Report on the 1st International Tunguska Expedition

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Some data on the First International Tunguska Expedition of 1990 are presented. It was one of the biggest expeditions since 1958. About 120 members from five countries took part. The field work was carried out from June 26 till August 25 and included the following main directions: (i) research on the physics of the Tunguska explosion; (ii) search for the substance of the Tunguska body; and (iii) study of the "ecological after-effects" of the Tunguska event.

1. Introduction

The first International Tunguska Expedition was carried out from June 26 till August 25 in accordance with the international program of the investigation of the Tunguska event 1908. About 120 persons took part in this expedition. There were 26 foreign members (France 8, Yugoslavia 7, Bulgaria 6, Sweden 2) and about 100 members were from the USSR. Let us note that this was the 32th expedition organized by the Complex Independent Expedition of the Tomsk Branch of the All-Union Astronomical-Geodetical Society and it was one of the biggest expeditions since 1958. The scientific program of 1990 fully corresponded to the International Program published in this journal and included the main topics discussed below.

2. Investigation of the physics of the Tunguska explosion.

The representatives from the Swedish academy of Sciences (L. Baath and C. Andersson), Yugoslavia (*IMO* member K. Korlević), Bulgaria (Chairman E. Bojurova, *IMO* member), and from the Soviet Union (Chairmen: N. Vasilyev and G. Andreev) took part in this program. The investigations covered:

- the determination of the border and the inner structure of the Tunguska fire of 1908;
- the determination of the border of the "light-burn" area of the trees and vegetation;
- the search for fragments of the Tunguska body which entered the Earth atmosphere separately (working in the possible ellipse of distribution of this particles); and
- taking samples of the soil for the search of radio-active elements.

Let us note that the search for fragments of the Tunguska body on the edge of the possible ellipse of distribution is a new part of the investigation. It is necessary to note that the probability to find some remains of the Tunguska body is connected with the possibility that this body had greater density and was an Apollo-type asteroid [1]. This project was chosen after joint discussion (April 1990, Tomsk) between *IMO* members (A. Knöfel, K. Korlević, J. Rendtel) and CIE members (G. Andreev, N. Vasilyev) and it is one of the promising projects in the Tunguska research. This investigation will continue in the next years. This year, only first steps were made, but we got some interesting results.

First, the possible ellipse of distribution was calculated by V. Goldin and G. Ryabova (they used only a ballistic model of motion without the effect of ablation to get results quickly). Second, a high sensitivity magnetometric survey near the epicenter was carried out by L. Baath and C. Andersson. A map of the distribution of the gradients of the magnetic field was obtained. In the place of the maximum anomaly of the magnetic field, geological and geochemical research was carried out which will be finished in the future. In the layer of 1908 on the depths of only 3-8 cm in the forest we found ashes, some burned particles of stones and tree resin, embedding the ashes and particles of the time of the post-explosion forest fire.

One group of biologists lead by G. Plekhanov confirm that a forest fire in 1908 covered the entire territory immediately after the explosion. The irradiation was the reason of the fire. Finishing mapping of the irradiation burn, we were able to calculate the fraction of energy transformed in light.

3. Search for the substance of the Tunguska body

This direction of the Tunguska expedition included research about:

- selection of the stratified columns of peat and soil from the different parts of the Tunguska meteorite reserve for future chemical research of presence of elements abounding in meteorites;
- selection of the samples of the trees for dendrochronological and carbonic analysis;
- selection of the sample leaves of some shrubberies for studying the accumulation of some chemical elements.

At the moment, the analyses of the material are in progress.

4. Study of the "ecological after-effects" of the Tunguska event

The effect of accelerated growth of the biomass of the plants and the effect of the mutations of the vegetation and the animal world in the Tunguska region were investigated (chairmen: N. Vasilyev and K. Korlević).

