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Discussion

Comments on “Kinematic variations across Eastern Cordillera at 24°S (Central Andes): Tectonic and magmatic implications” by Acocella, et al. [Tectonophysics 434 (2007) 81–92]

Ivan A. Petrinovic [a,*], Fernando D. Hongn [a], Cecilia E. del Papa [a], Pablo J. Caffe [b]

[a] CONICET and IBIGEO (Universidad Nacional de Salta), Mendoza No 2 (4400) Salta, Argentina
[b] CONICET and Instituto de Geología y Minería, Universidad Nacional de Jujuy, Av. Bolivia 1661, (4600), San Salvador de Jujuy, Argentina

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ABSTRACT

The interpretation of Acocella et al. about (i) westward increase of strike-slip motion, (ii) strain partitioning, (iii) symmetry of the Central Andes, as well as (iv) the interpreted cause for the occurrence of magmatic centres behind the arc, from the Late Miocene onward, is largely speculative and contains major flaws. We demonstrate all above, that successive phases of deformation from Middle Eocene to Quaternary in the edge of the Puna–Eastern Cordillera, as well as the occurrence of arc/intraplate signatures in the magmatic centres of the Eastern Cordillera, result in complex geological framework which requires more detailed and intensive work in order to achieve sustainable interpretations.

1. Discussion

The strain state of the edge of the plateau (Puna–Altiplano)–Eastern Cordillera is paramount to understanding major points in the Andean history from Eocene times, and it has been a repeatedly debated issue since the first systematic research works on the evolution of the Andean chain as an archetype of a major non-collisional orogen (among others, Jordan et al., 1983; Pardo-Casas and Molnar, 1987; Isacks, 1988; Allmendinger et al., 1997; Kley et al., 1999; Coutand et al., 2001; DeCelles and Horton, 2003; Riller and Oncken, 2003; del Papa et al., 2004; Elger et al., 2005; Horton, 2005; Carrapa et al., 2005; Mpodozis et al., 2005; Dekeen et al., 2006; Oncken et al., 2006; Strecker et al., 2007; Hongn et al., 2007).

In a recent paper, Acocella et al. (2007) tried to solve this major issue with 36 sets of fault-slip data of unknown age distributed in five major faults of the Eastern Cordillera. Acocella et al. integrate their own data with others from the literature, in order to propose a structural symmetry of the Andean orogen by deformation partitioning related to oblique convergence along both margins of the orogen. In this context, the Puna and western portion of the Eastern Cordillera would record strike-slip movements along main faults while the forearc and the foreland show faults with a stronger dip-slip component. However, this interesting proposal is based on a limited data set which does not consider previous information and ignores well-defined geological facts.

Firstly, the solution of the deformation timing is a *sine qua non* condition to infer the history of changes in strain state. Acocella et al. (2007) simplify the deformation timing relationships by assuming that the Eastern Cordillera has built up from Late Miocene to Quaternary, disregarding previous work suggesting or demonstrating a pre-Late Miocene age of deformation in the Puna and Eastern Cordillera (e.g. Boll and Hernández, 1986; Andriessen and Reutter, 1994; Salfity et al., 1993; Monaldi et al., 1993; Mon et al., 1996; Coutand et al., 2001; del Papa et al., 2004; Haschke et al., 2005; Dekeen et al., 2006; Oncken et al., 2006; DeCelles et al., 2007; Hongn et al., 2007).

Because Paleogene and Neogene kinematics in part responds to previous heterogeneities mainly related to basement fabrics and Cretaceous rift faults (Allmendinger et al., 1983; Mon, 1993; Hongn and Seggiaro, 2001; Riller and Hongn, 2003; Kley and Monaldi, 2002; Kley et al., 2005), a detailed cartography of structures that may record superposed deformations, as well as a meticulous knowledge of fault timing in key places, are critical to build regional models as that proposed by Acocella et al. (2007).

