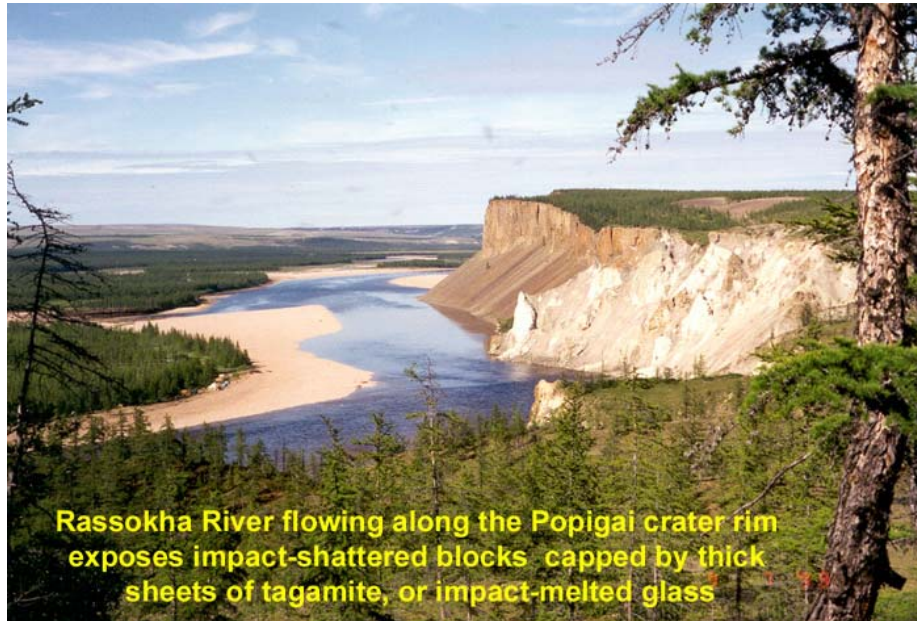


POPIGAI IMPACT STRUCTURE



OVERVIEW

About 36 million years ago in northern Siberia, a large asteroid impacted the Siberian platform to form a crater 100 km in diameter filled with melted and shocked material that included shock-generated impact diamonds.
 71°38' N 111°11' E - crater center
 North Central Siberia about 100 km from the coast of the Laptev Sea, an embayment of the Arctic Ocean.
 Late Eocene - 35.7 (± 0.2) million years [by stepwise heating Ar-Ar].



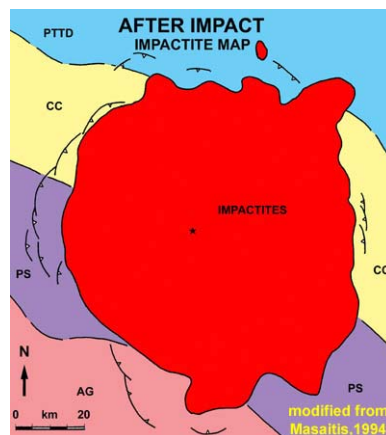
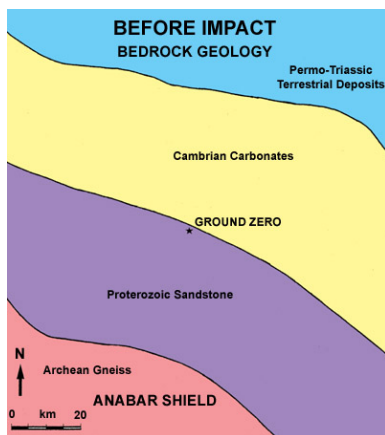
PRE-IMPACT GEOLOGY

Impact occurred at the Precambrian-Phanerozoic contact on the northeast flank of the Anabar Shield.

Basement of Archean graphite-bearing gneisses.

A simple homoclinal layer of sedimentary rocks, about 1500 m

thick, consisting of platform sandstones and carbonates of Proterozoic, Cambrian, and Permo-Triassic age.



IMPACTOR

Probably an ordinary chondrite, about 8 km diameter, 3.5 g/cm³, with a trajectory 210° -220°. Such a body, with a velocity of about 20 km/s, would deposit about 1.7 x 10²³ J of energy [Masaitis].

Use of Melosh's cratering program back-calculates a stony asteroid impactor slightly less than 5.0 km in diameter.

CRATER

The crater is 100 km diameter, as measured by the extent of deformation of bedrock by thrusting. The geophysical signatures of the structure are a magnetic low and a gravity low with a central gravity high.

The crater is filled with 2-2½ km of suevite [75%] and melt rock [tagamite] [25%].

