Pre-andean serpentinite-chromite orebodies in the Eastern Cordillera of Central Perú, Tarma province.

Ricardo Castroviejo
Universidad Politécnica de Madrid, ETSI Minas, c/Ríos Rosas, 2, 28003_Madrid (Spain)

Eurico Pereira, José F. Rodrigues
Departamento de Engenharia de Minas, Faculdade de Engenharia da Universidade do Porto, & LNEG, Laboratório Nacional de Energia e Geologia, Portugal

Jorge Acosta
Dirección de Recursos Minerales y Energéticos, INGEMMET, Av. Canadá 1470, San Borja, Lima 41, Perú.

Abstract. Ultramafic rocks occur scattered along a 300 km long NNW-SSE trending belt, lying parallel to the central Peruvian Andean direction in the Cordillera Oriental, from Tarma (Junín Dept.) to Huánuco and Tingo María (Huánuco Dept.). The Tarma occurrences (Tapo and Acobamba) are studied, as first step of a broader research. The Tapo massif comprises strongly tectonised serpentinites with scarce peridotitic relics, amphibolites and podiform chromitites. It is overthrust on the lower carboniferous metasediments of the andean basement (Ambo Group), and it shows evidences of a pre-andean deformational history, not found in the Ambo Group; the basal thrust plane is folded by andean tectonics. The two smaller Acobamba occurrences are also allochtonous and show similar tectonic characteristica. Major and trace element compositions of the amphibolites point to a tholeiitic basalt (to picrobasalt) protolith, compatible with an ocean ridge or ocean island environment. Small scale mining worked podiform chromitite lenses and chromite disseminations, strongly deformed, metamorphosed and overprinted by hydrothermal alteration related to deformation. The ores comprise mainly chromite, ferritchromite, spinel, magnetite, ilmenite and scarce sulphides, as well as the secondary minerals stichtite and nimite. Results of this work exclude current interpretations of the Tarma ultramafites as autochtonous igneous intrusives.

Keywords: Chromite, podiform, Tapo ultramafic massif, amphibolite, Cordillera Oriental Andes.

1 Introduction

The occurrence of ultramafic-mafic rock bodies in the Cordillera Oriental of the Central Peruvian Andes is known for some decades (Grandin and Zegarra Navarro, 1979, and references therein). They were commonly interpreted as sills and laccoliths, and explained by pre-tectonic intrusion of ultrabasic magmas of deep origin in a siliciclastic sequence of probable late Precambrian age, excluding a tectonic emplacement of the material (e.g. Grandin et al., 1977; Grandin and Zegarra Navarro, 1979). The proposed age for these ultramafic-mafic associations is, thus, also Precambrian.

This work points out a new interpretation for these ultramafic-mafic occurrences. They correspond to fragments of an allochtonous nappe emplaced in pre-Andean times over the cordilleran basement, the low grade, neoproterozoic metasedimentary sequence of the Huácar Group, and the palaeozoic deposits of the Ambo Group. Work in progress suggests a similar emplacement, on the *Complejo de Marañón* basement, for the ultramafic occurrences of Huancapallac, Huamalli, Andas, etc. (Huánuco Dept).

The Tapo massif is the most important of these occurrences. It occurs at ~ 3500 to 4100 m absl, near Tapo, Tarma province, and is composed of strongly tectonized serpentinites with scarce peridotitic relics and minor amphibolites (Fig. 1). Chromitite podiform bodies of small size (<100m x 1 m) and local chromite disseminations (Fig. 2 a, b) provided the only Cr source in the country. Production was enhanced by high demand in world war times, but visible operations are limited to small pits in the serpentinites (Fig. 1), although, according to mining reports, high grade chromite was first won from glacial drift and boulders.