One of the areas described by them (northern Calchaquí valley: site 62 in Fig. 2 of Acocella et al., 2007), preserves good evidence of Paleogene deformation (del Papa et al., 2004; Hongn et al., 2007) which is superimposed by Late Miocene–Quaternary faulting (Guzmán et al., 2006). Two major faults (Toro Muerto and Calchaquí faults, Méndez, 1975) with opposite dips define the present configuration of the northern portion of the Calchaquí valley (Fig. 1a). The west Toro Muerto Fault is a west-dipping east-vergent thrust that has been

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* Corresponding author. Museo de Ciencias Naturales, Mendoza 2 (4400), Salta, Argentina. Tel./fax: +54 387 4318086.
E-mail address: ipetrinovic@yahoo.com (I.A. Petrinovic).

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active since the Eocene (Fig. 1a, b; see also Hongn et al., 2007). The east-dipping Calchaquí fault marking the eastern boundary of the valley shows two segments: the south is a west-vergent thrust while the north is a high-angle (close to vertical) reverse fault. The linkage between the two segments occurs next to the Quaternary Los Gemelos volcanoes (Guzmán et al., 2006), east of the Cerro Bayo. The almost vertical northern segment of this fault records Quaternary deformation as described by Marrett et al. (1994) and Guzmán et al. (2006) and suggested by the following features: (i) the presence of Quaternary volcanoes (Fig. 1a) close to La Poma town, (ii) the very juvenile landscape along the eastern margin of the valley as displayed by the topography contour lines in the map of Fig. 1a, and (iii) the current seismic activity in the region (an earthquake destroyed La Poma town in 1930). The Saladillo fault splits from the Calchaquí fault and also shows evidence of Quaternary activity (i.e.: dykes and necks of the Quaternary Saladillo volcano are aligned following the strike of the Saladillo fault (120°–160°)).

Strike-slip motion in conjugated faults, slightly oblique to the major thrusts of the Calchaquí valley, was previously pointed by several authors (Marrett et al., 1994; Mon and Salfity, 1995; Riller et al., 1999; Riller et al., 2001; Guzmán et al., 2006: Fig. 2a, p. 53). The fault-slip data presented by Acocella et al. in the stereoplots of Fig. 2 (site 62), seems to be similar to those presented and interpreted as related to Quaternary deformation by Marrett et al. (1994; Fig. 18c, p. 194). This comparison suggests that the data collected by Acocella et al. came from the Calchaquí and linked faults, thus recording the young Quaternary deformation in the area. The very juvenile landscape along the eastern margin of the valley between the Saladillo and Cerro Bayo latitudes points to a very young and intense basement uplifting, which may be related to transpressional deformation as suggested by Riller et al. (1999) and Riller and Oncken (2003) according to the Quaternary conjugated faults mentioned above. In this context, a major dip-slip component of the Calchaquí fault during the Middle Miocene is well documented, according to the very close crystallization and exhumation ages of the Acay pluton (ca. 13 Ma; Haschke et al., 2005).

During the Eocene, the Calchaquí and Saladillo faults were also active thrusts and controlled the folding of the Cretaceous–Paleogene Salta Group strata and the deposition of the Middle Eocene Quebrada de Los Colorados Formation (del Papa et al., 2004; Hongn et al., 2007).

Thus, the present configuration of the northern portion of the Calchaquí valley results from a long and complex structural evolution, including fault reactivations and superposed deformations as also indicated by folds with different orientations (Fig. 1a; see also Marrett et al., 1994; Riller et al., 1999; Hongn et al., 2006, 2007). According to the information presented in Fig. 2 of Acocella et al. (2007), it is not possible to distinguish which major fault was measured (Calchaquí Fault or Toro Muerto Fault) because the fault drawn in this figure outlines the centre of the valley. As it was pointed out before, both faults are quite different in timing, style, angle and vergence. On this rather complex geologic framework, and based on data from a site with 8 measurements (6 data with undefined kinematics and two with dextral sense: Fig. 2 and Table 1 of Acocella et al., 2007), Acocella et al. interpret that the Calchaquí valley faults are dominantly strike-slip and define a key area for proposing a westward progression from dip-slip (contraction) to strike-slip motions at the Eastern Cordillera.