- *Determination of the variability in low migrating species of butterfly (Lepidoptera).* This investigation must be done in four regions: in the middle of the event, on the border and on two control points at 100 and 200 km from the event in similar ecological conditions. Unfortunately, no faunistic study of Lepidoptera exists of this region. The first step in this work was done by K. Korlević, collecting butterflies in this region to determine species for future variability research.
- *The control of the variability of ants in this region will be examined in a new way using electrophoresis analysis on samples collected this year.*
- *Search for the possible chemical reason (dioxine?) for the biological mutations will be made on samples of peat near the epicenter.*
- *Search for the possibility of transmission of genetic anomalies with seeds of the Pinus family.*
- *Macro scale monitoring in search of regions of increased variability in vegetation.* There is a suspicion that some regions of the Tunguska event show an earlier or later start in vegetation growth and different concentrations of chlorophile. To exclude the influence of common forest fires, it is essential to control also some other parts in Siberia involved in forest fires in the last period [2,3]. In cooperation with A. Petricono, responsible for the European branch of EOSAT in Rome, K. Korlević found the availability of photos from Landsat of this region in the form of computer files ready for image processing. Filters in use are blue, green, yellow, red and two infrared spectral windows; resolutions on the ground level is about 30 m, each pixel is 8 bit or 256 levels of grey. Since photos and computer files of the Tunguska region from 1974 to 1990 exist, it will be possible to study possible abnormalities in forest growth, and possible incrementings or decreasings in interesting zones. The problem is that for every filter picture the cost is 700 USD, or for all spectral windows 3500 USD (EOSAT Catalogue, 1989). C. Andersson and L. Baath from Onsala Space Observatory are now trying to find sponsors for this research. It is possible that photos and computer files from Soviet Union satellites will be available in 1991.

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Powerful bolide explosion over North Italy

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Abstract. In the night of 19 January 1993 at 00:33:20 ± 15 s UT, North Italy, Slovenia and Croatia were illuminated by powerful terminal flare during fireball disintegration. Some tens of KT were liberated as light. In the region of Emilia the low frequency, very strong roar (thunder) was also heard, shaking windows and walls, some 80–140 s after the bolide explosion.

The severe fragmentation and after that a complete destruction of the fireball body took place over the Italian region of Emilia at the height of 35–40 km. Sticky film traps were used for the first time after a bright fireball event and a probable fall down of glassy spherules sizing micron was captured. This is one more case where very large meteoroids, group (type) I, II and III or small asteroids/comets (density 0.2–5 g cm^{-3}) were completely destroyed by aerodynamic pressure and stress in the dense part of the atmosphere, leaving no geological consequences.

The presented data are the best possible to have been collected and studied up until 1 June 1993.

Description of the event

In the night of 19 January 1993 at 00:33:20 ± 15 s, UT, many people from North Italy, Slovenia and Croatia witnessed a very bright flash in the sky. On the Ondrejov observatory some 700 km from the epicentre, the sky in the direction SSW was illuminated much more intensely than before the rise of full moon to the elevation of 70°, and thus the source of light was below the real horizon (Borovička, 1993).

Only a few eyewitnesses saw the fireball entering the atmosphere and their descriptions are contradictory. However all eyewitnesses agree on the direction of the ending point of the fireball, between the cities of Imola, Faenza and Lugo. The fireball entered the atmosphere somewhere over the Adriatic sea or central Italy. The luminosity in the first part of the flight was $M \approx -13$ with incrementing intensity and at the end a very intense terminal flare (flash).

During this period, more than 10 s, no acoustic phenomena connected to the fireball were reported. Two indications exist of possible minor fragmentation of the fireball body in the first part of the atmosphere path. Sparks behind the fireball, and the two small pieces separated from the fireball before the terminal point, but disappeared before the terminal flare. During the final flash that lasted from one to two seconds the intensity of light varied, having two distinct peaks. At the peaks of luminosity, the globe emitted from 1 to 5×10^{13} W and possibly some tens KT of energy was emitted as light (this calculation was made from the estimation of 160 km distant surface illumination by one experienced eyewitnesses). At the terminal point where the fireball ended in a flare, an inflation of an orange light emitting ellipsoid sizing ≈500–800 m was reported at the height of 20–25 km (eyewitnesses data), 35–40 km (seismic records). Below the ellipse a colourful bell structure was seen, but all these light features faded fast.

No sparks, no multiple sources of light and no filaments or protuberance in the direction of flight were seen in the ending point. Because the light flash occurred near a cloud layer, the layer was intensely illuminated and distant observers described this effect as baffles or horizontal jets.

In the region of Emilia the low frequency roar (thunder) was also heard, some 80–140 s after the end of the explosion. The sound was very deep and strong. For 20 s the windows and, in the city of Faenza, walls, also vibrated. No fall of meteorite was reported in the area of the possible strewnfield.

