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Reply to the comments by G. Bertotti and V. Picotti on: "Uplift and contractional deformation along a segmented strike-slip fault system: the Gargano Promontory, southern Italy"☆

Bertotti and Picotti (2004) raise a number of questions with our paper (Brankman and Aydin, 2004) dealing primarily with the nature and origin of the structures in the Gargano Promontory in southern Italy. We welcome their comments and appreciate the opportunity to clarify our observations and interpretations.

Before discussing the scientific issues, we should first note that we regret the omission from our manuscript of several papers from the recent literature, which included several of those by the above authors and their associates. These omissions stem from the fact that this work was completed essentially by August 1999, and from the long time between the initial submittal of the manuscript in 1999 and resubmission and acceptance in 2003. Except for a few references that were brought to our attention during the review process, the literature survey for our publication was completed by August 1999. The omissions were therefore inadvertent but in any case we apologize for them. The authors (Bertotti et al., 1999; Casolari et al., 2000) did a commendable job on the stratigraphic and depositional history of the rocks in the Gargano area and their results should be great resources for future geological studies in the area. However, central to the discussion at hand is the origin of the structural deformation of the Gargano Promontory. In this regard, neither the authors' comments in this issue (Bertotti and Picotti, 2004) nor their models in their earlier published work (Bertotti et al., 1999) provide a sound alternative to the model proposed by Brankman and Aydin (2004).

The anomalous nature of the contractional deformation of the Gargano Promontory is not arguable. This deformation can be characterized by NW-trending thrust faults and folds and the nearly E–W-trending strike-slip faults localized within an approximately rectangular block. This block is surrounded by the adjacent regions of little disturbance several tens or hundreds of kilometers to the east and west. The following quote from Bertotti et al. (1999, p. 172) expressed this setting and its origin: "The localization of strain in the Gargano area could be due to the presence of older discontinuities such as a platform/margin transition and/or, more importantly, of Late Cretaceous to Palaeogene normal faults." In the same publication, they entertained the idea, attributed to Funiciello et al. (1991), that the Gargano Promontory "could be kinematically decoupled from adjacent areas by transverse fault zones". Therefore, Bertotti and Picotti's criticism of our model for the Gargano area as an isolated contractional block on the basis that the contractional structures are not in contrast to the rest of the Apulian Platform and that the proposed bounding transverse faults do not exist is disingenuous.

The second quote above, interestingly, is precisely the model that we propose in our paper—that the deformation within the Gargano block differs from, and is controlled by fundamentally different mechanisms than, the deformation in the surrounding Apenninic foreland region, and that strike slip faults, analogous to the 'transverse fault zones' of Bertotti and Picotti (2004), are the structures that controlled the contractional deformation. We have never claimed that there are not minor folds and thrust faults outside of the promontory within the Apulian Platform. However, the contractional deformation in the Gargano is pervasive and strong, whereas that in the remainder of the Apulian foreland is of a much lower intensity and sparsely distributed.

The most crucial information regarding the origin of the contractional structures in the Gargano area is the interrelationship between the thrust faults and folds and the E–W strike-slip faults. The former always merge or splay away from the latter with increasing frequency near the end of the transverse fault segments. One can even recognize this geometry from the schematic structural map of the Gargano area by Bertotti et al. (1999) (see their Fig. 1), as well as the fault patterns interpreted by Chilovi et al. (2000). The failure to recognize this relationship has serious consequences in terms of the interpretation of the contractional structures in the Gargano area and is partly responsible for this discussion.

The conceptual and mechanical models in Brankman and Aydin (2004) are based upon idealizations of the fault

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configuration in the area. We stated that the southern boundary of the Gargano structural domain is complex and comprised of more than one subparallel strike-slip fault. The Mattinata fault is one of these faults and helped us to illustrate the left sense of slip across E–W-trending transverse faults and their temporal and spatial relationships to the thrust faults, folds, and pressure solution seams. The Rignano fault, which has also been mapped by Salvini et al. (1999), Chilovi et al. (2000) and other earlier workers, trends subparallel to the Mattinata fault and is another of the fault strands that, taken together, form the southern boundary of the uplifted block. We disagree with the interpretation of Bertotti and Picotti (2004) that this is not a fault, but rather a fold limb.

Those of us who have mapped strike-slip faults in various scales have long realized that a large fault zone includes many strands and the associated structures. This aspect was also illustrated in an example from southern Apennines taken from Monaco et al. (1998) in our paper (Fig. 12a). Claiming that the single fault lines representing the boundary faults in our conceptual and mechanical models do not exist is missing the point.

