PROCESSES LEADING TO CONCENTRATION OF PLATINUM-GROUP ELEMENTS IN CHROMITE RICH ROCKS

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ABSTRACT. Platinum-group elements are enriched in the ultramafic parts of the Stillwater, Bushveld and Great Dyke Complexes. Processes whereby this enrichment may occur are considered.

It is well established that the ultramafic portions, and in particular the chromite layers, of many layered intrusions are enriched in platinum-group elements (PGE) relative to the amount that can be accounted for by a silicate trapped liquid fraction. Furthermore, the IPGE (Os, Ir, Ru) and Rh show a greater degree of enrichment than Pt and Pd. Two models are currently used to explain these enrichments. The first proposes that chromite crystallization leads to the saturation of the magma in laurite (RuS_2) resulting in the enrichment of Ru (and to a lesser extent Os and Ir, which occur as minor elements in laurite), in chromite layers. Platinum and Pd are added after laurite crystallization by addition of a small amount of base metal sulfide liquid to the chromite layers. The second model proposes that all of the PGE were originally collected on the cumulate pile by a base metal sulfide liquid, with the higher concentration of sulfide liquid in the chromite layers being due to the high density of chromite and sulfide liquid. Later, a hydro-magmatic fluid partly dissolved the base metal sulfides and Pt+Pd, leaving a cumulate enriched in IPGE and Rh. In order to consider these models more closely we have carried out a petrological, mineralogical and geochemical study of the Ultramafic series of the Stillwater Complex.

Based on the following observations the rocks appear to have lost S. The S content of the rocks is too low (<100 ppm) for them to contain cumulate sulfides. Many of the tiny (0.01-0.05 mm) base metal sulfide grains show disequilibrium textures and are rimmed by magnetite. The average S/Se ratio of the rocks is low (~1500). Given that S has been lost we will use Se as a proxy for S. If base metal sulfides collected the PGE then there should be a positive correlation between the PGE and Se. There are correlations between Pd, Cu and Se as illustrated for Pd (Fig. 1a) suggesting sulfide liquid collected these elements. There is no correlation between the IPGE or Rh and Se, as illustrated by Ru vs Se (Fig. 1b). The IPGE and Rh correlate with Cr, illustrated by Ru vs Cr (Fig. 1c). These observations and the platinum-group mineral study which shows that laurite is the most common PGM in the rocks tend to favor model 1.

However, the Rh and Pt data are not consistent with model 1; Neither laurite nor a base metal sulfide liquid has the correct ratios to be the carrier of these elements. The mantle normalized patterns of the chromite layers (G chromite layer illustrated in Fig. 1d) peak at Ru and Rh. The pattern for laurite does not match that of the chromite layers. The laurite does not contain enough Rh. The addition of a base metal sulfide liquid would add more Pt than Rh, therefore simply adding base metal sulfide liquid will not solve the problem. Model 2 might work, but the lack of correlation between IPGE, Rh and Se requires that Se was mobilized. Furthermore to have a correlation between Pd, Cu and Se it requires that they precipitate together which seems rather fortuitous.

We propose a new model based on recent results from lasering chromites from volcanic rocks. Chromites in volcanic rocks appear to contain the IPGE AND Rh within the structure.

