of usual solar magnetic storms. However, during a solar geomagnetic storm the first entry lasts 30 minutes on average, whereas in Irkutsk it lasted two minutes only. The third (main) phase of the solar magnetic storm usually lasts 5 to 10 hours. On June 30, 1908, this phase was much too short – just one and a half hours. And finally, the relaxation phase usually lasts 10 to 50 hours, while in the recording at Irkutsk it lasted not more than four hours. Such effects have *never* been observed by astronomers studying meteor phenomena.[7] The only parallel for this was the artificial geomagnetic storms that occurred in 1958 over Johnston Island during the high-altitude nuclear tests.

Many years later, in 1986, when talking with the ITEG member Victor Zhuravlev, Kim Ivanov confessed that he had recognized the similarity between the Tunguska geomagnetic effect and the nuclear-generated one, as well as its far-reaching implications, and had discussed this question with the author of the "spaceship hypothesis" Alexander Kazantsev and astronomer Felix Zigel. They attempted to convince Kim Ivanov that he should make this public. Kazantsev and Zigel believed that the scientific community would listen to the expert opinion of such a distinguished specialist. Yet Ivanov did not dare to do so, since he was sure that strong evidence in favor of Kazantsev's hypothesis would not only not have been accepted by established science but would have provoked plenty of protests, which would have hampered the Tunguska studies.[8]

Kim Ivanov was a serious researcher and became one of the leading Russian geophysicists. He examined the magnetograms from the Irkutsk Observatory and those from nuclear testing and wrote a paper for the Russian academic *Astronomical Journal*.

Ivanov did not offer any hypothesis for the origin of the effect discovered. He gave instrumental data and explained it – that was all. The *Astronomical Journal* rejected Ivanov's work, but the Committee on Meteorites (KMET) accepted his paper for publication in KMET's annual *Meteoritika*. They reasoned that the nature of the Irkutsk geomagnetic effect was probably vague, yet it was not a fancy finding and therefore should be published.[9]

Simultaneously with Kim Ivanov, and independently of him, the search for the Tunguska geomagnetic storm was also being pursued by the ITEG members. At that time, they were still trying to find the hypothetical "spaceship thruster." So, having heard about the nuclear geomagnetic storms, they began looking for information about the state of Earth's magnetic field during and after the Tunguska event. In 1959 Gennady Plekhanov and Nikolay Vasilyev sent inquiries to practically all geophysical observatories that had been functioning in 1908, and they received answers from 18 observatories and magnetometric stations.

For a long time these answers were disappointing: on June 30, 1908, the measuring instruments of the observatories had not recorded any disturbances. On that day the magnetic field of our planet had remained calm everywhere outside the Tunguska region. However, the magnetograms that Kim Ivanov sent to the ITEG were a true godsend, because they immediately led to a very detailed examination of those records, especially that by geophysicist Alexander Kovalevsky who had been specially invited to the ITEG to analyze the materials that were then arriving at Tomsk from Russian and foreign geophysical observatories.

Having compared the Irkutsk magnetogram with those recorded by American geophysicists during the high-altitude nuclear tests in 1958, Kovalevsky concluded that the Tunguska geomagnetic effect did not differ in any essential way from the artificial nuclear geomagnetic storms. Kim Ivanov had arrived at the same conclusion, but did not say this in his publications. It was already known that on June 30, 1908, no other magnetometric station on this planet had detected any disturbances. Therefore, the geomagnetic effect recorded at the Irkutsk Magnetographic Observatory had to be a very local effect. This was an important piece of information. Without it, one could have supposed that it had been just a simple, even if unusually short, solar geomagnetic storm. In

February of 1960, a paper entitled "On the Geomagnetic Effect of the Tunguska Meteorite Explosion" appeared in the journal *Fizika* (*Physics*) that was being issued by Tomsk University.[10] Referring to Ivanov's findings, its authors – Gennady Plekhanov, Alexander Kovalevsky, Victor Zhuravlev, and Nikolay Vasilyev – boldly likened this geomagnetic disturbance to the "artificial magnetic storms" that had followed thermonuclear explosions over the Pacific islands in 1958. Their sensational conclusion was that the "geomagnetic signatures" of the storms from both nuclear explosions and the Tunguska event were practically indistinguishable. In fact, if the only thing known about the Tunguska explosion had been its geomagnetic signature and no other traces or instrumental records had survived, we would have had to conclude that it was a nuclear explosion.

Subsequently, Kovalevsky made a great contribution to Tunguska studies, trying to find out the origin of the geomagnetic effect, looking for materials from the TSB in the soil, investigating traces of the light burn of vegetation and processing eyewitness reports. In 1979, his active research work was however interrupted for almost two years when he was flung into prison for keeping at home some dissident literature. But of course, it was not Kovalevsky who discovered the Tunguska geomagnetic effect. The true discoverer was Kim Ivanov.

