XIV CONGRESO GEOLÓGICO CHILENO
LA SERENA | OCTUBRE 2015

# The evolution of the Triassic-Jurassic Mitu rift system in the Urubamba valley, Cuzco, Peru: Preliminary results on the volcanosedimentary facies reconstruction

**Fernando Panca** [a], **Christoph Breitkreuz** [b]
[a] *Herencia Resources Chile S.A., Burgos 80, Piso 12, Las Condes, Santiago, Chile*
[b] *Institut für Geologie, Technische Universität Bergakademie Freiberg, Bernhard-v.-Cotta Str. 2, 09599 Freiberg, Germany*

** email: fpancamn@gmail.com*

**Abstract:** The stratigraphic record of the Triassic-Jurassic Mitu Group in the Peruvian Andes represents a continental rift system at the margin of Gondwana. In the Urubamba Valley, the Mitu succession is well exposed comprising terrestrial red beds, alkali basaltic lavas and rhyolitic to peralkaline ignimbrites. Panca and Breitkreuz (2011) carried out detailed field mapping around the Pallpa-Oqoruro section (POS), and measured additional sections in Pisac and Calca areas.
The ~2800 m sedimentary record of POS features fluvial sandstones, conglomerates, sheetflood deposits, and fine-grained floodplain deposits. In the lower 2000 m, volcanic intercalations with intra-plate signature vary from sub-alkali (bottom) to alkaline basaltic lava (top), varying from fluvial regime to alluvial fan systems respectively. The upper 800 m are dominated by thick welded ignimbrites intercalated with sheetflood deposits. Ignimbrites can be traced over 35 km and apparently they are a product of major caldera-forming eruptions during the end of the Mitu rift.
The Mitu rift displays coarsening upward sedimentation from fluvial to alluvial fan facies. This progradational trend might be related to uplift of intra-basinal blocks or to a local transpressive tectonic regime. Also, magmatism evolved towards more alkaline and $SiO_2$-rich composition and volcanic mode switched from effusive to explosive activity.

**Keywords:** Mitu rift, intra-plate volcanism, alkaline basalts, facies analysis, volcanosedimentary facies.

## 1 Introduction

The Permian to Early Jurassic Mitu Group is a widespread structural element in the evolution of the Peruvian Andes (Mégard, 1978; Laubacher, 1978; Noble et al., 1978; Kontak et al., 1985; Jacay et al., 1999; Sempere et al., 2002). The Mitu Group represents a chain of pre-Andean to early Andean extensional basins which underwent complex inversion tectonics during the Cretaceous-Cenozoic Andean orogeny (Sempere et al., 2002). In particular, competent blocks of volcanosedimentary successions and faults formed during Mitu basin evolution have strongly influenced the tectonic architecture of the Andean orogeny in Peru.
Current models on the basin evolution of the Mitu Group and its tectonic overprint are weakened by a number of issues. Some aspects needing additional research are the insufficient knowledge on volcanosedimentary facies, uncertain definition of depositional members in the basin fill, lack of biostratigraphic and chronostratigraphic constraints as well as scarce quality data on the isotopic and geochemical composition of the volcanic units.
Among Mitu basin systems in Peru, the Urubamba valley segment, located in the eastern Cordillera NE of Cuzco, is well suited for a complex investigation (Figure 1).
The lithology is varied including terrestrial massflow to fluvial and eolian sediments as well as numerous intercalations of alkaline basaltic lava and alkaline to peralkaline pyroclastic deposits (Noble et al., 1978; Kontak et al., 1985, 1990; Jacay et al., 1999, Sempere et al., 2002 and Rosas et al., 2007). In particular, silica-rich pyroclastic units are widespread and serve as excellent marker beds for understanding the stratigraphic evolution of the Urubamba basin system. U-Pb isotopic studies on rhyolitic lava flows (considered as the bottom of a Mitu section) in Sicuani area gave ages of 234 Ma (Reitsma et al., 2010). Miskovic et al. (2009) used a rhyolitic tuff in the same area obtaining 226 ± 10 Ma. U-Pb isotopic ages on detrital zircons of sandstones near the town of Abancay point to a maximum age of c. 225 Ma. Thus, Reitsma et al. (2010) suggested that probably the beginning of the Mitu sedimentation might have occurred during the Middle Triassic and not during the Late Permian as previously reported (Marocco, 1974).
The primary emphasis of the present study is to interpret and to associate the volcanic evolution and sedimentary facies architecture of the Mitu Group, in order to clarify styles of depositional environment and volcanism associated to the tectono-magmatic processes that occurred in the Urubamba valley during a rift developed at Permian?-Early Jurassic times.

