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NEOPROTEROZOIC ULTRAMAFIC AND MAFIC MAGMATISM IN THE EASTERN CORDILLERA OF THE CENTRAL PERUVIAN ANDES: THE TAPO MASSIF

Colombo C. G. Tassinari[1]; Ricardo Castroviejo[2]; Jose F. Rodrigues[3],
Jorge Acosta[4] and Eurico Pereira[3]

1- Instituto de Geociências da Universidade de São Paulo, Rua do Lago 562, Cidade Universitaria, São Paulo, Brasil, CEP 05508-080; ccgtassi@usp.br
2- Universidad Politecnica de Madrid. E.T.S. Ing. Minas, c/Ríos Rosas 21, 28003_Madrid, Spain; ricardo.castroviejo@upm.es
3- Fac. Engenharia Univ. Porto (FEUP), r/ Dr. Roberto Frias s/n 4200-465 Porto, Portugal; , felic@fe.up.pt, euricosousap@gmail.com
4- Instituto Geológico Minero y Metalúrgico. Dirección de Recursos Minerales y Energéticos. Av. Canadá 1470. Lima 41- Perú; jacosta@ingemmet.gob.pe.

INTRODUCTION

A highly dismembered assemblage of ultramafic and mafic rocks is exposed in the Eastern Cordillera of the Central Peruvian Andes, extending along a discontinuous NW-SE belt over some 250 km between 12° and 9° S of latitude. One of the most important occurrences is the Tapo Mafic-Ultramafic Complex, which occurs at 3750 to 4200 m above sea level, 2 km to the west of Tapo locality, in the Tarma province, about 200 Km west of Lima.
The Tapo complex is a lens-shaped body, 5 km long and 1-2 km wide, that consists mainly of strongly serpentinized peridotites and some gabbros. Several small open pits won chromite from podiform chromitite lenses (≥ 60% chromite) and from disseminated chromite in serpentinite. The main structural trend of the Tapo Complex is NW – SE and the massif is tectonically emplaced upon Lower Carboniferous sedimentary rocks. The rocks of the Tapo massif are overprinted by metamorphism reaching amphibolite facies (see Willner et al, 2010, for more information on the metamorphic conditions).
The main purpose of this work is to constrain the age determination of the Tapo Complex, using Sm-Nd technique direct dating of chromites and, also, amphibole, plagioclase and whole-rock samples from the host gabbro. In addition K-Ar age determination on amphibole is presented to date the metamorphic overprint.

GEOLOGICAL SETTING AND SAMPLING

The ultramafic–mafic rocks of the Tapo Complex comprise serpentinized peridotites and metabasites with some podiform chromitite lenses and chromite disseminations. These rocks 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

