RECONSTRUCTION OF THE TWANNBERG METEORITE FALL

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Introduction: The first and still largest (15.9 kg) Twannberg meteorite was found in 1984. Current progress in meteorite search shows a large (elongation of about 6 km) strewn field comprising more than 850 meteorites with a total known mass of ~100 kg. ~50 (38 kg) masses were found in the Gruebmatt area in proximity to the first find of 1984, another 78 (2.1 kg) in the Twannbach river and most recently 730 masses (~53 kg) on Mt Sujet [1]. The noble gas and radionuclide concentrations indicate a pre-atmospheric radius of up to 10 m [2]. The strewn field has been disturbed and partly destroyed by ice movements during the last two ice ages (part with masses > 1kg).

Method and Initial Conditions: We employ an atmospheric entry model [3] to explore the parameter space searching for pre-atmospheric masses, velocities and trajectory angles that would agree with: 1) the observed number and mass of meteorites on the ground; 2) the mass of the largest recovered meteorite; and 3) the shape of the strewn field. Our model combines two approaches and allows, in contrast to the original 'pancake' model [4], to predict fragments distribution on the surface and, in contrast to the SF model [5], is not restricted to a pair of fragments in each fragmentation cycle.

To describe ablation and fragmentation processes we use the following values typical for iron meteorites: density of 7800 kg/m^3, standard strength of 44 MPa for a 1-kg sample (plus 3 times higher and 3 times lower strength, LS and HS cases, respectively), and ablation coefficient is assumed to be 0.07 s^2/km^2 [5]. Strength of each fragment may vary in accordance with Weibull statistics with possible deviation +/- 50%. We vary pre-atmospheric velocities in the range of 11-30 km/s, entry angles – from 25 to 50° to horizon, and initial masses – from 10 tons (radius of 0.7 m) to 30,000 tons (radius of 10 m, according to estimates [2]).

Results: *Strewn field shape and impact angle.* The modelled strewn field dimensions weakly depend on the pre-atmospheric mass and velocity; the length increases from 4 km at 50° impact to 9 km at 25° impact. As the Twannberg strewn field is at least partially eroded, we could speculate that the entry angle was between 40-45° (fortunately, this is also the most probable impact angle). The modelled width of the strewn field is of about 200-300 m, i.e., slightly narrower than observations (the lateral velocity is the least constrained parameter and could be higher, also local winds could additionally disperse small fragments).

Total mass of meteorites on the surface. Our calculations show that the ratio of the final (near the surface) mass to pre-atmospheric mass does not depend on the latter, but mainly on the assumed initial strength and on the entry velocity. This ratio equals 0.002 for our nominal strength and is approximately ten times higher for higher strength. (in the LS case the ratio is too small to be included into our study).

Mass of the largest fragment decreases with impact velocity increase and increases with pre-entry mass increase. Impacts of 1-3 m in radius meteoroids with velocities of 16-20 km/s are able to produce the largest fragments in the range of 10-30 kg.

Size-frequency distribution of fragments on the surface. We compare our modelled SFD of fragments on the surface with mass of recovered meteorites in the mass intervals of 0.1-0.3, 0.3 -0.6, and >0.6 kg. The total number of fragments >0.1 kg is 150-400 depending mainly on the entry mass and velocity. Computed and observed SFD do not differ significantly if the meteoroid mass is 10-30 tons (radius of 0.7-1 m) and its velocity is about 16-18 km/s.

Conclusions: Combining all the results we suggest four feasible scenarios of the Twannberg event: 1) a low velocity (14 km/s) impact of an m-sized meteoroid; 2) an impact of 1.4 m in radius meteoroid at 18 km/s; 3) a high-velocity (30 km/s) impact of a m-sized meteoroid with high initial strength; 4) an impact of a significantly larger meteoroid (up to several m radius) which would not be accessible to the current modeling approach. The final mass on the surface in cases 1-3 is ~200 kg (i.e., approximately half of meteorite mass would have been recovered) and the largest fragment mass is 10-30 kg. A suggested radius of up to 10 m [2] would require that the total mass of meteorites on the surface must be much larger. Moreover, iron meteoroids larger than one meter usually produce craters or crater strewn fields: the Morasko pre-entry radius was ~ 2.6 -3.2 m [3] and the largest Morasko crater is ~90 m; the 2-m-radius Sikhote-Alin meteoroid resulted in a strewn field with 23 craters >9 m in diameter [5]. Either the pre-atmospheric size estimate [2] has to be revisited or the reconstruction of the event is impossible because erosion may have removed tons of meteorites and a few impact craters up to ~300 m in diameter from this area.

References: [1] Hofmann B.A. et al. (2016) *79th Meeting of the Meteoritical Society*, Abstract #6160. [2] Smith T. et al. *79th Meeting of the Meteoritical Society*, Abstract #6187. [3] Bronikowska M. et al. (2017) *Meteoritics and Planetary Science*, accepted. [4] Chyba C.F. et al. (1993) *Nature* 361:40–44. [5] Artemieva N. and Shuvalov V. (2001) *Journal of Geophysical Research* 106:3297–3310.