Boletin de la Sociedad Geologica del Perú

journal homepage: www.sgp.org.pe ISSN 0079-1091

Transtensional events, subidence, subaqueous volcanism and magmatism of the Chilca Formation (Casma Group) in the Rio Cañete Basin: "The marginal basin that never was"

Antenor M. Aleman, [1]. and Walther Leon[2]

(1) PG Services, Ecuador. (antenor.aleman@gpgservicesec.com, amaleman@gmail.com)

(2) SG-GEOANDES, Calle Godofredo García Díaz 190, Ofic. 203, Surco. (wleon@sg-geoandes.com wleonlecaros@hotmail.com)

During most of the Mesozoic, the western margin of Gondwana has undergone steady oblique convergence and rapid underplating of the Farallon Plate. As a result, the Peruvian margin underwent significant strain partitioning and development of trench parallel strike slip coeval with pervasive large scale transtension. Indeed, this relentless regional transtension was of paramount importance not only in allowing higher subsidence and developing of discrete depocenters for deposition of the Casma Group (CG), but also in establishing the space needed for the emplacement of the Coastal Batholith. The Chilca Formation (Casma Group) in the Rio Cañete Basin (RCB) is often overwhelmed by ash fall tuffs and tuffaceous and it is interbedded with sheet lava flows and lapilli tuffs and sparse limestones and pyroclastic breccias deposited in elongated grabens during active transtension. However, this basin lacks the ubiquitous and abundant thick bedded basaltic pillow and sheet lavas, hyaloclastic breccias and dyke sequences described in the Huarmey Basin that mirrors back-arc facies. The scarcity of these lithologies in the RCB can be explained either because of slightly deeper Moho than in the Huarmey Basin, of variable enriched and heterogeneous mantle wedge, or the absence of hot fingers in the mantle wedge. While early studies in the Huarmey and Rio Cañete Basin suggested a marginal basin type similar to the Western Pacific ones, new geochemical data supports a continental arc emplaced in a thinned crust (crustal boudinage) characterized by higher fluid and degree of melting during mantle enrichment associated with deep subduction components.

INTRODUCTION

Bosc (1963) used the name Chilca Formation to describe a sequence of limestones, shales and sandstones that is overlain the Pamplona Formation. However, Salazar, 1968, separated this calcareous unit as the Atocongo Formation, and used the Chilca Formation to describe the volcanic sequence overlain this carbonate unit. Indeed, the Chilca Formation, along the Quebrada Huigueras, is overlain the Atocongo Formation which is partially covered by dunes. This unit consists of mainly of thinly laminated ash fall tuffs and tuffaceous shales interbedded with sheeted lava flows and graded lapilli tuffs with occasional limestones beds and pyroclastic breccias (Fig. 1). This unit has been correlated with the Casma Group (Salazar, 1993; Aleman et al. 2004) described in the Huarmey area (Trottereau and Ortiz, 1963; Myers, 1974; Guevara, 1980; and Atherton and Webb, 1989). The rapid facies changes in time and space are the result of syn-extensional depositional process, and changes in volcanism style and also accounts for the proliferation of stratigraphic names. Indeed, the type locality of the Casma Group has been subdivided in six stratigraphic units with a composite thickness of 6600 meters (Myers,

