Comments on:

Inversion of extensional basins parallel and oblique to their boundaries: Inferences from analogue models and field observations from the Dolomites Indenter, eastern Southern Alps

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General comments

The manuscript presents a series of analogue experiments meant to explore the role of pre-existing normal faults in the subsequent continental collision and thrust evolution. The experimental setting takes inspiration from the natural case of the Southern Alps. The study is well designed and the experimental part straightforward and well-illustrated. The results are of interest not only for the Alpine community, but for all Earth scientists working on the structural style of continental polyphase deformation. In my opinion, the manuscript misses a discussion between paleostress and strain partitioning on single structures. I try to explain it better in the following paragraph.

The discussion on how the reconstructed paleostress evolution correlates with the large-scale kinematic evolution, i.e. if the recorded deformation phases are due to partitioning along local structures or to regional stress field variations is long-lasting and it was addressed by several authors (e.g. Varga, 1993; De Vicente et al., 2009; Simon, 2019; Hippolyte and Mann, 2021). In the Southern Alps, the different “events” or “phases” have been recognized through regional studies with hundreds of studied sites along the whole Southern Alps and dated with a tectonic stratigraphic approach. The main picture of the paleostress evolution from the Late Oligocene to the Pleistocene was published by Castellarin et al., 1992, Castellarin et al., 1998 and Castellarin and Cantelli 2000. Later on, Caputo et al. (2010), confirmed the same paleostress evolution for the late Miocene to Quaternary at the front of the eastern Southern Alps. This research was addressed far from the main fault systems and did not consider the highly deformed rock volumes, as established by the first authors that adopted this method (e.g. Angelier, 1979; Bergerat, 1987).

Furthermore, a detailed reconstruction of the Africa-Europe convergence path, based on the magnetic anomalies of the Atlantic Ocean of Dewey (1989), presented by Mazzoli and Helman 1993 suggests a similar timing and direction of convergence as observed in the paleostress reconstruction of Southern Alps and other Mediterranean areas (see also Fig. 20 of Fellin et al., 2005 and Fig. 12 of Caputo et al., 2010).

For the exposed reasons, it is clear the authors should keep strain and stress separated in their discussions. From the authors experiments, one can visualize the role of previous faults or lateral facies juxtaposition on the inversion strain pattern. However, if the stress is local or regional, this cannot be explored by analysing few structural sites, but from much larger statistical approach. This was the Castellarin et al 1992 and Caputo et al 2010 approach. I urge the authors to develop this point in the discussion. This new discussion would bring also to a change in the last sentences of the conclusion. In fact, I think the results of this

manuscript do not question the paleostress analysis of previous authors, but it emphasizes the role of pre-existing structures in partitioning the strain along regional fault systems, such as the Belluno thrust.

In chapt. 6.2, the presentation of the various deformation phases is somehow confusing. Several issues: 1) the use of grey literature, such as the Nussbaum unpublished PhD thesis; 2) the occurrence of the pre-Adamello phase in the eastern Alps: why adding this as D2 phase, if the authors (correctly) claim this phase was never recorded in the eastern Southern Alps? 3) The authors propose Miocene (D3), a Miocene to Pliocene (D4) top S, and a final top to the E Plio-Pleistocene phase (D5). However, Castellarin and Cantelli (2000) and Caputo et al. (2010) document variable shortening axis between N340˚and N310˚, from Serravallian to the Pleistocene. Therefore, how did the authors separate the 3 last phases? Please, explain the method used, or correctly refer the previous authors findings
Finally, in Fig. 14 a2, the top to the S could be due to the mixing of SW and SSE directed faults, maybe formed at different time. This is a common problem of structural sites in the polydeformed Southern Alps, when cross-cutting relationships cannot be found. The authors should consider this alternative interpretation.

Specific points

Line 53 add Bernoulli and Jenkyns, 1974 in the references as the first modern paper dealing with platforms and basins in the Southern Alps.
Line 94 Early Permian (geochronology) instead of Lower Permian (chronostratigraphy).
Line 94 to 97 Actually, the Early Permian event is highly debated but very likely not associated to the rifting of the Hallstatt-Meliata ocean. See f.i. Muttoni et al. 2003 for interpretation associated to large scale intracontinental transform. Most scholars place the start of the first rifting phase in the Late Permian (e.g. Bertotti et al., 1993), ending in the Carnian.
Line 100, 134 and 722: too many brackets after Vrabeč, Zampieri, Beccaluva and Doglioni.
103-105 the quoted papers of Martinelli, Pieri & Groppi and Masetti are not suitable for the depth of faulting, since they are not based on observations, purely speculative. Two case studies of depth prolongation of the normal faults in the western Southern Alps are the Lugano fault (e.g. Bertotti, 1990) and the Pogallo fault (Handy, 1987). I would find more convincing quoting these last authors, although they are dealing with structures that slipped more than the ones of the eastern Southern Alps.
Line 136 No reference to age in Fantoni and Franciosi (2010) and Vignaroli et al. (2020)! I double checked them, since Late Oligocene SSE directed shortening is in contrast with the tectonic stratigraphy presented by Castellarin et al. (1992), Castellarin and Cantelli (2000). These latter papers, based on data collected on large parts of the Southern Alps, document a Chattian to Burdigalian SSW directed shortening on a regional scale. See General Comments.
Line 150-151 better quote Venzo 1977 for the folded Pliocene.
172 Variscan
175 Late Permian
178 Please revise this sentence. Besides the two “are”, the message is not clear.
185 “bioclastic to marly sediments” is not correct for describing the Paleogene to Miocene stratigraphy. Please, use “limestone and marls”.

