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THE SAN JERONIMO FORMATION: VOLCANIC TURBIDITE DEPOSITION IN THE POST-INCAIC II CUSCO INTERMONTANE BASIN

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Resumen

Stratigraphic, structural, sedimentogical and isotopic age data together show that certain interpretations and conclusions concerning the Cuzco basin made over the past decades: e.g., Carlotto (2002, 2013), Carlotto et al. (2005), Perelló et al. (2003) require improvement. Instead, we believe the following: 1) All the rocks of the San Jerónimo Formation (SJF) postdate the Incaic II orogenic compressive phase (cf. Steinmann, 1929; Noble et al., 1979; 1985; Benavides, 1999), which in fact took place prior to 45 Ma (Noble & Wise, this meeting). 2) Rocks of the SJF were not deposited in a near-source orogenic environment with marked topographic relief directly bordering the basin. Instead, the relatively fine-grained nature of the sediments and the profound scarcity of conglomerate and the matrix-supported nature of the few beds present indicate deposition in a relatively stable environment well removed from the source of the sediments. 3) Previous interpreted braided-stream and fluival facies is completely equivocal; the SJF sedimentary structures indicate deposition as turbidite fans. 4) There is little or no angular unconformity between the Kayra and overlying Soncco members of the SJF and that evidence for a progressive angular unconformity between the Kayra (outer to mid-fan facies) and Soncco (inner-fan facies), or elsewhere within the group, is incorrect. Stratigraphic relations are commonly obscured by colluvium and observed relations can be readily explained by faulting. Overall bedding in the SJF is remarkable parallel, indicating uniform subsidence and sedimentation rates through time. 5) The Andahuaylas-Yauri batholith (AYB) was intruded in its entirety after the Incaic II orogeny, as shown by new zircon dating (Noble & Wise, this meeting) of the early part of the batholith. Batholith emplacement was concurrent with eruption of the Anta volcanics (AV) and voluminous middle Eocene volcanic rocks and stocks and mineralization. 6) The intricate and intense deformation of rocks of the SJF took place later during the late Oligocene (Aymara) and/or Miocene (e.g., Quechua I and II) phases of deformation.

1. Introduction

The Cusco intermontane basin is a composite depositional low that is filled on the northern end by the remarkably thick Eocene AV (including early mafic rocks and subsequent intermediate-composition rocks including beds of breccia, laharic material, and fanglomerate), by poorly-dated red beds of the Oligocene SJF, and by less abundant younger coarse conglomerate of the late Miocene Paruro Fm. (Carlotto, 1998; 2002). The presently-preserved width of folded and faulted units filling the basin is 39 km and the SJF extends for 200 km – nearly to Lake Titicaca. The basin follows the structural grain of the Andes such that in the south it runs NW-SE whereas towards Cusco the units and formations bend around towards the west as it approaches the Abancay deflection. Apart from the AV, the units filling the basin are remarkably poor in datable horizons, leading to considerable confusion and difficulty in developing a history for the basins of the region. Early workers placed the red beds in the latest Cretaceous, mainly on the basis of interpreted dinosaur tracks reported from three different localities (Noblet et al., 1995). Later K-Ar dating of a thin unit of tuff suggested an Oligocene age for this part of the section (Carlotto et al., 1995). Additional assumptions were made to estimate depositional rates and the context of the units, leading to the belief that deposition was strongly influenced by or related to the Incaic II orogenic event (Carlotto, 2002; 2013). These arguments were based on the claimed presence of rotated progressive angular unconformities, the thickness of the section, and the inferred timing for the filling events. Given clear new timing constraints on the upper limit for the Incaic contraction event preceding 45 Ma (Noble and Wise, this meeting), the interpretation that the Cusco basin was filled by debris shed during this deformation from post-42 Ma and continuing up to 30 Ma warrants revision. Steinmann (1929) introduced the concept and name of the Incaic phase of the Andean orogeny based on deformation of the late Cretaceous-early Paleocene Casapalca Formation in central Peru. Noble et al. (1979) placed an upper age bracket on the deformation K-Ar age determinations on volcanic units overlying the regional angular unconformity at about 40-41 Ma. Noble et al. (1990) reported K-Ar ages from northern Peru, defining the Incaic I and II events, upper ages at >54.8 Ma and 41-45 Ma, respectively. Benavides-Cáceres (1999), subdivided the Incaic into five events, placing the Incaic I at 55-59 Ma, Incaic II at about 42-43 Ma, Incaic III at 27-30 Ma (or Aymara Event of Sébrier et al., 1988), and Incaic IV at 22 Ma. These subdivisions are likely extended too far given the varying mechanical explanations for the driving forces leading to the deformation. We strongly recommend that the term Incaic pertains to deformation preceding 45 Ma, following the original relations established by Steinmann (1929).