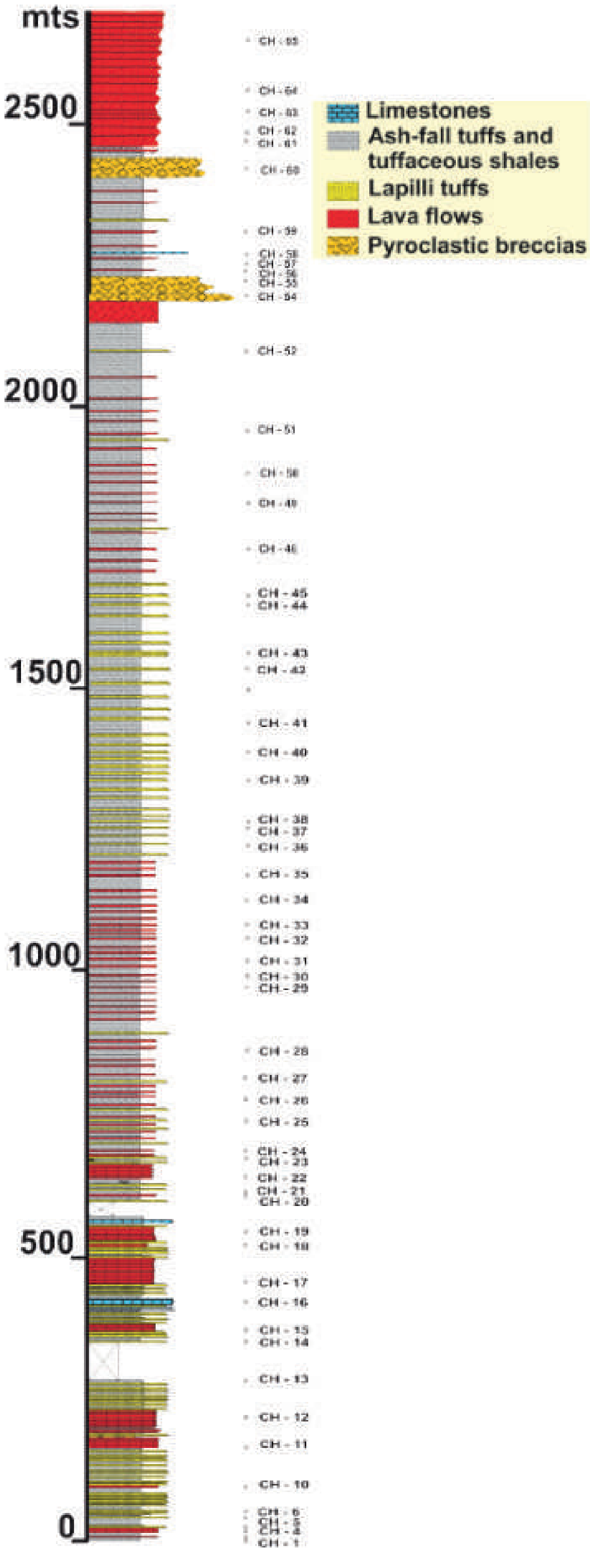

Fig. 1. Stratigraphic column of the Chilca Formation along the Quebrada Huigueras

1980); however, the usefulness of this subdivision is still being evaluated.

The Chilca Formation is overlain by the Atocongo Formation and this contact is well displayed in the Cerro Perico, south of the Condestable Mine and in the Hacienda Imperial near Cañete, and near Trapiche along the Chillon River (Aleman, 1996; Aleman et al, 2004). Indeed, the easternmost facies of the “Chilca Formation” in this locality is overwhelmed by lava flows as well as pyroclastic breccias and lapilli tuffs. Likewise, it is important to point out the presence of more than 30 meters of thick pillow lavas along the Quebrada Pucara, near Lurin. We interpret this odd outcrop as the result of much localized fissure volcanism.

THE QUILAMANA FORMATION AND THE MAASTRICHTIAN VOLCANISM

Another uncommon sequence of massive lava flows interbedded with thinly laminated ash tuffs and graded lapilli tuffs that changes upward to almost a tick bedded sequence of pyroclastic and hyaloclastic breccias of the Quilmana Formation is correlated with the Chilca Formation. Along the Mala River, this unit is folded and overlying by about 1000 meters of flat-lying basaltic flows that has been isotopically dated in 67.8 Ma (Noble et al, 2005) and mapped by Palacios et al (1992) within the Casma Group. This confirmed the K/Ar ages from sericites documented earlier by Vidal (1987). Similar concordat U-Pb ages ranging from 67.89 Ma to 69.71 Ma has been reported from a volcaniclastic sequence and crosscutting intrusives by Polliand et al. (2005). The Maastrichtian age volcanism is uncormably overlain the Casma Group (Noble et al, 2005) and suggest that protracted volcanism and extension continued into the Late Cretaceous interrupted by a short lived contractional event as implied by the folded underlain Quilmana Formation. This Late Cretaceous, perhaps suggest a reactivation of the old Tapacocha Fault which has been identified eastward of the Perubar mine.

