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A MULTIDISCIPLINARY INVESTIGATION IN THE SITE OF THE TUNGUSKA EXPLOSION

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Introduction

In July 14-30, 1999, an Italian scientific expedition ("Tunguska99") was carried out in Central Siberia, in the site of the 1908 explosion of a cosmic body. The disruption of the body occurred in the atmosphere between 5 and 10 km above ground, producing energy between 10 and 20 million tons TNT and more than 80 millions of trees were uprooted on an area of 2150 km². Data on forest devastation and records of the atmospheric and seismic waves have made it possible to deduce the main characteristics of the Tunguska explosion, i. e. its exact time, 00h 14m 28s UT and the coordinates of the point usually called "epicenter", 60° 53' 09" N, 101° 53' 40" E. No macroscopic fragments of the cosmic body, neither impact craters have ever been found. In spite of the vast amount of theoretical and experimental work done up to now (see [1] and references therein), the nature and composition of the cosmic body and the dynamic of the event have not yet been clarified.

To search for traces of the cosmic body, the "Tunguska99" expedition was organized by the Department of Physics of the University of Bologna, in collaboration with the Turin Astronomical Observatory and the Institute of Marine Geology (CNR Bologna) and with the local support of Russian personnel and researchers, mainly from Tomsk. The participants and the equipment of the expedition were transported from Italy to Krasnoyarsk by a Russian *Iljushin IL-20M* aircraft of the "State Research Institute of Aviation Systems" (GosNIIAS) and from Krasnoyarsk to Tunguska by a Russian *MI-26* helicopter. To perform the expedition tasks, a camp has been built in the taiga at some hundred kilometers from centers connected by roads. To plan the construction of the base camp, four of the authors (*A. C., M. D. M., G. L., R. S.*) together with Victor Chernikov made an *in situ* recognition on July 1998 [2]. The recent expedition had broader tasks in comparison with those of the first Italian expedition organized by the University of Bologna in 1991 to search in tree resin for microparticles from the cosmic body [3 4 5 6 7]. The main tasks of the "Tunguska99" expedition were: 1) to study the structure and sediments of the lake Cheko, a small lake located at 8 km from the epicenter of the Tunguska event; 2) to carry out an aerial photosurvey of the explosion site; 3) to collect wood, peat and rock samples; 4) to monitor gamma rays during the flights Italy–Siberia–Italy and in the Tunguska National Reserve. The analysis of the data and samples collected during the "Tunguska99" expedition will make it possible to deduce important characteristics of the Tunguska event and to refine, verifying their accuracy, the mathematical models concerning the interaction with atmosphere of cosmic bodies having different composition and dimensions. The "Tunguska99" expedition is a contribution to the international programs on the detection and physical study of asteroids and comets potentially dangerous to humankind.

1. The study of the lake Cheko

We carried out a geophysical/sedimentological study (see, for example, refs. [8 9 10]) of the lake Cheko (~ 500 m diameter, > 50 m max depth). The study of the lake have two main purposes: to verify whether the formation of the lake can be correlated to the 1908 event; to detect in the lake sedimentary sequence, geophysical and geochemical evidences of the event that can give information on the nature of the cosmic body. An inflatable catamaran designed (*Offshore Spa*) on purpose of the expedition was used both, for the geophysical survey, and for the coring operations. The field study, mainly carried out by researchers of the CNR Institute of Marine Geology, included the acquisition of the following data. POSITIONING: the boat position was determined by mean of a GPS receiver; the on-line differential satellite correction allowed us to obtain a precision of about +/- 1m. MORPHOBATHYMETRY: the bottom topography of the lake was obtained using a single-beam echo sounder; together with the depth sounding, reflectivity data from each ping have been collected by sampling and on-line analyzing the bottom echoes. HIGH

RESOLUTION SEISMIC REFLECTION: about 200 km of high resolution seismic reflection profiles were acquired with 2 different systems, a 400 Hz Bubble Pulser boomer (high penetrating source) and a 2 kHz FM Chirp II sub-bottom profiler (higher resolution source); Fig. 1 shows some profile obtained with the Bubble Pulser. SIDE SCAN SONAR SURVEY: carrying out 4 N-S Side scan sonar survey lines covered the entire area of the lake. GROUND PENETRATING RADAR SURVEY: about 10 km of radar profiles were obtained [11] using 50 MHz and 100 MHz antennas; GPR was used to image sub-bottom discontinuities in the 0-10 m depth range, including the water layer; the resolution attainable by means of GPR complements the acoustic data in the shallow depth range, as shows Fig. 2 reproduced from ref. [11]. CORING: sediment cores were obtained at 20 sites in the lake floor, the sites were chosen on the basis of the bathymetric and seismic reflection data.

