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The structural analysis of the San Antonio de los Cobres Valley and the available thermochronological ages, indicate active N-S main thrusts and NW-SE transpressive and locally normal faults during the middle Miocene. In this context, we interpret the Conglomerado Los Patos to represent sedimentation in a small, extensional and short-lived basin associated with the compressional Andean setting.

The development of Miocene extensional and short-lived basin in the Andean broken foreland: the Conglomerado Los Patos, Northwestern Argentina

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1. Introduction

In recent years, several contributions have improved the knowledge of the Andean foreland system in the northwestern Argentina. In particular, research has developed new insights and concepts on tectonics, sedimentation and volcanism (Coutand et al., 2001; Carrapa et al., 2005; Petrinovic et al., 2006;Hongn et al., 2007; Strecker et al., 2007; Mazzuoli et al., 2008; Folkes et al., 2011; Guzmán et al., 2011; del Papa et al., 2013; Canavan et al., 2014). The most important improvements include: the existence of an Eocene broken foreland basin in the Puna and in the Eastern Cordillera, the role of the inversion of the Cretaceous normal faults and basement heterogeneities in the deformation and in the generation of the double vergence structures, the existence of orogen-oblique transfer zones between double vergence master thrusts, the presence of Eocene growth-strata in the continental hinterland, and the increment of Paleogene and early Miocene ages of uplift and exhumation data (Carrapa and DeCelles, 2008; Payrola et al., 2009; Carrapa et al., 2011; Hongn et al., 2011; del Papa et al., 2013). The described scenario suggests the hypothesis that isolated basins -connected or disconnected- developed, with distinct evolutions. Thus, the new challenge in Northwest Argentina is to recognize and differentiate these basins, and also to interpret their tectono-stratigraphic signature in the context of the complex foreland system.

The Conglomerado Los Patos is a clastic sedimentary unit that crops out near the village of San Antonio de los Cobres, close to the eastern border of the Puna (Fig. 1). There are no previous detailed studies of this unit, which is most likely due to its discontinued, isolated outcrops and its low preserved thickness. Nevertheless, its position on the border of the Puna, its stratigraphic relationships, and particular features of the sediments suggest the Conglomerado Los Patos is a key unit to understanding the evolution of these foreland basins and the Miocene configuration along the Eastern Puna margin.

In this contribution, we present stratigraphic and sedimentological studies and new radiometric ages from volcanic clasts of the Conglomerado Los Patos. These new data integrate with a structural analysis of the area allow for a discussion of the formation of extensional short-lived basins in the compressional orogenic Andean setting.

2. Geological background

The Conglomerado Los Patos was first mentioned by Ramos (1973) as a fanglomeratic unit cropping out along the margins of the Los Patos River and in the Angosto de Piscuno, near San Antonio de los Cobres (Fig.1). This author described it from the base to the top, as integrated by red mudstones, coarse-grained sandstones and grayish white conglomerate rocks deposited in angular unconformity over the Cretaceous-Paleogene Salta Group. Donato and Vergani (1988) confirmed the angular unconformity relation with the Salta Group and described the Conglomerado Los Patos as mainly integrated by a polymictic orthoconglomerate deposited in alluvial fan setting.

Figure 1

3. Regional distribution and stratigraphy

The Conglomerado Los Patos crops out in a narrow longitudinal belt between the Angosto de Piscuno to the north (Ramos, 1973) and the Abra del Acay to the south (Fig. 1 A; B). Outside this belt, there are no deposits that can be attributed to the Conglomerado Los Patos. It lays in angular unconformity over the Santa Bárbara Subgroup – Salta Group, Fig. 2. In the Corte Blanco locality, along the train tracks, the base of the Conglomerado Los Patos lies by angular unconformity over Mealla (Me), and laterally over Maíz Gordo (MG) and Lumbrera formations of the Santa Bárbara Subgroup (Fig. 2 A; B). The basal contact is a very irregular erosional surface that, in some places, forms high relief gullies (Fig. 2 C). Moreover, along the unconformity surface, the units of the Salta Group show decolorization and brecciation, attesting to a weathering paleosurface (Fig. 2 B). The upper contact surface is an irregular unconformity, that is partly sealed by the pyroclastic deposits of the Viscachayoc Ignimbrite (Fig. 2 D) and/or by the Toba I pyroclastic rocks (Viramonte et al., 1984). This erosive surface is also marked by a lateral thinning up to the complete absence of the Conglomerado Los Patos (Fig. 2 A).

Figure 2

4. Sedimentology

The thickness measured in the Corte Blanco locality is 15 meters (Fig. 3), but laterally it reaches more than 40 meters. Ramos (1973) mentions thicknesses of up to 270 meters. The Conglomerado Los Patos is characteristically yellowish brown and shows a fining and thinning upward patterns, from boulder to pebble size deposits.

Figure 3

We recognized three lithofacies

a) **Matrix supported bouldery conglomerate** (Gmm). This facies is in the lower part of the unit and consists of very thick strata (up to 2 m) with crude stratification. The beds are reddish brown, with lenticular, cuneiform or tabular geometries (Fig. 4A). The clasts are boulder (~0.6 m) and cobble size, angular to subrounded, disorganized, ungraded, except for one level with inverse grading (Gmig), floating in a fine-grained sandy mudstone to wacke matrix (Fig. 4 A and B). Conglomerate clasts are composed of low to medium grade metamorphic (phyllites, schist), quartz-arenite, porphyritic rhyolite and pyroclastic rocks (Fig. 4 B and C). The porphyritic rhyolite is rich in tourmaline phenocrysts. The pyroclastic clasts are whitish in color and composed of a coarse-grained ash (Fig. 4 B), subrounded pumice fragments with biotite, clinopyroxene, hornblende and plagioclase phenocrysts and angular lithic fragments of meta-pelites and quartz-arenites.

The sedimentological characteristics suggest deposition by frictional freezing from cohesive debris flows (Nemec and Steel, 1984). The inverse grading level suggests debris flows with high dispersive pressure mechanism, also favored by the presence of boulder-sized clasts (Costa, 1984).

b) **Clasts supported conglomerate** (Gch). This facies consists of 40-50 cm thick beds, vertically stacked up to 4 m thick, with crude stratification (Fig. 4 D). It is integrated by pairs of cobble-rich levels at the base and pebble-rich levels at the top (Fig. 4 E). Internally, it shows clast supported fabric without grading; clasts are subangular to subrounded, elongated/flat clasts accommodated parallel to stratification. The matrix is composed of fine-grained muddy sandstones.