TRANSTENSIONAL TECTONICS, AND BASIN DEVELOPMENT COEVAL WITH CRUSTAL BOUDINAGE

Integration of seafloor spreading data, absolute hotspot motion for the last 100 million years and corrected paleomagnetic data for 200 to 100 Ma, have provided a very robust global plate motions (Morra et al, 2013). This study have corroborated the protracted Mesozoic oblique subduction and convergence rate of the Farallon Plate under the South America Plate accounts for strong strain partitioning and development of trench parallel strike slip faults (Myers, 1975; Soler, 1991). The development of this shear couple postulated by

Myers (1975) was of paramount importance and responsible for the development and compartmentalization of a deep subsiding basin as well as the space needed for the emplacement of the Coastal Batholith. Mesozoic transtension has been documented during Jurassic in the south as well as in Lima (Aleman et al, 2004) base in rapid thickness and facies changes. In the Lima area, there are quartz grains with silica overgrowths in the lapilli tuffs at the base of the Chilca Formation in the Perico Hill. This is not a local event, since we had also documented reworked quartz grains, south of Lima, near the top of the Chilca Formation in the Quebrada Huayuri west of the Santa Cruz village. Undeniably, U/Pb and Sr isotopic data for the Coastal batholith, (Mukasa, Soler, 1991), zircon initial Hf isotope values as well the absence of inherited cores in detrital zircons (Polliand, 2005) strongly suggest the lack of old basement under the basins formed between this shear couple known as the Western Peruvian Trough (WPT). Geochemical data also suggest the presence of primitive basalts with N-MORB and OIB affinities in the normalized chondrite diagrams (Fig. 2) and higher fluid and degree of melting during mantle enrichment associated with deep subduction components. Thus, integration of geochemical and isotope data strongly suggest crustal hyper-extension boudinage during the protracted Mesozoic transtension. The narrow, localized transtension between the Tapacocha shear in the east and the Paracas shear in the west, caused mantle upwelling and because of narrowness of the basin, the basement underwent pervasive boudinage that permitted the tapping of the mantle throughout the extensional faults and the necking of the crust. This hyper crustal extension could also explain no only the separation of the Precambrian Maranon Block in the east from the Outer Shelf High in the west, but also the mantle affinities of the Casma Group volcanic rocks. Furthermore, the distinctive volcaniclastic facies of the Huarmey and Rio Cañete basins might be related to the presence of hot fingers in the mantle wedge (Tamura et al, 2002), shallower mantle depth (Fig. 2), or heterogeneous mantle wedge, which caused more effusive volcanism in the northern basin.

MAGMATISM AND TECTONICS: PRIMITIVE ARC MAGMA DIVERSITY

The volcaniclastic sequence of the Chilca Formation in the classical classification diagrams have a wide spectrum of lithologies from Picrobasals and tephrite basanites to dacites and trachydacites with the bulk of lithologies between basalts and andesites (Le Bas et al, 1988). It is even worse in the AFM plot where the rocks are both tholeiitic and calc-alkaline series. This is because the use of mobile elements such as the total alkali-silica, iron enrichment, or K2O, or silica content diagrams that often distinguishes primate from more evolved rock types, LILE enrichment or degree of differentiation. However, other alternative diagrams that use immobile elements are more robust and help to classify the Chilca Formation rocks within a narrower range (Fig. 3). Although we have used Le Bas classification to understand the silica differentiated rocks, the basalts and andesites s.s. of the Chilca Formation are mainly N-MORB and Volcanic arc basalts (Fig. 4), with strong calc-alkaline character in Wood (1980) and Cabanis and Lecolle (1989).

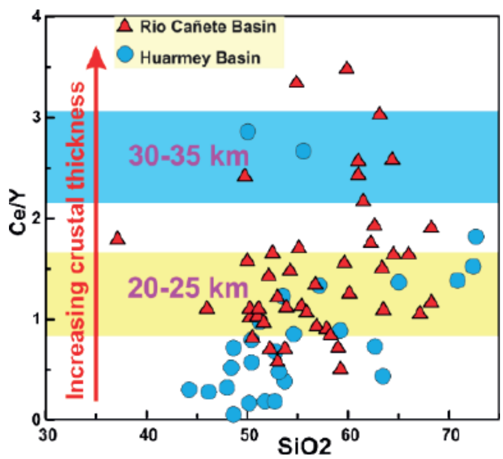

Fig.2. SiO2 vs Ce-Y diagram to illustrate the shallower moho depth in the Huarmey Basin

