DISTAL EJECTA FROM THE RIES CRATER – MOLDAVITES AND PROJECTILE. N. A. Artemieva. Institute for Dynamics of Geospheres, Russian Academy of Science, Leninsky pr., 38, bldg.1, 119334, Moscow, Russia, nata_art@mtu-net.ru

Introduction: Using detailed geological, petrographic, geochemical, and geographical constraints we have performed numerical modeling studies that relate the Steinheim crater (D_a = 3.8 km), the Ries crater (D_a = 24 km) in Southern Germany, and the moldavite (tektite) strewn field. The known moldavite strewn field extends from about 200 to 450 km from the center of the Ries to the ENE forming a fan with an angle of about 57°. An oblique impact of a binary asteroid from a WSW direction appears to explain the locations of the craters and the formation and distribution of the moldavites [1]. In a presented study we attempt to answer more questions concerning this particular strewn field as well as other questions common for all tektites. What is the maximum "numerical" size of the moldavite strewn field? How is this size connected with the crater size and the impact conditions? How many tektites may be found theoretically without weathering and surface erosion? What is the size of tektites? Why they are not contaminated by projectile? Where is the projectile material?

Hydrocode and EOS in use. Impact simulations were carried out with the three-dimensional (3D) hydrocode SOVA [3] coupled to a tabular version of the ANEOS equation of state package [4]. The code allows to describe particle motion in the evolving ejecta-gas plume, including the interaction of particles with the gas. Details of numerical model and geological iput may be found in [1.2].

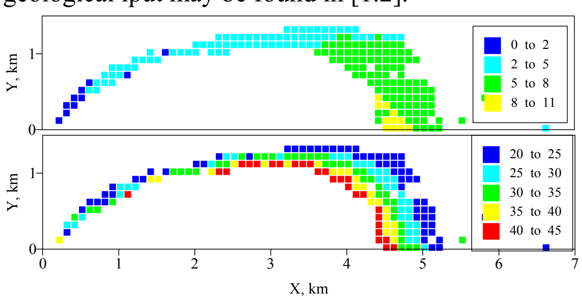

Fig.1. Initial position of tektite melt at the target surface (only half space with y>0) is shown. The projectile with diameter of 1.5 km strikes from the left at the point (0,0). Upper plate shows ejection velocity in km/s, bottom plate is for maximum compression in GPa.

Excavation depth and chemistry. Moldavites originate from the upper 40 m of sandy layer, presented in the numerical model and underlain by thick layer of limestone. In reality it is not a continuous unit, but, probably, some chaotic spots with various thickness. In this upper layer shock pressure drops quickly with a distance and at 5 km from the impact point is below melting pressure for a porous quartz (45 GPa). Figure 1 shows surface material, molten after an impact - possible tektites. It is totally within the growing crater (the Ries final diameter is 26 km). Ejection velocity varies from 1-2 km/s behind the projectile to 8-11 km/s in a downrange direction.

The model with more thick sandy layer reveals that 70% of all tektites originate from the upper 20 m, 90% - from the upper 40 m, and only 10% of the material is initially below this depth. The results correlate with ^{10}Be composition of tektites [5].

Tektites size and shape. The size and shape of individual particles are influenced by many processes (strain rates, surface tension, the ratio between melt and vapor) with poorly known parameters [6]. In our simplified approach, material disruption occurs when the density of the solid or molten material drops below the normal density - the material is subject to tension. The diameter of molten particles is in the range of 1-3 cm, corresponding to the average size of tektites [5,7]. Particle size drops to 0.01 cm if particles are produced from a two-phase mixture, where vapor and melt coexist (microtektites

Mixing with projectile. The meteoritical component in tektites is very low, if any [5]. This fact is widely used against an impact fusion hypothesis of tektites origin [8]. On the basis of numerical model we may suggest that two types of melts (projectile and upper target) have no enough time for mixing, as both are ejected from the growing crater very early, during the first seconds after an impact (**Fig.2**). Diffusion in a liquid, as well as the turbulent mixing, demands much longer time interval. Only gas diffusion may be important, but in our model tektites are produced from the pure melt with minor vapor content. Independent confirmation of no-mixing in moldavites is their chemical composition - a mixture of precursor sedimentary rocks (clay, sand,, limestone) prior the impact event [9]. Nevertheless, tektites and molten projectile material are ejected with similar velocities and move along similar trajectories. It means that they will be deposited not far from each other. Thus, the question arises – is it possible to find "tektites" of extraterrestrial origin?