It is worth repeating that not a single magnetometric station that existed in 1908 in Russia or elsewhere detected any noticeable variations of the geomagnetic field. But if it were just an unusually short solar magnetic storm that coincided by chance with the Tunguska event it would have been recorded outside Irkutsk as well. Therefore, this effect could only have been due to the Tunguska explosion. So did it mean that the Tunguska explosion could have been nuclear?

Although the ITEG researchers were looking for a geomagnetic trace of this explosion, starting from the association with similar nuclear-produced effects, it seems that Kim Ivanov's discovery had somewhat embarrassed them. Yes, they acknowledged a close similarity between the Tunguska magnetic storm and artificial magnetic storms of 1958, but they were in no hurry to declare it the final proof of the nuclear nature of the Tunguska explosion. Instead, they started to search for other, nonnuclear, explanations. This was the proper scientific approach to this question. Before accepting the nuclear explanation it had to be tested. As the famous philosopher Sir Karl Popper (1902–1995) used to say, every genuine test of a theory is an attempt to refute it. So it was necessary to look for another plausible explanation of the Tunguska magnetic storm. What else could have produced it? Could there be anything common in the thermonuclear explosions of 1958 and the Tunguska explosion of 1908, apart from possible radiation?

Certainly yes! There were shock waves! Let's remember that the magnitudes of these explosions were more or less comparable: some 4 Mt in 1958 and 40–50 Mt in 1908. Could it be the shock wave that had produced the geomagnetic effect in both cases? Independently, Kovalevsky and Ivanov developed the same hypothesis that the regional magnetic disturbance had started when the shock wave of the Tunguska explosion had struck the ionosphere.

True, even the "shock wave explanation" of the Tunguska geomagnetic effect looked from the meteoritic standpoint rather heretical, since it meant that there had occurred an *explosion* during the Tunguska event, whereas the meteorite specialists believed it had been a ballistic shock wave that had leveled the trees in the taiga. But no ballistic shock wave could have produced such a geomagnetic effect that had been recorded by the magnetometers of the Irkutsk Observatory. "Assuming that the recorded variations of the geomagnetic field were due to the ballistic shock wave of a swiftly flying meteorite," wrote Alexander Kovalevsky, "it would be impossible to explain the complicated character of these variations [of the geomagnetic field] and the time lag between the moment of the meteorite fall and the beginning of the [geomagnetic] effect."[11]

Generally, models proposed by various researchers to explain the Irkutsk geomagnetic storm are

1. Those assuming that the ionosphere was affected by the substance of the Tunguska comet's tail or by the high-temperature fiery ball that formed when its core exploded;
2. Models in which the main factor was the blast wave of the Tunguska explosion;
3. Those admitting that the geomagnetic effect was produced by hard radiation from this explosion – that is, highly penetrating alpha, beta, and gamma rays, as well as neutron radiation.

In particular, astronomers Grigory Idlis and Z. V. Karyagina accepted that the TSB "had definitely been a comet." They believed that the solar wind and comet tails are very similar. Consequently, Idlis and Karyagina supposed that the ionized comet's tail had to affect the magnetic field of Earth as does the solar wind. And since it is this wind that generates usual geomagnetic storms, the comet tail would produce a similar effect.[12] In fact, comet tails are composed of very rarified ionized gases and dust, whereas the solar wind consists of fast streams of electrons and protons. Therefore, the "Tunguska comet" tail could not produce a geomagnetic storm. Besides, from their theory it directly followed that the "cometary" geomagnetic storm would inevitably have encompassed the whole globe, as comet tails are much larger than our planet, while the localness of the Tunguska geomagnetic effect had been established beyond doubt. This is why the theory of Idlis and Karyagina failed to explain the event. Other astronomers had immediately noticed their mistake. For instance, Academician Vasily Fesenkov, even being the leading supporter of the cometary hypothesis, was not tempted by the spurious analogy between comet tail and solar wind and preferred to simply ignore the Tunguska geomagnetic effect.

Geophysicist Saken Obashev, realizing that the blast wave or comet's tail could not explain all features of the geomagnetic effect (nor even its origin), but having doubts about the nuclear explanation of the Tunguska event, made nonetheless a half-step toward its acceptance. Of course, he thought the TSB was a natural space body – an asteroid or the core of a comet. But how it exploded in the air is a separate question worthy of special consideration. Perhaps it was a thermal explosion? Why not? Such a hypothesis exists. But whatever was the cause of the explosion, this space body did definitely blow up – and such a powerful explosion, even a nonnuclear one, must have formed a fiery ball composed of plasma of high-temperature ionized gas. The fiery ball having expanded, its charged particles of opposite charges began to separate and move along the lines of force of the geomagnetic field. It was this motion (an electric current, in essence) that produced the geomagnetic storm.[13] However, Kim Ivanov proved that this model could not explain the duration of the effect. The TSB had exploded in the lower atmosphere, at a height less than 10 km, where high-temperature plasma can exist only several minutes before it recombines.[14]