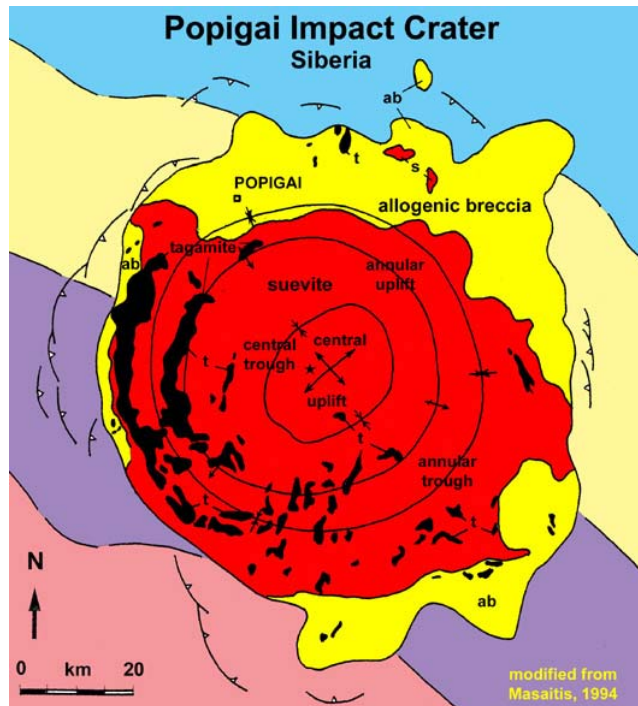
The crater floor has a low topographic high in the center of a central basin, with an outer synform-antiform.

SHOCK METAMORPHISM

The impact created:

- shatter cones in Archean gneisses
- PDFs [planar deformation features]
- lechatelierite and diaplectic glasses
- coesite and stishovite [polymorphs, or high-pressure forms, of quartz].

Shock pressures instantaneously transformed graphite to diamond within 13.6 km of ground zero.



SIGNIFICANCE

Popigai is a world-class impact structure that is well preserved and well exposed, providing a good view of impact structures and rocks and permitting access to internal materials. Three other craters are larger, but they are either buried [Chicxulub], strongly deformed [Sudbury], or deformed and severely eroded [Vredefort]. The exposures and preservation at Popigai permit a detailed account of the impact mechanisms to be interpreted [see *Impact Scenario* below].

Popigai may represent one of two or three simultaneous impacts. The 35.7 (± 0.2) Ma date precedes the 35.2-35.5 Ma Chesapeake Bay impact and the same-age Toms Canyon impacts, *but* the error bars do *not* preclude synchronism.

Popigai precedes the 33.7 Ma Oligocene/Eocene boundary. The 35.7 ± 0.2 Ma date corresponds to the 35.7 ± 0.4 Ma Ir and PDF quartz layer at Missignano, Italy, the stratotype section for the Eocene/Oligocene boundary.

IMPACT SCENARIO

A probable sequence of events in the formation of the Popigai impact structure would include:

A transient cavity about 8-10 km deep was excavated through the 1.5-km-thick sedimentary rock cover and into the Archean graphite-garnet gneisses

Peak pressure was about 624 GPa

Impactor and surrounding target rocks were vaporized

a vapor plume and vapor-melt cloud were ejected

99% of the impactor was vaporized and 1% was incorporated in meltrocks

About 1750 km³ of molten rock formed, about half of it was ejected

Shock metamorphism created shatter cones, PDFs, coesite and stishovite, and diaplectic glasses

Shock pressures transformed graphite to diamond within 13.6 km of ground zero

[*A fraction of a second has elapsed*]

Bedrock was shattered into blocks that were forced downward, outward, and upward, at supersonic speeds, to form the allogenic breccias

Fusion of gneiss formed sheets of meltrock [precursor of the tagamite] that covered most of the cavity/crater floor and flowed radially out to form annular ridges and streams of meltrock into and over the allogenic breccias

Explosion cloud of fragmental ejecta, vapor, and melt [similar to a pyroclastic flow] formed suevite almost simultaneously with tagamite flows

Rebound of cavity floor into a central peak squeezed melt layers into upper layers of suevites and possibly to the surface as flows

Subsidence of central peak formed annular rings [antiform and synform pair], thus creating a peak-ring complex crater or a multi-ring crater

Ejected blocks fall at least 70 km beyond the crater; some diamonds were blown 150 km to the east