2. Parallel beds versus angular unconformities

Carlotto (1998, 2002, 2013) reported the presence of rotated angular unconformities in the section of red beds of the SJF near Cusco, using this relationship to support the interpretation that the basin fill was syntectonically deposited. Despite the basin extending for 200 km this relationship has been described in only one relatively small area (Fig 1). This area lies south of Cusco, and north of the small pueblo of Huanoquito. Here three apparent angular unconformities were recognized on the basis on bedding truncation angles. The angular unconformity named after Ccorca occurs in the hinge zone of an anticline; the physical contact does not appear to be exposed. The apparent truncation angle of bedding across the contact can be explained equally well by a fault developed during hinge-zone accommodation while undergoing folding. The angular unconformity north of Occopata is even more poorly exposed, but there are no fold hinges nearby to explain away the feature; however, semi-bed parallel thrusting along the large-scale fold limb is an equally plausible explanation for the apparent bed truncation patterns. The best candidate for a true angular unconformity is located on the steep cliffs at the Ancaschaca locality (Fig. 1, location B). Again, part of this contact may be the result of faulting. In all of the above cases, the sedimentary facies appears identical across these features.

Progressively rotated angular unconformities commonly are found in foreland basin deposits where the advancing thrust wedge has tilted deposits shed during earlier stages of development. This scenario requires that the deposit be close to the source area, and therefore that the depositional facies are alluvial fans and braided stream-facies dominated alluvial plain deposits, which typically consist of coarse-grained material, including conglomerate. The absence of gravels in the SJF suggests that the basin was surrounded by areas of little local topographic relief. Carreño-Collatupa and López-Zapana (2005) gave persuasive evidence that the SJF in the section south of Cusco was not syntectonic. Having looked at the section from many angles, including both field and airborne perspectives (Fig 2A), we conclude that the beds are almost everywhere parallel (Fig 2B). Any apparent divergence in bedding relates to varying dips of beds on the flank of a large-scale syncline and their intersection with topography. Some structural complications, with bedding-subparallel limb thrusts, are present, but in no places were erosional angular discordances noted in the section. Given only three tentative contacts that could be angular unconformities, all with possible fault explanations as alternatives, there is certainly no persuasive geometric argument to apply the term “progressive”, which would imply systematic steepening of the beds beneath each of the proposed unconformities.

3. Depositional facies, grain size, and composition of detritus

The consistent stacking of planar bedded units that are dominated by plane-laminated sandstone suggests a depositional setting that was unconstrained laterally, of little relief, and of sufficient distal setting lacking energy to transport coarser material. Plane laminations, bed thickness patterns and lithology alternation, climbing ripples, and rip-up clasts (Fig 2C) all indicate deposition in turbidite fans. The sandstone beds are remarkably consistent in grain size, having an abundance of fine to medium-grained sandstone, accompanied locally by thick sections of siltstone and mudstone. As noted by Carlotto (2002), conglomerate beds are extremely scarce. Where present, conglomerate contains very well-rounded clasts, it is matrix-supported (Fig 2D), and the cobble sizes are rarely larger than the average around 3 to 4 cm. The maximum clast diameter found was 15 cm. These conglomerate beds represent fluidized debris flows formed within inner-fan facies. Most of the section consists of mid-fan facies alternating tabular sandstone and mudstone. The lack of bioturbation suggests very rapid sedimentation rates. The arkosic-sandstones contain abundant volcanic detritus. This fact is difficult to reconcile with the interpretation of these units being material shed from the mountains that formed during Incaic contraction, particularly given that the Cusco basin lies within the orogen, and is directly adjacent to folded Mesozoic units that are considered to have been deformed during the Incaic event.