## 2 Methodology

This study results from a ~2800 m detailed stratigraphic section in the Pallpa-Oqoruro valley, a short section in the Pilahuara area, SE of Pisac (Cenki et al., 2000) and two other sections in the Pisac-Tancayyna and Mancha Cancha valleys, NE of Calca (Figure 1). These sections cover a ~30 km stretch of the Mitu Basin in the Urubamba valley area and provide insight into the lithological evolution of the Mitu Group and its tectonic overprint.

The classification of volcanic rocks was carried out through whole rock analyses of 13 POS samples.

## 3 The Mitu Group: Facies analysis

The designation of strata into lithological facies and characterization of stratigraphic intervals using defined facies was applied to interpret depositional environments and to develop a stratigraphic framework for better understanding the sedimentation during the evolution of the Mitu rift in a specific area. For a general description and comparison, the nomenclature of Miall (1985, 1996) was used for the fluvial and alluvial deposits. Volcanic nomenclature was taken from Fisher and Schmincke (1984), Cas and Wright (1987) and McPhie et al. (1993), whereas the subdivision into syn-eruptive and inter-eruptive deposits was derived from Smith (1991). The lithofacies types can be grouped together to form lithofacies assemblages and inferred depositional settings. Based on lithology, external and internal geometries, and bounding surfaces, several depositional elements were identified including: lava flows, pyroclastic flow deposits, volcanoclastic deposits, clast-supported sheet conglomerate, clast-supported massive conglomerate, class-supported horizontally stratified conglomerate, coarse lithic pebbly sandstone, massive sandstone, cross-bedded sandstone, horizontally bedded sandstone, trough cross-bedded coarse grained sandstone, muddy siltstone, laminated silty mudstone and sandy calcareous sandstone. The Mitu Group has been divided into two deposits types: syn-eruptive deposits and inter-eruptive deposits. Syn-eruptive deposits are composed by primary and secondary volcanic deposits; and inter-eruptive deposits were classified according to the grain size (from conglomerate to muddy lithofacies assemblages) and calcareous affinity.

## 4 Depositional setting during rifting

Preliminary information on the facies associations of Mitu Group sections in the Urubamba Valley was used to describe volcanosedimentary successions and to infer depositional models. Ten members have been identified chronologically so far, according to the facies assemblage variations, volcanic activity, tectonic changes and climatic conditions. The sedimentary record of the Mitu basin includes deposits of effusive and explosive volcanism, fluvial channels, floodplains, alluvial fans, fluvio-eolian processes and presumable intracaldera-related pyroclastic deposits. Chronologically, the depositional settings were recorded from older to younger (Figure 1) as follows:
Member 1: Syn-eruptive deposits and fluvial channels
Member 2: Floodplain deposits
Member 3: Fluvial channels
Member 4: Transition from fluvial channels to alluvial fans
Member 5: Dominant effusive volcanism
Member 6: Alluvial fan deposits and explosive volcanism
Member 7: An increasing of effusive volcanism, fluvial channels and alluvial fans
Member 8: Fluvial and eolian deposits
Member 9: Predominance of alluvial fans (sheetflood deposits) and minor lava flows and fluvial channels
Member 10: Thick packages of parataxitic ignimbrites associated to a possible intra-caldera system and formation of alluvial fans.

## 5 Tectonic setting: results and interpretation

According to the stratigraphic position in the POS, the samples were labelled chronologically from L1 to L7 for lava flows and from T1 to T6 for ignimbrites.
In Figure 2, the Hf/3-Th-Ta diagram (After Wood, 1980) shows that most of the basalts (L4, L5, L6 and L7) plot into the field of within-plate alkali basalts (WPA) with an Hf/Ta ratio lower than 2.5, L3 plots into the field E-MORB and within-plate tholeiitic basalts (WPT) and L1 into the field of calc-alkaline basalts (CAB) with an Hf/Th ratio minor than 3. L2 represents a transition between CAB and WPT or it was a WPT that has undergone enrichment of Th due to the mobility of this element in altered basalts. Sometimes, crystal fractionation can cause some points to be plotted in the wrong fields. Crystal fractionation of most silicate minerals tends to remove Ta, Hf, Zr and Nb from the melt and the residual liquid is pushed towards higher Th concentrations. The possible mobility of Th during alteration could move the position of samples in the direction of MORB-types, if the samples have within-plate affinity.

