Platinum Group-Minerals in the Gossan from the Key West Cu-Ni-Pt Sulphide Occurrence (Nevada, USA)

/ SAIOA SUÁREZ (1, 2, 3*), HAZEL M. PRICHARD (1), PETER C. FISHER (1), IAIN McDONALD (1)

(1) Dpto. de Mineralogía y Petrología. UPV/EHU, Leioa, Spain.
(2) IKERBASQUE, Basque Foundation for Science, Bilbao, Spain.
(3) School of Earth and Ocean Sciences, Cardiff University, Wales, U.K.

INTRODUCTION

Eluvial deposits including gossans and laterites have long attracted attention as having the potential to be economically viable unconventional platinum group-element (PGE)-deposits (Green & Peck, 2005). However, the mineralogical changes to primary platinum-group minerals (PGM), and the secondary processes that redistribute precious metals in the surface environment are still relatively unexplored.

The weathering of PGE-bearing ores is likely to vary between climatic regions worldwide, affecting the behavior of PGE in supergene conditions and thus, their potential accumulation in valuable surface deposits. In this study we present the preliminary results of the PGE-mineralogy in the gossan capping the Key West Cu-Ni-Pt occurrence, in the desert of southern Nevada (USA). The main objective is to assess how PGM and PGE evolve in gossans developed in these extremely arid regions.

THE KEY WEST DEPOSIT

The Key West occurrence is part of the large Bunkerville Mining District in Clark County, Nevada. Originally known as the "Copper King district" on the west side of the Virgin Mountains, it hosts other commodities including Ni, Pt, Pd, Au, Ag, W, Co, U, Ti, gypsum, Be and mica. Key West is a small Cu-Ni-PGE sulphide deposit (31.000 t at 2.5% Cu, 1.9% Ni, 4 g/t Pt) that was sporadically mined between 1908 and 1953 for Cu and Ni (Tingley, 1989).

Rocks exposed at the Key West mine consist of a belt of Precambrian gneiss and schist that trends northeast and is intruded by both hornblendite dikes and plugs, and by aplite and pegmatite dikes. This belt is bounded by tilted and faulted Paleozoic sedimentary rocks and by overlying sediments composed of typical basin debris.

The ore deposit is associated with a lenticular hornblendite body which follows a steeply dipping fault zone that strikes N65º to 75ºE, parallel to the gneiss structure. Mineralisation occurs as disseminated small patches including chalcopyrite, pyrite, pyrrhotite, millerite, pentlandite and magnetite, with associated Pt and Pd as sulpharsenides and tellurides. Supergene oxidation of the ore is almost complete to a depth of about 12 m and forms a gossan zone grading 2.5% Cu, 1.3% Ni and 2.8 g/t Pt (Carpenter, 1954) composed of rusty rocks covered by a very thin soil (Prichard, 2006).

METHODS

Sixteen samples were collected in 2002 in the Key West pit and nearby trenches. Eight samples belong to the oxidised material from the surface gossan and the rest are fresh samples of cumulate rocks with interstitial sulphides. Samples were analysed for Pt, Pd and Au using fire assay and ICP-MS (Ultra Trace Pty. Ltd. Laboratories, Australia). PGM were searched for and analysed qualitatively in 12 polished blocks using a Veeco FEIXL30 field emission gun environmental scanning electron microscope fitted with an Oxford Instruments INCA energy-dispersive X-ray spectrometer (Cardiff University, UK).

PRELIMINARY RESULTS

The Key West gossan is composed of goethite, hematite, quartz, *limonite*, and Cu- and Ni-rich carbonates and silicates in shear zones. The main accessory phases are PGM, electrum, native Ag, barite, zircon, ilmenite, and secondary Ag-halide minerals (embolite series). Average precious metal contents recorded in weathered samples are 871 ppb Pt, 2612 ppb Pd and 496 ppb Au. The Pt/Pd ratio varies between 0.1 and 1.2 (average of 0.5), with the lowest values in the most oxidised samples.

