IMPACT MELTS IN EJECTA DEPOSITS: POPIGAI CASE STUDY. V. L. Masaitis[1] and N. A. Artemieva[2,3], [1]VSEGEI, Saint-Petersburg, Russia, vcmsts@mail.ru; [2]Planetary Science Institute, Tucson, USA, artemeva@psi.edu; [3]IDG RAS, Moscow, Russia.

Introduction: Impact melts are produced during high-velocity impacts and represent an important class of impactites. The total melt volume scales with crater size and helps to recontrand an impact scenario [1-3]. Typical melt-bearing deposits within and near the crater include sheets, lenses, irregular bodies, and dykes of coherent impact melt (tagamites); suevite layers and irregular bodies (melt fragment content up to 80%); various polymict lithic breccia. Proximal deposits are represented by suevites, melt bombs, and lapilli; tektites, impact spherules, and mycrokristites may be found hundreds and thousands km away from their source crater.

Appearance of various melt-bearing impactites depends on many circumstances such as their shock history, ejection conditions (velocity and degree of mixing), transportation regime (ballistic flight, melt flow, impact plume), deposition velocity (Stokes' precipitation versus ballistic sedimentation), post-impact alteration. At least part of these factors can be reconstructed if observations are combined with numerical models. In this paper we discuss possible emplacement mechanisms of melt-bearing impactites from Popigai.

Popigai: The 35 Ma Popigai crater situated on the northern edge of the Syberian platform (71°38'N, 111°11'E) is a multi-ring impact structure. Its main morphostructural characteristics are: (1) a circular center depression, D=40 km; (2) a peak ring, D=45 km; (3) and annular trough, D=72 km; and (4) an outer flat terrace, D=100 km; thickness of impactities in the central depression reaches 2 km, depth of the annular trough is also ~ 2km; the total erosion is estimated as ~300 m [4,5]. Small remnants of ejecta were found as far as 75 km to the north from the crater's center; microkrystites (condensation products of early ejecta) from the Popigai crater were identified in Upper Eocene sediments from North Atlantic [6]. The crater has been intensively studied and drilled to explore deposits of impact diamonds [7]. The total length of shallow boreholes exceeds 100 km with the deepest being 1.5 km in length.

Target rocks: The crater was formed in a two-layered target that is composed of Archean and Lower Proterozoic crystalline basement overlain by a 1.5-km-thick cover of flat-lying Upper Proterozoic, Lower and Upper Paleozoic, and Mesozoic sediments [4,5]. Crystalline rocks are represented mainly by various gneisses and schists; the sedimentary sequence is composed of siliciclastic and carbonate deposits.

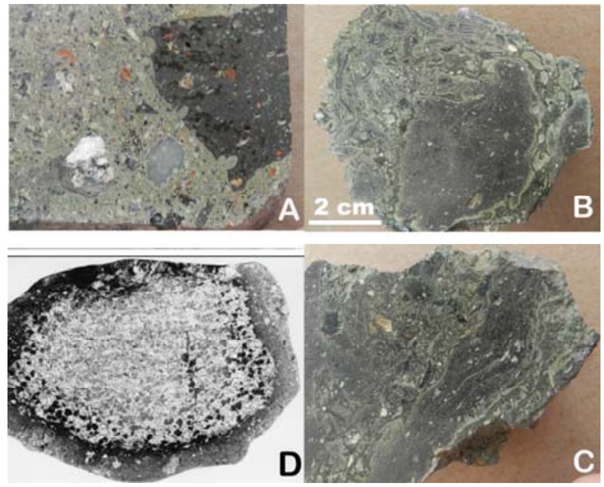

Fig.1. Variety of melt-bearing rocks from the Popigai crater. A: Suevite from the SE slope of the peak-ring: small glassy particles and a large angular lapillus of porous glass are embedded into the fine-grained clastic matrix. B: Welded suevite from the annual trough with minor matrix and clast content shows rotational structure of glass lapillus and fragments. C: Suevite with high content of melt lapilli having fluidal structure parallel to the boundaries of large melt lapillus. D. Polished surface of a glass coated garnet gneiss bomb with a diameter of 20 cm [8].

Impactites: Analysis of Popigai's boreholes allow to estimate the total intra-crater volume of melt as ~1750 km^3. This volume is evenly distributed between tagamites (melt rocks) and melt particles and fragments within suevites. Taking into account the erosion level, this number could be 10-20% higher.