This facies represents deposition from gravitational non-cohesive flows (Blair and McPherson, 1994). These flows are produced from catastrophic discharges of water, where water-sediment mixture is able to transport coarse material by dispersive and buoyant forces with low mud participation (Blair and McPherson, 2009). This is a common process in high relief apical zones of alluvial fans.

c) **Imbricated conglomerate** (Gci). It is made up of 20-30 cm thick stacked tabular beds of yellowish-brown pebbly conglomerate. Conglomerate is clast-supported with slight normal grading; clasts are subrounded and less frequently, subangular, elongated and flat shapes are parallel to the stratification and present well-developed imbrication (Fig. 4 F). This facies displays low proportion of matrix, of silt/sand fractions.

This facies is interpreted to be deposited by clast-rich, turbulent and unconfined flows, of sheet-flood type, which are common after heavy rains (Blair and McPherson, 1994; Blair, 1999; Jan and Cooker, 2016).

Figure 4

4.1. Paleoenvironment

The sedimentary facies and the interpreted processes are dominated, in all cases, by a gravitational component. This is typical of high relief environment such as mid-to-proximal alluvial fan settings. The irregular geometries of the cohesive debris flow deposits (Gmm) suggest the infill of paleochannels and gullies until the complete infill smooth the paleotopography. These characteristics are consistent with the infill of incised feeder channels in proximal to apical zones in alluvial fan settings (Blair and McPherson, 1994). The younger sedimentary processes were dominated by unconfined sheet-flood that produced tabular units, suggesting mid-to-proximal positions in the fan lobes (Blair and McPherson, 2009).

The vertical sedimentary pattern, in combination with the confined cohesive flow in the lower section which shifts to unconfined dilute flows in the upper section, indicates an aggradational to retrogradational system that is consistent with the local decreasing paleo-slope (Fraser and DeCelles, 1992).

5. Age and Provenance of the Conglomerado Los Patos

We carried out two new age determinations from both porphyritic and pyroclastic clasts included in Gmm facies to gain information on the age of the Conglomerado Los Patos. The two new U/Pb radiometric ages in zircons, were performed in the Geochronology Laboratory of the Brasilia University, on a LAM-HR-ICPMS (Neptune) equipped with 9 Faraday detectors, a multiplier central electrons to 5 meters ions coupled to a LA Nd-YAG 213 NewWave. The first radiometric age performed in porphyritic rhyolites clast results in (concordia) 483+/- 10 Ma (U/Pb), (Fig. 5 A). The second U/Pb radiometric analysis in zircons was carried out from a pumice fragment included in a pyroclastic clast located at few centimeters from the base of the unit (Fig. 3). The new age is 14.5 ± 0.5 Ma. (see Fig. 5 B for details). Taking into account this 14.5 ± 0.5 Ma age of the lower clast and the 13 ± 0.3 Ma age in the Viscachayoc Ignimbrite (Petrinovic et al., 1999), the age of the Conglomerado Los Patos is constrained between 14.5 ± 0.5 Ma and 13±0.3 Ma.

Figure 5

The clast compositions in the lower section of the Conglomerado Los Patos are of schist, phyllite, meta-pelite, porphyritic rhyolite and pyroclastic rocks (Fig. 3). Upsection, both porphyritic and pyroclastic rocks completely disappear and the main component is meta-pelites (40%) followed by phyllites, micaceous schist, quartz arenite and porphyritic rhyolite (Fig. 3).

The lithology of the metamorphic and plutonic clasts agrees with the local basement, which is formed by low-grade metamorphic Puncoviscana Formation (Turner, 1960) and Ordovician sedimentary and plutonic rocks of the Faja Eruptiva Oriental (Méndez et al., 1973) and/or the Oire Eruptive Complex (Blasco et al., 1996). All these units crop out in the surrounding area (Fig. 1). The first acquired Ordovician radiometric age confirms its provenance (Fig. 5 A). Rocks with similar composition have been described in the Organullo and Cajón creeks toward the SW of the study area (Fig. 1), interbedded in the clastic sedimentary succession of Ordovician age (Suzaño et al., 2015).

On the other hand, the provenance of the middle Miocene pyroclastic clasts is uncertain. There are no known equivalent ages in the proximities of the Corte Blanco outcrop. However, extended lava domes and related deposits, which remain undated, are exposed in the Rupasca complex (Fig. 1). Hence, we speculate that the provenance of these pyroclastic clasts may be from Rupasca, which is located 30 km toward the SW.

The upper section of the Conglomerado Los Patos is integrated by Gci facies that allowed paleoflow determination from imbricated clasts. The paleoflow analysis reveals currents toward the N-NE (Fig. 3). This direction agrees with the composition of the described detrital material and with the potential source areas.

6. The structural framework of the San Antonio Valley

In order to gain into the knowledge of the structural framework, we analyzed the available information from Ramos (1973), Marrett et al. (1994), Donato and Vergani (1988), Blasco et al. (1996), Gangui and Götze (1996), Riller et al (2001), Seggiaro (2006), Petrinovic et al. (2010), Santimano and Riller (2012), Salado Paz et al. (2016) and added new information from seven stations (Fig. 1 A), shown in the dataset of Table 1.

Table 1

The San Antonio de los Cobres Valley is limited by approximately N-S striking, reverse faults with opposite vergence (Fig. 1 A). The double- vergency of the structures is a common feature of the Andean deformation in the Puna-Eastern Cordillera transition. It has been interpreted to be controlled by the presence of previous heterogeneities in the upper crust (Hongn et al., 2010). From the west to the east the major faults are: the east vergence “West Salinas Grandes Thrust” (WSGT: Gangui and Götze, 1996) and its continuation in the Charco and Cajón thrusts and, the west vergence Muñano Fault (Fig. 1 A). The WSGT and the Muñano faults thrust the Precambrian and Ordovician rocks over the sediments of the Salta Group and over Neogene volcanic/sedimentary successions (Donato and Vergani, 1988; Gangui and Götze, 1996). The WSGF is, at least, of Miocene-Pliocene age (Schwab and Lippot, 1974), meanwhile the Muñano Fault and its conjugated planes, displace and fold volcano-sedimentary successions of late Miocene-Pliocene age (Donato and Vergani, 1988).

Towards the south, the valley is closed by a topographic high of ~1500 meters and to the north, by the active fluvial system draining to the Salinas Grandes playa-lake (Fig. 1 A). Numerous fault planes and small-scale folds cut the valley floor that are parallel and oblique (Fig. 1 A) to the strike of the main faults (Donato and Vergani, 1988; Marrett et al., 1994; Gangui and Götze, 1996; Seggiaro, 2006).