About 400 PGE-grains have been located in the weathered samples. Most of them are tiny grains that occur in groups close to larger PGM, and only 70 PGE-grains over 5 µm in size have been observed. These occur disseminated in goethite boxwork and at the edges of goethitic or quartz infillings, often concentrated along thin veins filled by late Fe-oxides/oxyhydroxides. More rarely, grains are associated with relic silicates and relic oxides (i.e. ilmenite, magnetite). More than 80 Au-bearing grains have been found spatially related to PGM.

PGE-bearing phases recognised in the Key West gossan are diverse. Most are secondary Pd-, Pt- and Fe-Pd/Pt-rich oxides (62%), and the rest are primary PGM, mainly Ir-PGM, that remain unaltered.

Residual PGM

Irarsite (Ir,Pt,Rh,Ru)AsS is a widespread residual PGM in the gossan (n= 97 grains located). It mainly occurs as equant grains within goethite or quartz, although elongate irarsite in laths is also common. These irarsites are sometimes broken and may appear as subrounded small fragments with corroded edges in goethite. Sizes are variable from less than 1x1 to 15x7 µm.

Accessory inherited PGM are laurite, osarsite and scarce hollingworthite. These phases occur as small grains in goethite and together total 50 grains. Pt-Pd-(Bi)-tellurides are rare and only one relic grain of keithconnite with altered edges was found in goethite. Tellurides occur at the contact between sulphides or associated with magnetite, ilmenite

palabras clave: Key West, Nevada, Sulfuros Cu-Ni-Pt, PGM, Gossan, Óxidos de PGE	*key words:* Key West occurrence, Nevada, Cu-Ni-Pt-sulphides, PGM, Gossan, PGE-bearing oxides

* corresponding author: saioa.suarez@ehu.es

or silicates in the primary sulphide zone, but are rare in the supergene zone.

Secondary PGE-Bearing Phases

Pd-rich oxides (n≈109) are the most abundant PGE-bearing phases in the gossan and can be tentatively divided into the following subgroups according to their composition and textural features:

- (i) Pd-oxides±Te-Bi. These have the highest Pd and Te contents and a common composition similar to X_2O. These occur as relic grains in goethite (≤8x4 μm) and may show a skeleton texture where they have been replaced by quartz. These grains appear to be altered Pd-Bi-tellurides associated with magnetite and ilmenite relicts in the gossan.
- (ii) Pd-Cu-rich oxides. These form a scarce group of grains with a notable Cu content in a composition close to XO_2. These occur as evenly weathered equant and subhedral grains (≤9x5.5 μm) within goethite or along late veins that cross-cut the rocks.
- (iii) Pd-Fe-rich oxides. These are the most abundant Pd-rich oxides with a variable Fe content and a consistant XO_2 composition. The grains with less Fe are smaller (≤9.3x7 μm) and occur within quartz or at the contact between quartz and goethite. Those with more Fe are larger (≤22.5x14 μm) and appear more weathered showing mottled surfaces or highly eroded edges, sometimes outlining C-shapes. These occur within goethite, sometimes along boxwork structures, and randomly distributed within late Fe-oxide-filled veins. There are a few less dense Pd-Fe-oxides (n=8) with a significant Pt content, all distributed within the same thin vein together with the Pd-Cu-oxides.

Pt-rich oxides are sparse (n≈24) and they show a composition similar to XO_2 with significant Fe and traces of Pd and Te. These are small subhedral to anhedral grains (≤6.5x4 μm), often mottled or with serrated edges in goethite. Only one euhedral, mottled Pt-oxide has been located and this occurs at the contact with ilmenite. The majority of the Pt-oxides found occur all together in the same sample, within goethite surrounding relic silicates.

Fe-Pd/Pt-(Cu-Si-Te)-oxides (n≈40) show variable Pd and a lesser Pt content. Those grains with more Pd are subhedral to subrounded (≤9x6 μm) and show strongly oxidised edges (Fig. 1). Grains with more Pt are larger (≤18x6.5 μm) although very scarce (n=4), and occur as anhedral grains in the Fe-oxides.

Commonly PGE- and Fe-oxides in Key West contain variable Cl- and to a lesser extent Br- in their compositions.