Possible registration on some barographs of the shock wave exists in the Emilia region, but more data are needed. Also a change in intensity of the Earth's magnetic field, probably connected with the fireball explosion was also recorded in central Italy from 0:56 and 1:00 UT.

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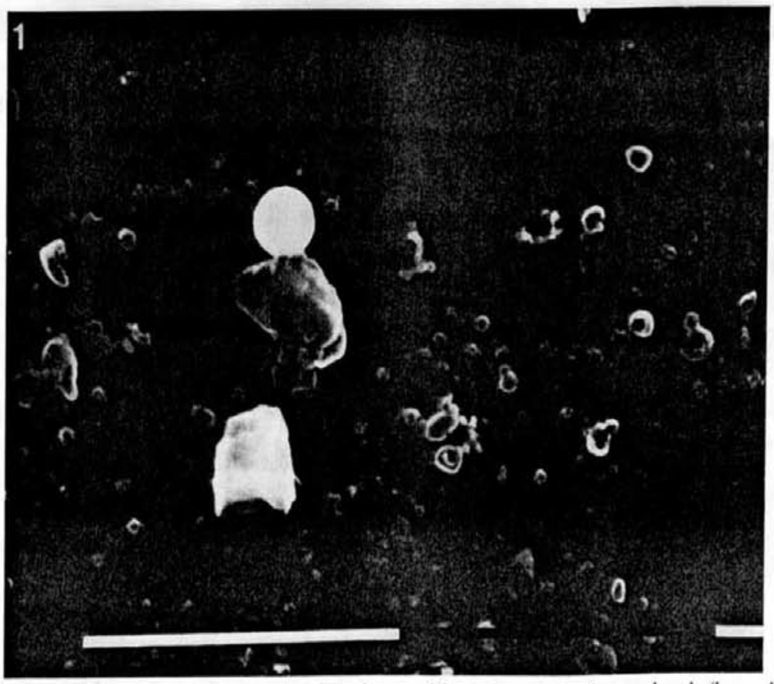

Fig. 1. Sticky film surface with trapped various dust particles and one 2 μm glassy spherule (bar = 10 μm)

By misfortune the direction of flight of the fireball was out of the region that is monitored by the European Network, and from the contradictory data the direction of flight is very uncertain. The possible azimuth value is from $A = 310°$ to $A = 17°$ and inclination from $v = 18°$ to $25°$ is possible. The velocity of the fireball in the atmosphere was greater than the 20 km s^{-1} (calculations from eyewitnesses data). All these parameters are too uncertain to give us one radiant, and the possibility to compute the corresponding heliocentric orbit.

The preliminary search for possible downfall of condensed meteoritic material from the plasma globe sizing microns, in the region of epicentre was probably successful. The collecting areas of sticky film and clean glass surfaces exceeding 2 m^2 were placed on 26 January, for 7 days in the uninhabited hill land ($\varphi = 44°15'$, $\lambda = 11°57'$) 7 km from the city of Faenza. The deposition was helped by stable anticyclone in the whole region during and after the fireball explosion.

The samples were analysed on an electron microscope, using the method described by Valdré and Korlević (1993), showing a great number of all possible particles. The majority of them are sharp edged particles sizing 2–5 μm, with some of them arriving to < 10 μm. As being of no great interest, their composition will be determined in some future time.

The most interesting presence between the trapped particles were the homogeneously distributed perfectly spherical particles sizing 1–2 μm (Figs 1 and 2). The deposition density of these trapped particles on the exposed surface is 10–20 particles per cm^2. The composition of these particles is Si (60–80%), Al (10–30%), K (5–10%) and Ca (5–10%), and low presence of Mg ($< 1\%$). The computed density of these spherule, compared with glass of such composition it is between 2.0–3.5 g cm^{-3}. Unfortunately weather prevented us making the comparison of these trapped particles with the background fall down in that region, as until now not one week after the original collection was without rain.

Now the search for more eyewitnesses, barograph's records, seismographs and magnetograph's records and background fall down is in progress. The possibility of more precise data on the trajectory exists, providing that some of the satellites for early warning bearing infrared radiometer registered the emitted infrared radiation of the fireball (Jacchia 1974), or the two flight radars, AWACS, that were in the region registered the event.