But Ivanov himself, trying to exorcize from his calculations the evil spirit of nuclear reactions, created a very unconvincing model of the Tunguska geomagnetic effect. He believed that it could have been due to the thermal ionization of the ionosphere. Yes, if some volume of the rarified air of the ionosphere (which is, of course, already ionized by solar radiation) is heated up to the temperature of 6,000–7,000°C it would be additionally ionized. But what could have raised the temperature of the air so much? According to Kim Ivanov, it was the blast wave of the Tunguska explosion that had such a high temperature and therefore must have heated the ionospheric air. Alexey Zolotov did, however, demonstrate – mathematically and by referring to direct measurements from nuclear tests – that the Tunguska blast wave could not be so hot. In fact, even the blast wave of a powerful thermonuclear explosion has the temperature of 6,000°C at a distance of 1.5 km from the center of the explosion. And its temperature decreases very swiftly with distance. Thus, in the ionosphere the temperature of the blast wave of the Tunguska explosion would not have exceeded 200°C – which is absolutely insufficient for the thermal ionization.[15]

There is, by the way, one more reason that prevents us from accepting the blast wave theory as a satisfactory explanation of the Tunguska geomagnetic storm. All specialists agree that the artificial geomagnetic effects, discovered in the nuclear tests of 1958, were very similar to that recorded in 1908. The shapes of the curves, the relative durations, and the amplitudes of various phases are practically the same. So, Victor Zhuravlev drew the attention of the Tunguska research community to a very simple error that had been made by the supporters of the blast wave hypothesis.

As it follows from the models of Ivanov's and Kovalevsky's, both hard radiation and the blast wave could have led to the same result, that is, to the local geomagnetic effects. Well, let's accept for a while that the Tunguska explosion was not accompanied by hard radiation and the Tunguska geomagnetic storm was produced by nothing but its blast wave. But then, it means that after a *nuclear* explosion *two* geomagnetic effects would have been produced. The first generated by the hard radiation and the second by the blast wave. Since the velocity of propagation of hard radiation exceeds that of the blast wave by many thousands of times, the interval between them would have been about 5 min. Why, then, did the high-altitude nuclear explosions in the atmosphere produce only *one* geomagnetic storm from the hard radiation of the fiery ball? Where is the second from the blast wave?

Can we suppose that the blast wave of a high-altitude nuclear explosion traveled through the ionosphere not disturbing the geomagnetic field, whereas the same wave from the Tunguska explosion did disturb it? No, we cannot. If a blast wave could have produced the local geomagnetic effect, the high-altitude nuclear tests would have recorded "paired" geomagnetic storms – from the hard radiation of the fiery ball and from the blast wave. Since there is no evidence of this, it means that a blast wave cannot produce such an effect. This is impossible theoretically and was never found in experiment. It is only the hard radiation of the fiery ball that can produce the local geomagnetic effect.

Nonetheless, great pains were taken to explain the Tunguska geomagnetic storm, both inside and outside the ITEG, while not referring to the nuclear model of this event. Two founding fathers of the ITEG – Victor Zhuravlev and Valentin Demin – demonstrated that such attempts were doomed to failure.[16] Again, it was Alexey Zolotov who called a spade a spade. In the monograph *Problem of the Tunguska Catastrophe of 1908*, he developed a detailed quantitative theory of an artificial magnetic storm.[17] According to this theory, the main phase of the local geomagnetic effect after a nuclear explosion arises due to fast electrons emitted by its fiery ball and caught in the geomagnetic trap – the layer of the terrestrial magnetosphere, inside which the configuration of magnetic lines of force prevents charged particles from leaving it. The sequence of events may vary, depending on the altitude of the explosion. However, Zolotov has showed conclusively that all possible schemes of the geomagnetic effect are based on nuclear reactions only. No contribution from a blast wave is needed to explain it.

Does the "nuclear explanation" of the Tunguska geomagnetic effect have any weak points? Or does this model explain every detail perfectly? Yes, it has some weak points. The first obstacle that Zhuravlev, Demin, and Zolotov faced when developing the nuclear model proved to be the time lag between the moment of the Tunguska explosion and the start of the geomagnetic storm. Kim Ivanov estimated its duration as some 2 min. As for the high-altitude nuclear explosions over Johnston Island, there was no time lag at all – both on August 1 (the explosion magnitude 3.8 Mt, the height 78 km) and on August 12, 1958 (the same magnitude, the height 42 km). The first phase of the geomagnetic effect started immediately after the explosions, the delay being less than one second. Assuming that the velocity of the blast wave of the Tunguska explosion was transonic (340 meters per second) and the lower boundary of the ionosphere was located at 80 kilometers over Earth, Ivanov determined that the blast wave must have reached this boundary in about four minutes.

