AGE AND GEODYNAMIC SETTING OF JURASSIC ARC VOLCANISM IN SOUTHERN COASTAL PERU

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INTRODUCTION AND GEOLOGICAL OUTLINE

The western margin of the South American Plate is the Earth's longest lived active continental margin, and hence serves as the type locality for active margin orogenic processes. The Tertiary evolution of the margin has been studied in detail (Dewey and Lamb, 1992), whereas the Mesozoic and older history is still poorly constrained. Our study aims to reconstruct the late Triassic(?) - Jurassic evolution of the southern Peruvian margin and to constrain the age, chemistry, and palaeogeographic setting of volcanic-sedimentary arc sequences in the Arequipa Terrane. The Triassic-Jurassic transition in southern Peru is characterized by a cessation of continental extension (the "Mitu" rift) and renewed subduction related magmatism along the present-day coastline and inland region of the Arequipa massif, south of 12°S. Several continuous rock sections proximal to the coast of the Arequipa Terrane are interpreted to have originated in a continental arc setting, which possibly commenced in the later Triassic (?) to Jurassic (Sempere et al., 2002). We speculate that the extensional geodynamic scenario which formed the Mitu Rift, may have terminated during renewed (orthogonal) subduction, giving rise to active margin magmatism. Understanding the timing and nature of Jurassic arc magmatism will also shed light on the reasons for the lack of Jurassic rocks in the 'craton-free zone', north of 12°S (north of Lima).

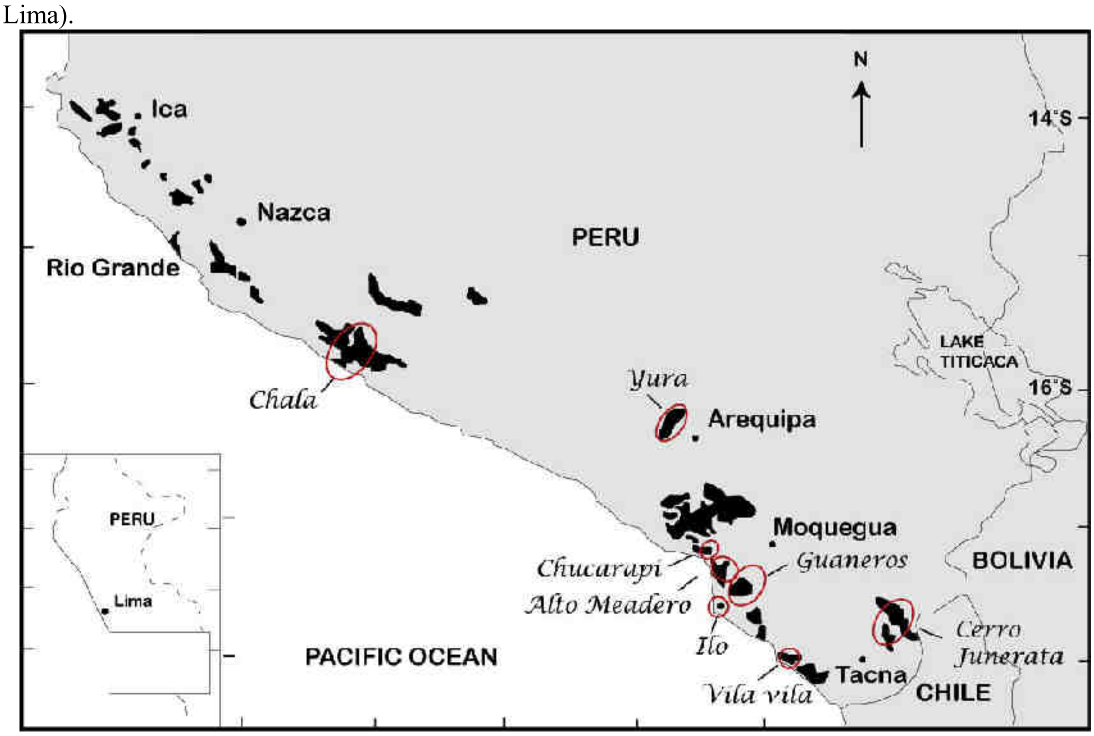

Figure 1. Location of Jurassic volcanic outcrops (black areas) in Southern Peru (modified after Romeuf et al., 1995)

