End-Permian Mineralized Phreatomagmatic Pipes of the Tunguska Basin: Volcanogenic IOCG Deposits Linked with the Siberian Traps Large Igneous Province

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The Tunguska Basin sedimentary sequence is 2 to 4 km thick in the area of iron ore-bearing basalt pipes. This sequence consists of Precambrian and Paleozoic evaporites, carbonates, and terrigenous rocks. Permian-Triassic volcaniclastic rocks overlie this sequence and consist specifically of coal-bearing terrigenous rocks. Precambrian and early Paleozoic oil source rocks contain numerous high potential oil and gas fields. Paleozoic evaporites contain rock and potassium salt deposits of commercial grade. Tunguska Basin evaporites are considered as a regional seal for the mineralizing brines.

The Tunguska Basin has been intruded by the Siberian traps large igneous province, composed of dolerite intrusions (sills), flood basalts (lavas), volcaniclastic sediments (tuffs), and basalt pipes (diatremes). The basalt pipes are genetically linked to the Siberian traps. They have pierced through all sedimentary strata and almost all dolerite sills, and occur everywhere in the southern Tunguska Basin. The age of the pipe mineralizations is geologically well constrained and coincided with the Siberian traps emplacement.

There are more than three hundred mapped magnetite-bearing basalt pipes, 43 of which are classified as diatremes. The diatremes are typically circular or elliptical, with multiple zones of brecciation reaching the surface, with preserved infilled crater lakes. The pipe size on the surface varies from a few tens of meters for small diatremes to about a kilometer in diameter, although the largest crater lake is 2.7 km^2. We have made a detailed study of the breccias of the Sholokhovsk basalt pipe, located within Nepa potash deposit in the Tunguska Basin, Siberia, Russia (about N 59° and E 107°), and find that the breccias are cemented by carbonate matrix (calcite, dolomite) and halite. Breccia clasts are altered at various temperatures, forming albite and garnet on basaltic glass, and diopside, garnet, magnetite, and chlorine-bearing amphibole (up to 1.8% Cl) on altered magmatic clasts. These mineral assemblages are consistent with high-temperature interactions with evaporites within the pipe conduits. The large number of pipes supports a model of degassing of halogen-rich volatiles that was widespread, violent, and had sufficient volume to have implications for the end-Permian crisis.

A phreatomagmatic origin of the pipes with iron oxide mineralization was proposed, but evidence had proven scarce. Our recent EMP studies of the pipes confirm their phreatomagmatic nature by ubiquitous occurrence of volcaniclastic lapilli, corroded by brine during initial stages of magma-evaporite (brine) interaction. Corroded lapilli have rims of diopside, chlorine-bearing hornblende, apatite, and magnetite. Iron-rich garnet is present on the tuff and glass fragments.

The main magnetite ores in the pipes occur as breccias, veins, subhorizontal massive fine- and coarse-grained calcite-magnetite ores, and bodies at the footwall contact of dolerite sills. A high-temperature assemblage of olivine-magnetite-apatite with pyrrhotite and chalcopyrite occurs in the deep parts of some high-grade deposits. Pipes with iron oxide mineralization typically also contain low-temperature minerals such as zeolite, amethyst, jasper, and calcite. Ore-grade celestine, magnetite, and copper ores occur within crater sediments that overlie some of the pipes. We hypothesize that some specific magnetite ores occurring in many of the iron ore deposits have a volcanogenic origin.