Carlotto (2002) takes significant space in interpreting these red beds as being syntectonic deposits, and yet in no place described the composition of the contained material: no results of thin-section petrography were reported. The few beds of conglomerate in the section are dominated by andesitic material and some hornblende dacite porphyry. At one location, a meter-thick framework-supported conglomerate bed with very well-rounded clasts contains a fair number of basement-derived rock and some locally-sourced or cannibalized clasts of red siltstone. There is no particular reason that the basement clast and the volcanic material had to be derived from near the Cusco basin. The overall high degree of rounding and fine-grained nature of the deposits suggest long transport and distal position relative to the probable source volcanic arc to the SW. The SJF did not receive detritus from the AYB, now widely exposed to the west; the first arrival of AYB detritus is seen in the Miocene Paruro Fm.

4. Age of the San Jerónimo Formation

Only a couple of isotopic ages have been reported from the SJF. The most important is sample SJ-2C of plagioclase from trachyte that yielded a K-Ar age of 29.9±1.4 Ma (Carlotto et al., 1995). This age is coincident with a whole-rock $^{40}Ar/^{39}Ar$ age of 30.84±0.83 Ma reported by Fornari et al. (2002); the agreement of the two ages argues for their reliability. The first age was used by Noblet et al. (1995) to discredit the Cretaceous faunal calls on multiple traces fossils. Carlotto (2010) reported an apatite fission-track age of about 52 Ma from near the base of the section (Kayra Fm.). It is not clear if the apatite grain(s) analysed are related to a pyroclastic eruption or detrital grains derived from eroded igneous or metamorphic rock of Paleogene or older age. Moreover, could this age have been reset by heating at the base of a very thick sedimentary pile? Available isotopic ages are too few, too poorly distributed stratigraphically, and too problematic to constrain the age and duration of deposition. Considering the poor age constraints and similarity of deposition facies in the Kayra and Soncco units, we recommend the San Jerónimo map unit be termed a formation instead having group standing.

5. Discussion and Conclusions

Although the age of the impressive sequence of parallel-bedded red beds near Cusco remains uncertain, the depositional history they record can no longer be argued to be syntectonic. The red beds clearly did not form in a proximal position within the mountains built by the Incaic deformational event. The SJF red beds consist of fine-grained material that is abundant in volcanic detritus and very poor in both conglomerate and material shed from the Mesozoic basement formations and the middle Eocene AYB. We reinterpret the entire section as representing a major fresh water turbidite fan. Finally, we conclude that the main argument that these units were syn-Incaic, the presence of progressively-rotated angular unconformities, is at best poorly demonstrated. The relatively fine grain size of the rocks suggests a lack of nearby active tectonics. All evidence indicates that the AYB in its entirety was emplaced following the Incaic II deformational event. The structural history of the Cusco basin clearly requires re-evaluation. We strongly suspect that the SJF does not reflect syn-basin contractional deposition, and that much, if not all, of the folding of the units was caused by the Aymara, early Miocene Quechua 1, and late Miocene Quechua II phases of shortening.