European newspapers and TV wrongly connected the fireball to a house fire 160 km from the epicentre, on the Istria peninsula in Croatia.

Conclusion

The massive body entered the atmosphere, suffered severe fragmentation and after that a complete destruction, 35–40 km above the Italian region of Emilia. The fall down of glassy perfectly spherical particles sizing micron, gave us a highly probable chemical composition (Si 60–80%, Al 10–30%, K 5–10% and Ca 5–10%, Mg $<1\%$) of the refractory part of the meteoroide.

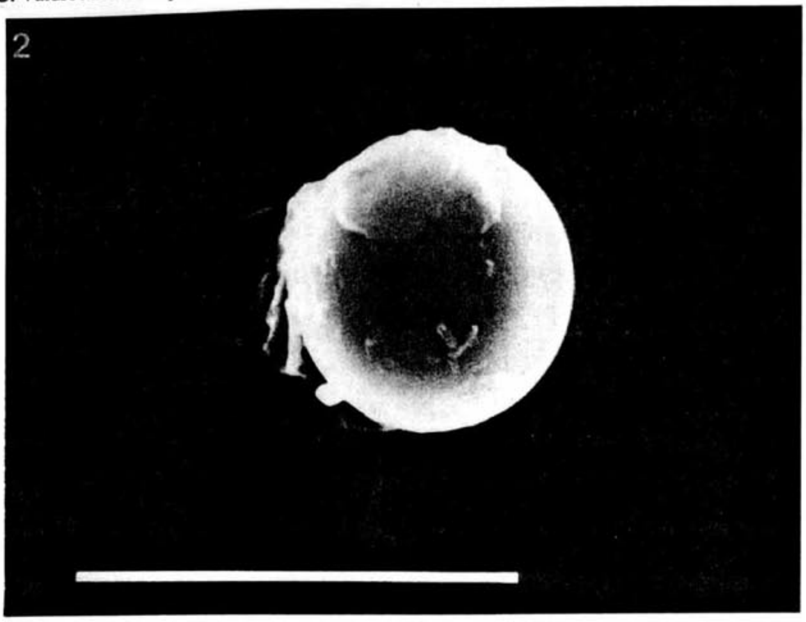

Fig. 2. Enlarged image of one of trapped spherules (bar = 1 μm)

For the first time tested sticky film traps worked properly. If their use becomes regular in the future, after very bright fireball events registered by the EN, these might probably give us a new dimension in fireball classification and their correlation to parent meteoroids' composition (Ceplecha, 1990).

This is one more case where very large meteoroids of group (type) I, II and III or small asteroids/cometary nuclei (densities from 0.2 to 5 g cm^{-3}) show us that they do not have the compressive and structural strength to survive the high velocity low atmosphere penetration, and are completely disintegrated by aerodynamic pressure and stress, as a confirmation of previously suspected phenomena (Sekanina, 1983; Chyba *et al.*, 1993).

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New method for the study of airborne particles based on tree-resin trapping and analytical electron microscopy

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This paper describes a new method for the study of datable airborne particles, of both terrestrial and extraterrestrial origin, and presents preliminary results of an application which casts light on the famous Siberia explosion of the beginning of the century. A dramatic, airborne explosion occurred on 30 June 1908 in Tunguska, Siberia, causing a fire in an area of about 2000 km^2, while in a larger region trees were felled in radial directions. No craters were found at the epicentre of the damaged area. A large amount of literature is available on the subject and several suggestions were made on the cause of the catastrophe, the more probable, comet or asteroid collisions, besides other less plausible speculations. The interest is diffused among different scientific disciplines such as astrophysics and cosmology, nuclear physics, earth and environmental sciences and even politics. Conventional chemical analyses of material picked up on the scene have been inconclusive in clarifying the cause of the event. This paper presents preliminary results obtained by a new method based on analytical electron microscopy of micro-sized airborne particles trapped in tree resin at the time of the explosion and preserved during the following years. The results clearly show that this approach can yield significant, historically reliable information. The method can be applied also in other fields, such as for monitoring and studying volcanic emissions and for investigating cosmic dusts which arrived on the earth before heavy modern pollution took place and different kinds of fall-outs.