Our project commenced with a detailed investigation of the Jurassic sedimentary and volcanic rocks along the Peruvian coastline between c. 15˚S and 18.5˚S. The distribution and depositional ages of Jurassic arc sequences are only tentatively constrained by inaccurate radiometric age data, and sparse fossil data (Martinez et al, unpublished). We will derive an accurate chronostratigraphic framework for the arc sequences using the U/Pb and $^{40}Ar/^{39}Ar$ dating techniques. Furthermore, a detailed description of the facies distribution of both volcanic and sedimentary rocks, combined with a geochemical study, will allow us to distinguish between back-arc and continental arc volcanism, and hence constrain the tectonic and paleogeographic evolution of the region.

STRATRIGRAPHY AND GEOCHRONOLOGY

THE JURASSIC CHOCOLATE FORMATION

We mainly sampled the Chocolate formation during our first field campaign, which is currently attributed to the Lower Jurassic. This is a dominantly brown coloured volcanic and volcanoclastic formation, which is 900 – 1500 m thick (its base rarely outcrops). Limestones at the base of the overlying Pelado Fm. yield Sinemurian ammonites. Sempere et al. (2002) report the Yura Group (Yura area, close to Arequipa) as being the most complete section of Jurassic rocks. We consider it to be an almost complete type section for volcanism and sedimentation in the Jurassic arc. It consists of the volcanic and volcanolastic *Chocolate Formation* (fig.2) at its base, which is successively overlain by limestones, and siliclastic formations, whose marine facies include turbidites, deep shales, shallow limestones and marls, to lagoonal evaporites and fluvial sandstone deposits.

