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Longitudinal fracture generation in the Fiastrone anticline, Sibillini thrust sheet, Northern Apennines (Italy)

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Abstract: The statistical analysis of folding-related fracture distributions is a well known tool to obtain structural constraints on fault-fold kinematic evolution. In this work we illustrate the fracture pattern exposed in the Fiastrone anticline (northern Appenines) to determine the relationships between longitudinal fracture patterns and fold growth. Results indicate a mostly syn-folding origin, with a fracture network dominated by hinge perpendicular extension in the crest and hinge perpendicular compression in the fold limbs.

Keywords: fold, fractures, pressure solution, northern Appenines.

During fault-related folding, stratigraphic (Corbett *et al.*, 1987), environmental (Chester *et al.*, 1991) and structural (Srivastava and Engelder, 1990) factors interact to determine the type, frequency, and attitude of folding-related fractures. Accordingly, analysis of folding-related fracture patterns can provide information about fault-fold kinematic evolutions. Moreover, field studies of folding-related fracturing are very useful to provide analogues for fracture distribution predictions at depth. This is particularly relevant because of the influence that fractures exert on the migration and accumulation of fluids in the subsurface.

Fracture network in thrust-related anticlines is commonly characterised by different subsets displaying well-known geometrical relationships with the host-fold. Fractures strike parallel, perpendicular and oblique to the fold axis (Stearns, 1968; Hancock, 1985; Cooper, 1992) and are mostly at high angle to bedding (Tavani *et al.*, 2006). The last feature frequently led to pre-folding interpretations of fracture networks (Thorbjornsen and Dunne, 1997). On the other hand, statistical analysis of large high-angle fracture datasets frequently indicates the existence of a relationship between fracture attributes and structural position within folds (Srivastava and Engelder, 1990; Cooper, 1992).

This works reports on fracture data collected in the Fiastrone anticline (Northern Appenines, Italy), where we performed statistical analysis of fracture distributions with the purpose of investigating fracture attitude and relative chronology with respect to the anticline growth.

The Miocene-Pliocene Fiastrone anticline is located in the central part of the Sibillini thrust sheet, one of the major thrusts of the Northern Apennines (Fig. 1). The folded multilayer consists of alternating limestones, marls and clays (Umbro-Marchean stratigraphic succession). The anticline is characterised by an eastward transport direction,