1. Introduction

The dramatic event which took place at 00:14:28 GMT on 30 June 1908 in the area between Podkamennaja and Nizhnjaja Tunguska, 800 km North of Baykal, Siberia (60° 53′ N, 101° 53′ E) is referred to as the Tunguska explosion [1]. Although a huge amount of research work has been done and many papers and books have been published during the 84 years since the explosion took place, the clue to the mystery has not been found yet. Research into the Tunguska mystery has recently been reactivated and expeditions to that region have been resumed, at international level, under both scientific and political pressure, the latter to improve our ability to distinguish between natural and man-produced explosions and thus to reduce the risk of a nuclear war being triggered by mistake [2,3].

During the first International Tunguska Expedition [4] (ITE, 1990), a cross-section of a red Siberian tree trunk (*Picea Obovata*), about 20 m tall and 160 yr old, was cut 1 m above ground at Vulfing Hill, 5 km Northwest from the epicentre of the impact area.

After polishing, the cross-section revealed regular growing rings. The most interesting feature was a nearly horizontal branch emerging from the

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New method for the study of airborne meteoritic particles trapped on tree-resin: some results from the Tunguska region

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Abstract. After the complete disintegration of large meteoroids or small asteroids or cometary nuclei that have not the structural and compressive strength to survive the aerodynamic pressure and stress during the penetration in the dense part of the atmosphere, only a few methods to reconstruct the chemical composition of the parent meteoroid exist. The described methods of using natural or artificial sticky traps, were tested on two of such events: Tunguska 1908 (natural traps) and Emilia 1993 (artificial traps). Here the preliminary results of the former are described.

Introduction

After powerful air explosions and complete disintegration of large meteoroids and small asteroids and cometary nuclei that have not the strength (density < 3.7) to survive the aerodynamic pressure and stress during high-velocity penetration in the dense part of atmosphere, the only possibilities to reconstruct the bodies compositions after the events are:

- Search in the strewnfield for possible meteorites that entered the atmosphere separately from the main body, and slowed down enough to survive the dense atmosphere flight.
- Search of micron-sized particles condensed or escaped during the ablation or the disintegration in the terminal flare.

Until now, natural traps used for the search of deposited small particles after such events were peat bogs, glaciers, lake, swamp and sea bottoms (Rendal 1990). The difficulty of working with samples collected in these places is the great number of ballast particles present which complicate the search enormously. With such sedimentation traps there is also the problem of precise dating of the layers.

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Results and discussion

During the first International Tunguska Expedition ITE, 4 km SE from the epicentre of the Tunguska explosion, the first piece (50 g) of partially burned tree-resin was found in the test excavation in search of the 1908 ash layer (Andreev and Korlević, 1990). The resin dropped on the ash layer from the burning tree during the forest fire after the Tunguska event. The number of ballast particles was lower than in the peat, swamp or lace sediments but still very high. Since enormous work is needed to search through such a big piece of resin with scanning electron microscopy (SEM), this has not been done yet (Korlević, 1993).

Fortunately, by serendipity, on the cross-section of a red Siberian tree trunk (*Picea obovata*) about 160 years old, cut 5 km NW of the epicentre of the explosion, one very interesting feature was found after polishing (Cecchini *et al.*, 1991). The cross-section revealed a horizontal branch emerging from the stem, debarked long before the explosion. Resin was renewed year by year on the scar. The tree-resin was then completely embedded in the growing wood.

In such a clean trap the particles are being preserved from the following airborne contamination over the years. The dating of the trapped particles is possible by counting the tree rings, and only small shifts in position were possible due the pressure of the growing tissue, and bark thickness.

The tree slice was cut into pieces corresponding to the year 1908, and earlier and later years, and resin samples were prepared for conventional SEM and field emission SEM (FE-SEM) observations, and for X-ray microanalysis (EDS), (Valdrè and Korlević, 1993) in order to detect if and what kind of particles were trapped in the resin.

