Platinum-group minerals (PGM) in the Freetown Complex, Sierra Leone

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The Freetown Complex in Sierra Leone consists of layered gabbroic and troctolitic rocks which outcrop to form an arcuate peninsula jutting out into the Atlantic (Wells, 1962) for a strike length of 36 km. Geophysical studies of the continental edge (Baker and Bott 1961; Jones et al., 1988) show that the complex extends out to sea and to the North of the known outcrop on land. The Freetown Complex has been dated as 193 Ma (Beckinsale et al., 1977). This is the same age as coast-parallel dyke swarms nearby in Liberia and suggests that the origin of the intrusion is associated with the early opening of that part of the Atlantic and mantle plume activity. The overall impression is that the intrusion resembles a large tension gash parallel to the continental edge which opened during the tensional stage preceding the opening of the Atlantic.

The complex consists of a 7 km thick layered sequence of mafic cumulate igneous rocks, composed of generally troctolitic rocks which show cyclic units of igneous layering with layers ranging from 5 mm to 150 m in thickness (Wells, 1962). Troctolites occur at the base of a unit passing upwards through pyroxene troctolites, troctolitic gabbro, olivine gabbro, gabbro to leucogabbro and anorthosite at the top. Few cyclic units are complete since either the top or bottom (or both) are missing. The variation in rock type is brought about almost entirely by variations in the proportions of olivine, plagioclase and pyroxene with little variation in mineral composition (Wells, 1962; Bowles 2000).

At platinum-bearing horizons (Bowles, 2000) there is a perturbation in the silicate compositions. The best exposed such anomaly has been traced for 5.2 km along strike and is located in the more pyroxene-rich rocks, mainly pyroxene troctolites. In this layer the olivine has a more Mg-rich composition (Fo 0.75 compared with Fo 0.66 in layers above and below), the plagioclase is more Ca-rich (Ab 0.27 compared with Ab 0.39) as is the clinopyroxene (Ca 0.46 compared with Ca 0.42). At these horizons platinum mineralization (up to 0.69 g/t Pt) occurs with elevated levels of other metals (Bowles, 2000).

PGM have been located *in situ* in the rocks of the Freetown Layered Gabbroic Complex, Sierra Leone for the first time occuring in this stratiform layer of pyroxene troctolite. Cooperite (PtS) is the main PGM. Some PGE arsenides and antimonides occur in lower horizons but are rare. Pd-Cu alloys are to be found within another unique horizon.

The PGM are frequently associated with sulfides, mainly chalcopyrite and minor pentlandite (Figure 1). Many of the PGM grains are less than 1 micron in size with a few in the 2–4 micron range and one example of Pt-Fe alloy is 9 by 6 microns. The PGM occur in a late magmatic, high Ca-amphibole which has formed interstitially to plagioclase or plagioclase and olivine (Figure 1a, 1b, 1c). Some droplet-shaped cooperite can be found attached to droplet-shaped magnetite within the amphibole (Figure 1b). The most common PGM occurrence is near the margin of the sulfides (Figure 1d, 1e, 1f, 1h). The PGM-sulfide assemblage is found at the edge of the amphibole or in interstitial sites associated with the amphibole, mica (Figure 1g) or quartz. Cooperite located at the edge of the amphibole or in the interstitial locations has later been altered to Pt-Fe alloy. In one case part of the PGM grain hosted by amphibole remains as cooperite whilst the part of the same grain projecting from the amphibole boundary into altered silicate has been altered to Pt-Fe alloy.

The PGM in the rocks are considered to have formed following an event - a reduction in pressure cased by tension early in the opening of the Atlantic perhaps accompanied by an injection of fresh magma - which caused the silicates to form at more primitive compositions. As crystallization proceeded at these PGE-enriched horizons, the residual interstitial magma became supersaturated in metals, volatiles and sulfur. This led to the formation of an immiscible PGE-rich sulfide liquid followed by sulfide saturation. Sulfide saturation led to sulfide crystallization which acted as a collector for the PGE. Droplets formed from the immiscible PGE-rich liquid were enclosed in the core of the late magmatic amphibole. The slightly later PGE-sulfide assemblages were trapped at the rim of the late magmatic amphibole or formed interstitially in association with the amphibole, mica or, occasionally, quartz.

PGM have been known in eluvial and alluvial deposits derived from the Freetown Complex for more than 70 years. 0.5 to10 mm grains were extracted from streams draining westwards into the Atlantic (Pollett, 1931; Pollett, 1951). Platinum-iron alloy (with a composition close to Pt3Fe), laurite, erlichmanite and Ir-Os alloys are the most abundant PGM in these deposits (Bowles, 1981) with minor tulameenite, Bowles, 1981. The PGM assemblage within the rocks is substantially different from those found within the weathered profile. Weathering of the intrusion since the Eocene has been under tropical rainforest for at least part of that time and has created a deep laterite with local hard pan. The weathering has also affected those rocks now exposed at the surface leading to alteration of the primary magmatic PGM assemblage predominantly PtS to Pt-Fe alloy.