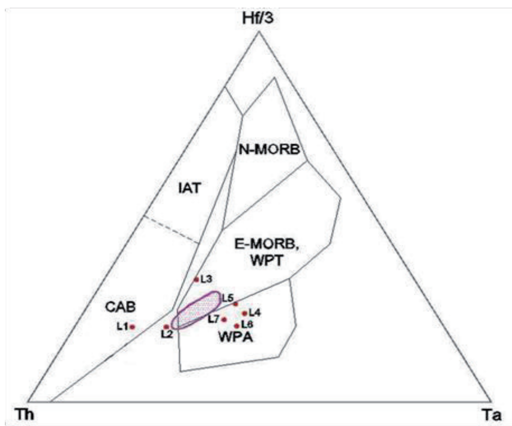


**Figure 2.** Hf/3-Th-Ta plot for basalts (after Wood, 1980).

The Th/Yb-Ta/Yb diagram (Pearce, 1982), indicates that the basalts would have developed within-plate enrichment of the mantle source (OIB-like source) and transitional behaviour from crustally-contaminated transitional basalts (sub-alkaline basalts) to alkali basalts (dotted arrow in Figure 3). Ignimbrites are considered highly affected by crustal component or subduction-slab related to Th enrichment during mantle-derived magma and crustal interaction at higher levels of magmatic fractionation.

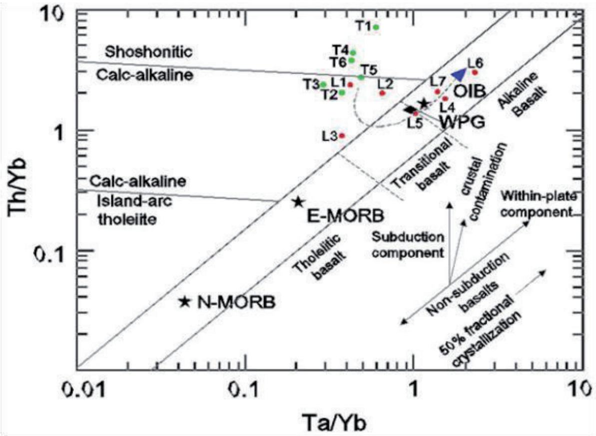


**Figure 3.** Ta/Yb-Th/Yb diagram (Pearce, 1982) for basalts and ignimbrites.

## 5 Discussion and conclusions

The beginning of the Mitu sedimentation in Urubamba valley area was characterized by a short-lived early stage of sub-alkaline volcanism synchronous with the development of fluvial channels, and followed by a long-quiescent floodplain environment with lack of volcanism. Later, coarsening-upward sedimentation took place favouring the development and widespread distribution of fluvial channels which were associated with the increase in volume and alkalinity of basaltic effusive volcanism. Increasing topographic uplift due to extensional syn-rift evolution, subsequent high rates of sedimentation and increasing volume of volcanic products favoured the formation of alluvial fans which were coeval with the decrease of the development of fluvial channels. Occasionally, the Mitu sedimentation was possibly affected by a period of fluvial-eolian setting (Member 8). Mitu rift sedimentation ended with the formation of caldera-related peralkaline ignimbrites with subduction component contamination, associated with alluvial fan deposits.

A relative decrease of quartz content, lack or shortage of olivine crystals, enrichment in crustal components (Hf, Sm, small negative Eu anomaly and small Nb depletion) and tectonic changes from calc-alkaline basalts to within-plate tholeiitic basalts, suggest that the beginning of Mitu volcanism was affected by slightly crustal contamination and/or decreasing influence of the subduction slab during the rift evolution. The increasing alkalinity and enrichment in primitive source (OIB-like source) at the top may indicate a tectonic evolution towards an active rift associated to a lithospheric thinning from the Middle Triassic to, at least, the Early Jurassic.

## References


Cas, R.A.F.; Wright, J.V. 1987. Volcanic succession. Modern and Ancient. Allen and Unwin.: 528 p. London.

Cenki, B.; Jaillard, E.; Carlotto, V. 2000. Estudio Petrográfico-Geoquímico del vulcanismo Pre-Huancané de la región de Cusco-Sicuani (Sur del Perú): Interpretación Geodinámica. Boletín de la Sociedad Geológica del Perú 89: 45-56.