Near the Nevado de Acay (Fig. 1 A), the Muñano Fault uplifts Precambrian basement rocks over Salta Group sediments (Fig. 6 A) and is, in turn, covered by lava flows from the Negra Muerta volcanic complex, dated 7.4 Ma (Petrinovic et al., 2005). The trace of the Muñano Fault continues to the south in the high angle Calchaquí Fault (Fig. 1 A) that uplifted the Puncoviscana Formation over the Salta Group and over Andean orogenic sediments. The Calchaquí Fault shows evidence of activity from the middle Eocene (Hongn et al., 2007) to the present day (Santimano and Riller, 2012).

In the inner area of the San Antonio de los Cobres Valley, several minor order faults with NW strike and folds with N-NE axis directions (Fig. 1 A) affected the Salta Group sediments and younger volcanic rocks (Donato and Vergani, 1988). On the other hand, the Cajón Fault thrusts Ordovician granitoids over sediments of the Salta Group (Fig. 1 A). The N-S and low angle fault plane (Fig. 1 A and Table 1) displays a 10 meter wide brecciated zone that mainly affects conglomerates of the Pirgua Subgroup (Fig. 6 B). Its northward prolongation is the Western Charco Fault (Fig. 1 A), which also uplifted granitoids over the Salta Group, with the same characteristics. The fault plane presents *ca*. 45º angle (Fig. 6 C and Fig. 1 A) and predates the 13 +/- 0.2 Ma (JICA 1993) Concordia volcanic center (Fig. 1).

Figure 6

The Eastern Charco Fault uplifts Precambrian and Ordovician sediments over the Salta Group through high to moderate angle fault plane (Fig. 1 A). Both faults (Western and Eastern Charco) limit a narrow bivergent valley that controls the Concordia volcanic center emplacement and its mineralization (Petrinovic et al., 2010). This complex fault system continues to the north in the WSGF, which limits the western border of the Salinas Grandes, as observed in seismic profiles (Gangui and Götze, 1996).

To the south, the Pastos Grandes fault thrusts basement rocks over the Eocene to Miocene sediments with west-vergence (Fig. 1 A) and shows a vertical offset of hundreds to thousand meters. This master fault system quickly loses entity northwards, until it reaches the Calama-Olacapato-El Toro (COT) fault system (Fig. 1 A).

The Toro Muerto Fault, that limits the western side of the heads of the Calchaquí Valley (Fig. 1 A), represents a series of east-vergence fault planes that uplift the Precambrian and Ordovician rocks over the Salta Group (Fig. 6 D) with variable dip (Hongn et al., 2010). This fault attenuates towards the north, close to the Nevado de Acay zone, probably due to dissipation in NW and E-W transfer faults with normal to left lateral strike-slip component in the Saladillo Fault (Fig. 1 A). Parallel fault planes with similar characteristics control the emplacement of the Negra Muerta volcanic vents (Riller et al., 2001).

The Calchaquí Fault (Fig. 1 A) is a west-vergence, high angle thrust that uplifts Precambrian basement and provoke drag folds in the Salta Group (Donato and Vergani, 1988, Hongn et al., 2007). To the north, it continues as the Muñano Fault (Fig. 1 A) with similar characteristics. The emplacement of the 12.6±0.3 Ma Nevado de Acay Granite along this fault-plane, plus the low-temperature thermochronological data (Insel et al., 2012) attests the syntectonic character of the intrusion. Several minor order faults oblique to the Calchaquí Fault and parallel to the Saladillo Fault (Fig. 1 A) are interpreted as conjugated and transfer faults in the northern Calchaquí Valley (Riller et al., 1999). Our data on the NW prolongation of the Saladillo fault planes (Fig. 1 A) and those from the Acazoque fault planes (Salado Paz et al., 2016) confirm the oblique (normal to left lateral) component (Table 1 and Fig. 1 A) of this fault.

The morphological connection between the northern Calchaquí Valley and the San Antonio de los Cobres Valley occurs through a NW trending belt that forms a topographic high (~1500 m) from Saladillo to Rupasca-Organullo (Fig. 1 A and DEM of Fig. 7). This belt is composed of Precambrian basement and Ordovician rocks (Blasco et al., 1996) covered by middle Miocene lava flows and pyroclastic deposits (Petrinovic et al., 1999). Interestingly, this belt is highlighted by the absence of Salta Group sediments.

7. Interpretation and discussion

The Conglomerado Los Patos represents the clastic accumulation in alluvial fan setting developed at the foot of a paleo-topographic break (Donato and Vergani, 1988). The composition of the clasts and paleoflows indicate provenance from the south-southwest, suggesting the drainage area and rock sources in these directions. Despite the fact, the Conglomerado Los Patos is always overlaying the Salta Group rocks; we did not recognize clastic components ascribable to these deposits, suggesting that this sedimentary unit did not integrate the drainage area. Instead, the source areas are composed of Precambrian- early Paleozoic units, with subordinated participation of Miocene volcanic rocks (Fig. 3). At present day, these units crop out in a 4000-4500 m range that divides the San Antonio de los Cobres Valley to the N, the Pastos Grandes-Centenario Valley to the SW, and the Calchaquí Valley to the SSE (Figs. 1 A; 7 A). These three valleys are limited by west-vergence and east-vergence reverse faults, with evidence of fault activity controlling basin configuration since the Paleogene (del Papa et al., 2013). The absence of Salta Group rocks as detritus sources confirm the early activity of faults, as was previously shown in Cretaceous paleogeographic reconstructions (Salfity et al., 1984). This indicates that the Salta basin was developed eastwards and northwards of the Pastos Grandes ranges and the COT fault system (Fig. 7; from now COT).

Figure 7

Contrary to the expected “typical” sedimentary pattern in alluvial fans progradation systems related to continuous uplift of the source areas (Frazer and DeCelles, 1992), the sedimentary facies succession that evolves from cohesive debris flows to dilute flows and the decreasing grain-sizes suggest the retraction of the topographic gradient (Blair and McPherson, 1994; Frazer and DeCelles, 1992). The stratigraphic pattern, along with the restricted distribution of the Conglomerado Los Patos, displays characteristics of extensional basins (e.g. Davila and Astini, 2003). Importantly, this unit crops out in the intersection zone between major N-S faults, such as the Calchaquí-Muñano, Pastos Grandes-Cajón-Charco faults and the NW-SE COT (Fig. 1 A).

COT activity predates the Andean cycle. The absence of Salta Group sediments to the SW of the COT in the Puna (Fig. 1 A) has been interpreted as a normal rift fault dipping to the north (Seggiaro, 2006). This interpretation agrees with the Cretaceous and post-Cretaceous paleogeographic reconstructions and explains the presence of a highly fractured crustal zone along the COT (Fig. 7). Additionally, the recent 107.6 Ma ZHe age determination has confirmed the Cretaceous thermal cooling and exhumation event (Reiners et al., 2015).