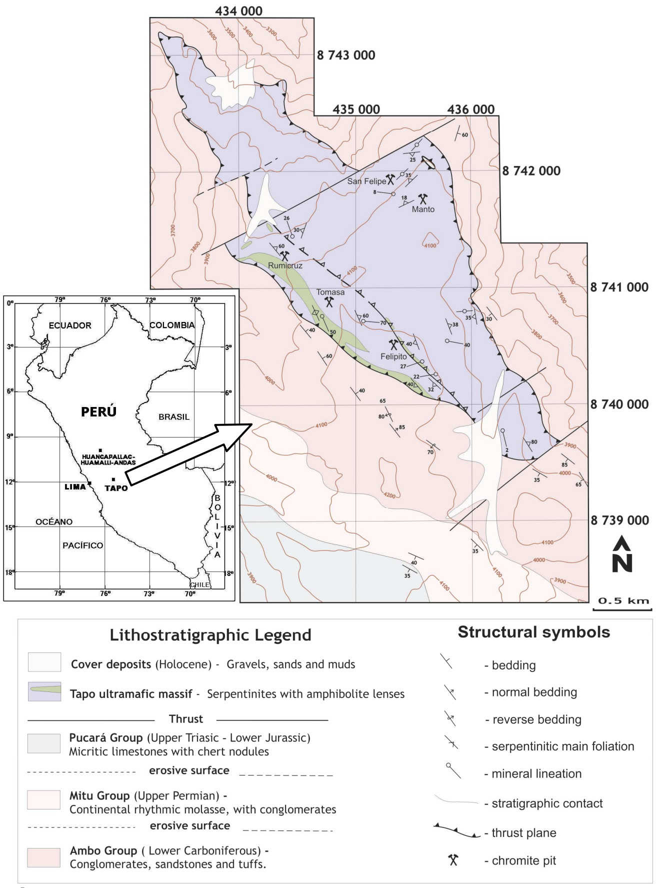

Figure 1. Geology of the Tapo ultramafic massif.

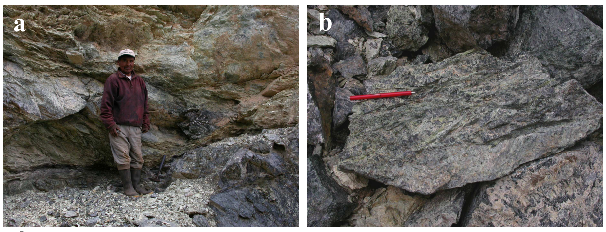

Figure 2. San Felipe mine: a) podiform chromitite lens (hammer), underlying serpentine mylonite; b) dark chromite porphyroclasts in serpentinite, stained by light pink stichtite.

4 Geological and structural setting

The pre-andean basement crops out extensively in the Cordillera Oriental. Some first order stratigraphic and metamorphic discontinuities are recognized following Dalmayrac et al. (1988), whose scheme is adapted to the Tarma region. The oldest unit is a low grade metasedimentary sequence of terrigenous origin with some metavolcanic intercalations (Huácar Group), for which a precambrian (neoproterozoic?) age is assumed (Megard et al., 1996). This unit is overlain unconformably by a lower Palaeozoic marine sequence which represents the sedimentogenesis of the variscan cycle in Peru and which is covered by late Palaeozoic to lower triassic sediments of marine and continental facies: an event of tardi- or post-tectonic variscan sedimentation including the Ambo and the Mitu Groups. The sedimentary sequences of the andean cycle rest upon an erosional surface over the former units (from Precambrian to Upper Paleozoic). In the studied region the Andean cycle begins with an Upper Triassic – Lower Jurassic carbonate sequence (Pucará Group). Recent deposits and intrusive rocks of various ages complete the regional framework.

In the Tarma area, three ultramafic occurrences are known: Tapo, named after the near village E of Tarma, and two small bodies ~7 km NE of Acobamba.

The Acobamba occurrences comprise serpentinites in contact with phyllites of the Huácar Group. The contact is marked by a mylonitic foliation with late cataclasis. This mylonitic foliation post-dates the main penetrative metamorphic foliation in the underlying phyllite sequence, and is folded by the NNW-SSE to N-S folding phase that generates the synformal structures where the serpentinitic rocks crop out. A crenulation cleavage is associated. No signs of thermal metamorphism are observed in the phyllites, but intense silicification may occur locally along the mylonitic contacts.

Interference patterns of this late crenulation cleavage with a vertical axis folding phase related to regional andean strike-slip faults, together with the fact that to the South this same crenulation cleavage is covered by the Upper Permian sediments of the Mitu Group, show clearly that the tectonic emplacement of the ultramafic bodies was pre-andean.

Tapo is the main body of ultramafic rocks (Fig. 1). It comprises serpentinites with minor lenses of amphibolites which lie over the lower carboniferous sandstones, conglomerates, and tuffs of the Ambo Group; these sediments show no signs of thermal metamorphism. The contact shows clear evidences of cataclasis, both in the serpentinites of the hangingwall, and in the Ambo deposits of the footwall. This basal contact, as well as the overlying serpentinites, are folded together with the Ambo sediments by a NW-SE Andean folding phase.

The internal deformation of the ultramafites shows a strongly non-coaxial character that is interpreted as the result of their pre-andean tectonic emplacement. Yet the main foliation transposes another one, observable in microlithons, that should correspond to an older episode of mantelic deformation.

3 Ore Petrology

Most of the ultramafites are totally altered to serpentinites and extremely deformed. Serpentinites and serpentine mylonites are the most common lithology. Peridotitic remnants are scarce and, when found, are usually overprinted by alteration; olivine or pyroxene relics, suggesting dunitic and harzburgitic protoliths, are rarely seen.

