Syn- and post-eruptive volcanic processes in the Yubileinaya kimberlite pipe, Yakutia

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Introduction

With a surface area of 59 ha Yubileinaya is one of the largest kimberlite pipes in the Yakutian kimberlite province, Siberia. The Devonian pipe was emplaced under structural control into karstic Lower Paleozoic limestone. The pipe is overlain by approximately 70 m of Permian and Carboniferous sediments and intrusive trap basalts. The maximum estimated erosion since emplacement is 250 m.
Open pit mapping of a 180 m thick kimberlite sequence and examination of two drill cores (150 m each) documents the transition from the main eruptive phase to the waning phase of volcanic activity forming the pipe and the onset of its crater infill by resedimentation.

Pipe shape and general geology

Yubileinaya pipe consists of the central, roughly spherical main pipe with a present day surface diameter of about 700 m. The pipe is located on a NE-SW striking zone of structural weakness, which is about 200 m wide and can be traced for several dozen kilometers. Adjacent to the main pipe and on strike with the fracture zone are several smaller pipes which are cross-cutting each other at the surface, forming an ~1200 m long pipe complex. Debris flows of precursor material into the main pipe suggest that the main pipe is the youngest volcanic body and cuts the older precursor pipes (Fig. 1).

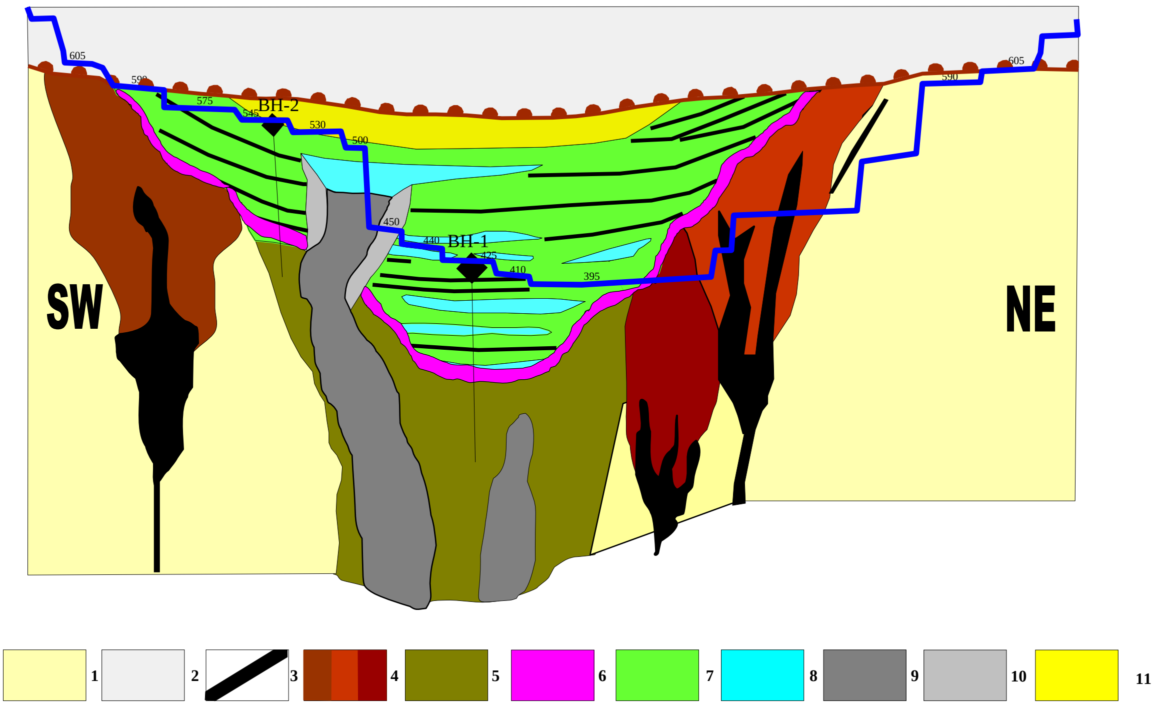

Fig. 1. Schematic geological cross section through the Yubileinaya pipe complex (not to scale)
Legend: 1: Country rocks (Carbonates) 2: Overburden of Permo-Triassic rocks 3: Hypabyssal kimberlites (dikes and plugs) 4: Precursor pipes 5: AKB of main pipe 6: Xenolith belt 7: Resedimented volcaniclastic kimberlites (main pipe) 8: Primary pyroclastic kimberlites (main pipe) 9: Feeder conduit 10: Collapse zone around feeder conduit 11: Lake beds. - Blue line: profile of open pit with figures indicating depth of benches; BH-1 and BH-2 - number and location of bore holes made available for study.