The extensional character of the COT has been well documented by previous kinematical analyses in the region (e.g. Fig. 4 in: Riller and Oncken 2003). Riller et al. (2001) interpreted normal faults close to the intersection between the COT with the Calchaquí Fault trace and a NW-SE which are, in turn, the favored planes for the volcanic rocks emplacement of the Miocene Negra Muerta volcanic center. Petrinovic et al. (2005) interpreted a transfer zone with NE normal faults westward of the San Antonio Valley, in the Pleistocene Tocomar volcanic center. Lanza et al. (2013) interpreted it in the same way, extensional components along the COT, while Norini et al. (2013) proposed local extension near San Antonio de los Cobres village. Close to the Cajón fault (Fig. 1A), minor fault planes related with the early Miocene Aguas Calientes caldera has oblique (normal-dextral) relative displacement of blocks (Salado Paz et al., 2016).

At a regional scale, most of the master N-S fault planes are not continuous north and southward from the COT fault system (Figs. 1 A and 7).

At a mesoscale structural analysis, our data and the kinematic analyses in both intersections of the COT with the Cajón and Toro Muerto faults (Fig. 1 A) reinforce NE-SW and E-W extensional component of the COT in the San Antonio de los Cobres segment (Fig. 7). The dilation zones in strike-slip systems act as potential accommodation space for sediments storage (Allen and Allen, 1995; Reijs and McClay, 1998). Furthermore, in broken foreland systems -such as the Argentinean northwestern one- it is common that the vergence of the major faults changes along their trace, and locally involves strike-slip components (Jordan, 1995, pp. 360 and references therein). The integration of the sedimentological data and the regional and mesoscale structural information, leads us to propose that during the middle Miocene, the horizontal extension related to the COT fault system activity favored the formation of the accommodation space for Conglomerado Los Patos deposition.

The brief life period (14.5 ± 0.5 Ma to 13±0.3 Ma) of the Conglomerado Los Patos basin correlates with a period of shortening and uplift in the area. The available AFT thermochronological ages constrain a rapid middle Miocene tectonic uplift. In the study area, the uplift of the Cachi granite is dated at 15 Ma and the Oire Eruptive Complex at 16 - 17 Ma (Deeken et al. 2006). The intrusion of Las Burras monzogranite at 14.4 Ma (Hongn et al., 2002) and the collapse of the Cerro Aguas Calientes caldera, at 17.5 Ma (Petrinovic et al., 2010) occurred coeval with the structuration of the eastern border of the Puna. In the same way, the Nevado de Acay monzonite (Llambías et al., 1985) of 12.61 ± 0.25 Ma, displays a rapid exhumation age (Insel et al., 2012). The new age of 14.5 +/- 0.5 Ma presented here represents the maximum depositional age for the Conglomerado Los Patos, and the top is limited by the 13 +/- 0.3 Ma Viscachayoc Ignimbrite (Petrinovic et al., 1999). Consequently, the basin formation was contemporaneous with the maximum period of shorting and uplift in the region.

Although data is limited due to the occasional exposition of the Conglomerado Los Patos, the data presented here, in combination with data from other research, is consistent and suggest the development of a local, extensional and short- lived basin developed between *ca.* 14.5 and 13 Ma in a regional transpressive setting (Fig. 7). Nevertheless, further detailed structural studies are needed to define the complete geometry of the basin. The Conglomerado Los Patos represents the remnant deposits of this basin and spatially confined to the Corte Blanco-Los Patos depocenter in the San Antonio de los Cobres Valley. The southward limit of the basin was the Precambrian – early Paleozoic block that today forms the Pastos Grandes Range (Cerro Áspero and Abra de Acay: Fig. 1A), which sourced the detritus to the basin. The subsequent events of deformation uplifted and folded the Conglomerado Los Patos, producing its dismemberment and partial suppression.

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FIGURE CAPTIONS

Figure 1. A. Regional map of major structures and outcrops of the units described in the text. B. Local map of outcrops and main structures at Corte Blanco. Modified from Donato and Vergani (1988); Blasco et al. (1996); Petrinovic et al. (1999); Arnosio (2002); Riller et al. (2001).

Figure 2: Stratigraphic relations of the Conglomerado Los Patos with the underlying and overlying units in the Corte Blanco area. MG: Maíz Gordo, Me: Mealla formations.

Figure 3: Sedimentological log and provenance of the Conglomerado Los Patos at Corte Blanco.

Figure 4: Sedimentary lithofacies and clast compositions. A. Gmm facies at the basal section. B. Boulder clasts of Miocene volcanics (v) and schist (sch). C. Cobble-sized clast of Gmm facies. Qs: quartz arenite, Phy: phyllite, Sch: schist. D. Gch facies, note the organized aspect respect to Gmm facies, outcrop is 9 meters. E. Close-up view of Gch facies, cobble-rich and pebble-rich pair layers. F. Gci facies, note the well-organized deposit and the imbricated clasts.

Figure 5: U/Pb radiometric determinations in zircons from volcanic clasts in the lower section of the Conglomerado Los Patos (see Fig. 3). Methodology and characteristics are explained in the text.

Figure 6: a) Muñano Fault; b) breccia fault in conglomeratic deposits of the Salta Group, Quebrada de Piedra Caída; c) Charco Oriental Fault, mineralized breccia; d) Saladillo Fault (recumbent fold in Salta Group). Dotted lines indicate the approximate dipping of the fault plane.

Figure 7: Structural interpretation scheme of the Calchaquí and San Antonio de los Cobres valleys, the topographic position of the interpreted tectonic transfer zone (DEM: SRTM 30m). Red stars indicate the location of the Miocene eruptive centers.

Table 1: Structural data (graphs in Fig. 1A). Rb: strike; Bz: Dip; C: quadrant dip; PE: striae plane; IE: Striae dip; M: relative movement of blocks; Q: quality (1-4); Lat / Lon: geographical coordinates of the stations.