Fisher, R.V.; Schmincke, H.U. 1984. Pyroclastic rocks, Springer Verlag:472 p. Berlin.

Jacay, J.; Sempere, T.; Carlier, G.; Carlotto, V. 1999. Late Paleozoic–Early Mesozoic plutonism and related rifting in the Eastern Cordillera of Peru. IV International Symposium on Andean Geodynamics. p. 358-363. Göttingen.

Kontak, D.J.; Clark, A.H.; Farrar, E.; Strong, D.F. 1985. The rift associated Permo–Triassic magmatism of the Eastern Cordillera: a precursor to the Andean orogeny. In: Pitcher, W.S.; Atherton, M.P.; Cobbing, J.; and Beckinsale R.D. (Eds.), Magmatism at a plate edge: The Peruvian Andes. Blackie, Glasgow, and Halsted Press. p. 36-44. New York.

Kontak, D.J.; Clark, A.H.; Farrar, E.; Archibald, D.A.; Baadsgaard, H. 1990. Late Paleozoic-Early Mesozoic magmatism in the Cordillera de Carabaya, Puno, southeastern Peru: geochronology and petrochemistry. Journal of South American Earth Sciences 3: 213-230.

Laubacher, G. 1978. Géologie de la Cordillère Orientale et de l'Altiplano au nord et nord–ouest du lac Titicaca (Pérou). Travaux et Documents de l'ORSTOM 95: 217 p.

Marocco R. 1974. Estudio geológico entre de la region entre Cusco y Macchu Picchu. En: Bull. Inst. Fr. Et. And., III N°2: 1-27.

McPhie, J.; Doyle, M.; Allen, R. 1993. Volcanic Textures: a Guide to the Interpretation of Textures in Volcanic Rocks. University of Tasmania Centre for Ore Deposit and Exploration Studies: 198 p.

Mégard, F. 1978. Etude géologique des Andes du Pérou central. Travaux et Documents de l'ORSTOM, 86: 310 p. Paris.

Miall, A.D. 1985. Architectural-element analysis: a new method of facies analysis applied to fluvial deposits. Earth Sci. Rev 22: 261–308.

Miall, A.D. 1996. The Geology of Fluvial Deposits: Sedimentary Facies, Basin Analysis, and Petroleum Geology, Springer: 582 p. New York.

Miskovic, A.; Spikings, R.A.; Chew, D.M.; Kosler, J.; Ulianov, A.; Schaltegger, U. 2009. Tectonomagmatic evolution of the Western Amazonia: Geochemical characterization and zircon U–Pb geochronologic constrains from the Peruvian Eastern Cordillera granitoids. GSA Bulletin, Vol. 121, n° 121: 1298-1324.

Noble, D.C.; Silberman, M.L.; Me´gard, F.; Bowman, H.R. 1978. Comendite (peralkaline rhyolites) in the Mitu Group, central Peru: evidence of Permian-Triassic crustal extension in the Central Andes. U.S.G.S. Journal of Research 6: 453-457.

Panca, F. and Breitkreuz, C. 2011. The Mitu Group in the Urubamba valley, NE of Cuzco, Peru: volcanosedimentary facies analysis of an early Andean inverted basin, Bol. Soc. Geol. Peru 102: 5-35.

Pearce, J. A. 1982. Trace element characteristics of lavas from destructive plate boundaries. In: Thorpe, R. S. (ed.) Andesites: orogenic andesites and related rocks. In Chichester: John Wiley: 525-547.

Reitsma, M.; Schaltegger, U.; Spikings, R.; Winkler, W.; Carlotto, V. 2010. Constraining the age of the Mitu Group, south-east Peru: U–Pb ages of detrital and igneous zircons. Geophysical Research, 12, EGU2010–0.

Rosas, S.; Fontboté, L. and Tankard, A. 2007. Tectonic evolution and paleogeography of the Mesozoic Pucara Basin, central Peru. Journal of South American Earth Sciences 24: 1-24.

Sempere, T.; Carlier, G.; Fornari, M.; Carlotto, V.; Jacay, J.; Arispe, O. 2002. Late Permian-Middle Jurassic lithospheric thinning in Peru and Bolivia, and its bearing on Andean-age tectonics. Tectonophysics. 345: 153-181.

Smith, G.A. 1991. Facies sequences and geometries in continental volcaniclastic sediments. In: Fisher, R.V., Smith, G.A. (eds.). Sedimentation in Volcanic Settings, SEPM Spec. Pub.: 1-257.