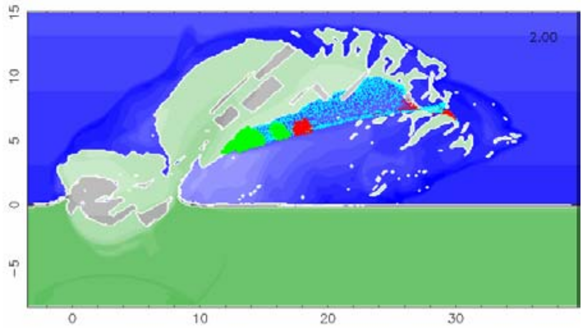

Fig 2. Ejecta in the plane of symmetry 2 seconds after the 30-degree impact for the Ries crater. The projectile strikes the surface at the point (0,0). Red particles are tektites, green ones – solid target ejecta, blue particles correspond to projectile material (part of the projectile is still a vapor).

Size and shape of the strewn field. For 30°, 20 km/s impact total melt production from the upper layer is ~700 Mt [1]. Practically all the melt is ejected and disrupted into the particles – 150 Mt of tektites and 510 Mt of microtektites. The total time from tektites ejection to their deposition as a strewn field varies from 10 minutes to hours. The temperature of the entraining gas is high, the particles do not cool quickly, having enough time to be aerodynamically shaped and to lose volatiles. Some of the particles reach an altitude above 1000 km and their deposition is influenced by the Earth's rotation and local weather conditions. Neglecting those processes we receive huge strewn field even for the Ries crater. All tektites and 80% of microtektites are deposited and the resulting strewn field stretches 6000 km along the projectile trajectory and 4000 km in the perpendicular direction (**Fig. 3**, upper plate). The shape of this strewn field differs substantially from the known moldavite strewn field (and is an order of magnitude larger), but its trefoil strongly resembles the youngest Australia-Asian strewn field.

Molten projectile is deposited similarly with higher area density, but the size projectile particles is much smaller than tektites (projectile has higher compression and higher temperature in average). The role of asteroid composition, which is different from granite, is not clear yet. These particles degrade much quicker in terrestrial environment than tektites and may be found only within a young strewn field. The soil near tektites may be contaminated by the extraterrestrial material – the problem should be investigated in a future more carefully in collaboration with geochemists.

Impact angle strongly influences final strewn field size and tektites' concentration. In the case of an oblique impact of 15°, the projectile distribution is similar, while tektites strewn filed is much smaller. Concentration of tektites in the vicinity of the crater is an order of magnitude higher (**Fig.4**).

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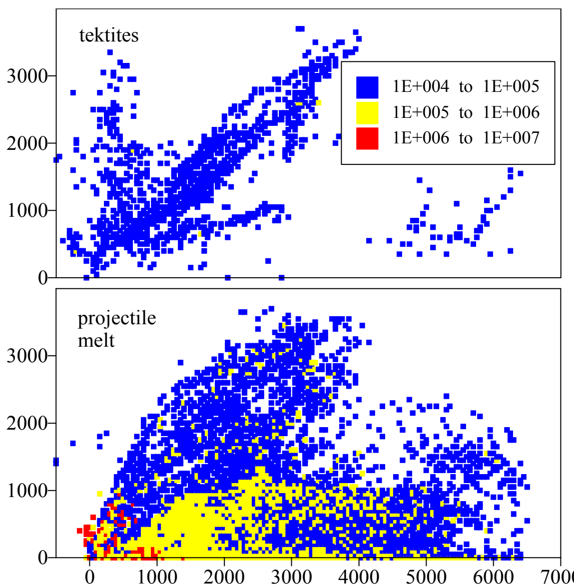

Fig. 3. Half of the strewn field (y>0) for 30-degree, 20 km/s impact into the Ries target. Mass of tektites (upper plate) and projectile melt (bottom plate) per square km, averaged over the area 50km×50km, is shown (10^6 kg/km^2 means 1 kg of tektites per m^2, or 30 tektites with average size of 3 cm).

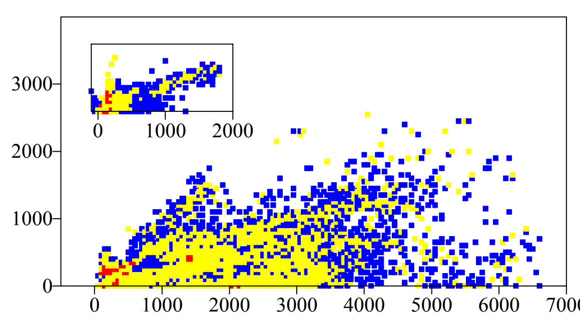

Fig. 4. The same as Fig. 3 for lower impact angle of 15°. Tektites distribution is shown in the left upper corner.