DETERMINING THE INITIAL PARAMETERS OF THE MORASKO METEOROID M. Bronikowska[1], N. A. Artemieva[2,3], K. Wünnemann[4], W. Szczucinski[1] [1]Institute of Geology, Adam Mickiewicz University, (Makow Polnych 16, 61-606 Poznan, Poland malgorzata.bronikowska@amu.edu.pl), [2]Institute of Dynamics of Geospheres, Russian Academy of Sciences, [3]Planetary Science Institute, Tuscon, [4]Museum für Naturkunde, Leibniz Institute for Evolution and Biodiversity Science, Berlin

Introduction: The Morasko strewn field is located near Poznan, Poland, in a nature reserve area. It comprises 7 well - preserved craters with diameters between 20 and 90 meters. All of them are formed in glacial tills and sands. Numerous meteorites have been recovered in the area with the biggest weighing 261 kg. The composition and distribution of the meteorites suggest an iron projectile with a trajectory form NE to SW. Recent studies [1] confirmed that the impact happened about 5400 years ago.

Fig. 1. The biggest Morasko crater (90 meters in diameter) as seen in spring 2013, (courtesy of A. Muszynski)

Currently, the Morasko strewn field is investigated in the framework of an international research project including fieldwork (sample collection including shallow drill cores, geophysical measurements, and numerical modeling. The main goal of this research project is to study environmental consequences of this impact event.

Here we present preliminary modeling results of the atmospheric break-up of the original object, the distribution of fragments, and the formation of the observed craters on the ground.

Methods: In our study we combine an atmospheric entry model with modeling of crater formation. The aim is to determine initial parameters of the Morasko meteoroid (pre-atmospheric mass, velocity and trajectory angle), to reconstruct its evolution in the atmosphere, and, finally, to investigate formation of individual craters using pre-impact parameters from the atmospheric model.

We used standard equations describing deceleration and ablation of a meteoroid in the atmosphere [2]. The motion of a fragmented meteoroid is described in the frame of the so-called “pancake” approximation: when dynamic loading exceeds the internal strength of the meteoroid, it is transformed into a cylindrical cloud of fragments with increasing radius [3]. When the cloud radius exceeds its initial radius by a factor of 3.5 the cloud is transformed into separate fragments with the prescribed size-frequency distribution ($N_{>m}=m^{-b}$, $b=0.8$). The initial position of each fragment within the cloud is defined by the Monte Carlo method, its initial velocity is equal to the local cloud velocity. The largest fragment mass is usually a quarter of the cloud mass, fragments smaller than 0.01% are excluded (they do not produce craters but small meteorites on the surface). All of those new-born fragments move independently toward the surface according to the standard model [2] and may be subjected to further fragmentation. Their final masses, velocities, and positions were used to estimate a ‘computational’ strewn field.

To investigate crater formation we use the multi-rheology multi-material hydrocode iSALE-2D [4-6]. We adjusted material parameters for the Morasko target by running a suite of 2D simulations to match numerical results and the observed crater morphometry. In a second step we ran a series of models varying impactor size and velocity to derive specific material-dependent scaling-parameters required for well-established Pi-group scaling of transient crater size [7]. The target specific scaling laws are an efficient method to predict craters sizes for a wide range of possible impact scenarios avoiding computationally expensive hydrocode simulations of individual impacts.

Results: Each set of pre-atmospheric parameters has been used 100 times to find 'average' near-surface masses, velocities, and crater diameters using specifically calibrated scaling laws. Three criteria are used to exclude pre-atmospheric parameters of a meteoroid which are not suitable for the Morasko strewn field:

1) the average number of craters with diameters from 25 to 100 meters is larger than 10 (assuming that a few additional craters could be eroded after the impact);

2) the average number of craters with diameters from 25 to 100 meters is smaller than 7;
3) the biggest modeled crater is too big (>100 m.) or too small (<80 m.).

At the beginning, the initial conditions for further simulations have been restricted as follows: the initial trajectory angle was set to30-50°; the initial mass was assumed to be 500 - 1200 tons; the initial velocity varied between 11.2 - 18.5 km/s. The influence of these parameters on the biggest transient crater diameter and the total number of craters has been studied and is presented in Fig. 1. In case of a single fragmentation event, the diameter of the largest crater does not depend on random procedures. However, if the second fragmentation occurs, the random procedure in our algorithm can significantly influence the biggest transient crater diameter. Because of this, for each set of initial parameters we present an average output of 100 simulations.

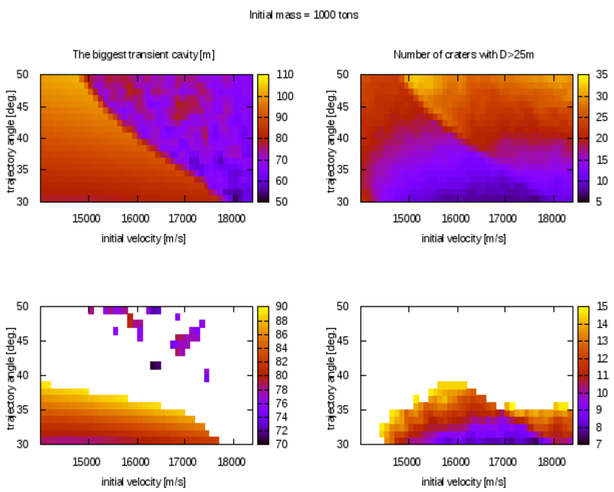

Fig. 2. Pre-atmospheric mass is 1000 tons. Top left: the biggest transient cavity (see color scale) as a function of - initial velocity (on x-axis) and initial trajectory angle (on y-axis). Top right: number of craters with transient diameter > 25 meters. Bottom left: the same as on the top plot, but with diameters restricted to 70-90 meters; bottom right: number of craters restricted to 7-15.

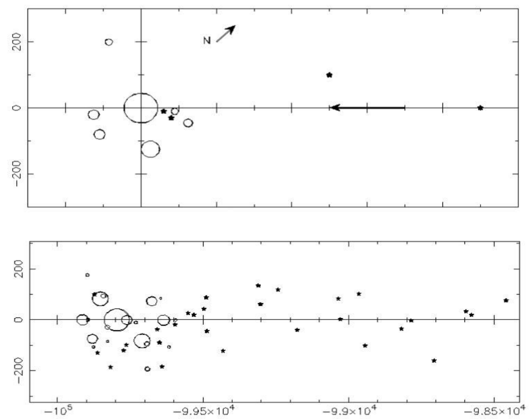

Fig. 3. The observed Morasko strewn field (top) and an example of the modeled crater distribution (bottom). The meteoroid's trajectory is marked by the black arrow. Some meteorites tens of kilograms are shown by stars.

Conclusions: Our simulations have shown that initial masses smaller than 500 tons or greater than 1100 tons are very unlikely in case of the Morasko strewn field. The following sets of pre-atmopsheric parameters of the Morasko meteoroid have been determined:
1) pre-atmospheric mass between 500 and 800 tons, initial velocity: 16 – 18 km/s, initial trajectory angle: 33 – 48 degrees,
2) pre-atmospheric mass between 800 and 1100 tons, initial velocity: 15.6 – 17.8 km/s, initial trajectory angle: 30 – 34 degrees.
Final impact velocities for crater-forming fragments vary from 1.5 to 7 km/s (important for possible shock metamorphism). The total number of craters could be bigger as it cannot be ruled out that some smaller craters were eroded during the last 5000 years.

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