Geochemistry has therefore to rely on metabasites. These are often altered as well, but careful mapping allowed to find some useful samples. The metabasites are, when fresh, banded metagabros or hornblende-plagioclase amphibolites with flaser or nematoblastic fabric, sometimes mylonitic. They represent basaltic to picrobasaltic protoliths, and show a tholeiitic affiliation (Figs. 3 a, b) and a flat REE spider diagram, with a slight LREE depletion and a positive Eu anomaly suggesting magmatic accumulation of plagioclase, in an ocean ridge or ocean island environment (Figs. 3 c, d).

Strong hydrothermal overprint and leaching of most trace elements, enhanced by dynamometamorphism, prevents further definition of the protoliths. Resulting petrographic types are varied (chlorite or chlorite-serpentine schists, mylonites or blastomylonites, garnet-epidote granofelses, etc: Fig. 4a), and include peculiar rock remnants with skarn mineralogy (garnet, zoisite, epidote, wollastonite, chlorite, albite, titanite, tremolite, etc.). Field relations are obscured by extreme deformation, and tectonic transposition of the contacts masks the original geometry.

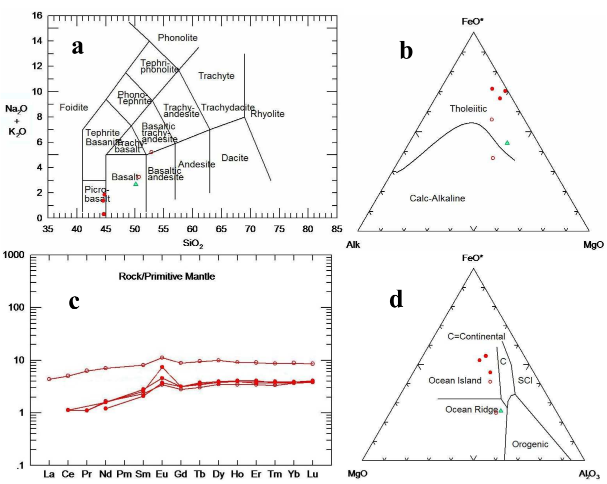

Figure 3. Metabasite projections, diagrams: a) TAS, LeMaitre et al, 1989; b) Alk-Fe0*-MgO, Irvine & Baragar, 1971; c) REE spider, Palme & O'Neil, 2004; d) Al_2O_3-Fe0*-MgO, Pearce et al, 1977.

Extreme metasomatism of the ultramafites produces locally silica and carbonate-silica hydrothermalites, birbirites and listvaenites, due to hydrothermal fluid circulation enhanced along thrusts and faults. These fluids may concentrate gold and PGE (Castroviejo et al., 2004, Proenza, 2004), but the Tapo analytical results to date show only a slight enrichment in Au (up to 6 ppb) and in Pt and Pd (up to 5 ppb) in altered rocks, while PGE contents in chromitites are up to 30 ppb Ir, 29 ppb Os, 4 ppb Pd, 12 ppb Pt, 4 ppb Rh, 69 ppt Ru, and < 5 ppb Au.

Chromite ores occur as small podiform chromitite lenses and disseminated in chromite serpentinites throughout the massif (Fig. 4b). Both types show a relatively simple primary mineralogy (chromite, magnetite; traces of pyrite, as minute inclusions), later modified by metamorphism and metasomatism (e.g. replacement of chromite by ilmenite). Conspicuous cataclasis and metamorphic zoning (with chromite cores and magnetite / spinel rims) are observed in the chromite ores. No PGM were found, as expected from the low #Cr composition of these chromites and from their possible ocean ridge environment (Proenza, 2004). Metamorphism of the chromite ores is subject to further research, and detailed microprobe study by Fanlo et al., 2009, shows amphibolite and relic greenschist facies.

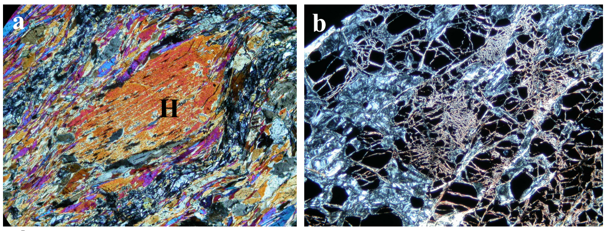

Figure 4. a) Hornblende fish (H) in amphibolitic blastomylonite (length of photomicrograph 1,5 mm, XN, sample 090606.2); b) Chromite cataclasite (black) partially altered to stichtite (pink), with interstitial antigorite, bluish (length of photomicrograph 6 mm, XN, sample 090606.62).

4 Discussion and conclusions

In spite of the very strong tectonic and hydrothermal overprints, the essential features of the Tarma ultramafites allow to establish some basic facts about their origin, and to exclude some previous hypothesis.