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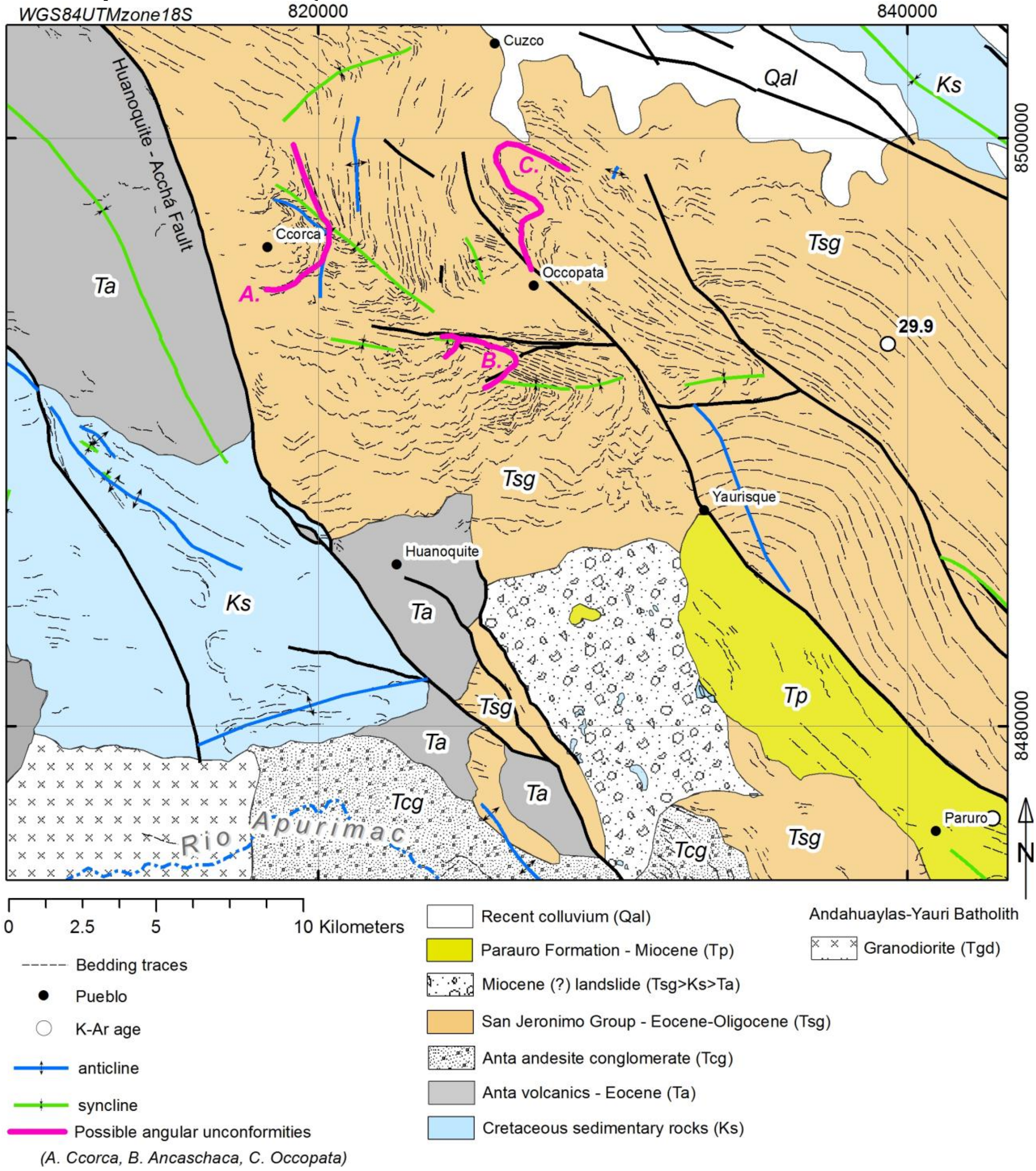

Figure 1. Simplified geology map of northern part of the Cuzco basin.