Figure
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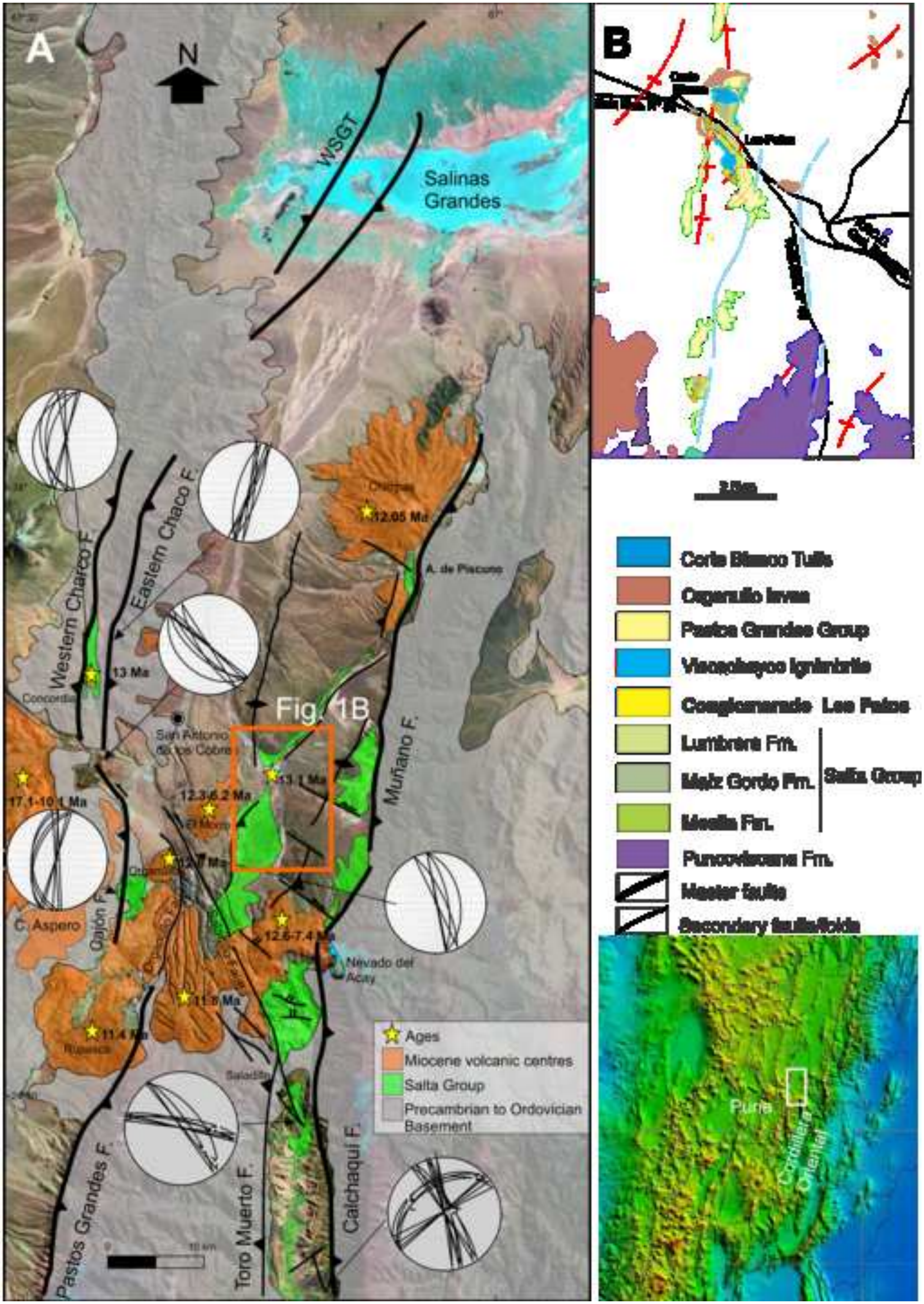

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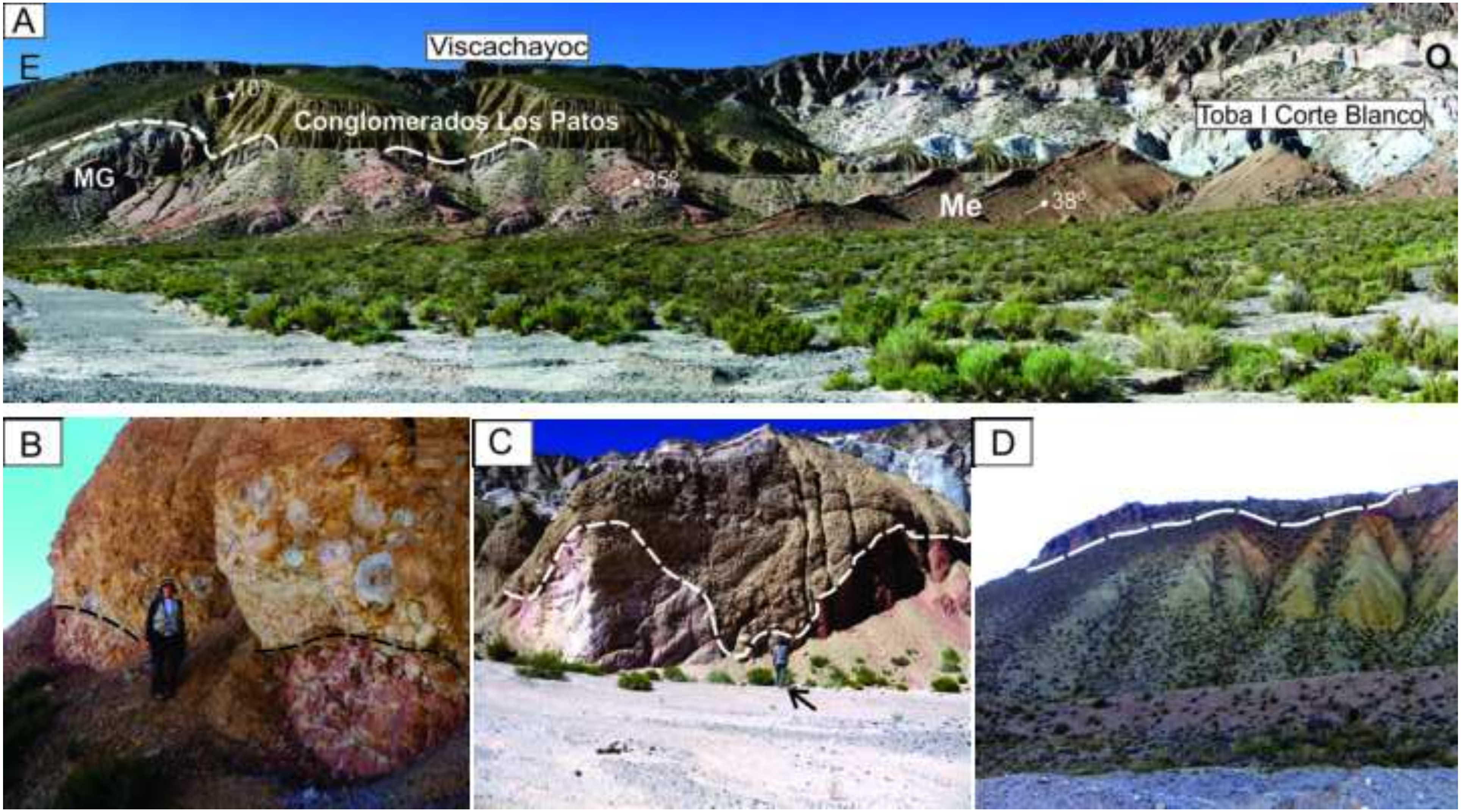