The existence of a strong shear deformation with mylonites and phyllonites associated to the basal contact of the ultramafites with the siliciclastic sequences of the basement (either Huácar or Ambo Groups), and the absence of any evidence of thermal metamorphism show clearly the allochtonous character of the ultramafic bodies and preclude the hypothesis of ultrabasic magma intrusion in these sequences. The interference patterns on the mylonites of these contacts point to a pre-Andean emplacement, followed by late tectonic reworking during the Andean cycle, and relict internal features in the ultramafites withness a previous deformational history not found in the footwall rocks.

The chromite ores are of the podiform type, and do not correspond to the stratified concentrations typical of intrusions. Moreover metabasite geochemistry suggests an ocean ridge or an ocean island protolith, of basaltic to picro-basaltic composition and tholeiitic affiliation.

The orebodies are totally dismembered by post-mineral dynamic metamorphism, and even the original relationships of the mafic and ultramafic rocks are obliterated or transposed. The age of the ultramafites could not be established either, since the contacts with the underlying formations are thrust faults, but they are certainly pre-andean as shown -absolute dating of the scarce fresh rocks is in progress. Metamorphic and hydrothermal fluids did not mobilize significant amounts of precious metals (gold, PGE), which are scarce as expected from a ridge environment. Yet chromite ores show conspicuous metamorphic zoning and fine compositional readjustments.

Acknowledgements

This work has been funded by Universidad Politécnica de Madrid through the projects AL06PID0010, AL07PID027 & AL08PID25. Support by Dr. H. Chirif, Director of Recursos Minerales, D. Romero, and J. Quispe, INGEMMET, by Dr. R. Carrascal, UNI, Lima, and by the company REPSA, Peru, is gratefully acknowledged, as well as by Dr. F. Bellido, IGME, Madrid, for discussion of the geochemical data.

References

Castroviejo R, Moreno T, Prichard H, Fallick AE (2004) Metalogenia de las ofiolitas de Galicia y unidades asociadas (NW del Macizo Ibérico, España). In: Pereira E., Castroviejo R., Ortiz F. (eds, 2004) Complejos Ofiolíticos en Iberoamérica, Proyecto XIII.1_CYTED, Madrid, p. 231-266.

Dalmayrac B, Laubacher G, Marocco R (1988) Caracteres Generales de la evolución geológica de los Andes Peruanos. INGEMMET, Estudios Especiales, Bol. 12, 313 pp.

Fanlo I, Gervilla F, Castroviejo R, Rodrigues JF, Acosta J, Pereira E, Uribe R (2009) Metamorphism of chromitites in the Tapo ultramafic massif, Eastern Cordillera, Peru. 10th Biennial SGA Meeting, Townsville, Australia (subm.).

Grandin G, Aumaitre R, Huaman A, Vilca C (1977) Exploración por rocas ultrabásicas en la Cordillera Oriental. Acción Conjunta ORSTOM-INGEOMIN, Informe Final, tercera parte, Lima, Perú.

Grandin G, Zegarra Navarro J (1979) Las rocas ultrabásicas en el Perú: Las intrusiones lenticulares y los sills de la región Huánuco – Monzon. Bol. Soc. Geol. Peru, 63: 99 – 115.

Irvine TN, Baragar WRA (1971) A guide to the chemical classification of the common volcanic rocks. Can. J. Earth Sci., 8: 523-548.

Le Maitre RW, Bateman P, Dudek A, Keller J, Lameyre P, Le Bas MJ, Sabine PA, Schmid R, Sorensen H, Streckeisen A, Woolley AR, Zanettin B (1989) A classification of igneous rocks and glossary of terms. Blackwell, Oxford.

Megard F, Caldas J, Paredes VJ, Cruz N (1996) Geología de los cuadrángulos de Tarma, La Oroya y Yauyos (Memoria). Bol. Nº 69 serie A, INGEMMET, Lima, 227 p.

Palme H, O'Neill HC (2004) Cosmochemical Estimates of Mantle Composition. Pp 1-38, in: Carlson RW, ed. The Mantle and Core. Vol 2, Treatise on Geochemistry (Holland HD, Turekian KK, eds.). Elsevier-Pergamon, Oxford.

Pearce TH, Gorman BE, Birkett TC (1977) The relationship between major element chemistry and tectonic environment of basic and intermediate volcanic rock. E.P.S.L., 36:121-132.

Proenza J (2004) Principales guías de exploración de metales preciosos (EGP y oro) en complejos ofiolíticos. In: Pereira E, Castroviejo R, Ortiz F (eds, 2004) Complejos Ofiolíticos en Iberoamérica, Proyecto XIII.1_CYTED, Madrid, p.359-372.