During the first morphological investigation on the 1908 ring the following number, type and size of particles embedded in the resin were found: 14 Ca carbonates and/or oxides 1–5 μm, 6 Fe chloride and sulphide 1–5 μm, 5 (Na, K, Ca) chlorides 10–15 μm, 5 Bi 1 μm, 4 Ba sulphide 1–5 μm, 3 (Na, Al, K) silicates 2–3 μm, 2 Pb–Br 1 μm, 1 Co–W 1 μm, 1 Ca–Ti–Fe 1 μm, 1 Fe–Ni 1 μm. In the period from 1908 to 1910 an enstatite crystal sizing 30 μm was also found, with submicron Ba sulphide particles, and submicron and micro-sized particles of Ca, Fe, Cu, Zn, Au. The presence in the 1908–1910 resin of aggregated particles similar to that found in the cosmic dust collection confirmed the validity of the tree-resin traps to us.

Many of the observed trapped particles are sharp edged or crystal like, showing no trace of melting, and their nature probably must not be correlated to the Tunguska body. Except for Ca and chloride particles, the composition reported above has been found only in the years' 1908–1910, none in the confining rings, so their presence is probably in some way connected to the Tunguska event. The calcium carbonates and/or oxides found, are common in plants and should not to be considered related to the Tunguska body.

Conclusion

The SEM, FE-SEM and X-ray microanalysis of the tree-resin, or other natural and especially artificial sticky traps, are new, very promising methods in meteor astronomy. At last we have a method to find a meteoroid refractory composition, after its complete disintegration.

The preliminary analysis of one tree-resin trap from the Tunguska region, gave us only the indication for future search and the correlation find particles, to the possible composition of the Tunguska body must be taken cautiously.

The promising fields to use natural and artificial sticky traps are:

- This century mayor collision that left no geological consequences: Tunguska 1908, Rio Curoça 1930, Marudi mountain 1935, Revelstoke 1965 and Emilia 1993.
- Using artificial sticky film traps it will be possible to capture particles of future fireballs, days after, and find the refractory composition of the parent meteoroide.
- If we use mineralized tree-resin (amber) for the analysis, there is also the possibility of studying the trapped micron sized meteorite particles during the geological ages.
- With these methods it will be possible to study fallen meteoritic particles before air pollution and dust contamination of the atmosphere in the last century.

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stem and debarked long before the explosion. On the scar, a resin deposit was renewed year by year. The resin deposit was then completely embedded by the growing wood. During the period of growth the resin formed a trap for airborne particles.

This paper is the first report of a preliminary study of the Tunguska material which is based on a new method of investigation which analyses the particles trapped in resin deposits extracted from a tree slice and dated from their position with respect to the tree rings. The method is based on the following argument. If during its life a resinous tree (such as a conifera tree) suffers injuries, the leaked resin acts as a trap for airborne particles at the time when the injury occurred. Cross-sections of the tree will allow the dating of the time when trapping took place, by counting the tree rings, with an accuracy of a few years. It is the first time, to our knowledge, that such a study has been performed by means of analytical electron microscopy (AEM).

The tree slice collected during the 1990 ITE was cut into pieces corresponding to the year 1908, and to earlier and later years, and resin samples were prepared for conventional scanning electron microscopy (SEM) and field emission gun SEM (FEG-SEM) observations, and for X-ray microanalysis (EDS) in order to detect if and what kind of particles were trapped in the resin.

2. Experimental methods

A Philips SEM 515, equipped with an EDAX PV9900 windowed EDS X-ray spectrometer, and a Hitachi S-4000 FEG-SEM were employed to investigate the samples. The SEMs were operated at 30 kV with a probe current of 5 nA at the specimen level. Specimens were usually carbon-coated to avoid electrostatic charging. Care was taken to avoid spurious results which might have been produced by contaminants during the preparation and handling of the samples. In particular the Hitachi SEM was operated at both 30 and 0.9 kV; in the latter case observations and analyses were performed on freshly prepared uncoated samples. Since at this low voltage it is not possible to excite K and L lines of heavy elements, microanalysis was performed at 30 kV