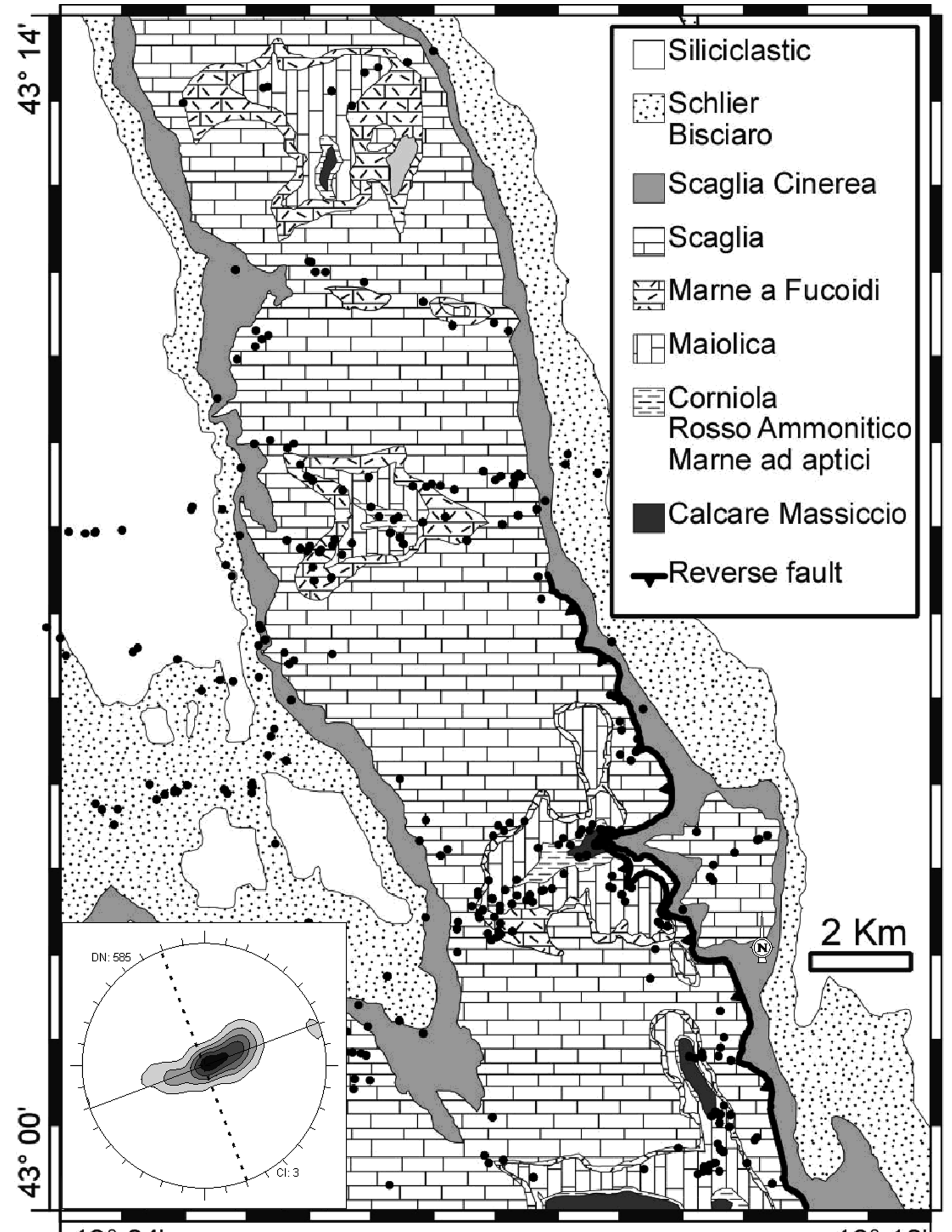

Figure 1. Geological map of the Fiastrone anticline with location of the measurement taken (black dots) and cumulative contour (equal area stereographic projections in the lower hemisphere) of poles to bedding.