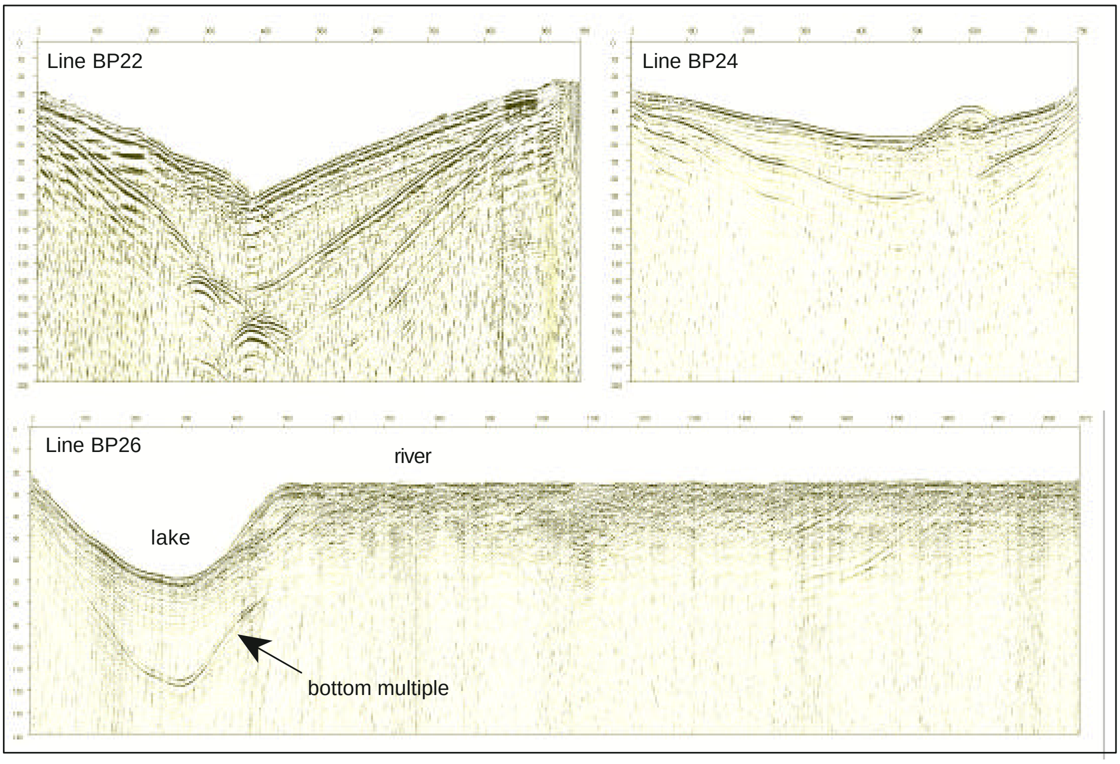

Fig. 1 **-** Seismic images of the sedimentary sequence that constitutes the filling up of the lake. Line BP26 extends along the river that constitutes the main sedimentary input.

Processing of both acoustic and GPR data is in progress. The GPR profiles processed to date successfully image discontinuities at depths greater than 7 m. Comparison with acoustic results shows that GPR provides high resolution images of the depth range of interest (0-5 m) which complement the information obtained from sub-bottom profilers and can be calibrated by the gravity cores. The future work will focus on the core analysis, and on the detection of possible physical effects within the sedimentary successions (i.e. gravitative failures of the slopes) that could give important insights on the energy of the event. The mineralogy, geochemistry and micropaleontology of the lake's sediment cores will be studied. We also plan to date the sediments using isotopic methods (^{7}Be, ^{210}Pb and ^{14}C). The results of all this analytical work will allow us interpretations concerning the regional and local phenomena that have affected the deposition in the lake, and to possibly continuously monitored with a GPS system and the geographical coordinates were linked to the photographs. Contemporarily, we have measured on the ground the geographical coordinates of different reference points in the same area in order to connect the aerial images to the regional topographic net. The GPS measurements on ground have been performed with an error less than 20 m. The results of the aerophotosurvey and of the topographic measurements on ground will be used to re-examine the aerophotographic material, obtained in 1938 under the direction of L.A. Kulik [12] [13] in order to check details of the 1908 explosion (single or multiple, fragmentation, etc…) and to verify some recent hypothesis on the event.