Wood, D.A. 1980. The application of the Th–Hf–Ta diagram to problems of Tectonomagmatic discrimination and to establishing the nature of crustal contamination of basaltic lavas of the British Tertiary volcanic province. Earth Planet. Sci. Lett. 50: 11–30.

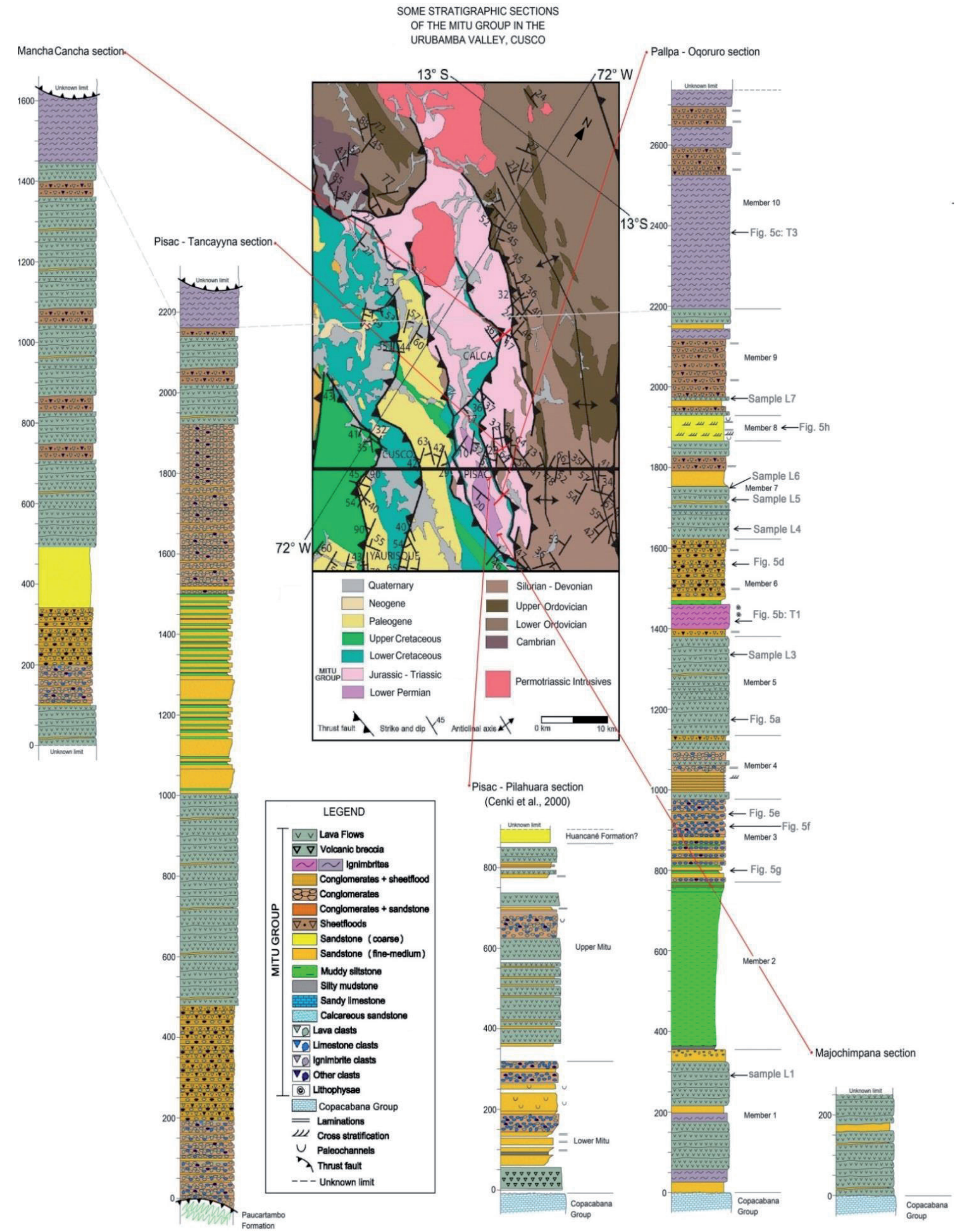


**Figure 1.** Geological map of the Urubamba Valley showing locations of some preliminary sections: Mancha Cancha (Calca area), Pisac-Tancayyna, Pallpa-Oqoruro (POS), Majochimpana and Pisac-Pilahuara (Cenki et al, 2000).