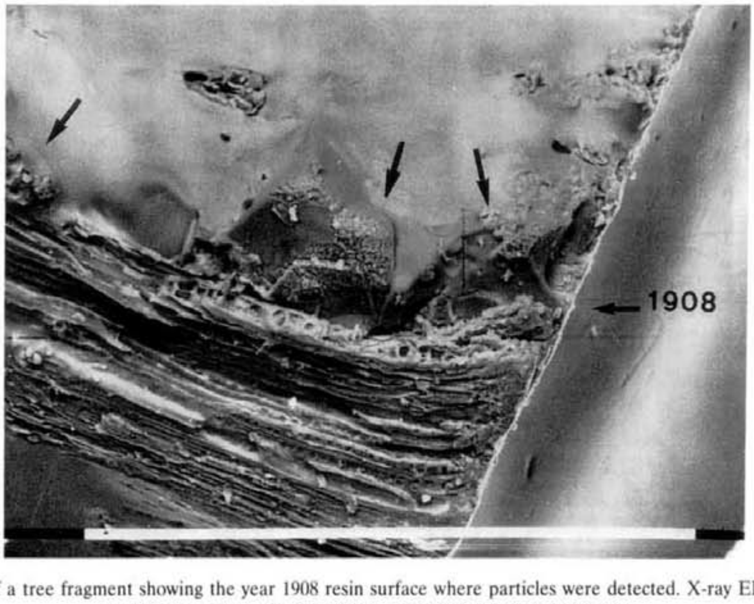

Fig. 1. SE image of a tree fragment showing the year 1908 resin surface where particles were detected. X-ray EDS analyses were performed on areas indicated by arrows. Scale bar indicates 1 mm.

after having selected the region of interest; the results confirmed those obtained on carbon-coated specimens.

3. Results and discussion

Morphological investigations performed on material of the 1908 ring (fig. 1) showed the presence of a number of micro-sized particles embedded in the resin (fig. 2); EDS analyses revealed their chemical nature as summarized in table 1 (particles were roughly round and their approximate diameter ∅ is given in μm).

In addition, a crystal of enstatite (size 30 μm) was found in a region of the same resin sample about 2 years younger (1910). Its composition, in wt% oxide, is: MgO 32.9, Al_2O_3 1.0, SiO_2 65.7 and FeO 0.3. This crystal bore on its surface some tiny (< 1 μm) particles of Ba sulfide. Fluffy particles and aggregates of particles and sticks (fig. 3) were also found in the proximity of the enstatite crystal. They have a morphology similar to those found by Bradley and Brownlee in cosmic dusts [5] and are made mainly of Ca and Si; however, some sticks were found to contain also Sr. Submicrometer- and micro-sized Ca, Fe, Cu, Zn, Au particles and silicates were also found between 1908 and 1910.

Table 1
Number and type of particles observed and analyzed

Number	Type	∅ (μm)
14	Ca carbonates and/or oxides	1–5
6	Fe chloride and sulfide	1–5
5	(Na, K, Ca) chlorides	10–15
5	Bi	1
4	Ba sulfide	1–5
3	(Na, Al, K) silicates	2–3
2	Pb–Br	1
1	Co–W	1
1	Ca–Ti–Fe	1
1	Fe–Ni	1

Altogether, about 3 mm^2 of surface has been observed and analyzed for each of three different periods: 1908, and immediately before and after 1908. Except for Ca and chloride particles, the composition reported above has been found only in the years 1908–1910, none in the confining rings. Calcium carbonates and/or oxides are

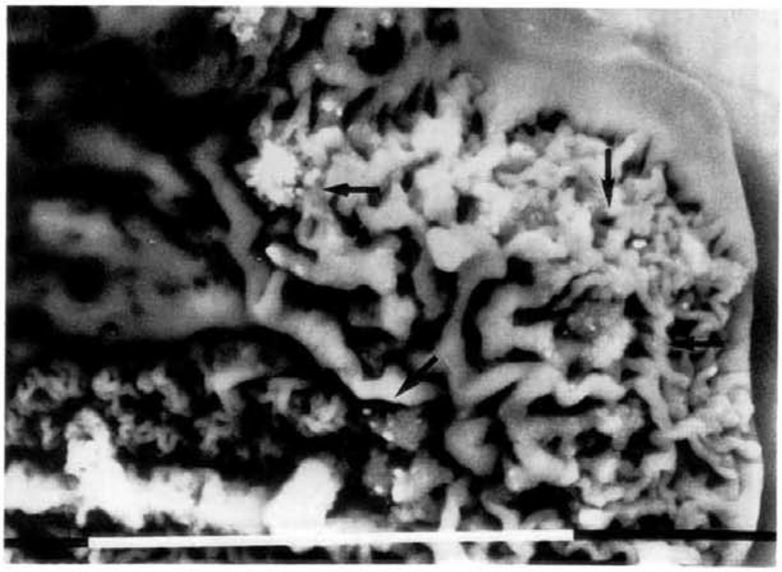

Fig. 2. High-magnification image of a detail of fig. 1. Arrows indicate "white" particles trapped in the resin deposit of the 1908 ring. Scale bar indicates 100 μm.