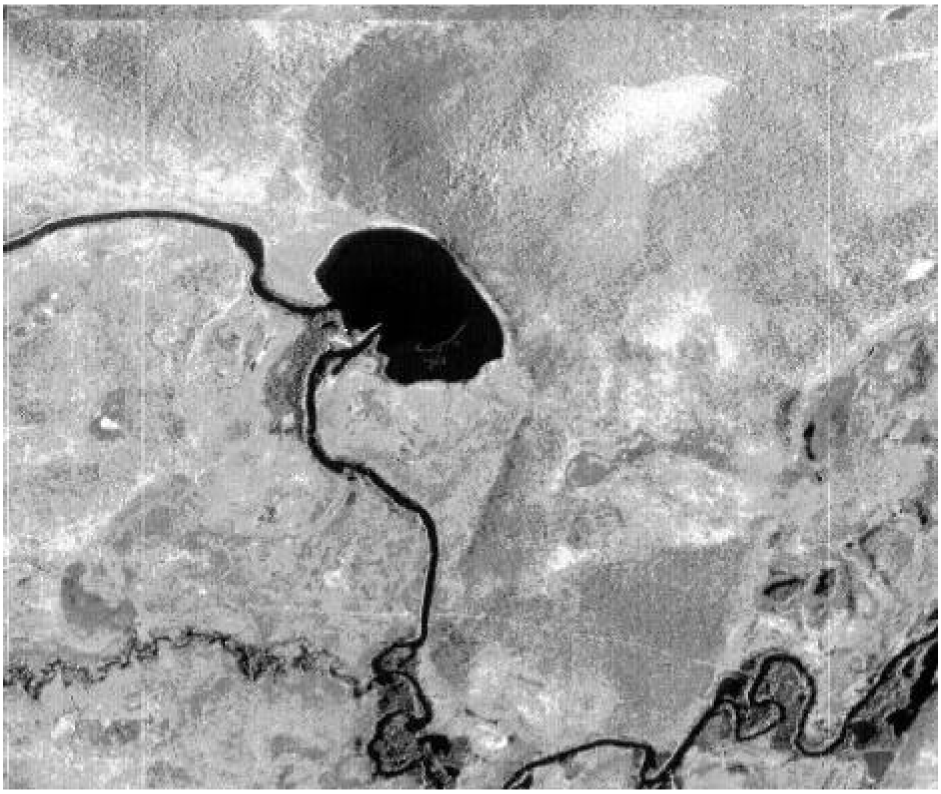

Fig. 3 **-** Cheko lake and Kimchu river (spectral band: 0.61-0.69 ìm).

3. Collected samples

WOOD. Wood samples from trees surviving the 1908 explosion have been collected at different distances from the "epicenter" in order to further the investigation carried out by the first Italian expedition in 1991.

PEAT. A piece of peat (50 x 20 x 70 cm) has been taken at 500 m to the SE from the SE border of the lake Cheko. Isotopic analysis and pollen examination will be carried out to find indications on the composition of the cosmic body.

POLLEN. The pollen deposited in cores of Cheko lacustrine sediments and in the peat sample in layers preceding and following the Tunguska event is being studied. For these purpose samples of flowers have been collected in different places of the site. The pollen study should make it possible to obtain information on vegetation changes due to the 1908 impact.

ROCKS. The petrology and geochemistry of the Mesozoic igneous rocks outcropping in the Tunguska region is being studied. Collected pieces of the so-called "John rock" will be analyzed to obtain evidence about its terrestrial or cosmic origin.

GRAVEL. Two kilograms of gravel from the bottom of the lake is under examination to find whether the vitrification should be connected to volcanism or to the Tunguska event.

4. Gamma ray measurements

One detector of the VRC (Cosmic Ray Variation) group of the University of Bologna has monitored gamma rays both during the flights Italy-Siberia-Italy and during the two-week stay in the Tunguska Natural Reserve [14]. The group has used in the past similar detectors [15] to study gamma ray variation in dependence of solar activity, of the geomagnetic field, and of the environmental conditions in Italy, Antarctica, Svalbard islands, Himalayas and during the sea voyages Italy-Antarctica-Italy.