As these figures were of the same order, Kim Ivanov decided that it had been the blast wave that had produced the Tunguska geomagnetic storm. He completely agreed, however, that when a thermonuclear bomb exploded in the upper atmosphere, the geomagnetic disturbance was due to the hard radiation from the explosion. That is why there was no time lag between the moments of the explosions and the beginnings of the geomagnetic storms during the nuclear tests in the Pacific in 1958. Neutrons and gamma rays travel much faster than even a powerful blast wave.

In fact, the duration of the time lag between the moment of the Tunguska explosion and the start of the geomagnetic storm was then known with an accuracy of several minutes. It was therefore necessary to find out its *exact* value. But the only way to refine it would be determining, from other instrumental data, the exact moment of the Tunguska explosion itself.

It was Professor Ivan Pasechnik (1910–1988) who was asked by the academic Committee on Meteorites to take on this difficult task. Pasechnik was the leading Soviet specialist in monitoring foreign nuclear tests. He organized in the Soviet Union and supervised a net of observing stations that detected all nuclear explosions outside the USSR and measured their parameters. It was Pasechnik who persuaded his colleagues and government officials both in the Soviet Union and in the West that measuring instruments existing early in the 1960s could detect even the weakest nuclear explosions in every corner of the world. Thanks to this, the USSR, the United States, and the United Kingdom signed in 1963 the Partial Test Ban Treaty prohibiting nuclear tests in the atmosphere, in outer space, and under water.

One of the main methods of keeping track of nuclear explosions was by analyzing seismic waves of the explosions. The Tunguska explosion left records of its seismic waves on the bands of seismographs in Irkutsk, Tashkent, Tbilisi, and Jena – but only the Irkutsk and Jena seismograms exist today. Attempts were made to determine the exact moment of the Tunguska explosion from this seismic data, first by director of the Irkutsk Magnetographic and Meteorological Observatory, Arkady Voznesensky. He arrived at the figures 0 h 17 min 11 s GMT, but Voznesensky in his calculations used the "average" velocity of seismic waves known at that time, which made his result not too precise. Fortunately, in 1986, Russian geophysicists managed to measure the velocity of seismic waves along paths that practically coincided with the paths of those waves that had been recorded during the earthquake produced by the Tunguska explosion. And Professor Pasechnik used these data in his calculations. It turned out that the Tunguska explosion had occurred between 0 h 13 min 30 s and 0 h 13 min 40 s GMT.[18]

Now this is important, because we know that the Tunguska geomagnetic storm started at 0 h 20 min 12 s GMT. Therefore, the time lag was as long as 6 min 23 s. When we also consider that the blast wave of the Tunguska explosion took some 10 seconds to reach Earth's surface (obviously, the earthquake could not have started earlier), it means that the time lag was in fact about 6.5 minutes. And what of it the reader will ask? Well, this figure refutes the blast wave model for the Tunguska geomagnetic storm. With such a time lag, the speed of the blast wave that would have been needed in the ionosphere to produce a magnetic disturbance would have been 200 meters per second – much too low. The velocity of sound waves is about 330 meters per second, and no blast wave can travel below that speed.

So how did the time lag originate? In the theories of Ivanov's and Kovalevsky's it fits naturally. This is the time the blast wave had to reach the ionosphere. But the "nuclear" model of the geomagnetic effect did not need any time lag. Hard radiation propagates much faster than any blast wave, and it would have reached the ionosphere in a split second. This is why Alexey Zolotov tried to prove that there had been no real time lag between the explosion and the geomagnetic effect – it must have arisen, he said, in calculations due to the low precision of initial data. But Professor Pasechnik has convincingly proved that this was not the case; the time lag was for real and it was rather large. So where do we go from here?

Victor Zhuravlev, pondering this problem, noted an important detail: the fiery ball of the Tunguska explosion was usually thought of as stationary. It had to emit hard radiation but not to move.

Reality is different. The fiery ball of a nuclear explosion that occurs at a height of several kilometers almost immediately starts to rise into the stratosphere – just because it is lighter than air. And its ascent lasts 6–10 min.

This relatively slow motion of the fiery ball has to be the cause of a time lag. Only after reaching an altitude where the air density is low enough can the hard radiation of the fiery ball influence the ionosphere and produce a local geomagnetic effect. Since a store of radioactive substances in the fiery ball of a nuclear explosion is very large, the artificial geomagnetic storm can last one hour or more.

Thus, it seems that for 6 min 30 s after the Tunguska explosion its fiery ball was rising and only then the upper atmosphere felt the influence of its hard radiation. The concentration of electrons and ions in the ionosphere over the Great Hollow sharply increased. At that time a magnetic wave moved toward Irkutsk.[19] The result? The intensity of the geomagnetic field jumped, and this jump was detected by magnetometers of Voznesensky's Observatory.