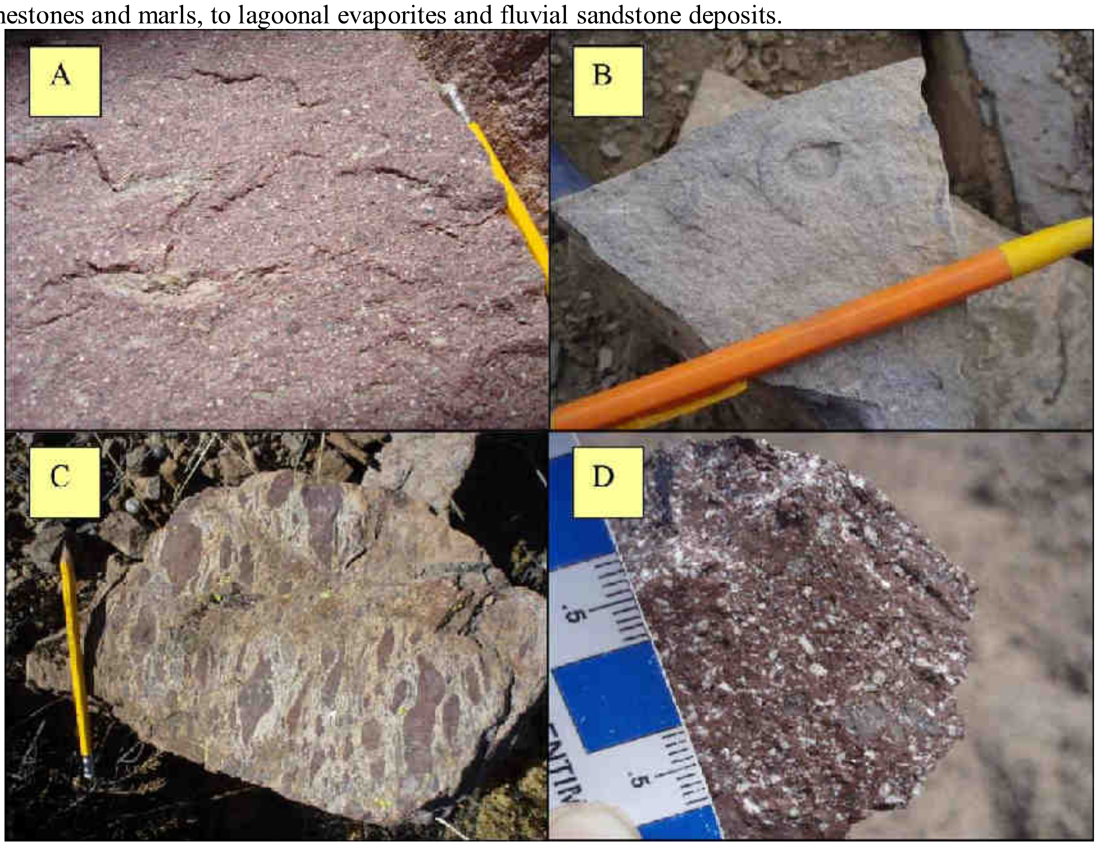

Figure 2. Some typical chocolate formation rocks A volcanic breccia (Chala), B a limestone with ammonite (Cerro Junerato), C an ignimbrite (Cerro Junerato) and D Andesite (Alto Meadero).

Stratigraphy: Logging of stratigraphic columns dispersed along the coastline of the Arequipa Terrane, and small scale geological mapping has been performed to establish temporal and structural relationships between geographically distinct regions. A series of localities were chosen based on the continuity of the section and the quality of the outcrops. Sampling has been carried out in the following sedimentary sections so far (see figs. 1, 5).

Chala, E – NE of Chala
Yura valley, NW of Arequipa
Chucarapi, NE of Cocachacra
Alto Meadero, SW of Moquegua
Quebrada Guaneros, SW of Moquegua
Ilo beach, in the village of Ilo
Beach Vila Vila, S of Punta Colarada
Cerro Junerata, SE of Palca

The sections described below are shown in figure 5.

Chala: The Chala section, (1 km in length) comprises a thick sequence of basaltic andesite flows intercalated with volcaniclastic sediments. At the base of the section a 50-100 m thick, tectonically disturbed zone was identified, showing magma mingling textures accompanied by numerous generations of faults and folds at metric and decimetric scales. The section becomes more continuous at stratigraphically higher locations. The sedimentary rocks are prominently volcaniclastic, although minor horizons of well sorted arenites occur in isolated channels.

Figure 3 (left). Shallow marine carbonates found at the top of the Yura section, yielding gastropods.
Figure 4 (right). Magma mingling of basaltic and rhyolitic sub-volcanic rocks at Ilo.

Yura: The 300m thick Yura section hosts volcanoclastic rocks, which are intercalated with lavas of basaltic andesite. The lava flows are progressively more scarce towards the top of the section, which is sharply overlain by fossiliferous, shallow marine carbonates (fig.3). E-W oriented sinistral faulting is observed throughout the whole section roughly, which have total displacements of a few to tens of meters.

Chucarapi: Paleozoic sedimentary rocks occur at the base of the Chucarapi section, and are overlain by the Chocolate formation. The section is highly deformed, similar to the sequence found in the lower part of the section at Chala. Several basaltic dikes and stocks intrude into the Chocolate formation. Similar to other locations, a transition from volcanic and volcanoclastic rocks to well laminated sandstones interbedded with sandy limestones was found. The top of the section is defined by a conspicuous conglomerate, which contains clasts of the Chocolate Fm., which are up to 0.5m in size.

Alto Meadero: The section at Alto Meadero has a thickness of approximately 1 km, and mainly consists of a volcanoclastic unit in its lower part, which alternates with laminated andesitic lavas. Towards the top of the section there is a rapid change into limestone strata (a few meters thick), which is overlain by sandstones.

