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Large-scale crescent-like structures in the western Mediterranean ultimate arc (Gibraltar arc orogenic system)

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The external wedge of the Gibraltar arc orogenic system, in the westernmost Mediterranean, is a natural case of fold-and-thrust salient in a tight arc. This arc is mainly shaped by the tectonic complexes distribution, the outer boundary of the internal zone, and the structural trend of the folds and thrusts of the external zones. In terms of leading edge (350km), chord length (240km), curvature and type of substrate (Triassic evaporites), the external wedge of the westernmost part of the Gibraltar Arc (west of 4º30'W) is comparable with the Jura arc in the Alps. Accordingly, around the Gibraltar arc, it would be expected to observe a relatively simple swing of the fold and thrust directions. Nevertheless, our data reveal that the geometry of the structures within the external fold-and-thrust belt is much more complex. Indeed, although at regional scale the aforementioned swing of the structural trend can be observed, the presence of closed, crescent-like structures, several of them more than 25km long, characterizes the northern branch of the Gibraltar Strait area. It must be stressed that these anomalously directed structures are localized in front of an entrant of the internal zone which acted as a backstop during the shortening episodes related to arc-building.

Detailed geological mapping, structural and kinematic analyses, and relationships between Miocene to Pliocene structures and syn-orogenic sediments show that these half-moon type large-scale structures are formed by thrust systems stacked during the first stages of the main shortening (WNW-ESE to E-W compression direction in the fold-and-thrust belt in this area of the Gibraltar Arc), then refolded. This type of interference in an orogenic external zone can occur only if it rises from the succession of two sub-perpendicular shortening events. Applied to the westernmost part of the Gibraltar Arc, a N-S to NNE-SSW direction of compression should be evoked, which is incompatible with the known structural evolution of the area.

In fact, in the light of analogue modelling, our field data and the available age constrain suggest that these large-scale crescent-like structures result of a progressive deformation and started to form during the main shortening event. Some of the thrust stacks formed originally with a highly oblique direction with respect to the main structural trend during the first stages of the main compressional event. These highly oblique structures were then refolded during a late stage; meanwhile, the structures perpendicular to the shortening direction and drawing the main trend were only tightened and the structures oblique but not sub-perpendicular to the shortening direction probably rotated. In turn, these first stage oblique structures can be due to a combination of factors in which both the presence of an entrant drawn by the backstop geometry associated with a substrate of Triassic evaporites which favour lack of cylindrism are decisive, but the presence of transfer faults, reactivated paleomargin faults or normal faults associated with arc parallel stretching are not negligible.

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