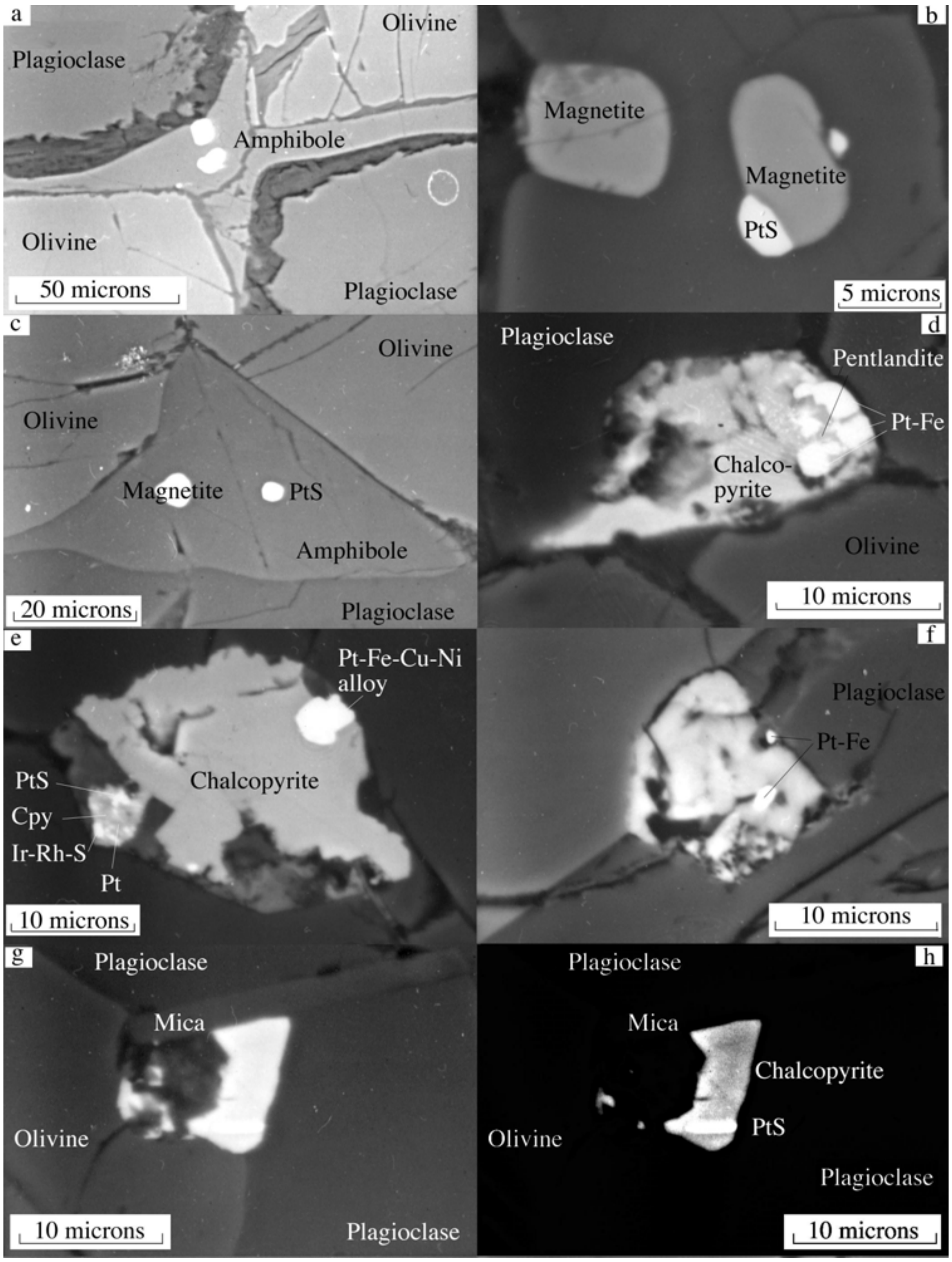

***Figure 1**. SEM images to show the PGM and their host minerals. A0, b), and c) show cooperate in amphibole. B) shows an enlaged area of a) at higher contrast to distinguish the PGM and the oxides. d), e), f), g) and h) show PGM contained within chalcopyrite. h) shows the same area as g) with increased contrast to sistinguish the PGM and the chalcopyrite.*

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