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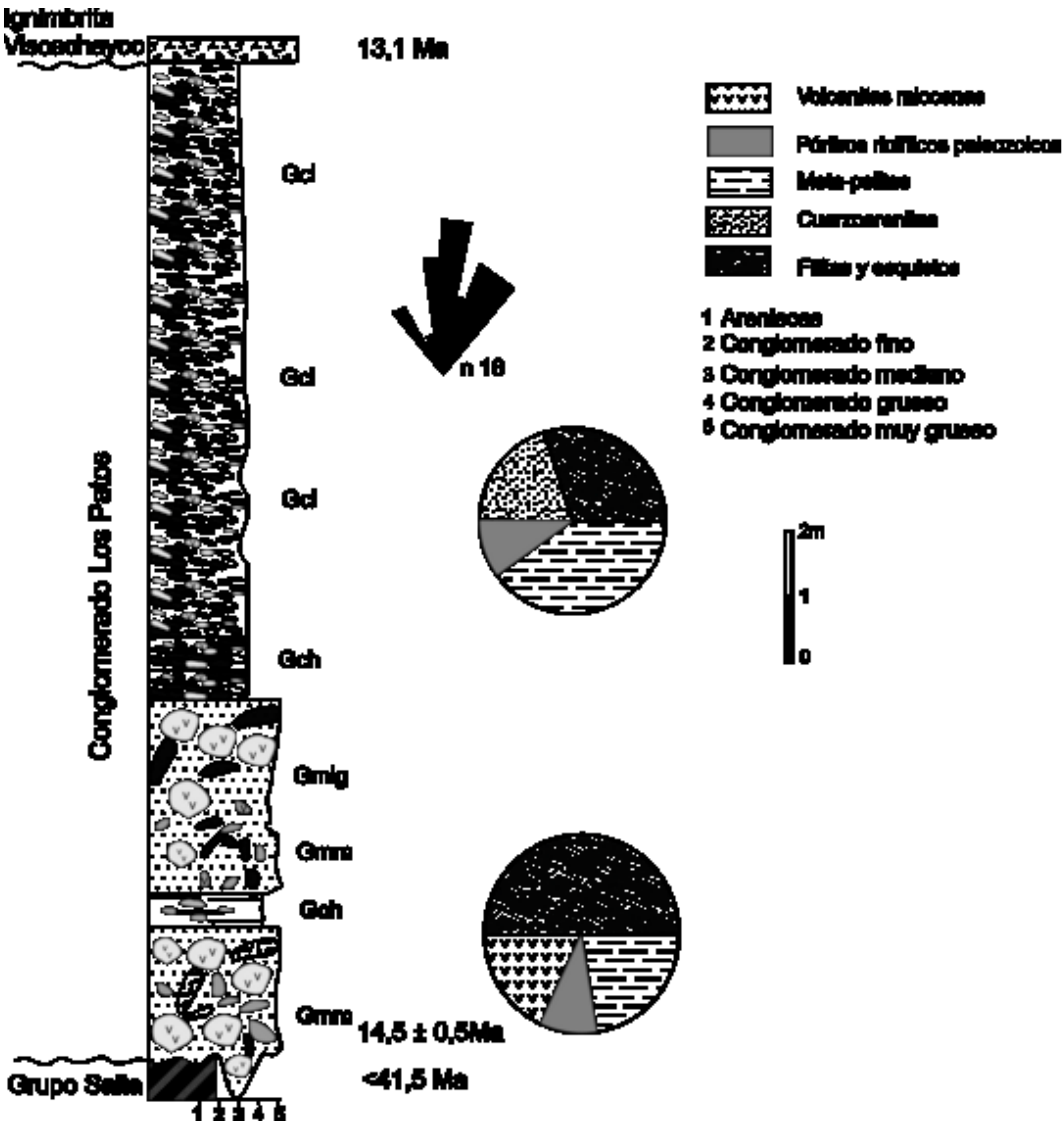

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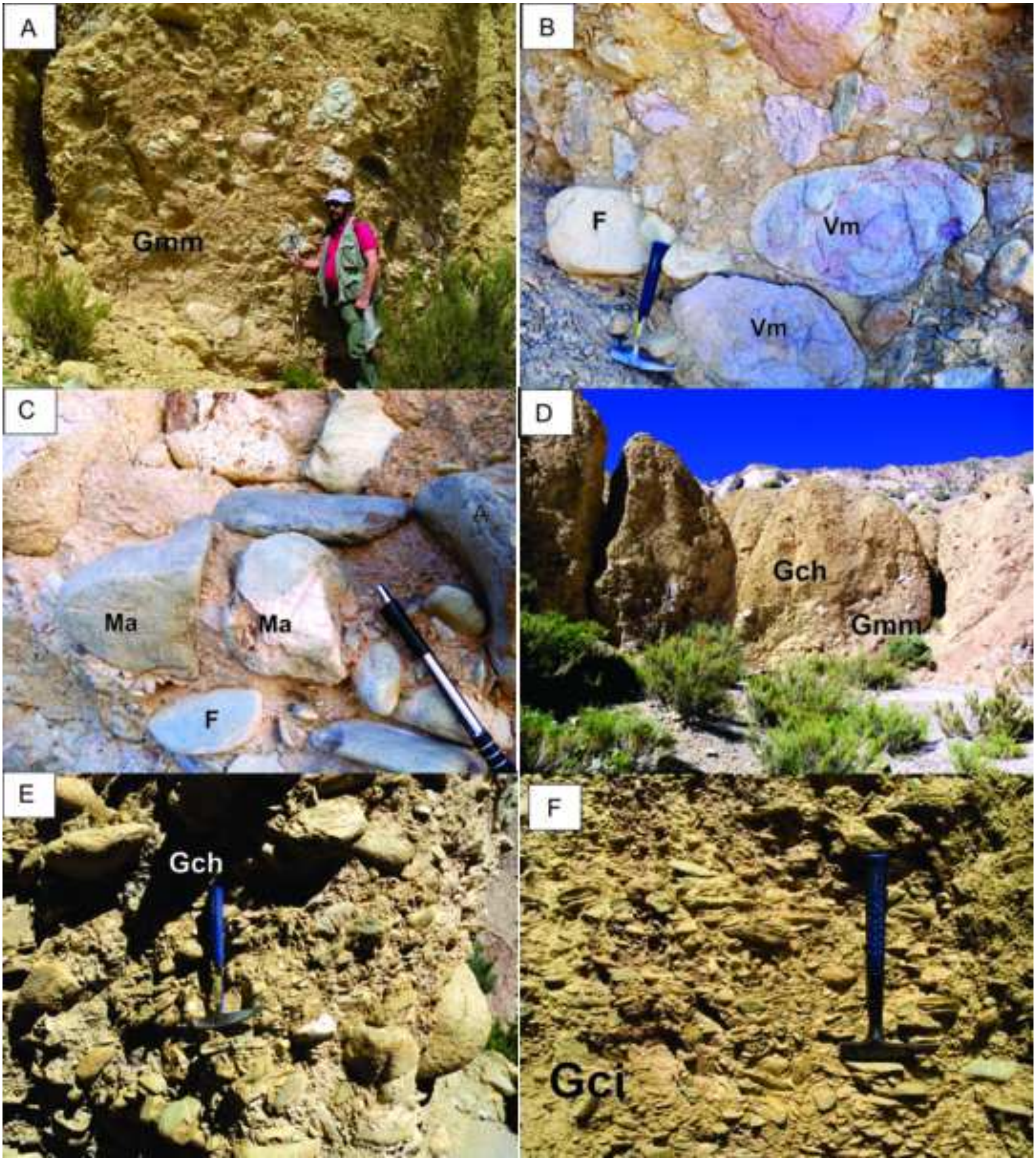