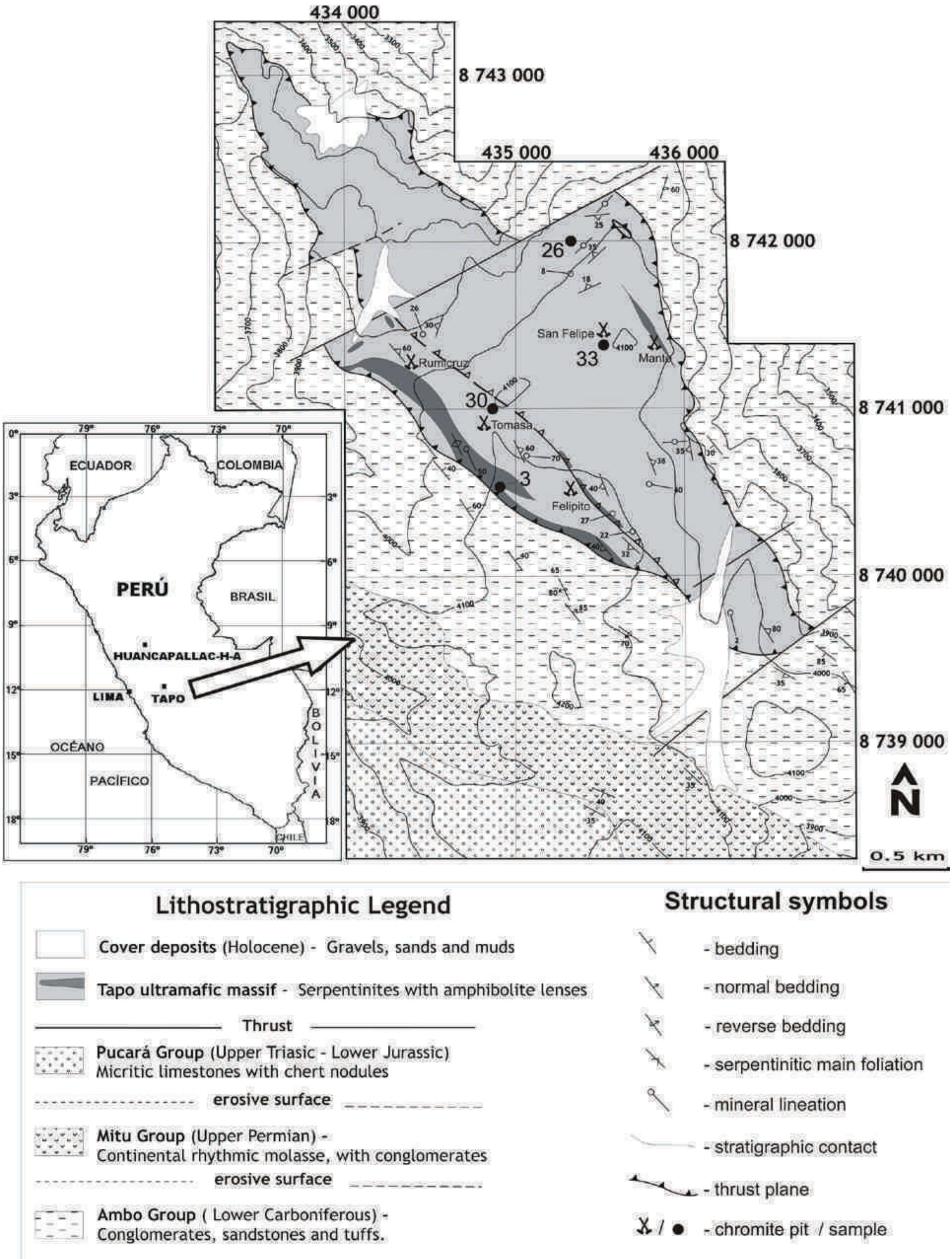

Fig. 1.- Geological map of the Tapo massif, with location of samples analysed.

microlithons that should correspond to an older episode of mantelic deformation (Castroviejo et al., 2009). Most of the ultramafites are totally altered to serpentinites and extremely deformed. Sheared serpentinites and serpentine mylonites are the most common lithology. Peridotitic remnants are scarce and, when found,

are usually overprinted by serpentinisation; olivine or pyroxene relics, suggesting dunitic and harzburgitic or lherzolitic protoliths, are rarely seen.
The metabasites are, when fresh, banded metagabbros or hornblende-plagioclase amphibolites with flaser or nematoblastic fabric, often brecciated and sometimes mylonitic. They represent basaltic to picrobasaltic protoliths, and show a tholeiitic affiliation. 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. Resulting petrographic types are varied (chlorite or chlorite-serpentine schists, mylonites or blastomylonites, amphibole-chlorite-serpentine-titanite schists and breccias, garnet-epidote granofelses, etc.), and include rodingites or gabbro-derived metasomatic rocks with a peculiar calc-silicate mineralogy (grossular, zoisite, epidote, wollastonite, titanite, tremolite) as well as chlorite ± albite, ilmenite and relic pyroxene / plagioclase. Chromite ores occur as small podiform chromitite lenses and disseminated in chromite serpentinites throughout the massif. Both types show a relatively simple primary mineralogy (chromite, magnetite; traces of pyrite, as minute inclusions), later modified by metamorphism and metasomatism.
Due to the widespread metamorphic and/or metasomatic overprint, enhanced by deformation, the identification of reliable rock samples to date the protoliths has been a difficult task, requiring several field campaigns. Most of the original olivine and pyroxene disappeared, but some relatively fresh samples of chromitite or chromite rich serpentinite and of meta-gabbro or amphibolite could be found which, after careful petrographic survey and mineral processing, proved adequate (location in Fig. 1).