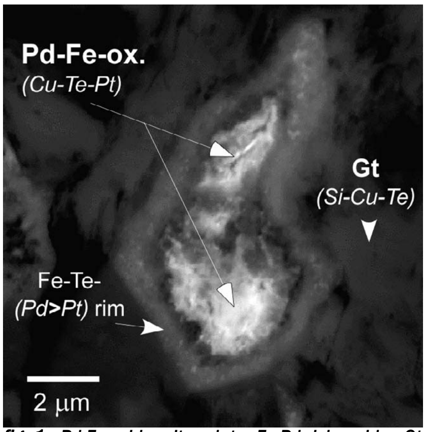

fig 1. Pd-Fe-oxide altered to Fe-Pd-rich oxide. Gt goethite, ox. oxide.

DISCUSSION

The PGM in the Key West gossan show a variable evolution during weathering with Ir-, Os-, Ru- and Rh- minerals much better resisting oxidation than the Pd- and Pt-rich ones. Only one relic primary Pd-PGM has been located whereas Pd-oxides are the chief PGE-bearing minerals in the gossan. In contrast, Pt-rich minerals other than Pt-bearing irarsite are rare, with only a few small Pt-Fe-oxides having been located.

It is known that relatively acidic fluids in supergene conditions, such as the ones originating during oxidation of Ni-Cu-sulphide orebodies, may dissolve Pt and Pd (as well as Au) and transport them most likely in hydroxide- or chloride-complexes (i.e. Wood et al., 1992). Supergene solutions in Key West were probably enriched in chlorine, as revealed both by the presence of halide minerals, and the Cl (±Br) content recorded in the main Fe-oxides and in the secondary PGM in the gossan. However, this transport mechanism is not supported by the observation that no PGE have been recorded in halide minerals themselves. Also, there is no clear evidence for recrystallization of new secondary PGM away from the primary PGM.

It seems that Pd-PGM persist in the gossan and are altered *in situ* to form Pd-rich oxides. The smaller ones are being partially replaced by larger Fe-Pd-oxides, which form a thick rim around grain cores that may act as a local barrier to Pd dispersion (Fig. 1). The Pt-oxides preserved in the gossan have also been mostly altered to Fe-Pt-rich oxides, but these are scarce and occur as deformed grains embedded in the goethite groundmass.

This lack of Pt-PGM in the gossan compared to Pd-PGM is unusual as Pd is typically more remobilised and dispersed than Pt in the surface environment. However, the low Pt/Pd ratios of the weathered rocks as well as the textural and mineralogical features of the PGM in the Key West gossan suggest a different behavior of the main PGE, as has been pointed out already by Prichard (2006). It is possible that a greater mobility than usual of the Pt characterises the PGE exogenic cycle in these very dry regions. In any case, these preliminary observations still need to be checked by laser ablation analysis to compare the dispersion of each PGE more widely in the gossan.

ACKNOWLEDGEMENTS

We thank the Department of Education, Universities and Research of the Basque Government (Refs. IT340-10, BFI-2011-254).

REFERENCES

Carpenter, A. F. (1954): Report on the Key West Mine. Bunkerville Mining District, Clark County, Nevada, 19 p (Unpublished).

Green, T., Peck, D. (2005): PGE Exploration: Economic Considerations and Geological Criteria. In "Exploration for PGE Deposits". Mungall JE (ed). Mineral Assoc Canada. Short Course 35, 247-274;

Prichard, H. M. (2006): Natural and Artificial Platinum and Palladium Occurrences Worldwide. In "Advances in earth science: from earthquakes to global warming". Royal Society Series on Advances in Science. Imperial College Press, London, 273-291.

Tingley, J.V. (1989): Mineral resources of the Overton 30' by 60' quadrangle. Nevada Bureau of Mines and Geology. Report 45, 20 p.

Wood SA, Mountain BW, Pan P (1992): The aqueous geochemistry of Pt, Pd and Au; recent experimental constraints and are-evaluation of theoretical predictions. Can. Mineral., 30, 955–982.