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Interactive comment on "Three-dimensional approach to understanding the relationship between the Plio-Quaternary stress field and tectonic inversion in the Triassic Cuyo Basin, Argentina" *by* L. Giambiagi et al.

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Review Report by Enrico Tavarnelli for SOLID EARTH, manuscript N. 7 (pp. 59-494), 2015

"Three-dimensional approach to understanding the relationship between the Plio-Quaternary stress field and tectonic inversion in the Triassic Cuyo Basin, Argentina" by L. Giambiagi, S. Spagnotto, S.M. Moreiras, G. Gòmez, E. Stahlschmidt & J. Mescua

GENERAL OBSERVATIONS:

The results of a study carried out in the Cacheuta sub-sabin, a part of the inverted Triassic Cuyo Basin located in the Central Andes of Argentina, are presented. The study describes the geometry and kinematics of structures controlled by pre-existing basin-boundary extensional faults that were partly reactivated during a major episode of positive tectonic inversion of Pliocene-Quaternary age. In particular, the study aims at unraveling the three-dimensional geometry of structures resulting from fault reactivation processes, and at constraining the orientation of the main stress field responsible for geologically recent basin inversion. It is shown that the tendency to reactivate for pre-orogenic normal faults largely depends on their orientation with respect to the new superimposed stress field. The study also demonstrates that the orientation of pre-orogenic basin-boundary normal faults is a primary control on the kinematic character of structures produced during subsequent orogenic contraction, that is achieved through reverse-reactivation in part of the thrust belts, and by strike-slip reactivation in other domains. The analithical support consists of a detailed study of stratigraphic variations in thickness of Triassic deposits, integrated with surface and subsurface information on the present geometry of the main deformation features, such as fauts and related folds. The recent (Pliocene-Quaternary) stress field responsible for basin inversion is reconstructed through stress inversion methods from reliable kinematic indicators present on well-exposed minor faults. The propension for normal fault reactivation under the new superimposed stress field is investigated in terms of current slip tendency analysis methods. The results support the hypothesis of a control by pre-orogenic normal faults on the location and orientation of subsequent thrusts in terms of positive inversion tectonics. The general topic is of great interest not only because it explains the present geometry of the fold-and-thrust belt in this part of the Andean orogen, but also for their implications for hydrocarbon prospectivity in the area.

The manuscript is well written and well organised, with a generally good English form, that could though be further improved with the review and aid from an anglo-saxon mother language reviewer. Overall, it represents a very interesting and thought-provoking contribution, that deals with topics that are of great impact on the under-

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standing of the geometry and evolution of orogenic processes in basin inversion settings. General credit is given to the existing literature, both methodological and regional. However, papers specifically dedicated to structural controls on inversion, to the 3D aspects of precursor basins and to the mechanics of repeated reactivation resulting from fault-zone weakening are not mentioned. By coincidence, I happen to have authored several contributions on these topics. In general, I am reluctant to self-referentialism and to encourage other colleagues to cite my own research; however, under this specific circumstance, given my experience in the inversion tectonics field (which probably let to ther choice of my person for reviewing this contribution), I feel that I can point a short list of papers to the Authors' attention. The manuscript would, in my view, benefit from acknowledgement of those studies on positive inversion, mainly derived from the circum-Mediterranean fold-and-thrust belts, such as the Alps and especially the Apennines. These papers, a reference to which is provided separately, should be taken into account and acknowledged in the text and reference list.

The illustrations and tables are all clear, legible and informative. As a structural geologist trained to constrain geometry and kinematics of deformation structures, in examining the Cacheuta (Fig. 5a), the La Pilona (Fig. 5b) and the Tupungato (Fig. 6a) balanced sections I found that the depth to the main décollements at the base of these sections are not always justified by first-hand evidence. The Authors should, in my view, discuss the reasons that led to the choice of the depth to the main dècollements more extensively in the text.

Based on the abovementioned comments, I found this a valid and original contribution and believe that it will make an interesting title for Solid Earth. I believe that the manuscript needs a minor revision by the Authors before it is eventually accepted for publication. The revisions must incorporate several essential references to previous papers, and an extended discussion on the reasons for the location of the main dècollements at depth. More minor comments, linked to the text, are listed at the end of the general revision. I require no anonimity and wish that all my comments are for-

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warded to the Authors. In case of need, I declare my availability in providing a further review for the submitted manuscript. I hope that my review is received as a constructive indication, that may assist the Authors to achieve an even more suitable and better documented paper, and the Editors in formulating a final decision.

Siena, 28 February 2015 Enrico Tavarnelli

Specific comments keyed to the text:

1 - Page 462, line 9. The Authors quote the use of the MOVE academic software. A reference to its Author (Alan Gibbs) or to his firm (Midlend Valeey, Inc.) is required in the reference list.

2 – Page 462, line 21. Here and elsewhere in the text. Use is made of the term “meso-scale”. This is not wrong, in principle, although I would rather use the term “mesoscopic”.