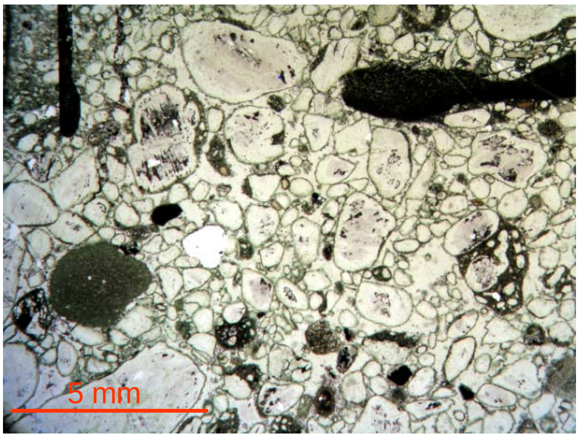

Fig. 2a: Thin section photograph of "AKB" in drill core 030-288A (117 m). The volcaniclastic rock is clast supported and consists mostly of olivine with thin serpentinised rims. Plane polarized light.

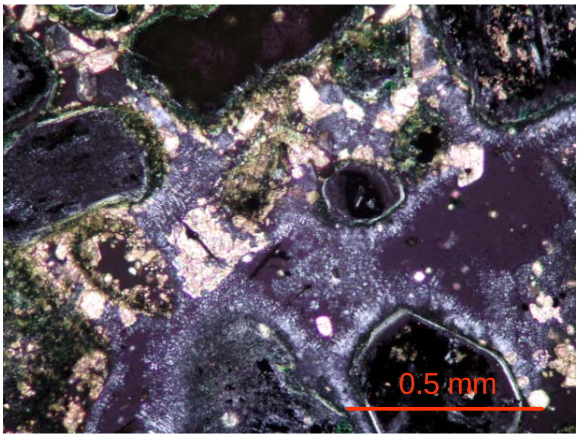

Fig. 2b: Thin section photograph of "AKB" in drill core 030-288A (149 m). The matrix of the rock consist of radial laths of chlorite, carbonate and clinopyroxene. Serpentine forms the base of the rock. Crossed polars.

The main pipe has a flaring top part (~45°) which at depth becomes steep-sided (Fig. 1). The transition towards its steep-sided part is at a depth of about 300 m from the present surface and is marked by the presence of a coarse, bowl-shaped limestone xenolith layer (the "xenolith belt"). In contrast, the precursor pipes are smaller, narrower at surface and have a more irregular shape towards depth.

While the precursor pipes show many features typical of root zones or lower diatreme levels (dominance of HK intrusions, HK breccias, contact breccias, and volcaniclastic material), the main pipe is filled by well bedded volcaniclastic sediments typically formed in the upper diatreme zone of a pipe.

Main pipe comprises layers of volcaniclastic rocks of variable bed thicknesses and granularity. Breccias with a high abundance of local limestone xenoliths are frequent along the pipe margins. These beds dip steeply (between 30° and 40°) along the pipe contacts and become horizontal, thinner and finer-grained towards the centre of the pipe. The deeper levels of main pipe consist of a massive volcaniclastic rock called "AKB".

Emplacement sequence of the main pipe

The internal structure of the main pipe can be subdivided into three phases, with each phase comprising a characteristic set of massive or bedded volcaniclastic rocks deposited during different episodes of volcanic activity.