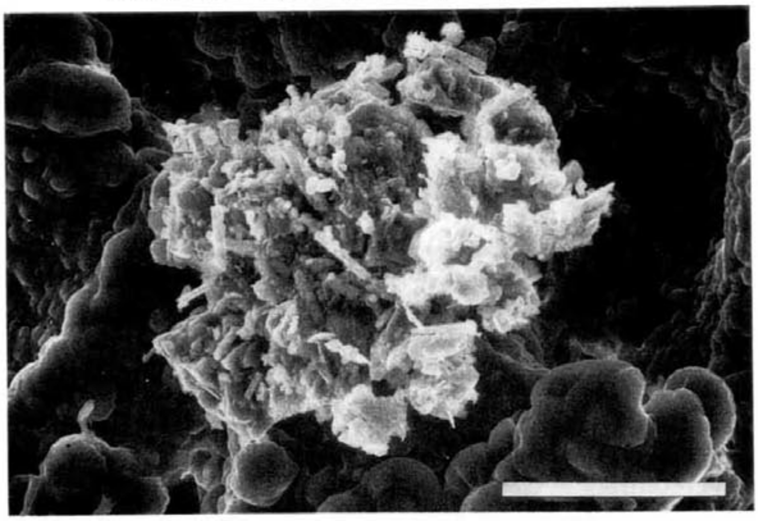

Fig. 3. Aggregated particles of rounded and sticky material, similar to those found in cosmic dust collection. Scale bar indicates 10 μm.

commonly spread in plants and are not to be considered related to the explosion.

The scarcity of Fe–Ni particles seems to rule out the high-density asteroidal cause; however, more data are needed. Rather, the presence of pyroxenes and anomalous elements such as Bi, Pb, Br, Co, W, Sr, Cu, Zn, Au is peculiar and might suggest either a low-density asteroidal and a cometary cause, since cosmic-like particles were collected, or a solar-dependent cause for the presence of high-atomic-number elements, similar to those found by Hallgren et al. [6].

The fact that the same type of unusual particles has been found a few years after the impact is not surprising; it is reasonable to assume that the enormous scale of the explosion has produced a vast amount of particles all around the area; the particles were removed in the following years by the atmospheric agents before being completely dispersed and dissolved in the ground. Of paramount importance is the absence of such materials a few years after the explosion and before it.

Although it is not possible so far to reach conclusions about the type of event which occurred in the Tunguska area, these preliminary results clearly demonstrate that the tree-resin trapping and AEM technique here introduced is a new, powerful method which has the capability of separating time-dependent and nature-dependent events and therefore may solve the Tunguska problem, provided a systematic and statistically significant program of sampling and particle detection is undertaken. The origin and genesis of the particles can be considered only when the petrographic framework and the composition of soil particles from the site have also been studied as well as other kinds of solid material that can be collected from the Tunguska region.

4. Conclusions

The novel method introduced here, based on the exploitation of the mechanism of trapping and preservation naturally offered by tree-resin, has produced exciting results when applied to solve the Tunguska mystery. In fact, the above results have stimulated the organization of the 2nd ITE which took place in July 1991 [7]; the vast amount of material already collected is being systematically analyzed.

From the foregoing investigation of material trapped in tree-resin deposits we conclude that

FEG-SEM and EDS can be the best-suited techniques despite the laborious effort needed for data collection and analysis. The technique may be improved by the use of a windowless EDS detector to extend the range of detectable Z down to boron and to separate oxides from carbonates.

The combined use of a (scanning) transmission electron microscope (S)TEM and microanalysis (EDS and parallel-detection electron energy loss spectroscopy, PEELS) may be necessary to understand the genesis of the particles found in the resin.

The method herewith presented which takes advantage of the tree-resin as a particle trap for assigning the date of occurrence of various types of events may be extended to other phenomena. This finding suggests, for example, the use of the tree-resin method for the study of cosmic particles before the contamination of the atmosphere in modern times took place and for monitoring and studying volcanic eruptions and sources of atmospheric pollutants.

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