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The critical role of the Bushveld magmatic event for a modern society

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The Palaeoproterozoic Bushveld magmatic province extends from central Botswana in the west to the vicinity of the South Africa - Mozambique border in the east and from south of Johannesburg to the southern margin of the Limpopo Belt in the north. The province comprises a suite of mafic sills, Rooiberg volcanics, the Rustenburg Layered Suite (RLS), the Lebowa Granite Suite, and satellite intrusions of similar age including the Molopo Farms, Nkomati-Uitkomst and Phalaborwa complexes. Magmatism occurred over a very short time interval. Recent high precision U-Pb dating indicates that the RLS crystallised between 2055.91 ± 0.26 Ma, and 2054.89 ± 0.37^1 . Estimates of the volume of magma in the whole magmatic province are in excess of 1 to $1.5 \times 10^6 \text{ km}^3$, which is comparable in volume to that in major flood basalt provinces such as the Deccan and North Atlantic Tertiary Province. The province is a major provider of some of the critical metals that are essential to a modern society. The RLS is known as the world's leading producer of platinum (73%), rhodium (80%) and chromium (46%) and second largest producer of palladium (39%) and vanadium (35%). However, although not currently economic, there are significant concentrations of germanium, selenium and antimony in the Platreef and traces of cobalt and other metals, along with PGE-Ni-Cu, in the UG2 chromite, the Merensky Reef, the Platreef and the Waterberg Reefs. Chromium is sourced from chromitite layers of the Critical Zone, whilst vanadium is derived from magnetite layers in the Upper Zone. Platinum, palladium and rhodium are used in catalytic converters to decrease harmful emissions from automobiles as well as in the chemical, petroleum and electronics industry. Medical applications include uses in dentistry and in cancer drugs. Vanadium and chromium are vital additives to steels for specialist uses.

In the Bushveld granites, early magmatic Sn-W-Mo-F ores, typified by the Sn-W mineralisation at Zaaiplaats, were followed by an intermediate fracture-related Cu-Pb-Zn-As-Ag-Au paragenesis, as typified by the Spoedwel and Albert deposits, and a final stage of Fe-F-U mineralisation as at the Albert Silver Mine². Tin mining ceased in the 1990's although a brownfields project is being evaluated for new open-cast production. Tin is a valuable metal in modern society; of its many uses is the production of indium tin oxide, which is used in thin film coatings on touch-screen displays. At Vergenoeg mine, a 900 m wide fluorite-bearing iron-rich felsic pipe comprises a surface cap of fluorite and iron oxides overlying an assemblage of 25-30% fluorite plus magnetite, haematite, siderite, stilpnomelane and apatite with accessory sulphides. The open pit mine is one of the largest single fluorite mines in the world, producing acid grade ($>97\%$ CaF₂) and metallurgical grade fluorspar ($<97\%$ CaF₂) which is vital to modern society for steelmaking, refrigerants and in aluminum smelting. The Bushveld Complex has an estimated total metal endowment value, representing past production and current reserves and resources, of \$US 3.6 trillion³ and that does not include commodities other than PGE-Ni-Cu or the satellite complexes such as Nkomati. The satellite Phalaborwa Complex is composed of pyroxenites, phoscorite and carbonatite. U-Pb isotopic age dating suggests emplacement between 2062 ± 2 Ma and 2060 ± 2^4 . The complex is unique because of its copper production but it is host to phosphates, zircon, vermiculite, phlogopite, magnetite, nickel, cobalt, gold, silver, platinum, palladium and uranium.

In addition, the hydrothermal circulation created by emplacement of the Bushveld Complex has upgraded iron to mineable grades at Sishen and Thabazimbi, is responsible for the Pb-Zn deposits at Pering, for F mineralisation at Zeerust and for contemporaneous gold-bearing veins at Pilgrim's Rest. Also, world-class resources of andalusite occur in the metamorphic aureole. However, the whole Bushveld magmatic province and its mineralisation has not been studied in a holistic way. This subject forms the focus of a major research theme under the National Centre of Excellence, CIMERA.

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