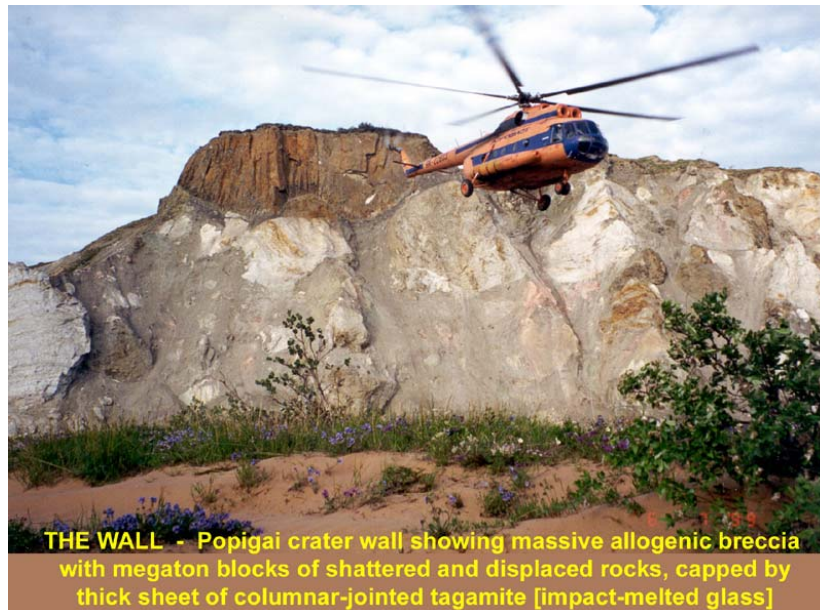
Centrifugal bottom-flow material of allogenic breccia and tagamite sheets overtaken by suevite clouds and material intimately mixed

[Probably minutes have elapsed]

Fallback of condensed volatilized material, mixed with fine fragmental ejecta, probably formed a surface blanket of material that was subsequently removed by erosion

Tagamites up to 600 m thick may have required thousands of years to cool

Crater was filled to a shallow depth by Neogene-Quaternary sediments



IMPACT DIAMONDS

Prior to the impact, biogenic carbon that was originally deposited in pelitic sediments underwent granulitic metamorphism at 2.4 Ga to form graphite.

Graphite is usually less than 1% of the gneiss, although it occurs locally up to 5%.

The isotopic signature of the carbon [$\delta^{13}\text{C}$] in the diamonds is the same as in the graphite and the same as that in diamonds in gneiss in the authigenic breccias.

The impact pressure wave instantaneously transformed the graphite to diamond.

The distribution of diamonds in the impact structure is complex:

Graphite was irregularly distributed in Archean gneisses;

Diamonds were formed, and not subsequently destroyed, in a hemispherical shell about 1.6 km thick, from 12 km to 13.6 km radial distance, which straddled the outer edge of the melt; this was a volume of about 1600 km³;

Shock pressures for the martensite transition from graphite to diamond required ≥ 35 GPa pressure, so diamonds did not form beyond a radial distance of about 13.6 km;

Post-shock temperatures corresponding to pressures greater than 50 GPa [<12 km] were high enough to destroy diamonds by regraphitization, conversion to SiC, melting, or vaporization;

Diamonds were distributed radially outward mostly in the melt [some in gneiss fragments], both in tagamite flows and suevites.

In tagamite sheets, diamonds reacted with the melt, given the opportunity, by corrosion, graphitization, and oxidation, so diamond content was secondarily controlled by the cooling history of the tagamite;

diamond content is higher in the chill borders than in the interior of tagamite sheets

diamond content is higher in tagamites that incorporated greater amounts of cool fragmental material.

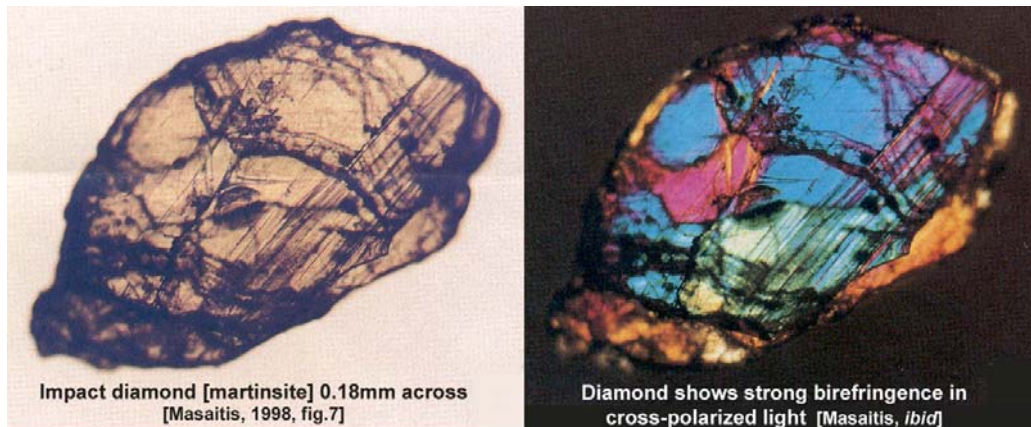
Diamonds are unlike kimberlitic diamonds; they occur as microcrystalline aggregates paramorphous after graphite:

their overall shape is that of their graphite precursor, including twinning and cleavage

thin-sections may show birefringence [≤ 0.02]

individual crystals are about 1 micrometer in diameter, about half-and-half:

cubic diamond and hexagonal diamond [lonsdaleite]



The grade of diamondiferous rocks is closely held information. Total caratage likewise has not been revealed, but it was stated to exceed the world's known supply of diamonds.

Popigai diamonds have not been produced.

Impact diamonds are known from nine other impact sites.

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