Intense drilling down to a depth of 1 km shows that in the central depression (restricted by the peak ring) impactites are represented mainly by tagamite and suevite sheet-like bodies with tagamites prevailing in deeper sections. At the top fine-grained polymict lithic breccia occur together with suevite lenses and impact glass bombs. Suevites from the lower level are rich in glass particles with fluidal features while in the upper part they are less common and angular fragments prevail (Fig. 1A). Within the annular trough the proportion between crystalline/sedimentary rocks in allogenic breccia and melt content increases from bottom to top. At the top a sheet-like tagamite body is overlain by suevites (Fig. 2). Contact between melt inclusions in suevite shows deposition in highly (Fig. 1B) or moderate (Fig. 1C) turbulent conditions.

Glass-coated gneiss bombs (Fig. 1D) ranging from 2 to 40 cm in size are abundant. They are irregularly distributed in suevites and in fine-grained polymict lithic breccia. The core (shocked to 25-45 GPa gneiss) is usually rounded; glassy crust is 1-3 cm thick and differs in composition from the core [8].

Hypotheses: Geological observations allow to put forward the following probable modes of impactite emplacement in Popigai**:**

Tagamites/suevites in the central depression originated during the transient cavity collapse. Their sheet-like structure is a consequence of gradual pressure decay within the target after the impact. Sharp boundaries between tagamites and suevites suggest highly viscous (if not quenched) melt at the end of the crater collapse.

Tagamites/suevites within the annular trough could result from melt-like flows during the central uplift collapse [10] or, alternatively, from melt/granular flows originated after ballistic deposition [11] (e.g., they were ejected from the crater during the excavation flow albeit with a low velocity of <500 m/s). Turbulence within the flow (independently of its origin) is defined mainly by melt velocity and its viscosity, which, in turn, depends on the melt composition, temperature, and fraction of clasts.

Glass-coated bombs recorded the time - temperature history of ejected gneiss clasts [8]. First, they passed through an impact plume and were rounded and partially molten by hot vapor/melt mixture. However, this heating ceased quickly due to plume expansion. Later, at the descending part of their trajectory, the clasts met with a highly turbulent ejecta cloud and attained their outer crust .

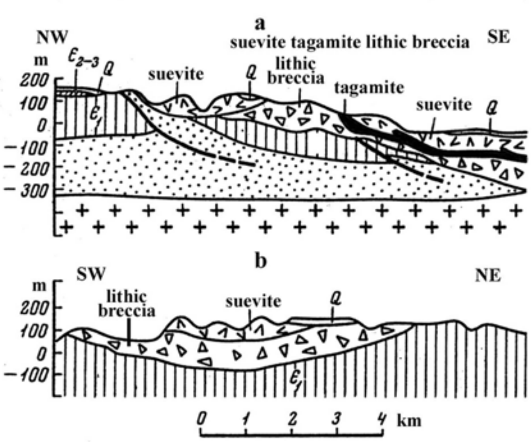

Fig.2. Longitudinal (a) and transverse (b) cross sections through the radial trough at the NW outer wall of the annular trough (terrace zone) of Popigai. Various shadings show target rocks (dots – PR_3, crosses – AR), impactites are explained within the sketch [9].

Numerical Models: The single so far crater model [12] successfully reproduced the crater structure and the calculated melt volume (2600 km^3 in total with 2200 km^3 in the central depression). Melt transported as a non-viscous flow during the crater collapse is mainly buried in the annual trough at a depth of ~ 4 km (twice ldeeper than field data). Ballistically ejected melt is deposited in the vicinity of the crater rim. Spatial resolution of 200 m and an absence of sediments in this model do not allow to reproduce suevite formation and mixing of melts originated from different precursors.

Numerical model [13] showed that distal ejecta, microkrystites, have been formed from high-velocity, high temperature melt/vapor mixture ejected from the central part of the crater. Shock pressure exceeded 150 GPa, ejection velocity was > 4-5 km/s.

Perspectives: Current numerical models just started to touch the problem of suevite formation and its emplacement [14-16]. Still, these models do not allow to reproduce mixing processes due to their low resolution and simplified equation of states. An alternative approach could be macro-scale modeling of melt interaction either with volatiles delivered during the impact or with the atmosphere. Emplacement of melt flows of various rheologies could be modelled with high resolution separately from impact models if the results of crater formation are inserted as boundary conditions.

Excellent outcrops, large number of drill cores, and wealth of geochemical data make Popigai ideal for the study of cratering processes despite its remote location. In forthcoming years VSEGEI plans to organize the International Research Project which includes field work at the Popigat site. Many samples as well as borehole data will be open for analysis in St. Petersburg prior to the excursion.

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