THE FEATURES OF THE POPIGAI: A GUIDING KEY FOR LARGE-SCALE IMPACT CRATERING PHENOMENA.  S. A. Vishnevsky, Institute of Mineralogy and Petrology, Novosibirsk-90, 630090, Russia <nadezhda@uiggm.nsc.ru>.

Introduction: The simple model of cratering is well established, and typical features of the simple craters (shape, rim, overturned flap, ejecta deposits, etc.) are studied in details. However, the theory of impact cratering cannot explain some features of large complex craters [1,2]. For example, in spite of the numerous investigations, an origin of ring and central uplifts is still a matter of debates [2,3]. Some other features of the craters are less debatable but not less important; their origin is also an open question. One of the ways to have a progress here might be based upon the field investigations and attempts to explain the debatable features. In this connection, some geological observations on the Popigai astrobleme (PA) and their interpretations may be of definite interest. Following to its size (100 km), young age (~35 Ma), well preservation and good exposure, as well as to plenty of impact formations and diversity of target lithologies, the PA is a unique test site for the theory of large-scale cratering. Some key geologic features of the PA are presented below. Their description is based upon our nomenclature of the PA impact formations [4,5].

Description:
1. Impact diatremes and horsts are specific impact-induced tectonic structures, known in the PA only [5 and ref. therein]. They are locally present in Cambrian terrain in the west, northwest, east and southeast surroundings of the crater, 3 to 5 km far from its tectonic rim. Impact diatremes are pipe-like bodies up to 3.5 km in diameter, filled up with a chaotic mixture of fragments (from the pebble size up to the blocks of 700 m across) derived from various target lithologies. Impact horsts, from 300 m to 2 km in size, are made up of Proterozoic arenites. The elongation of both the structures, if present, follows to regional W-NW faulting trend. Except for the "gries" breccia, no other traces of shock metamorphism (SM) are recognized in these structures.

2. Proximal ejecta deposits are very poor in close vicinity around the PA, except for the north surrounding of the crater where they have a wide enough extent and are observed to up to 20 km from the tectonic rim of the crater. At the same time, the relics of pre-impact Paleogene planation surface and old river valleys with remnants of loose Mesozoic sediments are preserved around the crater. So, the lack of the proximal ejecta blanket cannot be explained by erosion only and indicates any specific feature of the origin of the PA. At this, there is an evidence of more distant, up to 500 km far from the crater, ejecta deposits, traced by the strewn field of impact diamonds [6]. Besides it, a global dissemination of the PA distal ejecta deposits is well grounded [7], and at least one of the Eocene/Oligocene impactoclastic horizons can be related to the Popigai impact event.

3. The principle of "reversal stratigraphy" is not valid for the explosion cloud deposits (suevite formations) in inner part of the crater. Clastic material derived from the loose Mesozoic target lithologies dominates in the deposits. Suevite megabreccia formation is especially paradoxical in this respect. It forms a belt in the middle part of the crater and contains a number of large, up to 80 m in size, lumps of loose, mainly Cretaceous, Mesozoic target lithologies. Suevite megabreccia is known in the PA only [5,8].

4. Two principally different spatial sources of the material are another paradoxical feature of the major part of the PA suevites, and of the suevite megabreccia in the first turn. These source materials are: 1) weakly- or non-shocked at all clasts of mainly loose sedimentary target lithologies derived from the middle and marginal zones of the growing crater (traces of shock metamorphism either are absent at all, or are limited by "gries" breccia and shatter cones only); 2) strongly-shocked (up to the state of high-temperature impact melt) material of Archean gneisses, derived from the inner part of the growing crater [5,8]. A model of simple mixing in the ejecta plume cannot be applied for the origin of large (not less than 500-700 km$^3$ in volume) body of the suevite formations of the PA, accompanied by a lack of the "reversal stratigraphy".

