GEOPHYSICAL SEARCH OF THE STERLITAMAK METEORITE

Ural Federal University named after the first President of Russia B.N.Yeltsin

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Introduction

Meteorite Sterlitamak fell on August 17, 1990 at 23:55 local time, 1 km from the central estate of the Sterlitamaksky state farm (Oktyabrsky, Bashkir ASSR, Former USSR). The fall on the field with a soft soil formed an impact crater with a 10 m diameter and a 5 m depth [1]. Several small samples were found almost immediately near the crater, then the search continued with an excavator with a long boom and a bucket of a quarter of a cubic meter. In total, about 10 kg (the largest 6.6 kg) of meteorite material were found. As a result of the excavations, the depth of the crater reached about 18 m, and the diameter was 50 m. The excavated pit was quickly filled with water. Currently, the crater is distinctly visible on high-resolution space images. A large sample 315 kg was found in a barrow by chance in the next year. Now this meteorite fragment is stored in Ufa (Bashkortostan, Russia) in the Museum of Archeology and Ethnography.

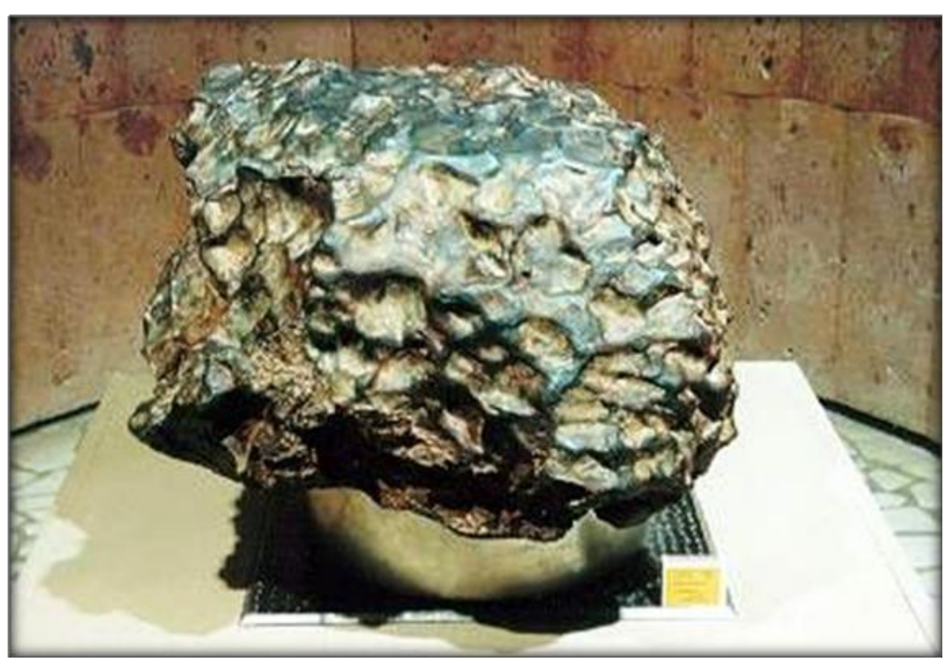
Compositional analysis of the meteorite showed that it iron-nickel and 98% of the volume represented by minerals: kamacite, taenite, Daubreelite and troilite. The meteorite is classified as Iron, IIIAB.

After finding a massive fragment, the search was terminated, although the question remains whether the found fragment is the main mass, or another large piece is expected to be found in the crater. Especially, estimations of the impact mass of the Sterlitamak meteorite is in range ~1 – 1.5 ton [2]. Geophysical methods are effective ways of searching for a meteorite substance [3], in particular magnetic survey proved to be effective when searching for the main mass of the Chelyabinsk meteorite [4]. So we decided to restore interest in the problem and carry out geophysical surveys on this abandoned for more than 20 years site.

The original impact crater of the Sterlitamak meteorite. Photo by Petaev MI, 1990. Ejections of reddish plastic clays are visible, which sharply contrast with dark chernozem soils. Crater depth 4 m, diameter up to 10 m.