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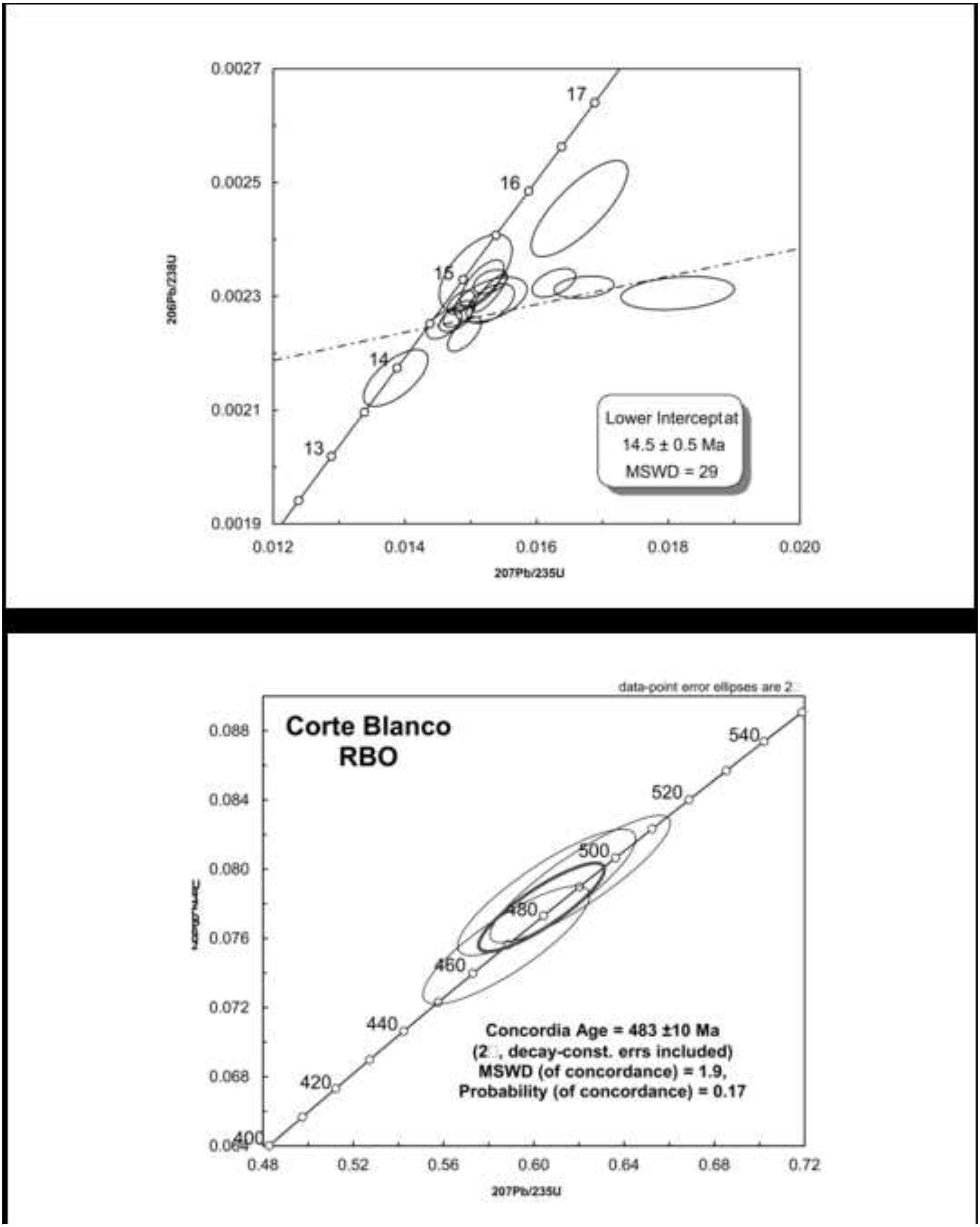

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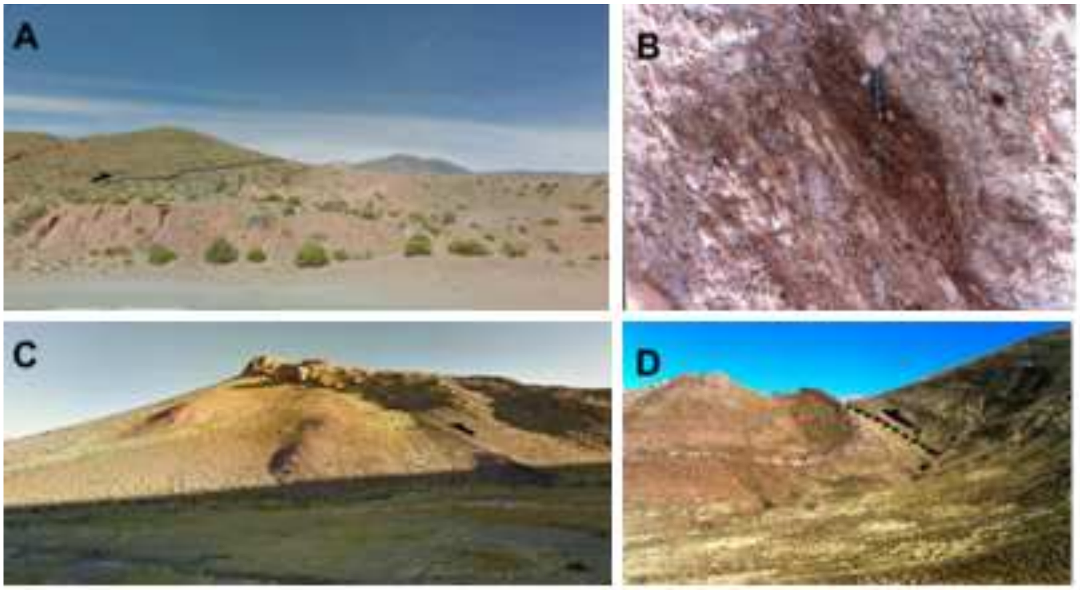