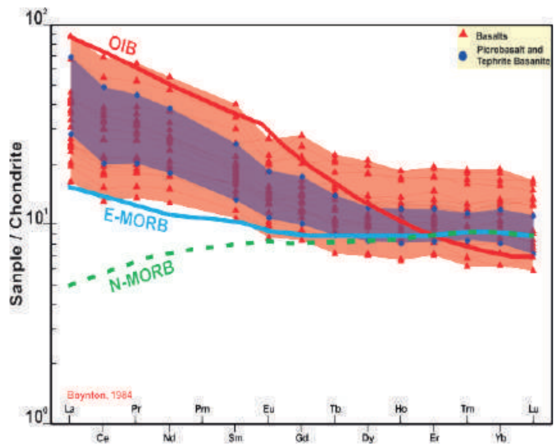

Fig.3. Chondrite normalized diagram of basic rocks from the Chilca Formation compared with OIB, E-MORB and N-MORB (Boynton. 1984)

There are incontrovertible evidences that hyper-extensional processes had a critical role in their generation and evolution of magmatism. New interpretation refinement supports and elucidates the significant contribution from subduction process that was previously questioned (Petford and Atherton, 1995). Indeed, while the consistent increase in the Th/Nb ratio suggest a deep subduction component the sudden Ba/Nb increase indicates also a shallow subduction component without crustal contamination. REEE and trace element ratios analysis also suggest strong amphibole fractionation and differentiation, variable enriched mantle wedge, and striking subduction enrichment with both strong slab melt and fluid component signature similar to those cocummented in the Mariana Arc (Shuto et al, 2015). The variable La/Ta and Ba/La ratios and the lack of relationship suggest variable asthenosphere wedge volume in time and space (Goss et al, 2013) and perhaps protracted increase of crustal thinning.

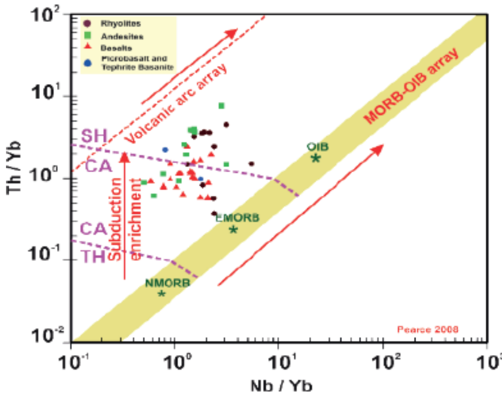

Fig.4. Nb/Yb vs Th/Yb ratios (Pearce, 2008) that depicts the calc-alkaline to shoshonite nature of the Chilca Formation rocks with significant subduction enrichment.

CONCLUSSIONS

The Chilca Formation in the Rio Cañete Basin was deposited in a hyper extended basin formed during the motion of a shear coupe developed during oblique convergence. In spite of their chondrite patterns that vary from EMORB and OIB, this volcanic sequence never developed as a marginal basin. Instead, new diagrams strongly support a significant contribution from deep and shallow subduction melts.

REFERENCES

ALEMAN, A. (1996). - Stratigraphy, Sedimentology and Tectonic Evolution of the Rio Cañete Basin: Central Coastal Ranges of Peru, U, Third ISAG, 261-264.

ALEMÁN, A., BENAVIDES, V. & LEÓN, W (2004). - Excursión Geológica, Estratigrafía, Sedimentología y Evolución Tectónica del Área de Lima. Soc. Geol. Perú. Guía de Campo, 95p.

ATHERTON AND WEBB S. (1989). – Volcanic facies, structure, and geochemistry of the marginal basin rocks of central Peru. Journal of South American Earth Sciences, vol. 2, n. 3, pp. 241-261.

BOSC E. (1963). - Geología de la región comprendida entre la Quebrada de Parca (Chilca) y el Valle de Mala, Tesis U.N.M San Marcos.

CABANIS, B. & LECOLLE, M. (1989). Le diagramme La/10-Y/15-Nb/8: un outil pour la discrimination des séries volcaniques et la mise en évidence des processus de mélange et/ou de contamination crustale. Comptes rendus de l'Académie des sciences.Série 2, 309, 2023–2029.

GOSS, ADAM R.; KAY, SUZANNE MAHLBURG; MPODOZIS M., CONSTANTINO (2013). - Andean adakite-like high-Mg andesites on the northern margin of the Chilean-Pampean flat-slab (27-28·5°S) associated with frontal arc migration and fore-arc subduction erosion. Journal of Petrology, vol. 54, n. 11, pp. 2193-2234, November 2013.

GUEVARA C. (1980). - El Grupo Casma del Perú Central entre Trujillo y Mala. Sociedad Geológica del Perú. Boletín, n. 67, pp. 73-83, diciembre 1980.