1. Main eruptive phase: Autolithic kimberlite breccia (AKB)

The deepest and oldest unit of the main pipe is a massive fragmental rock known as "Autolithic Kimberlite Breccia" (AKB) in Russian literature. This rock unit is internally structureless and appears similar to South African "Tuffisitic Kimberlite Breccias" (TKB). It is a grain-supported, xenolith-rich, crystal lapilli ash tuff with serpentinised olivine as the main constituent (Fig. 2a). The olivines occur mostly as solitary crystals or with a very thin and often incomplete skin of highly chloritised material. The interclast matrix consists of chlorite, carbonate and clinopyroxene growing as radial halos from the margins of the pyroclasts into the clear serpentine base (Fig. 2b). Some olivine grains appear abraded and broken or have multiple rims of kimberlite coatings, suggesting reworking and repeated involvement in eruptions.

The AKB is thought to be related to the main volcanic phase where violent explosions in the root zone homogenized the overlying diatreme tephra.

2. Syn-eruptive phase: Primary and resedimented volcaniclastic kimberlite

The transition from massive AKB to the overlying bedded rocks of the syn-eruptive phase is rather sharp and marked by the xenolith belt (Fig. 1). The units above the belt are

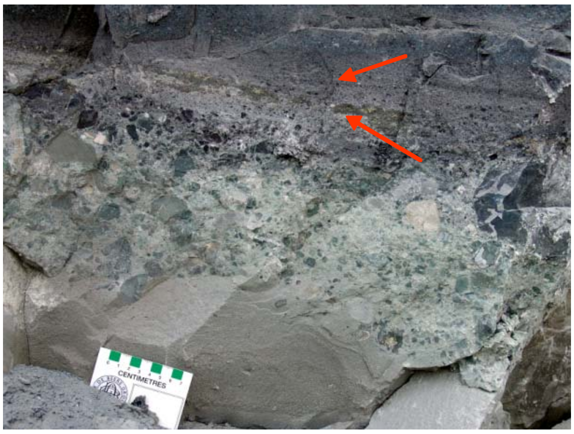

Fig. 3: The photograph shows the effective fine-coarse separation of the volcaniclastic rocks. Note the low angle cross bedding (arrows), suggesting deposition from base surges.

Fig. 4: Frequent soft sediment deformation textures suggest that the volcaniclastic material has been wet during deposition.

comprised of mass flow, fallout and base surge deposits with low angle cross beds (Fig. 3). Many of these beds show a well developed fine-coarse separation and soft sediment deformation textures (Fig. 4). A feeder conduit comprised of volcaniclastic material cuts through the bedded sequence as a vertical body.

The syn-eruptive phase shows a mixture of well-bedded primary pyroclastic and resedimented volcaniclastic beds which contain abundant fines. Base surge deposits as well as soft sediment deformation textures give evidence that meteoric water was present during eruptions and deposition, most likely in the form of temporary crater lakes.

3. Post-eruptive phase: resedimented volcaniclastic kimberlites and crater lake beds

The third and youngest unit consists mainly of resedimented volcaniclastic material and lake beds. During the sedimentation of this facies, primary volcanic activity was only minor and finally absent while resedimentation processses dominated the crater infill. Turbidites and lake beds have been identified, testifying to the progressing infill, decreasing relief gradient and the generally low erosion rate of the pipe.

Conclusions

The rocks exposed in pit and drill core document changes in the volcanic emplacement history of the pipe. Initially, kimberlite explosive activity occurred in several locations along the feeder dyke and was ongoing over an extended period of time, demonstrated by the presence of a series of cross-cutting small precursor pipes. Only after these pipes were consolidated the large main pipe grew on cost of the adjacent precursor pipes.

The main pipe itself experienced an early phase of violent eruptions which excavated the large pipe and homogenized the pipe tephra. Waning volcanic activity allowed gravitational crater and tephra wall collapse to become more dominant, resulting in a wide crater and interbedded primary and resedimented volcaniclastic material.

Finally, all primary pyroclastic activity ceased and resedimentation processes dominated. A permanent crater lake was formed.

Although there is clear evidence that water was present at this final stage of the crater infill (phase 3), it is highly likely that temporary crater lake(s) and wet tephra also existed during deposition of the syn-eruptive rock sequence (phase 2). This is suggested by abundant soft sediment deformation textures in the fines-enriched bedded rocks. Base surge deposits in this unit give evidence that water was present also in the eruption clouds and that phreatomagmatic processes played an important if not dominant role in the emplacement of Yubileinaya pipe.

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