186 During the Early Jurassic. “Footwall of rifted margins” is not correct: footwall refers to a fault limb; rifted margins refer to a larger scale epicontinental sea. You can use: “footwall of the major normal faults”, instead.
193 evaporite-bearing shales, instead of facies associations.
340 which simulates
397 preferentially instead of preferred? Change e.g. (*exempli gratia*), used when you choose some examples from a larger list, with i.e. (*id est*), used when, as in this case, the authors deepen the meaning of the previous words.
445 Fig. 9 appears prior to Fig. 8, which is named first in Line 461. Consider revising the order and number of the Figures…
453 and 471 Compared to, instead of Comparable
500 Both model 7 and model 8 show. No commas
610 not clear to what are the authors referring with “former”
611 …developed, as…
676 to 678 Unclear this change of scale and the relevance of the Calignano et al 2017 paper. Please, motivate it.
688 …2022), we focus…
747 “steep to the S dipping backthrust” Please, change in: backthrust steeply dipping to the S.
771 …along major fault zones.
779 D’Alberto
936 Carnico-Friulano, 1992. Studi Geologici Camerti. Nuova Serie (1992): 275-284.
1091. Memorie di Scienze Geologiche, Padova, …

References

Angelier, J. (1979). Determination of the mean principal directions of stresses for a given fault population. *Tectonophysics*, *56*(3-4), T17-T26.

Bergerat, F. (1987). Stress fields in the European platform at the time of Africa-Eurasia collision. *Tectonics*, *6*(2), 99-132.

Bernoulli, D., & Jenkyns, H. C. (1974). Alpine Mediterranean and central Atlantic Mesozoic facies in relation to the early evolution of the Tethys.

Bertotti, G. (1990). *Early Mesozoic extension and Alpine tectonics in the western Southern Alps: The geology of the area between Lugano and Menaggio (Lombardy, Northern Italy)*(Doctoral dissertation, ETH Zurich).

Castellarin, A., Cantelli, L., Fesce, A. M., Mercier, J. L., Picotti, V., Pini, G. A., Prosser, G. & Selli, L. (1992). Alpine compressional tectonics in the Southern Alps. Relationships with the N-Apennines. In *Annales tectonicae* (Vol. 6, No. 1, pp. 62-94).

Castellarin, A., & Cantelli, L. (2000). Neo-Alpine evolution of the southern Eastern Alps. *Journal of Geodynamics*, *30*(1-2), 251-274.

De Vicente, G., Vegas, R., Muñoz-Martín, A., Van Wees, J. D., Casas-Sáinz, A., Sopeña, A., ... & Fernández-Lozano, J. (2009). Oblique strain partitioning and transpression on an inverted rift: The Castilian Branch of the Iberian Chain. *Tectonophysics*, *470*(3-4), 224-242.

Handy, M. R. (1987). The structure, age and kinematics of the Pogallo Fault Zone; Southern Alps, northwestern Italy. *Eclogae Geologicae Helvetiae*, *80*(3), 593-632.

Hippolyte, J.-C., and P. Mann, 2021, Neogene paleostress and structural evolution of Trinidad: Rotation, strain partitioning, and strike-slip reactivation of an obliquely colliding thrust belt, in C. Bartolini, ed., South America–Caribbean–Central Atlantic plate boundary: Tectonic evolution, basin architecture, and petroleum systems: Tectonic evolution, basin architecture, and petroleum systems: AAPG Memoir 123, p. 317–346. DOI: 10.1306/13692249M1233851

Muttoni, G., Kent, D. V., Garzanti, E., Brack, P., Abrahamsen, N., & Gaetani, M. (2003). Early Permian Pangea 'B'to Late Permian Pangea 'A'. *Earth and Planetary Science Letters*, *215*(3-4), 379-394.

Simón, J. L. (2019). Forty years of paleostress analysis: has it attained maturity?. *Journal of Structural Geology*, *125*, 124-133.

Varga, R. J. (1993). Rocky Mountain foreland uplifts: Products of a rotating stress field or strain partitioning? *Geology*, *21*(12), 1115-1118.

Venzo, S., with collaboration of Petrucci, F., & Carraro, F. (1977). I depositi quaternari e del Neogene Superiore nella bassa valle del Piave da Quero al Montello e del Paleopiave nella valle del Soligo (Treviso). *Memorie degli Istituti di Geologia e Mineralogia dell'Universita di Padova*, *30*, 1–27.