MORRA, G., SETON, M., QUEVEDO, L., MÜLLER, R.D. (2013). - Organization of the tectonic plates in the last 200 Myr. Earth Planet. Sci. Lett. 373, pp. 93–101.

MUKASA S. (1986).- Common Pb isotopic compositions of the Lima, Arequipa and Toquepala segments in the Coastal batholith, Peru: Implications for magmagenesis. Geochimica et Cosmochimica Acta, vol. 50, n. 5, pp. 771-782, May 1986.

MYERS, J.S. (1975). - Vertical crustal movements of theAndes in Peru. *Nature,* 254,672-674.

MYERS J. (1974). - Cretaceous stratigraphy and structure, Western Andes of Peru between latitudes 10-ao 30, Bull Amer. Ass. Petr. Geol. 58, 474-487.

MYERS J. (1980).- Geología de los cuadrángulos de Huarmey y Huayllapampa, Hojas 21-g y 21-h. Ingemmet. Boletín. Serie A: Carta Geológica Nacional, vol. 33, 153 p., 1980.

NOBLE, D., RIOS, A., VIDAL, C., SPELL, T., ZANETTI, K., ANGELES, C., OCHOA, J. Y CRUZ, S. (2005): Late Cretaceous basalt in the rio Mala valley, central Perú: Evidence for extensión and mafic amgmatism prior to Latest Cretaceous-Paleocene plutonism and silicic volcanism. Soc. Geol Peru, 141-148.Palacios et al (1992)

PALACIOS MONCAYO, OSCAR; CALDAS VIDAL, JULIO; VELA VELÁSQUEZ, CHURCHILL (1992). - Geología de los cuadrángulos de Lima, Lurín, Chancay y Chosica; hojas 25-i, 25-j, 24-i, 24-j. Ingemmet, Boletín. Serie A: Carta Geológica Nacional, n. 43, 163 p.

PETFORD, N. AND ATHERTON, M. 1995). Cretaceous-Tertiary volcanism and syn-subduction crustal extension in northern central Peru, in Smellie, J.L. (ed.), 1995 *Volcanism Associated with Extension at Consuming Plate Margins,* Geological Society Special Publication No. 81,233-248.

POLLIAND, M., SCHALTEGGER, U., FRANK, M. Y FONTBOTE, L. (2005): Formation of Intra-arc volcanosedimentary basins in the western flank of the central Peruvian Andes during Late Cretaceous oblique subduction: field evidence and constraints from U-Pb ages and Hf isotopes. Int. Jour. Geol. 94: 231 – 242.

SALAZAR H. (1993). - Geología de los cuadrángulos de Mala, Lunahuaná, Tupe, Conayca, Chincha, Tantarà y Castrovirreyna. Ingemmet. Boletín. Serie A: Carta Geológica Nacional, vol. 44, 96 p.

SHUTOI K, R. NOHARA-IMANAKA, M. SATO, T. TAKAHASHI, E. TAKAZAWA, H. KAWABATA, K. TAKANASHI, M. BAN, N. WATANABE AND N. FUJIBAYASHI (2015). - Across-arc Variations in Geochemistry of Oligocene to Quaternary Basalts from the NE Japan Arc: Constraints on Source Composition, Mantle Melting and Slab Input Composition, Jour. Of Petrl. 56, pp. 2257-2294.

SOLER, P. (1991). - Contribution a l`étude du magamatisme associe aux marges actives pétrographie, géoquimmie et geochimie isotopique du magmatisme crétacé a Pliocène le long d'une transversale des andes du Pérou central implications géodynamiques et metallogeneques. Thèse no publicado de Doctorat des Science Naturelless, Paris, université Pierre et Marie, 832 pg

TAMURA, Y., TATSUMI, Y., ZHAO, D., KIDO, Y., AND SHUKUNO, H., 2002. Hot fingers in the mantle wedge: new insights into magma genesis in subduction zones. EPSL *Earth,* 197 (1–2):105–116.

WOOD, D. A. (1980). The application of a Th–Hf–Ta diagram to problems of tectonomagmatic classification and to establishing the nature of crustal contamination of basaltic lavas of the British Tertiary volcanic province. *Earth and Planetary Science Letters* **50,** 11–30.

VIDAL, C. (1987). - Kuroko-Type Deposits in the Middle Cretaceous Marginal Basin of Central Peru. Econ. Geol. 82, 1408-1430