Station 22 in Acocella et al. is on the Muñano fault (Ramos, 1974). This structure is a reverse fault with a high topographic basement block in its eastern hanging wall (Donato and Vergani, 1988), a framework comparable to that described for the Calchaquí fault. From 9 measurements of fault-slip (6 with dextral movement, 1 reverse, 1 reverse-sinistral and 1 sinistral) the authors interpret a strike-slip, dominantly dextral movement. The Muñano fault is apparently the northern continuation of the Calchaquí fault as a west-vergent thrust (Donato and Vergani, 1988). However, Acocella et al. draw the west-vergent Muñano fault to the south in apparent connection with the east-vergent Toro Muerto thrust without the necessary data evidencing any kind of transference. As in the northern Calchaquí valley, the scarce data collected by Acocella et al. in site 22 allowed them a new interpretation that is not totally compatible with the geological framework.

According to Acocella et al., sites 62 and 22 record well-defined evidence for interpreting a strong strike-slip movement along main faults on the western border of the Eastern Cordillera. We consider that the interpretation of Acocella et al. is not entirely supported by the presented data set, which consists of measurements in undated faults and may be valid only at a local scale.

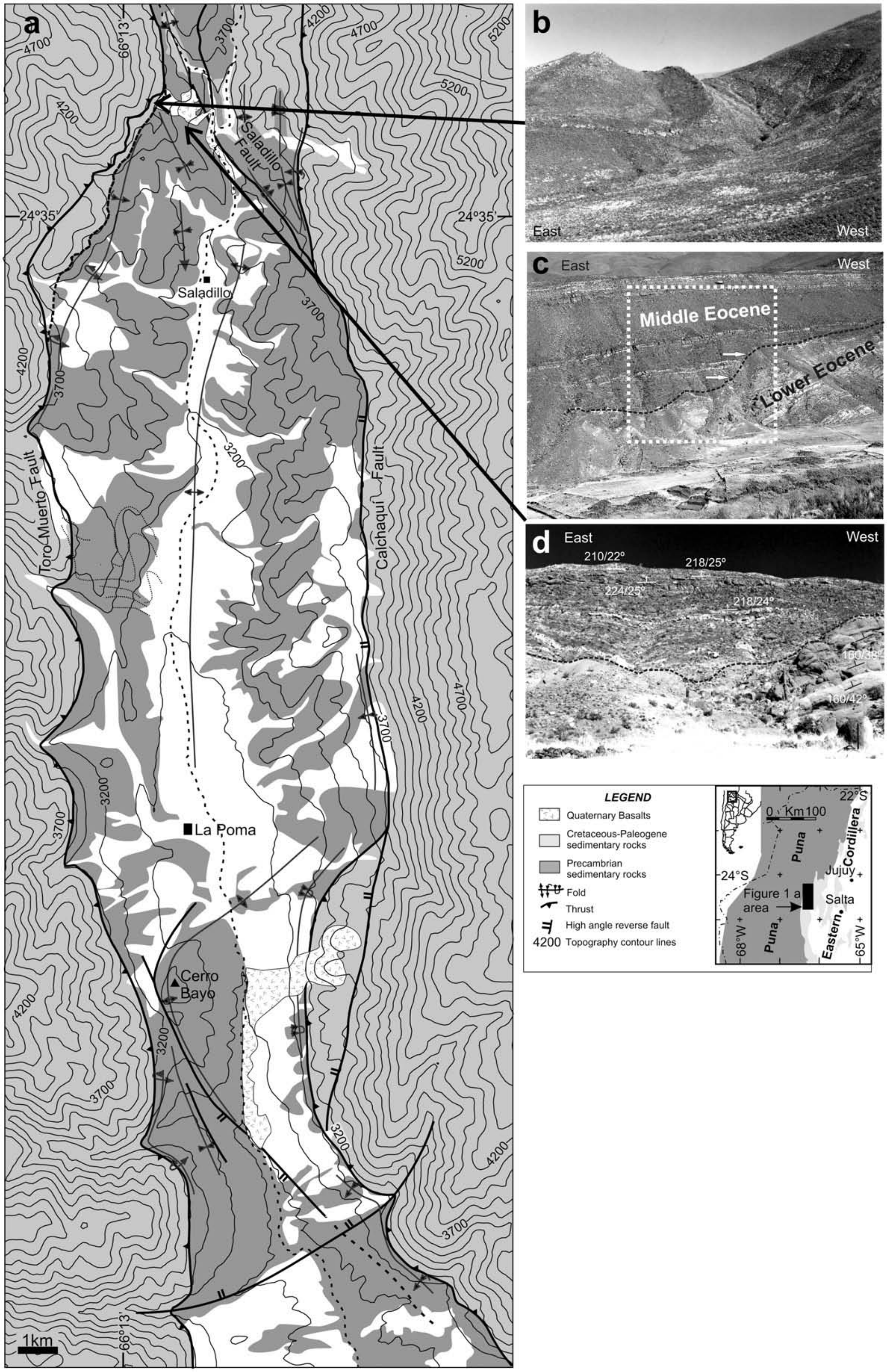
Furthermore, with the same data set, Acocella et al. try to calculate the amount of horizontal displacement by a simple relationship between shortening and strike-slip component based in the pitch of striations on faults. This seems an oversimplification since data are scarce and came from areas in which the complex geologic framework compels more detailed and intensive work in order to achieve more sustainable interpretations.