The continuity of the faults forming the southern boundary of the Gargano block to the west is a fair question. The low-lying region west of the Gargano is covered with Quaternary sediments, and Fig. 2 of Brankman and Aydin (2004) shows the faults dashed under the eastern extent of these deposits. Bertotti and Picotti (2004), referring to Chilovi et al. (2000), claimed that the Mattinata fault is continuous to the west and therefore cannot be the southern bounding fault (the southern rail in their terminology) of our contractional block. In fact, Chilovi et al. (2000), both in their inferred fault map (red lines in their Fig. 4, p. 5) and their conceptual model (Fig. 6, p. 7) traced the Mattinata fault to the west under the young sedimentary cover as discontinuous segments consistently stepping to the north for a combined distance of about 20 km, which is about the distance between the exposed trace of the Mattinata fault (inner southern rail) and the southernmost strand of the northern boundary fault (inner northern rail). Hence, the picture envisioned by Chilovi et al. (2000) is supportive of the notion proposed by Brankman and Aydin (2004), except for their proposal of a change of the sense of slip along the E–W faults. However, this is not the appropriate venue to discuss this difference.

The northern boundary of the Gargano block is also complex and not well exposed. However, there are several lines of evidence for the presence of a series of E–W-trending transverse structures again within a broad zone:

(1) The E–W-trending geomorphic lineaments and occasional outcrops of disrupted bedding and brecciation similar to those found along the better exposed transverse faults in the south. Some of these have been shown by previous workers in regional geologic maps near the town of Rodi Garganico as well as in the region between Lago di Varano and Lago di Lesina (Cremonini et al., 1971; Funiciello et al., 1988) and in the surface and subsurface to the northwest (Chilovi et al., 2000).
(2) Occurrence of isolated volcanics at Pietra Niore in trend with the geomorphic features, which may have localized along this broad shear zone.
(3) It is possible that there are transverse faults to the north of the Gargano under the sea. While we are unable to investigate this possibility, the nearest exposures in the north of the promontory are those in the Tremiti Islands, which suggest the presence of similar transverse structures therein (Funiciello et al., 1991). Ironically, the Tremiti transverse fault was considered as a decoupling zone between the Gargano contraction and the area with little deformation to the north by Bertotti et al. (1999, p. 172).
(4) The apparent left-lateral offset of the Apenninic front along strike with this boundary zone is also strong evidence for the presence of transverse structures with possible left sense of slip. In fact, this piece of evidence is what we referred to as the western continuation of the left lateral strike slip fault zone and westernmost extension of any transverse structure from south of the Gargano Promontory to Tremiti Island. It is therefore justified to assume that whatever the actual fault pattern under the young deposits between the Apulian platform and the Apennine fold and thrust belt is like, the northernmost strands are also the westernmost extension of the system.

We take issue with the statement by Bertotti et al. (2004) that we have “placed the faults where layers are steep, but without detailed fault observations”. We note that highly disrupted, steeply dipping bedding does occur immediately adjacent to faults (e.g. along the Mattinata fault, west of San Giovanni Rotondo). We do not exclude or deny the presence of dipping beds elsewhere; however, we did not use the presence of steep bedding as the sole criteria for interpretation of a fault. Rather, we use instances of sharp, dramatic variations of bedding away from the regional dip as one of several indications for the presence of a fault in an area of poor exposure. While we agree that detailed exposures of several of the NW–SE striking reverse faults are rare, we note that our fault locations and lineaments largely agree with those shown by Bertotti et al. (1999), and thus our interpretation of the location and sense of slip of these reverse faults is not contradictory to theirs. In addition, more faults in this orientation are mapped in similar locations and orientations by Chilovi et al. (2000).

Finally, we note that the interpretations provided by Bertotti et al. (1999), while intriguing, do not fully address the basic question of why the deformation is localized in a zone of such finite dimensions. They state that the Gargano formed as a series of SW-vergent thrust slices. However, the cross-section that forms the basis of their model is largely qualitative and lacks quality subsurface control or, in the absence of borehole or seismic data, a defensible balanced kinematic model. There is no discussion of why the NW–SE striking thrust sheets are obliquely truncated by the E–W-trending transverse faults (or their interpreted folds), or why these thrust sheets define an E–W-trending uplifted block that is oblique to the strike of the thrust sheets. So while the often limited surface exposure in the Gargano allows several differing interpretations of the underlying structure, we conclude that their interpretations relying on an uncertain thrust fault at depth or normal faulting explanation (see the quote above) do not provide a sound alternative model for the localized contractional deformation of the Gargano promontory.

In summary, we again apologize for the inadvertent omissions of the papers by Bertotti and Picotti and their co-workers from the literature review in our paper. We understand their disappointment that unfortunately appears to color their scientific comments. However, we maintain that strike-slip-related deformation is a sound mechanism for localized contractional deformation in an otherwise predominately extensional belt in eastern Italy and similar environments.

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