In 2003, speaking in Moscow at "The 95th Anniversary of the Tunguska Problem" conference, Kim Ivanov agreed that the blast wave in itself could not have produced the geomagnetic effect. Additional ionization of the ionosphere over the place of the explosion was necessary for that. "The source of this additional ionization remains unknown," he said. It appears that after many years of investigations and discussions, the opinions of Tunguska researchers on the origin of the local geomagnetic storm – if not on the origin of the TSB – had drawn nearer.

True, the "additional ionization" does not necessarily imply a "nuclear explosion." The nuclear model of the geomagnetic effect just meets one more difficulty. The Tunguska local geomagnetic storm was, paradoxically, "somewhat too strong" and "somewhat too long" to be regarded as the final proof of the nuclear hypothesis of the Tunguska explosion.

How to explain this peculiarity? Victor Zhuravlev and Alexey Dmitriev suggested that the plasma cloud (without which no model of the regional geomagnetic effect would work) did not originate at the moment of the explosion. Instead, it came to the atmosphere of Earth as a "plasmoid" generated by the Sun. It was the American physicist Winston H. Bostick (1916–1991) who coined the term "plasmoid" in 1956, implying a coherent structure consisting of plasma within a magnetic field and able to exist for some time outside of the source that generated it.[20] Such structures arise, for example, when plasma is injected into a vacuum chamber in which a strong magnetic field exists. But the lifetime of these artificial plasmoids is rather short. As for the TSB, it could be, according to Zhuravlev and Dmitriev's opinion, a huge and stable natural plasmoid shaped as a spindle-like "magnetic bottle" and surrounded by an external magnetosphere.

Recombining over the Great Hollow, protons and electrons of the plasma cloud generated hard radiation, after which the process developed in the same manner as in the wake of a nuclear explosion. This radiation, in its turn, gave rise to a system of electric currents in the ionosphere that produced the regional geomagnetic effect. The amount of plasma in the "magnetic bottle" had to be great enough to maintain this system of currents for about five hours.[21]

Trying to calculate the strength of magnetic field for their model, Zhuravlev and Dmitriev have however obtained an unbelievably high figure: 16 teslas. Such a field would be stronger than the terrestrial magnetic field by about half a million times. Even though fields of this order of intensity have been produced in some terrestrial laboratories – with the help of superconducting solenoids – they have never been detected on the Sun. It seems therefore that attempting to introduce into the Tunguska problem a new "natural" hypothesis for the TSB origin, Zhuravlev and Dmitriev have instead built a novel version of its "artificial" model, something like a starship with, figuratively speaking, a "plasma-magnetic engine." For a purely natural object, the intensity of the magnetic field inside the hypothetical plasmoid would have been much too high. Besides, the idea itself bore little if any hard evidence – such objects have never been observed in the Solar System.

But whether or not this hypothesis can explain all the circumstances of the Tunguska event, it at least suggests that the TSB itself was the source of a strong magnetic field. And this supposition of Zhuravlev and Dmitriev's appears to have been confirmed not only by the local geomagnetic storm but also by a paleomagnetic anomaly in the soil of the Great Hollow.

Geophysicists have long been aware that many igneous rocks were magnetized when they formed. That is when hot liquid magma cools. More exactly, it is ferromagnetic minerals making up the rocks (especially, magnetite and hematite) that become, under such conditions, permanently magnetized. Usually the directions of these residual magnetizations are parallel to the direction of the geomagnetic field that existed at the time of their formation. When deposited in water basins, the magnetized minerals do also tend to align themselves along the lines of force of this field.

Although paleomagnetic research began to develop only after World War II, it has become a mature field of science that has, in particular, greatly helped to establish the theory of continental drift. The natural remanent magnetization is well maintained in the rocks and may be measured with modern magnetometers. In 1971, Saulas Sidoras, a specialist in paleomagnetic geological prospecting, and the mathematician Alena Boyarkina asked an important question: Could the same cause that had produced the geomagnetic effect recorded at the Irkutsk Observatory also have affected the residual magnetization of soils in the Great Hollow? Their work led to the finding of the Tunguska paleomagnetic anomaly.

It was a long and painstaking investigation. From an area of 600 km^2, in friable deposits of the near-surface layer of the soil, the researchers took samples that were marked with arrows indicating direction to the northern magnetic pole. After that, by a conventional procedure, the strength and direction of the natural remanent magnetization were measured in the lab.