In the Quebrada del Toro and neighbouring areas (Fig. 2, sites 50 and 53: Acocella et al., 2007), the Neoproterozoic–Early Paleozoic basement is covered by a sedimentary sequence including the Upper Cretaceous to Eocene Salta Group and Neogene strata (Schwab and Schäfer, 1976; Marrett and Strecker, 2000; Strecker et al., 2007). Although the geological picture seems comparable to that described in the nearby Saladillo–northern Calchaquí valley sections (Hongn et al., 2007), Paleogene sediments filling basins related to Andean shortening have not yet been described in the Toro basin. However, Acocella et al. assume an Oligocene age for the sediments in the valley interior and a Late Miocene, or younger, age for the faults juxtaposing the basement on the sediment. Again, the authors show an oversimplified picture that does not consider well known geological features indicating Oligocene uplifting ages close to the Toro basin (Andriessen and Reutter, 1994) or Middle Miocene deformation controlling the emplacement of the Las Burras pluton (ca. 14 Ma) as described in their paper.

Recent research demonstrated that the Puna and the Eastern Cordillera preserve evidence of the first stages of the Andean deformation and uplifting at the Middle Eocene (Mon et al., 1996; del Papa et al., 2004; Hongn et al., 2007; DeCelles et al., 2007) and at Late Eocene–Oligocene times (Kraemer et al., 1999; Coutand et al., 2001; 2006; Dekeen et al., 2006). Hongn et al. (2007) documented an important phase of contraction during the Eocene (Fig. 1c), contemporaneous with the deformation described by Mpodozis et al. (2005) in the Atacama region, reinforcing the complex nature of the southern Central Andes deformation since the Eocene. Again, Acocella et al. show a conceptual error by constraining their Andean strain model only from the Late Miocene onward.

Another point in which the authors based their model is the magmatism and its relation with the strain field. The postulated absence of magmatic centres east of the Eastern Cordillera might be explained by processes other than the control of purely contractional structures. For instance, all the available geophysical data (e.g. Chmielowski et al., 1999; Zandt et al., 2003; Haberland et al., 2003) which support the existence of the mid-crustal partial melting zone depicted in Fig. 7 of Acocella et al. (2007), suggest that the easternmost limit of the Altiplano–Puna Magmatic Body (APMB) at 23–24° S is close to the Puna–Eastern Cordillera boundary (65.5°–66° W). Assuming that the APMB represents the relics of a 10 Ma to Present reservoir of crustal magmas (Babeyko et al., 2002; Zandt et al., 2003; de Silva et al., 2006), the simplest way to explain the lack of magmatic centres of crustal affinity to the east of the Puna–Eastern Cordillera limit is the sole absence of the APMB, needing not a structural (pure contraction) cause.