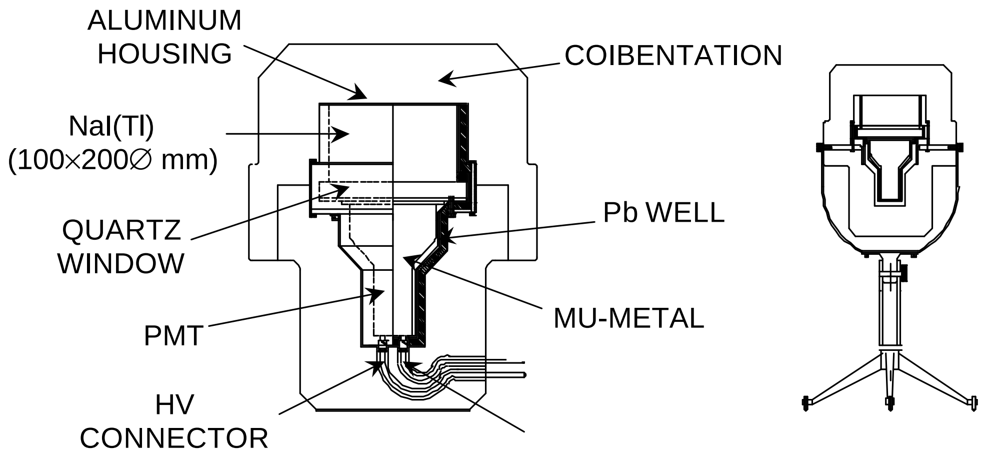

Fig. 4 – The detector of gamma rays from cosmic and environmental radiation.

The detector was an improved version of that already used in [16]. It was based on a NaI (Tl) monocrystal (10 cm x 20∅ cm) shielded by 2 cm of Pb, 0.1 cm of Cu and 0.3 cm of Al shaped around the crystal and the phototube (PMT) (see Fig. 4). No KOH source was present in order to have continuous adjustment of PMT gain as the HV supplied through the new ACQ system (a PC card) was found to be very stable. A program allowing accumulating 2048 channel spectra every 10-15 minutes with 3-keV/ch resolution drove the new multichannel PC card. An online program allowed a quick-look analysis and graphical inspection of data accumulated in different pre-set energy bands. Pressure data were available at different times sporadically.
At the base camp, gamma rays from cosmic and environmental radiation have been continuously monitored (at 60 57' 49" N and 101 51' 22" E) on time scale of 15 minutes, in the 0.05-3 MeV and in the 3-10 MeV energy bands. Nearby the lake Cheko, as Fig. 5 shows, daughter radionuclides from the ^{238}U and ^{232}Th chains have been recorded. The data are being processed to find other natural or man-made radionuclides. The in-flight measurements indicate great gamma ray variations in dependence on altitude, longitude and latitude.

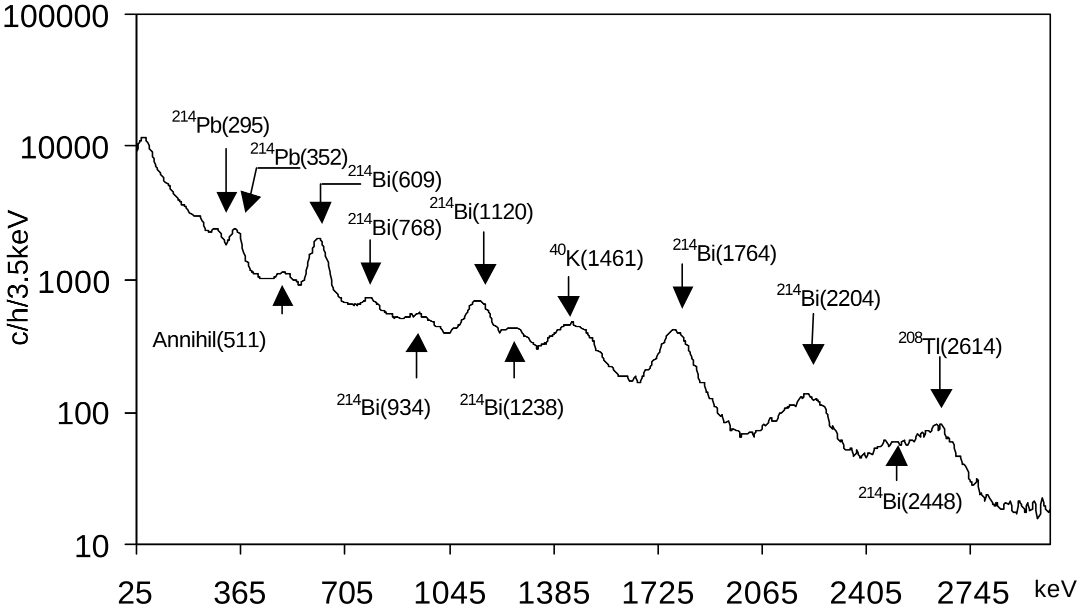

Fig. 5 **-** Gamma ray spectrum measured nearby the lake Cheko.

5. Acknowledgments

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