Guaneros: The stratigraphic section in the Quebrada Guaneros is structurally repeated numerous times, and hence it is difficult to compile the temporal evolution of the section. However, a combination of isotopic dating and lithological observations may spatially constrain each structural block. Basaltic dikes cross-cut the volcanoclastic and volcanic rocks that are currently assigned to the

Chocolate formation.

Ilo: Intrusive rocks crop-out along the beach at Ilo, and reveal complex magma mingling textures (fig.4). Basaltic dikes, as well as granitic and granodioritic rocks can also be found along the coastline. These rocks are thought to be the basal part of the Chocolate formation of the Guaneros section. We plan to test that hypothesis via U-Pb dating and isotopic analyses, to characterize the sources of melts.

Vila Vila: Several hundred meters of sedimentary and volcanic rocks, with highly complex structures, crop-out at the Vila Vila beach. Dextral faulting occurs on a metric scale, and these are in turn faulted by decimetric scale faults. The fault array significantly obscures the original stratigraphic relationships. The sequence mainly contains volcaniclastic deposits, which range from fine to coarse grained (containing pebbles up to a few centimeters).

Cerro Junerato: An incomplete sequence of the Chocolate formation has been logged at the Cerro Junerato, although the presence of an overlying unconformity and contact with the Sinemurian Pelado Fm. suggests it is the upper part of the Chocolate fm. Ammonite bearing limestone reefs occur at the base of the Pelado Fm., which are in turn overlain by cross-bedded sandstones (on a meter scale), and rare conglomerates.

Sinemurian ammonites were found at the Yura, Cerro Junerato and Alto Meadero regions, which provide a constraint for our preliminary correlations between the sections (fig. 5).