The first stage of the search and excavation using an excavator

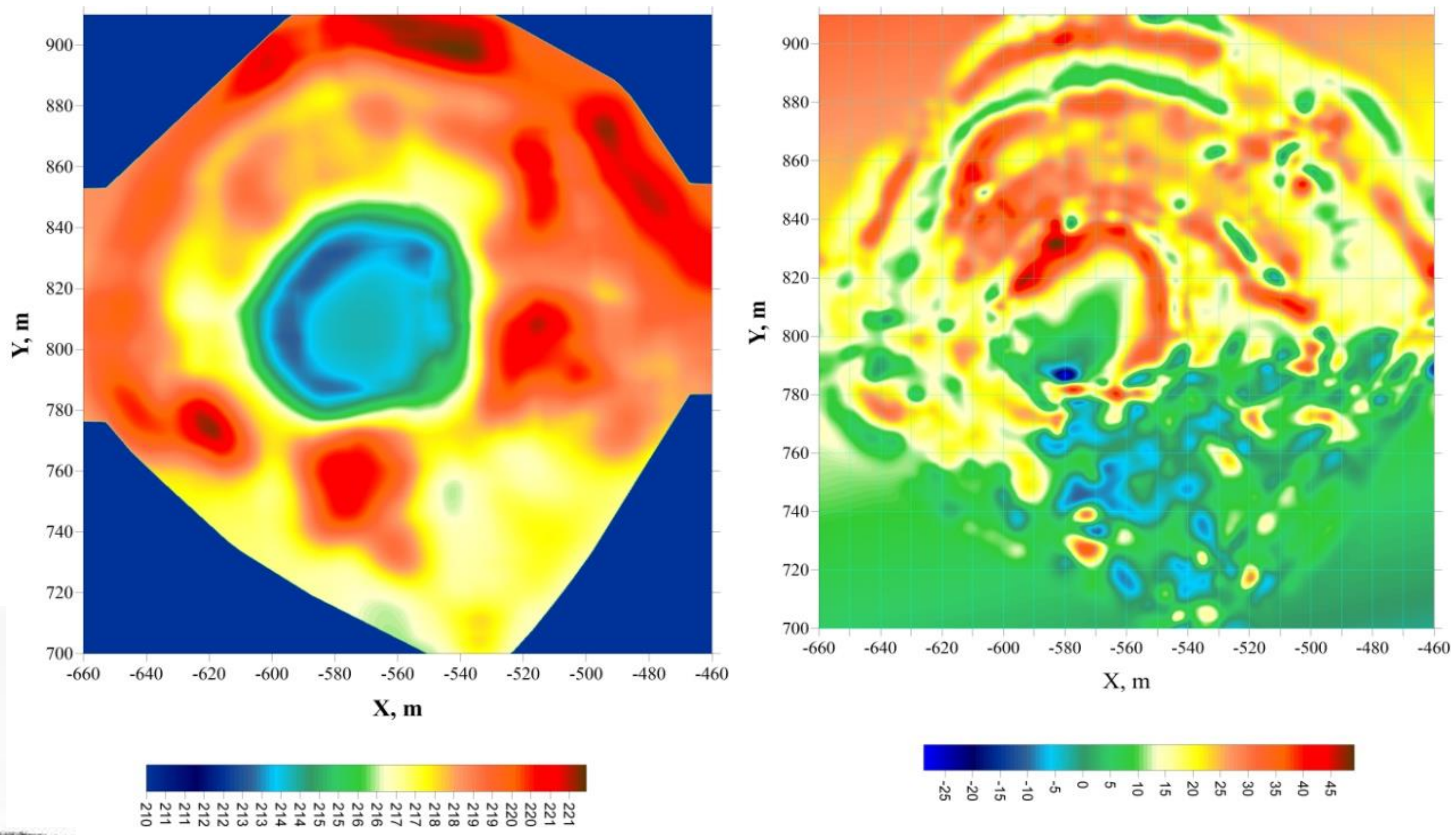
Satellite image by Global Image&Yandex map, 2021 (left) and foto by A.V. Ovcharenko, 2014 (right)



The main fragment of a meteorite weighing 315 kg and several small fragments found in 1990

Method

Magnetic survey around the meteorite crater was produced in the summer of 2014. In winter of 2015, a magnetic survey of the central part of the crater was made on the ice, and the detailing of the coastal part was performed in the summer of 2016. The magnetic induction module measurements was made with a quantum magnetometer G859-Geometrix. The use of a Novatel satellite positioning module (accuracy of 15-20 cm) made it possible to perform the height mapping along with magnetic measurements. Search studies of near-surface heterogeneities using a metal detector showed that, along with iron garbage, there are samples with metal inclusions.