The finding from this research is that there exist in the Great Hollow two components of residual magnetization instead of the usual one. This is definitely strange because one of these components coincides with the direction of the expected geomagnetic field while the other does not. Around the Ostraya Mountain, at a distance of about 4 km from the epicenter along the first of Fast's TSB trajectory (according to which the TSB was flying to the west-northwest), the structure of the remanent magnetization looks the most chaotic. It was therefore here that the magnetic influence of the TSB was greatest. "It seems reasonable to suppose," wrote Sidoras and Boyarkina, "that this effect is due to the influence of a magnetic field whose direction was opposite to the normal geomagnetic field. Such a field could decrease the residual magnetization."[22] Closer examination of the paleomagnetic anomaly in the Great Hollow has shown that zones of equal residual magnetization exist around the Ostraya Mountain, extending to the northwest and then to the north. Outside these zones the residual magnetization of local soils does not differ from the background one.

Figure 7.2 shows how this anomaly looks. Computations carried out by Victor Zhuravlev have led to the conclusion that the surface paleomagnetic anomaly could be produced by the same source that generated the first phase of the local geomagnetic storm of June 30, 1908. To disrupt the residual magnetization around the Tunguska epicenter to the extent that was measured by Sidoras and Boyarkina, the magnetic field imposed on the site of the catastrophe must have been 50–60 times stronger than Earth's magnetic field. But if the source itself was at an altitude of several kilometers, the strength of the field at its source must have exceeded the strength of Earth's geomagnetic field by 500 times! In Irkutsk, that is, at a distance of 970 km from the Great Hollow, such a source could have produced the start of the geomagnetic effect that was recorded at the Irkutsk Observatory.

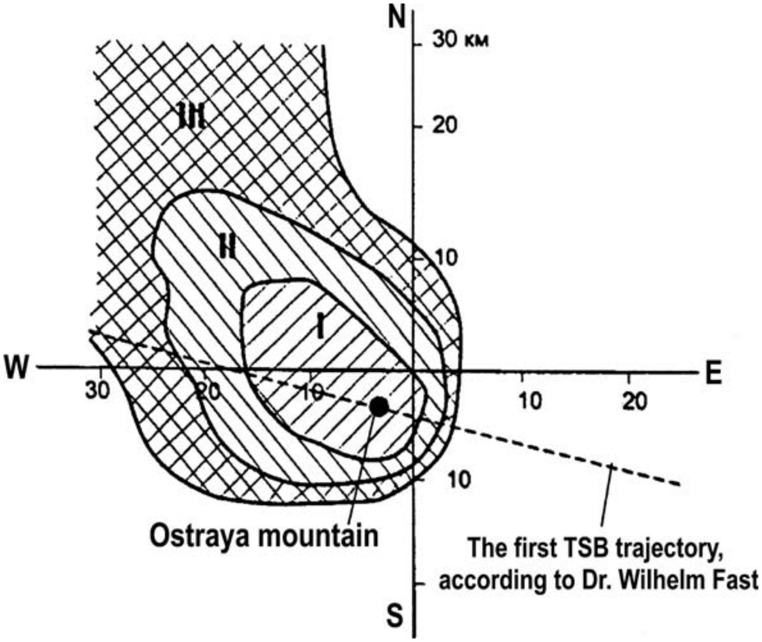

FIGURE 7.2. The area of the paleomagnetic anomaly testifying that the Tunguska space body was the source of a powerful magnetic field (*Source*: Vasilyev, N. V. *The Tunguska Meteorite: A Space Phenomenon of the Summer of 1908.* Moscow: Russkaya Panorama, 2004, p. 149.).

So the paleomagnetic anomaly and the local geomagnetic storm complement each other very well. But they are still not the strangest aspects of the magnetic trace of the Tunguska catastrophe. At least, they originated *after* the Tunguska explosion, being its results. But there also exists a third aspect of the magnetic trace of the event – the most enigmatic one, which may be called the "magnetic precursor" of the Tunguska phenomenon. We mean here the so-called "Weber effect."

By the irony of fate, the uncovering of this peculiar effect preceded discoveries about the local geomagnetic storm and the paleomagnetic anomaly. In the spring of 1959 two leaders of the ITEG – Gennady Plekhanov and Nikolay Vasilyev – were perusing scholarly journals dated back to the year 1908, looking for information that could have had anything to do with the Tunguska event. And suddenly they came across a short report published in the German *Astronomische Nachrichten* journal. It was entitled "Von Herrn Prof. Dr. L. Weber, Kiel, Physikalisches Institut der Universität, 1908 Juli 11." According to this report, Professor Weber, when working at a laboratory of Kiel University, Germany, observed from June 27 to June 30, 1908 a very unusual geomagnetic effect. "Throughout the last 14 days," he wrote, "the photographically recorded curves... did not demonstrate any disturbances that usually accompany aurorae. But I would like to note that several times, during many hours, were permanently observed small, regular, uninterrupted oscillations with an amplitude of two angular minutes and period of 3 min. These variations are not attributable to any known causes (say, to the disturbances arising from tramways in the city)."[23]

The variations were recorded three times. First, they started at 6 pm, June 27, and lasted 7 hours 30 minutes – until 1.30 am June 28. These oscillations recurred exactly at the same time interval on June 28–29 from 6 pm to 1.30 am. Next day, that is, June 29, they commenced at 8.30 pm and finally stopped at 1.30 am, June 30.[24] This time they lasted only 5 hours. Nikolay Vasilyev and his colleagues tried to find the originals of these magnetograms, but they had been destroyed during World War II.