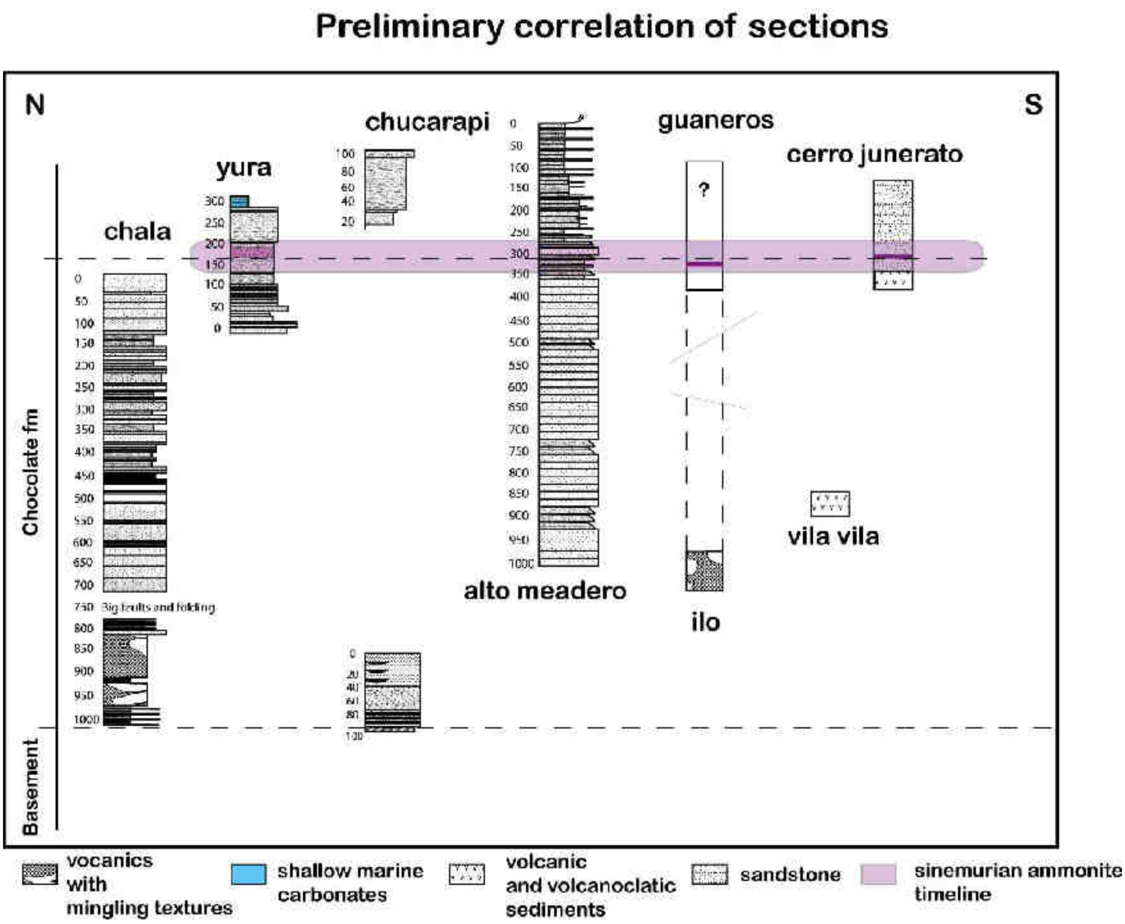

Figure 5. Preliminary correlation of sections based on the occurrence of Sinemurian ammonites. Columns are in meters

Previous geochronology: Numerous K/Ar ages, and a restricted number of $^{40}Ar/^{39}Ar$, Rb-Sr and U-Pb ages have been reported from these rocks (Sempere et al. 2002; Kontak et al. 1985, 1990). The $^{40}Ar/^{39}Ar$ age determinations of Kontak et al. (1985) demonstrate that the isotopic systems have been disturbed and neither the K-Ar nor the $^{40}Ar/^{39}Ar$ ages can be interpreted with any degree of confidence. The dispersion between Ar-Ar, Rb-Sr and U-Pb ages from the same rocks, or between several K-Ar age determinations of the same lithologies, is up to 100 my. This may be explained by multiple effects of open system behaviour in the K-Ar and Rb-Sr systems, and by inherited components analyzed in multigrain, zircon U-Pb analyses (see the compilation of data in Sempere et al. 2002).

The past assignment of formation names was dependent on the locality, and hence the literature can be confusing when comparing age results from different localities. Previous K-Ar ages display a range from 130 to 190 Ma (e.g., Romeuf et al. 1995, Kontak et al. 1985, 1990; Roperch and Carlier 1992; and ages in Martinez et al., unpubl.); most of these are considered unreliable because of intense potassic alteration, oxidation, and likely thermal overprinting. According to our field observations, the Chocolate Formation is overlain by limestones reported to contain Sinemurian fossils, constraining its age to the late Triassic - early Jurassic. This time period may be coeval with waning extension and alkaline magmatism in the Cuzco region, implying that the volcanic rocks of the Chocolate Fm. were emplaced in extensional basins, and are transitional to an active arc. Such an interpretation is corroborated by unpublished geochemical data (INGEMMET - Martinez et al., unpublished). Several lines of evidence suggest that the volcanic sequences in the regions of La Yarada, Guaneros and Punta de Bonbón are younger than the Chocolate Fm. Martinez et al. (unpublished) indicate that they are overlain by ammonite-bearing strata of Bajocian to Callovian age (170-160 Ma), and geochemical analyses of the volcanic rocks yield a subduction-related, calc-alkaline character (Romeuf et al. 1995; Martinez et al., unpublished). All of these localities host acidic volcanic rocks, (volcanic pyroclastic breccias, ignimbrites, rhyolitic and dacitic lava flows, and tuffs), which can be dated using U-Pb zircon techniques.

PRELIMINARY CONCLUSIONS

Anticipating the preliminary age data, our correlation of the logged sections is based on the presence of Sinemurian ammonites that are preserved in some of the sections (fig.5). The carbonaceous reef and shallow marine rocks in the youngest parts of the sections indicate a cessation of magmatic activity, which does not directly imply a temporal tie between the sections because i) the cessation may have been transitional, ii) the timing of deposition of carbonaceous rocks may be highly dependant on location. The Guaneros section has not been placed in this preliminary correlation due to the complicated structural relationships that have been partly mapped, along its length.

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