5. Evidences of the dynamic interaction between the components in a dense/condensed state of the matrix are once more paradoxical features of the suevite megabreccia formation. This interaction took place while the matrix of the megabreccia was already lithoid-and-plastic, and even lithificated [5,8]. Traces of fast forced movement of the target rock lumps in this matrix are among the evidences. Streamlining deformations and dragging trains behind the lumps indicate this movement. Evidences of turbulent mixing between various kinds of suevites, which compose the matrix of the formation, are also very common. "Brecchia-within-breccia" relations when fragments of one suevite are cemented by another suevite are also observed in the megabreccia matrix. Proponents of volcano-tectonic origin of the PA used this feature as an evidence of its prolonged multiphase origin [9].

6. Sharp contacts between various suevites are observed by places within the suevite strata of the PA. At
first glance, this feature is also consistent with the volcanic-tectonic origin of the structure.

7. Bedding of the suevites on the Archean gneisses is often observed on the crest of the inner ring. Moreover, mixtures of gneiss lumps and suevites are known in some places here. It shows that the ring originated very quickly, while a part of the explosion cloud material was still either in flight, or in a mobile state during the collapse and emplacement.

**Interpretation:** Simple models of cratering cannot explain the features of the PA geology described above (items 1 to 6). Our interpretation is made on the basis of the hypothesis of the dynamic barrier (HDB); we suppose that this barrier was originated in the explosion cloud of the Popigai impact event [5,8]. Following to HDB, the subsurface lag of the shock wave front in soft surficial Mesozoic target rocks originated in middle and marginal zones of the growing crater. Propagation of attenuating shock wave in this zone was accompanied by the elastic precursor. This lag originated as a result of a density contrast between the Mesozoic (~1.8-2 g/cm³) and other target lithologies (~2.6-2.8 g/cm³). With application of simple cratering mechanics after [10], we can conclude that due to the lag, the soft Mesozoic lithologies were ejected along high-angle to vertical trajectories; as a result, a torus-shaped cloud of low-shocked rock fragments rose vertically up above the middle and marginal zones of the growing crater. This cloud would function as a dynamic barrier for expanding conical plume of high-speed strongly shocked ejecta derived from Archean gneisses in inner part of the crater.

A scarcity of proximal ejecta deposits around the tectonic rim of the PA can be explained by means of HDB (a screen effect of the dynamic barrier). The same screen effect of the barrier would serve also as a course for the local sharp contacts between various suevites. An origin of the suevite megabreccia in the middle zone of the crater, a lack of the “reversal stratigraphy”, and two principally different spatial sources of the material for the suevitic formations can be explained by means of HDB also (colliding at the dynamic barrier and intensive mixing between the high-speed and strongly-shocked crystalline rock ejecta and the torus-shaped cloud of Mesozoic fragments). Evidences of the dynamic interaction between the lumps and matrix of the suevite megabreccia, as well as the traces of turbulent mixing between various kinds of suevites and “breccia-within-breccia” relations between them in the matrix of the megabreccia can be explained by the colliding of ejecta at the dynamic barrier also (a partial condensing/compacting of the suevitic material to a dense lithoid and even lithified state, and a dynamic interaction between them). More detail interpretation of the PA geological features on the background of HDB is discussed in [5,8].

Origin of impact diatremes and horsts can meet an explanation by means of subvertical ejection also: these specific impact-induced tectonic structures are the evidence for subvertical shock impulses transmitted from the deep interior of the growing crater. Very fast origin of the inner ring of the Archean gneisses is considered as a result of coherent centrifugal plastic flow of the basement rocks under the crater bottom. It took place at the excavation stage. Its origin is similar to the origin of the base stage of the rim in simple craters. Following to this interpretation, the inner ring of the PA is just a rim of the inner crater, elaborated in the crystalline basement rocks. Other models of its origin (isostatic relaxation, gravity collapse, etc.) seem invalid according to the very fast rising up of the ring.

Of course, some our interpretations presented above would not be possibly confirmed later. Anyway, the discussion on the subject will be useful for the better understanding of large-scale impact cratering