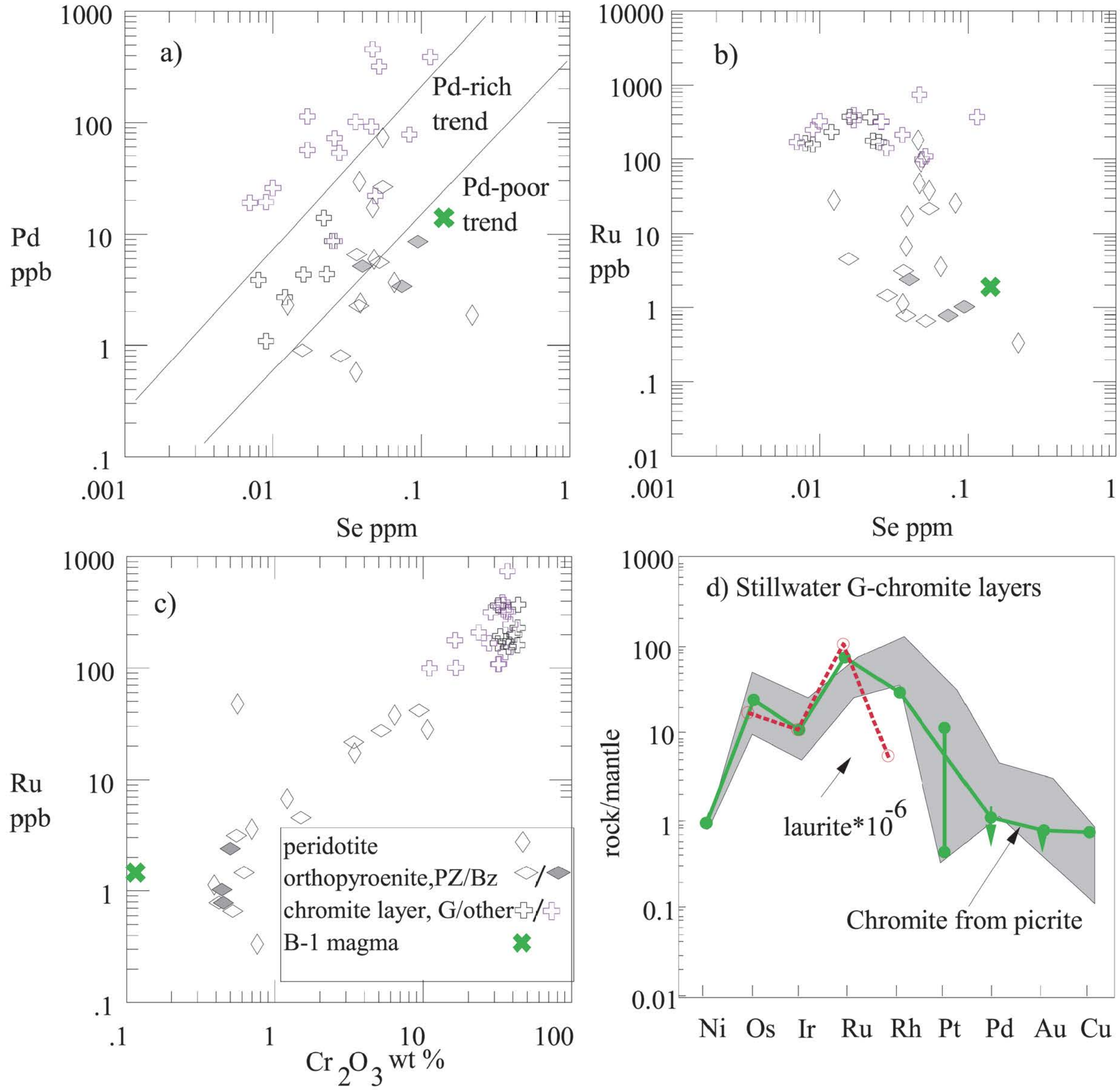

Fig. 1. a) Pd vs Se showing that Pd and Se correlate suggesting collection of Pd and Se by a sulfide liquid; b) Ru vs Se showing that Ru does not correlate with Se suggesting that Ru was not collected by a sulfide liquid; c) Ru vs Cr_2O_3 showing a good correlation suggesting the phase collecting Ru was concentrated in the chromite layers; d) Mantle normalized patterns of the chromite layers, laurite and chromite from picrite (Page et al., 2013) showing that the whole patterns from Stillwater chromite layers most closely resemble the patterns from chromite grains from picrite

The mantle normalized pattern for chromite from a continental picrite (Fig. 1d) is similar to that of the G chromite layer, which is the layer with the greatest enrichment of IPGE and Rh. This model proposes that the IPGE and Rh partitioned into the G chromites at high temperature. The chromite grains underwent grain boundary migration during cooling. Small amounts of base metal sulfide crystallized from the trapped liquid and were incorporated in the chromites during this process. As cooling continued the Fe and Ni in the sulfide diffused into the chromite and the IPGE and Rh in the chromite diffused into the sulfide transforming the base metal sulfide into laurite with remnant sulfides and a few PGM grains. Laurite is the main PGM produced because Ru is the most abundant PGE in the chromite. If this model is correct it would apply to the Bushveld and Great Dyke because the chromite layers in these intrusions show the same types of patterns.

REFERENCES

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