POPIGAI: GNEISS BOMBS COATED WITH IMPACT MELT - HEATING IN THE FIREBALL? V. L. Ma-
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Introduction. The Popigai structure was formed 35.7 Ma ago [1]. The about 100 km sized, complex impact crater [2-4, and references therein] is world-famous for it’s impact diamonds [5]. Aside from all the other excellently preserved characteristics of this crater, gneiss bombs coated with chilled impact melt form an outstanding impact feature (Fig. 1A).

Mode of occurrence. The gneiss bombs ranging from 2 to 40 cm in size are quite abundant at the Popigai impact site. They are irregularly distributed in suevites (especially in the vitro-granoclastic type [3]) and fine-grained polymict breccias ("coptoclastites"), which occur mainly in lower and upper parts of the allogenic breccias sequences.

Macroscopic and microscopic characteristics. The bomb’s cores are angular but mostly round-shaped (Figs. 1B, C), and consist of biotite-garnet gneiss, which may contain pyroxene, sillimanite, and cordierite. Most gneiss cores are shocked at pressures of 25 to 45 GPa; quartz and plagioclase (An35-40) are transformed into diaplectic crystals, or diaplectic, or fusion glasses. Some weakly shocked rocks contain coesite in significant amounts. In moderately shocked gneisses, the pink garnet (almandine with 25-30 mol% pyrope) lacks shock features except heavy fracturing. In strongly shocked samples, garnet is transformed into fine-grained opaque aggregates, and biotite consists of irregularly oriented tiny flakes of oxybiotite (?).

The glass coating of the bombs, about 1 to 3 cm thick, displays a rough outer surface like a bread crust. Generally, these coatings are sintered with the surrounding host rocks - suevite or coptoclastite. The coatings carry numerous small fragments of shocked and partly annealed rock-forming minerals from the gneiss. Most of these clasts display sharp contacts, fusion or reaction rims are nearly absent. The rims include different materials (Fig. 1C): massive, fresh colorless transparent glass, and fluidal textured zones with alternating thin strings, and lenses of light- and dark-colored, mostly brownish non-transparent crypto-crystalline glasses. Mixture of these two glass types led to an emulsion-like structure, where small spheroids of one glass are included in the other type. The mean SiO2 content of the glasses is 63 wt%, similar to that of the massive tagamites at Popigai [2,4]; whereas, the gneiss usually contain more silica but less magnesia, lime etc. Therefore, the rims represent accretional coatings, not fused gneissic material.

Contact zones. The boundaries between the gneiss cores and coatings are either sharp or gradational. In most cases, however, the fragment’s surface display features of intense mechanical abrasion (Fig. 1D). The gneiss becomes jointed, and injected by glass veinlets carrying tiny mineral clasts of the wall rocks.

Annealing. The gneiss bombs show signs of thermal overprinting: Small bombs are totally annealed, the larger ones have an up to 1.5 cm thick annealed "shell". This zone occurs even there, where a glass coating is lacking. Due to the annealing, the garnet becomes dark colored (Fig. 1B), and biotite either appears opaque or is decomposed into oxides; whereas, these minerals lack similar effects in central part of the bombs. This observation clearly indicates that the post-shock waste heat of the gneiss is not the reason for the annealing. Using the onset of thermal decomposition of garnet and biotite at 1 atm as analogue, we estimate 785° C as minimum temperature during the post-shock annealing. As glass coating is not always accompanied by the presence of an annealed "shell", these thin films of impact melt are also not the reason for the short thermal pulse. Taken into account that the temperature diffusivity of a granite is about 0.5 x 10^-6 m^2 s^-1, and the thickness of annealed zones is ≤ 2 cm, the maximum duration of the thermal pulse was on the order of several minutes. As equilibration was not reached, this pulse obviously has been much shorter. The sharp gradient in the thermal transformations of minerals in a narrow zone confirms this conclusion.

Interpretation. The glass coated bombs record the time - temperature path from ejection of the shocked gneiss fragments till deposition as part of an allogenic breccia. The trajectory of the ejected clasts passed in part the expanding fireball. Thereby, the originally angular fragments were rounded and annealed by the superheated gaseous media. In some cases, the heating caused even melting of the outer zone of a clast. The heating was very short, because of the fast temperature decrease in the expanding fireball. At the distal part of their trajectory, the bombs moved in a turbulent cloud of melt droplets and lumps, mixed with clasts from the brecciated and ejected target material, especially from the loose sediments. In this media, bombs were further abraded; simultaneously or slightly later, drops of the homogenous impact melt accreted. This melt partly mixed with the local gneiss melt, formed during the passage of the fireball. The now melt coated bombs landed together with relatively cold lithic fragments, dust and sandy particles (coptoclastites), in certain areas chilled impact melt glass fragments were present too (suevites). The still hot melt coatings were sintered with the surrounding fragmental matrix and chilled.

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Figure 1. A Polymict allogenic breccia ("coptoclastite") at the East bank of the Rassokha River with rock and mineral clasts and two gneiss bombs. The head of the hammer is 10 cm across. B Polished surface of a glass coated gneiss bomb (ø about 20 cm) displaying on three sides an annealed "shell" with dark-colored garnets. C, D Photomicrographs, the scale grid is in mm. C Sample 97075 with two types of glass coating. D Sample POP-A063 with a knife-sharp abrasive contact between gneiss (right) and melt. See text for further explanations.