Del Papa y Petrinovic, Fig. 6

Figure

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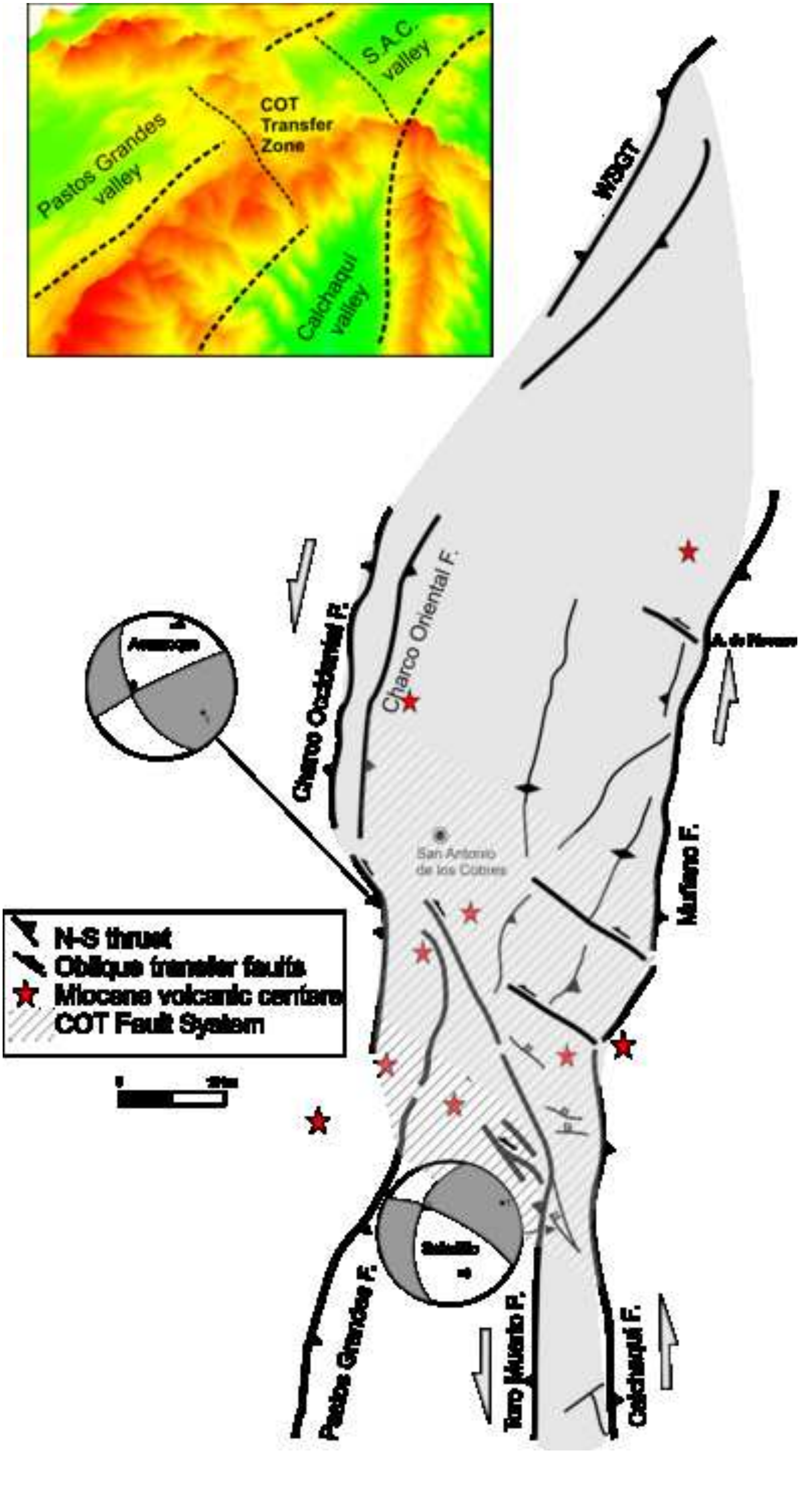

Table

Station	S	D	Q	PS	SD	M	Q	Lat	Lon
Acazoque	200	55	W			R	3	24°23'4.83"S	66°20'27.49"O
	185	48	W			R	3	24°23'4.83"S	66°20'27.49"O
	196	51	W			R	3	24°23'4.83"S	66°20'27.49"O
	178	49	W			R	3	24°23'4.83"S	66°20'27.49"O
Chorrillos	130	65	S			R	2	24°16'10.73"S	66°23'25.06"O
	130	40	S			R	2	24°16'10.73"S	66°23'25.06"O
	135	72	S			R	2	24°16'10.73"S	66°23'25.06"O
	148	74	W			R	2	24°16'10.73"S	66°23'25.06"O
Gemelos	342	81	E	82	80	N	1	24°45'2.61"S	66°10'8.02"O
	325	76	E	63	75	N	2	24°45'2.61"S	66°10'8.02"O
	233	37	S	292	32	R	2	24°45'2.61"S	66°10'8.02"O
	246	39	S	295	31	R	2	24°45'2.61"S	66°10'8.02"O
	345	81	E	68	80	R	1	24°45'2.61"S	66°10'8.02"O
	330	75	E	72	74	N	3	24°45'2.61"S	66°10'8.02"O
	352	86	E	68	85	R	3	24°45'2.61"S	66°10'8.02"O
	230	45	S	278	36	R	2	24°45'2.61"S	66°10'8.02"O
	238	48	S	40	18	N	2	24°45'2.61"S	66°10'8.02"O
Organullo	335	75	E				2	24°19'12.45"S	66°19'35.23"O
	350	50	E				2	24°19'12.45"S	66°19'35.23"O
	350	70	E				2	24°19'12.45"S	66°19'35.23"O
Saladillo	278	75	E	87	35	N	1	24°33'32.80"S	66°12'13.29"O
	325	78	E	132	45	N	2	24°33'32.80"S	66°12'13.29"O
	322	60	E	133	15	R	3	24°33'32.80"S	66°12'13.29"O
	282	80	E	94	35	N	2	24°33'32.80"S	66°12'13.29"O
	285	78	E	93	44		4	24°33'32.80"S	66°12'13.29"O