3 – Page 462, line 26. The Authors quote the use of the T-Tecto 3.0 software. A reference to it, that is indicated in the text, should also be acknowledged in the reference list.

4 - Page 463, line 10. See point 1.

5 – Page 463, line 15. The Authors use the term “the seismically active front suffers a pronounced along-strike segmentation”. I would rather state that “the seismically active front exhibits a pronounced along-strike segmentation”.

6 – Page 464, line 13. “partially” instead of “parcially”.

7 – Page 464, line 20. “Zavattieri and Arcucci, 2007”, quoted in the text, is not found in the reference list.

8 – Page 465, line 5. “Kokogian and Mansilla, 1989” in the text, is spelt “Kokogian and Mancilla, 1989” in the reference list.

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9 – Page 465, line 5. The reference to the paper by “Dellapé and Hegedu, 1995” in the text, is spelt “Dellapé and Hegedus, 1995” in the reference list.

10 – Page 465, line 22. “With the advance of the deformation front toward the foreland, the basin became. . .”.

11 – Page 466, line 1. The Authors use the term “bivergent” when referring to a fault system. Although the sentence is intelligible, the use of vergence is wrong when referring to faults, since vergence is an attribute of asymmetrical folds (inferred from the dip of a fold axial surface). I would rephrase stating that “The Precordillera is uplifted by a fault system with similar strike and opposite downward dip (Fig. 2), that can be structurally divided into. . .” .

12 – Page 466, line 22. In commenting the geometry of structures illustrated in Fig. 5 and 6, the Authors clearly state the reasons for their choice to locate a main décollement in shallow levels. However, the sections of Figs. 5 and 6 also show deeper décollements. The Authors should clarify the reasons that led them to locate those décollements at that depth.

13 – Page 467, line 24. See point 2.

14 – Page 469, line 21. See point 2.

15 – Page 470, line 15. “. . . as the result of local permutation of. . .” (of local, 2 separate words!).

16 – Page 472, lines 6 and 9. I would use the term “suitably” rather than “optimally”.

17 – Page 472, line 17. The Circum-Mediterranean orogenic belts have long been and are increasingly been recognized as a suitable ground for the study of inversion tectonics (Butler et al., 2006). In spite of many previous studies focused on the 2D geometrical analysis across structures resulting from inverted basins in the Apennines (e.g. Tavarnelli, 1996a) there is still a remarkable paucity of examples focused on the attempt at unraveling the 3D geometrical aspects of the precursor inverted basins. One

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pioneering reconstruction is that described by Tavarnelli (1996b). These studies (Butler et al., 2006; Tavarnelli 1996a, 1996b) should, in my view, be acknowledged in the text and cited in the reference list of the present contribution. The references are as follows:

- Butler R.W.H., Tavarnelli E. & Grasso M. (2006) – Structural Inheritance in Mountain Belts: an Alpine-Apennine Perspective. Journal of Structural Geology, 28, 1893-1908.

- Tavarnelli E. (1996a) - The effects of pre-existing normal faults on thrust ramp development: an example from the Northern Apennines, Italy. International Journal of Earth Sciences, 85, 363-371.

- Tavarnelli (1996b) - Tethyan heritage in the development of the Neogene Umbria-Marche fold-and-thrust belt , Italy: a 3D approach. Terra Nova, 8, 470-478.

17 – Page 472, line 19. The Authors correctly state that, after a first period of studies on geometrical and kinematic controls on positive inversion, during the last two decades particular attention was also devoted to questions on mechanics. An example, described by Tavarnelli et al. (2001) is provided by episodes of recognized, repeated reactivation during episodes of tectonic inversion, an evidence supporting the hypothesis of fault weakening through time. This study should, in my view, be acknowledged in the text and cited in the reference list of the present contribution. The reference is as follows:

- Tavarnelli E., Decandia F.A., Renda P., Tramutoli M., Gueguen E. & Alberti M. (2001) - Repeated reactivation in the Apennine-Maghrebide system, Italy: a possible example of fault-zone weakening? Geological Society of London Special Publication 186, "The Nature and Tectonic Significance of Fault Zone Weakening" (Holdsworth, R.E., Strachan, R.A., Maglouglin, J.F. & Knipe, R.J. , Eds.), 273-286.

18 – Page 472, line 21. "... there is a good agreement that the degree of reverse-reactivation of the inherited normal faults...". I would use the term "reverse-reactivation", as also used by Kelly et al. (1999), rather than "inversion" in this specific

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sentence.

19 – Page 472, lines 25-26. “. . . of the Cuyo Basin have assumed . . .” (have instead of has).

20 – Page 473, line 3. “Sarewicz, 1988” in the text, is spelt “Sarewitz 1988” in the reference list.

21 – Page 473, line 28. “. . . to slip under reverse/strike-slip. . .” I believe that the best term to use here is “transpressional”.

22 – Page 474, line 12. See point 21.

23 – Page 475, line 9. See point 22.

Siena, 28 February 2015, Enrico Tavarnelli

Interactive comment on Solid Earth Discuss., 7, 459, 2015.