As emphasized by one of the leading ITEG members, Boris Bidyukov, the beginning of the Weber effect falls upon that very day (June 27, 1908), when over Europe, and especially over Germany, became visible "optical precursors" of the Tunguska explosion – the peculiar light anomalies in the atmosphere. It finished in 16 min after the explosion. As far as we can judge, neither before nor subsequently were similar effects ever recorded. So, a chance coincidence of these events is highly improbable.

"The interval between these oscillations," Bidyukov writes, "was *24 hours exactly*, that is, one revolution of the Earth on its axis."[25] Perhaps, the only association that comes to mind in this connection is the idea of a satellite traveling in an elliptical orbit with a period of 24 hours and its closest point over Germany. If such a satellite was the source of a powerful magnetic field it could have influenced Professor Weber's magnetometer. We will later consider a complicated theory, recently developed by a group of Russian scientists, connecting the hypothetical "Tunguska comet" with the Weber effect. However, we have to agree with Professor Weber that these oscillations cannot be attributed to any known natural causes.

Now, in which direction does the "third Tunguska key" turn? One can say with confidence it does not point in the direction of a comet core or a stony meteorite. Rather, it points to a nuclear explosion, though the opinion of Alexey Zolotov and Victor Zhuravlev that the local geomagnetic storm is the final proof that the Tunguska explosion was nuclear should be viewed with some reservation. Anyway, the importance of this key should not be underestimated. Karl Popper believed that no hypothesis could be finally proved; it could only be "not falsified." In other words, a lot of evidence in favor of a hypothetical model does not mean it is entirely vindicated, whereas a single piece of evidence *against* it does refute the hypothesis. From this viewpoint, even if the magnetic traces of the Tunguska event have not fully established the correctness of the nuclear model, they at least may be considered as convincing evidence against the "standard" cometary-meteorite model. Neither the core of a comet nor a stony meteorite could have produced the local geomagnetic storm or have left a paleomagnetic anomaly at the epicenter of the explosion.

The favorite method of adherents to the meteoritic models of the Tunguska phenomenon is to declare any puzzling find a "chance co-occurrence." But in this case it does not work. The geomagnetic effect of June 30, 1908, differed radically from usual solar geomagnetic storms, being at the same time very similar to those geomagnetic disturbances that are produced by nuclear explosions in the atmosphere. And besides, would a global or near-global solar geomagnetic storm affect the residual magnetization just in the Great Hollow at the epicenter of the Tunguska explosion? Certainly not.

Notes and References

1. Strictly speaking, a gamma is 1/100,000 of an oersted, the unit of measurement of the magnetic field induction, but this is not important for our considerations. When we are dealing with magnetic fields in the vacuum or in a very rarified air, the difference between magnetic induction and magnetic field intensity becomes negligible.
2. See Matsushita, S. On artificial geomagnetic and ionospheric storms associated with high-altitude explosions. – *Journal of Geophysical Research*, 1959, Vol. 64, No. 9; Mason, R. G., and Vitousek, M. J. Some geomagnetic phenomena associated with nuclear explosions. – *Nature*, 1959, Vol. 184, No. 4688.
3. See Leypunsky, O. I. On the possible magnetic effect of high-altitude explosions of atomic bombs. – *Zhurnal Eksperimentalnoy i Teoreticheskoy Fiziki*, 1960, Vol. 38, No. 1 (in Russian).
4. Kalashnikov, A. G. On observation of the magnetic meteor effect by the induction method. – *Reports of the USSR Academy of Sciences*, 1949, Vol. 66, No. 3; Kalashnikov, A. G. Magnetic meteor effect. – *Reports of the USSR Academy of Sciences, Geophysical Series*, 1952, No. 6 (in Russian).
5. See Zhuravlev, V. K., and Zigel, F. Y. *The Tunguska Miracle: History of Investigations of the Tunguska Meteorite*. Ekaterinburg: Basko, p. 52 (in Russian).
6. Here is a more detailed description of the Tunguska geomagnetic effect, with some figures. The first entry led to an increase of the horizontal component of the geomagnetic field (H) for 4 gammas. Its second phase started at 0 h 22 min GMT with a new increase in the H magnitude. In the course of 18 min, it rose for 20 gammas more. For the next 14 min, the H component remained at the same level, after which, at 0 h 36 min GMT, the phase of fall began. During 1 h 41 min, the H component's value decreased by 67 gammas. The last phase started at about 2 h 17 min GMT and lasted some 3 h, until 5 h 20 min GMT (or 12 h 20 min, local time). The vertical component of the geomagnetic field (*Z*) did also change, although it returned to its usual value 2 h earlier

than the H component – at 3 h 20 min GMT. The magnetograms seemed not to show any change of the magnetic declination. But paying due attention to the usual daily variation of the geomagnetic field, Kim Ivanov and another Russian geophysicist, V. I. Afanasieva, succeeded in discovering alterations in the magnetic declination D as well. It turned out that the plane of the magnetic meridian had deviated by 10 angular minutes to the west and this deviation persisted during 5 to 6 hours.