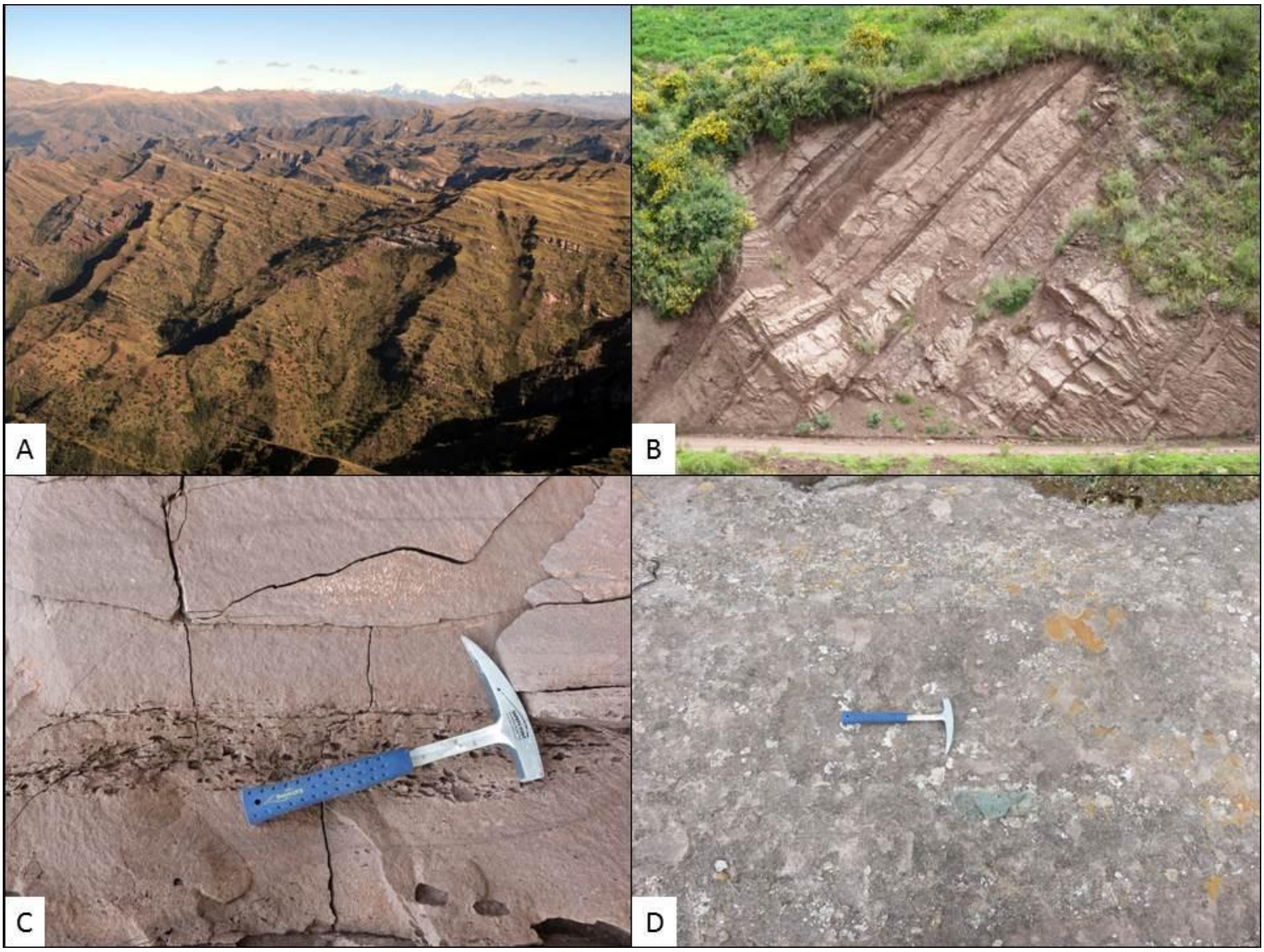

Figure 2. A. Photograph of parallel bedded sandstone in the SJG as seen in oblique aerial view looking north beween Occopata and Huanoquite. B. Photograph of parallel bedded sandstone in the SJF from road cut SE of Cusco. C. Photograph of rip-up clasts in plane laminated fine-grained sandstone bed near Occopata. The clasts have weathered out leaving behind elongate holes. D. Photograph of matrix-supported conglomerate unit representing inner fan facies debris flows northeast of Yaurisque. Bedding parallels the hammer, a single long clast below and right of the hammer (slightly greenish area ; outcrop has orange to light gray mottleing from lichen) is supported by matrix sandstone and has its long axis aligned parallel with bedding. The conglomeratic beds are plane laminated and do not have imbricated cobbles.