The latter point is reinforced by the observation that the easternmost magmatic centre of the Eastern Cordillera included in Acocella et al.'s study (the Las Burras monzonite), appears to have originated predominantly from mantle sources. Particularly, the Las Burras stock


a
66°13'
24°35'
Saladillo Fault
Saladillo
Toro-Muerto Fault
Calchaquí Fault
La Poma
Cerro Bayo
4700
4200
5200
3700
3200
1km
b
East
West
c
Middle Eocene
Lower Eocene
d
210/22°
218/25°
224/25°
218/24°
160/38°
160/42°
LEGEND
Quaternary Basalts
Cretaceous-Paleogene sedimentary rocks
Precambrian sedimentary rocks
Fold
Thrust
High angle reverse fault
4200 Topography contour lines
22°S
24°S
0 Km 100
Puna
Cordillera
Eastern
Jujuy
Salta
Figure 1 a area
68°W
65°W

and nearby intrusives have $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios which range 0.70454–070531 and 0.51268–0.51259, respectively (Matteini et al., 2005a,b). These ca. 14 to 15 Ma rocks represent one of the least radiogenic magmas erupted in the Central Andes during Cenozoic times, and are isotopically similar to the Late Oligocene Chiar Khollu basalt (Davidson and de Silva, 1995) with which an intraplate-like chemical signature is also shared. The same mantle signatures have been proposed for a sub-crustal end-member of mafic Pliocene- to Quaternary volcanic rocks from the Eastern Altiplano (Davidson and de Silva, 1995), and for the mantle end-member of 14–12 Ma intermediate volcanic rocks from the easternmost northern Puna (Caffe et al., 2002). Although the presence of magmas erupted so faraway from the arc is truly intriguing, there seems to be not a unique explanation for the variety of compositions seen in rocks from the area, especially those regarding intraplate-like signatures (see Halls and Schneider, 1988; Kay et al., 1999; Davidson and de Silva, 1995; Caffe et al., 2002; Matteini et al., 2005a,b). Unfortunately, to link them to the APMB would be the least likely possibility to consider, because the latter is thought as the remains of a reservoir of hybridized melts dominated by crustal components (Kay et al., 1999; Caffe et al., 2002; Babeyko et al., 2002; de Silva et al., 2006).

With regards to the tectonic control on volcano emplacement, Acocella et al. (2007, p. 897) consider that “detailed field investigations suggest that most of the magmatic activity is locally focused along a releasing bend induced by the activity of N–S strike-slip fault (Matteini et al., 2005a)”, but neither Matteini et al. (2005a) nor Acocella et al. (2007) present any data to demonstrate this relationship. In any case, the emplacement of the ca. 14 Ma Las Burras monzonite (Hongn et al., 2002) is incorrectly included to prove the alleged relation between Late Miocene–Quaternary faulting and magmatism. Again, the authors did not consider the available ages of magmatic units in their model.

In summary, the data presented by Acocella et al. (2007) are of interest to the scientific community, in order to improve the knowledge of the Eastern Cordillera strain, but the propositions of westward increase of strike-slip motion, strain partitioning and symmetry of the Central Andes, as well as the interpreted cause for the presence of magmatic centres behind the arc are largely speculative and contain major flaws.

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Fig. 1. a: Simplified geological map of the northern portion of the Calchaquí valley (site 62 in Acocella et al., 2007). The map shows thrusts and high-angle reverse faults. The very juvenile landscape along the eastern border of the valley is related to young vertical motion on the high-angle reverse faults. Topographic contour delineate altitude variations close to 1500.00 m between the top of the elevations and the valley floor, defining the tectonic depression. Note the variability on fold axis orientation, which is related to folding superposition from the Eocene. b: Overturned fold and Eocene syntectonic unconformity related to Eocene activity of the Toro Muerto thrust. For more details see Hongn et al. (2007). c: Lower–Middle Eocene unconformity at Saladillo. For more details see del Papa et al. (2004). Box in stippled white line indicates the area shown in d. d: Detailed view of the Saladillo unconformity showing changes in bedding orientation (dip direction–dip) of sequences separated by the discontinuity.

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