GEOCHRONOLOGICAL RESULTS

In order to characterize the age of the Tapo mafic-ultramafic complex, six Sm-Nd analyses were performed on chromite and on whole-rock, plagioclase and amphibole from the associated gabbro. The two groups (chromite and separated minerals from the gabbro) overlap in $^{147}Sm/^{144}Nd$ and $^{143}Nd/^{144}Nd$ ratios, and together both define a line on Sm-Nd isochronic diagram, with slope that corresponds to an age of 677 ± 59 Ma with an initial $^{143}Nd/^{144}Nd$ of 0.512185 ± 0.00008 and MSWD value of 1.5. The defined age is interpreted as the age of the chromites and associated gabbro crystallization.
The ε_{Nd} values, calculated for 670 Ma, for both chromite and gabbro whole-rock samples, are in close agreement and show a narrow range of values between + 7.7 and + 8.3. Such a positive ε_{Nd} values suggest that Nd was derived from the depleted mantle and both, chromite and host gabbro, were formed at the same time from the same magma source, which indicate that the chromitite pods have a magmatic origin.
The K-Ar analysis performed on amphibole sample from metamorphosed gabbro yield an age of 448 ± 26 Ma. This result can be interpreted as the cooling age, indicating that temperature dropped below 500°C at upper ordovician times, just after the metamorphic peak of the overprint event that reach the amphibolite facies.

DISCUSSION AND CONCLUSIONS

Based on the regional geochronological pattern established for the Eastern Cordillera (Chew et. al. 2007; Cardona et. al. 2006 and Dalmayrac et. al. 1980) and on our geochemical results, the Sm-Nd isochronic age of 677 ± 59 Ma defined for the gabbro and associated chromite of the Tapo Complex could be interpreted as the age of production of oceanic lithosphere, near the NW margin of Amazonia. This interpretation appears as the only reasonable to explain the geochemical character of the Tapo protoliths as oceanic crust and, also, the allochtonous character of the massif as well. It implies local rifting related to some regional extensional event and a subsequent closure and accretion of the newly generated crust to the continental margin, as is typical of ophiolites. The new K-Ar age of 448 ± 26 Ma could be related to the cooling of the medium to high grade metamorphic episode dated back at 484 – 474 Ma by Chew et. al. (2007) in the Eastern Cordillera or represent the cooling at 500 °C, very close to metamorphic peak, of another younger orogenic event.
Tp conclude, our new Sm-Nd data indicate that the Tapo Mafic-Ultramafic magmas seem to have crystallized at about 680 Ma. and it is suggested that both gabbro and chromite are contemporaneous and they were derived from the same mantelic source. The K-Ar geochronology shows that the Tapo Complex was affected by an Ordovician metamorphic episode, which reached the amphibolite facies; cooling below 500º C occurred at ca. 450 Ma (late Ordovician).

Despite of the lack of more complete geochronological pattern, some fundamental facts related to the evolution of the central Peruvian Eastern Cordillera can already be established:

- as a consequence of pre-cambrian rifting probably related to the early stages of rodinian break-up, ca. 680 Ma, oceanic lithosphere was generated near the NW Amazonian craton, pre-andean margin;
- some slices of this newly formed crust including podiform chromitite bodies were accreted as ophiolites, involved in the Famatinian or Terra Australis Orogen and subject to metamorphism in middle ordovician times (up to 450 Ma);
- fragments of this oceanic lithosphere were subsequently overthrust on upper paleozoic sequences of the pre-andean amazonian margin, and incorporated to the andean orogen.

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