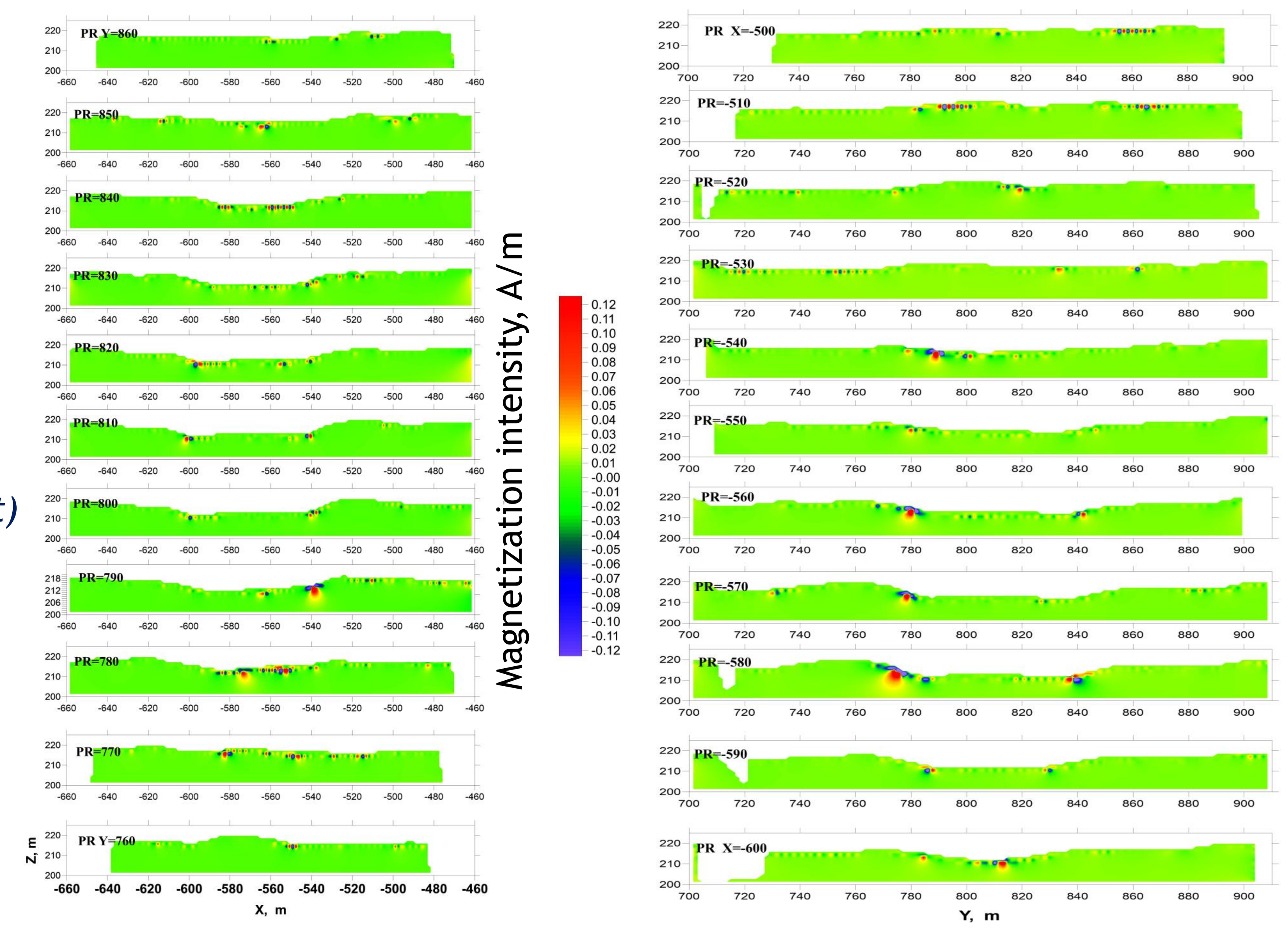
Topography map (left) and magnetic anomalies (right)

Results

Visual analysis of the obtained magnetic maps shows that they have a very noticeable multi-ring zonality, which can be caused by both the dynamic effect of the meteorite, and the result of the mechanized excavation of the primary crater with the annular placement of the removed soil.

The soils of the place of the meteorite's crater-forming fall are represented by chernozems and gray soils with a thickness of 1.5-2 m and plastic red-colored clays with a thickness of more than 20 m. Under the shock impact, zones of compaction and extension were probably formed in the clays with the formation of high-pressure phases of silica and the sputtering of meteorite matter in them.

The most extended local magnetic anomalies were studied using a metal detector and shallow (up to 30 cm) hand excavations. To interpret survey results and study the deep structure of the crater, we applied the magnetic tomography method based on the construction of sections of magnetization by the grid method (solving a linear integral equation of the first kind). The sections were built in an automatic mode, taking into account the relief of the day surface.



Magnetic tomogram with latitudinal (left) and meridian (right) sections

Discussion

Crater-forming falls of meteorites are quite rare. It is essential to make the most of the opportunities to study recent falls. Sterlitamak fall was unique both witnessed and crater-forming. These near-ideal fall conditions would allow to make a detailed study of the structure of the target area as a medium: flat field, soft and unconsolidated rocks. But unfortunately, these opportunities were not used at that time.

On our opinion, based on the results of magnetic survey, a significant mass of the meteorite may still be in the crater. As follows from the obtained magnetic maps, the anomalies that are promising for prospecting tend to the side parts of the modern excavation, i.e. to the shores of the lake. The depths of the magnetic inhomogeneities are 2-3 meters.

Possible methods for additional detailed study of anomalies are: deep metal detectors and ground penetrating radars, manual mechanical probing of anomalies with small diameter steel pins (up to 5 mm), manual borehole drilling and final mechanized excavation with a light excavator.

References

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