7. See Zhuravlev, V. K. The geomagnetic effect of the Tunguska explosion and the technogeneous hypothesis of the TSB origin. – *RIAP Bulletin*, 1998, Vol. 4, No. 1–2, p. 9.
8. Zhuravlev, V. K. op. cit., p. 5.
9. Ivanov, K. G. Geomagnetic effects that were observed at the Irkutsk Magnetographic Observatory after the explosion of the Tunguska meteorite. – *Meteoritika*, Vol. 21, 1961 (in Russian).
10. Plekhanov, G. F., Kovalevsky, A. F., Zhuravlev, V. K., Vasilyev, N. V. On the geomagnetic effect of the Tunguska meteorite explosion. – *Proceedings of Institutions of Higher Educations. Physics.* 1960, No. 2.
11. Kovalevsky, A. F. The magnetic effect of the explosion of the Tunguska Meteorite. – *The Problem of the Tunguska Meteorite*. Tomsk: University Publishing House, 1963, p. 192 (in Russian).
12. Idlis, G. M., and Karyagina, Z. V. On the cometary nature of the Tunguska meteorite. – *Meteoritika*, Vol. 21, 1961 (in Russian).
13. Obashev, S. O. On the geomagnetic effect of the Tunguska meteorite. – *Meteoritika*, Vol. 21, 1961 (in Russian).
14. Ivanov, K. G. The geomagnetic effect of the Tunguska fall. – *Meteoritika*, Vol. 24, 1964 (in Russian).
15. Zolotov, A.V. *The Problem of the Tunguska Catastrophe of 1908*. Minsk: Nauka i Tekhnika, 1969, pp. 161–168 (in Russian).
16. See Zhuravlev, V. K. On the interpretation of the geomagnetic effect of 1908. – *The Problem of the Tunguska Meteorite*. Tomsk: University Publishing House, 1963 (in Russian); Zhuravlev, V. K., Demin, D. V., Demina, L. N. On the mechanism of the magnetic effect of the Tunguska meteorite. – *The Problem of the Tunguska Meteorite*. Vol. 2, Tomsk: University Publishing House, 1967 (in Russian).
17. See Zolotov, A.V. *The Problem of the Tunguska Catastrophe of 1908*. Minsk: Nauka i Tekhnika, 1969, pp. 155–191 (in Russian).
18. See Pasechnik, I. P. Refinement of the moment of explosion of the Tunguska meteorite from the seismic data. – *Cosmic Matter and the Earth*. Novosibirsk: Nauka, 1986, p. 66 (in Russian).
19. The so-called Alfvén wave – a traveling oscillation of the ions and the magnetic field.

20. See Bostick, W. H. Experimental study of ionized matter projected across a magnetic field. – *Physical Review*, 1956, Vol. 104, No. 2; Bostick, W. H. Experimental study of plasmoids. – *Physical Review*, 1957, Vol. 106, No. 2.
21. See Dmitriev, A. N., and Zhuravlev, V. K. *The Tunguska Phenomenon of 1908 as a Kind of Cosmic Connections Between the Sun and the Earth.* Novosibirsk: IGIG SO AN SSSR, 1984, pp. 125–127 (in Russian).
22. Sidoras, S. D., and Boyarkina, A. P. Results of paleomagnetic investigations in the region of the Tunguska meteorite fall. – *Problems of Meteoritics*. Tomsk: University Publishing House, 1976 (in Russian). See also Vasilyev, N. V. *The Tunguska Meteorite: A Space Phenomenon of the Summer of 1908.* Moscow: Russkaya Panorama, 2004, p. 149 (in Russian).
23. *Astronomische Nachrichten* Journal, 1908, Vol. 178, No. 4262, p. 239; see also: *Nature*, 1908, July 30, p. 305.
24. When recording the oscillations, Weber most probably used middle European time which differs from Greenwich time for an hour. We know that the Tunguska explosion occurred at 0 h 14 min GMT; therefore, the variations of the magnetic needle in Kiel stopped 16 min after the moment of the explosion.
25. Bidiukov, B. F. The "Weber Effect" and anomalous luminous phenomena in the Earth's atmosphere in the period of the Tunguska event of 1908. – *RIAP Bulletin*, 2006, Vol. 10, No. 2, p. 13.