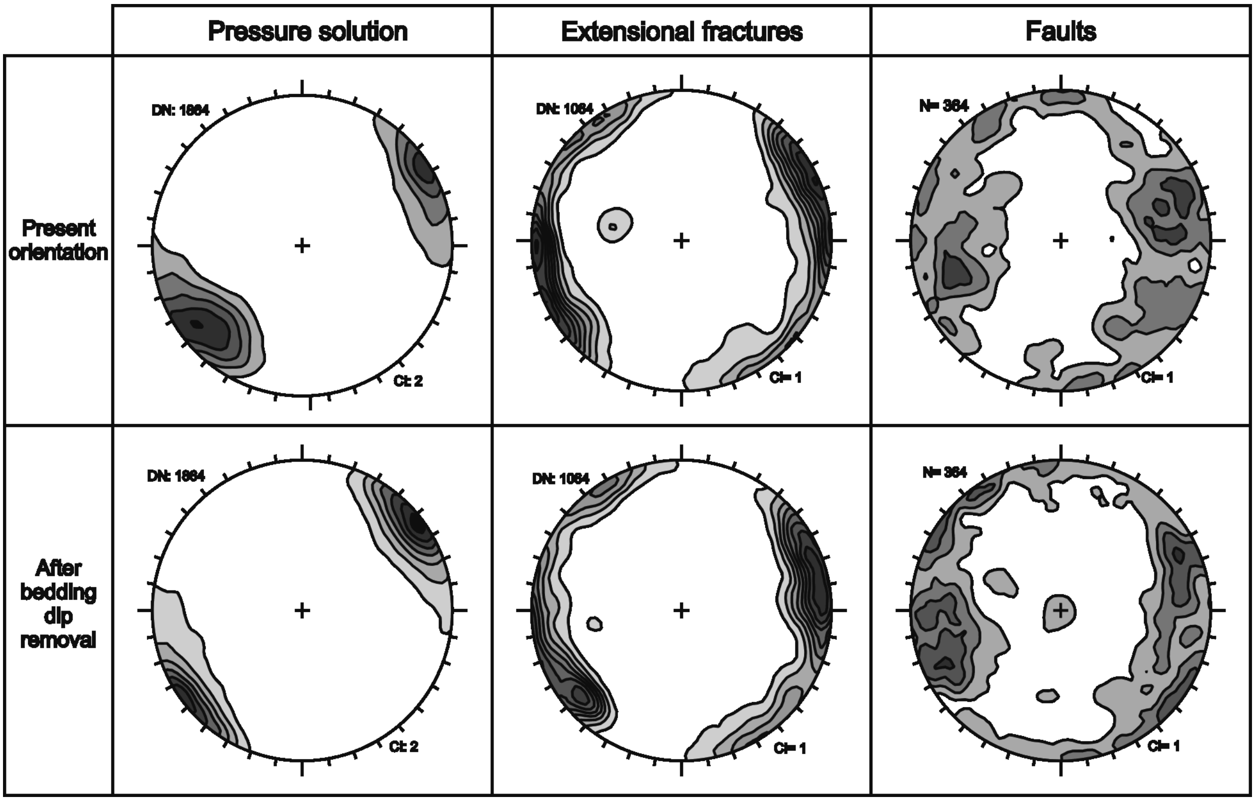

Figure 2. Cumulative contouring of the present-day orientation and after bedding dip removal (rotation of data for each station in order to make bedding horizontal) of poles to pressure solution cleavages, joints and normal faults.

being 340°N the average fold axial trend (Fig. 1). The anticline geometry includes a gently westward-dipping back limb, a wide flat crestal panel and a steep eastward dipping to overturned forelimb. Data were collected in 325 georeferenced field analysis sites in the Maiolica (marly limestones) and Scaglia (limestones) Formations, where deformation structures were characterised by their orientation, overprinting relationships, spacing, termination or non-termination at bedding, and geometric relationships to bedding. The thickness of the boundary layers was also measured for stratabound elements.

In the Fiastrone anticline, pressure solution cleavage is at high angle to bedding and strikes parallel to fold axis (Fig. 2). Joints are characterized by two sets at high angle to bedding: the first one corresponds to elements striking about parallel to fold axis; the second one corresponds to elements striking perpendicular to fold axis. Fault data are scattered, with two relative maxima corresponding to conjugated longitudinal normal fault sets.

Pressure solution cleavage mostly locates in the fold limbs, whereas joints and normal faults mostly locate in the crestal sector. This is well imaged (Fig. 3A), where the normalized frequency of pressure solution cleavage and joints vs. bedding dip is plotted.

The progressive reduction of the pressure solution cleavage frequency, from the fold limbs towards the crestal sector is also well imaged in the structural transect across the fold (Salvini *et al.*, 1999) of the pressure solution cleavage H/S ratio (equivalent to C/B fissility of Durney and Kisch, 1994) (Fig. 3B). The H/S ratio is high in the fold limbs and reduces towards the crest, indicating a progressive transition from hinge perpendicular compression to hinge perpendicular extension.

Conclusion

The longitudinal fracture distribution in the Fiastrone Anticline is schematically illustrated (Fig. 4) and can be summarized as follows:

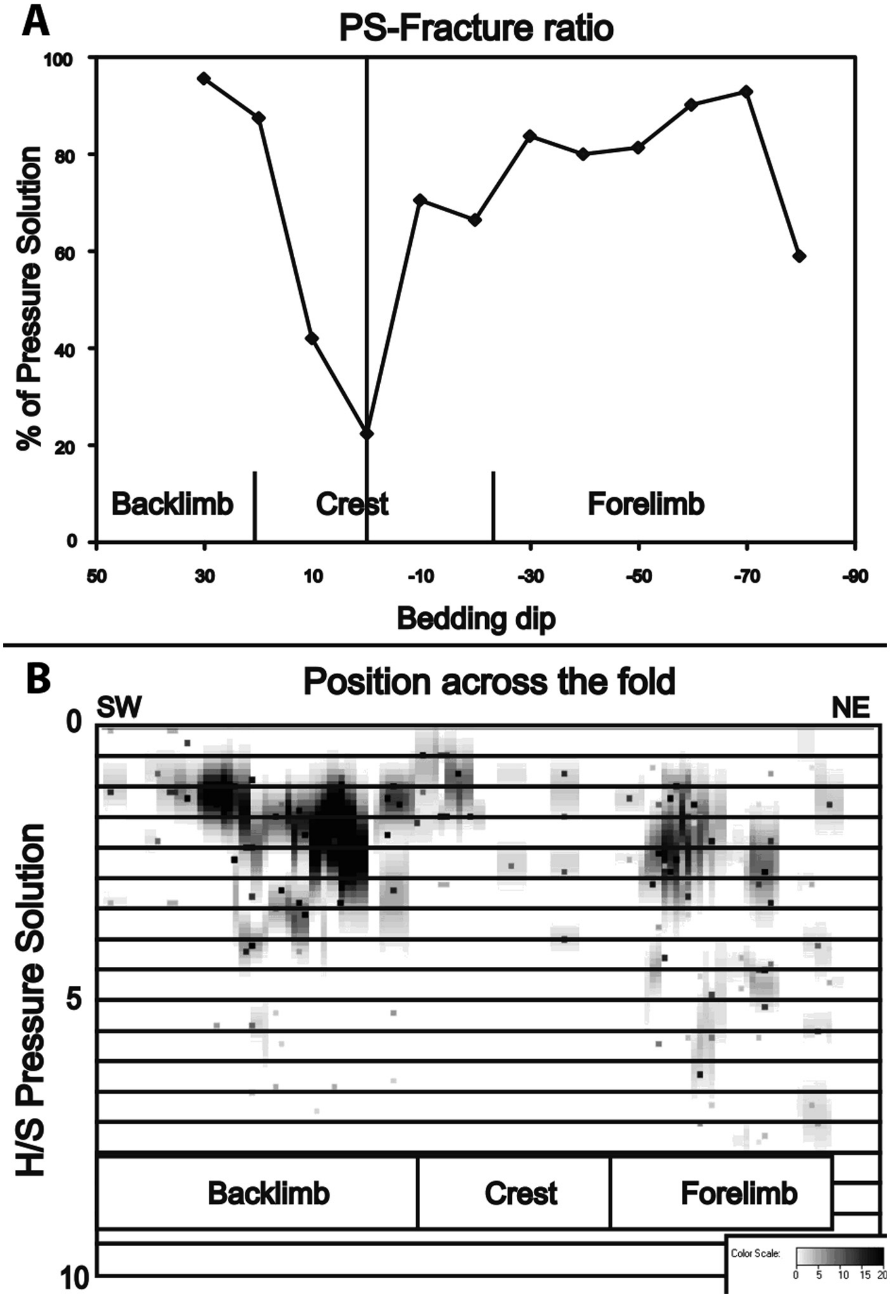

Figure 3. A) Normalised frequency of pressure solution cleavage and joints vs. bedding dip (the elements have been grouped in 10º of bedding dip intervals), B) structural transect of the pressure solution H/S ratio (Salvini *et al.*, 1999)

1. Pressure solution cleavage is at high angle to bedding and strikes parallel to fold axis.

2. Joints at high angle to bedding strike parallel to fold axis. In a greater detail the longitudinal pattern includes also other subsets, possibly related to the 3D evolution of the fold.

3. Normal faults and joints locate mostly in the crest, whereas pressure solution cleavage locates mostly in the fold limbs.

These observations, coupled with the progressive cleavage and joint frequency variations suggest a mainly syn-folding origin for the longitudinal fracture pattern in the Fiastrone anticline.

Acknowledgements

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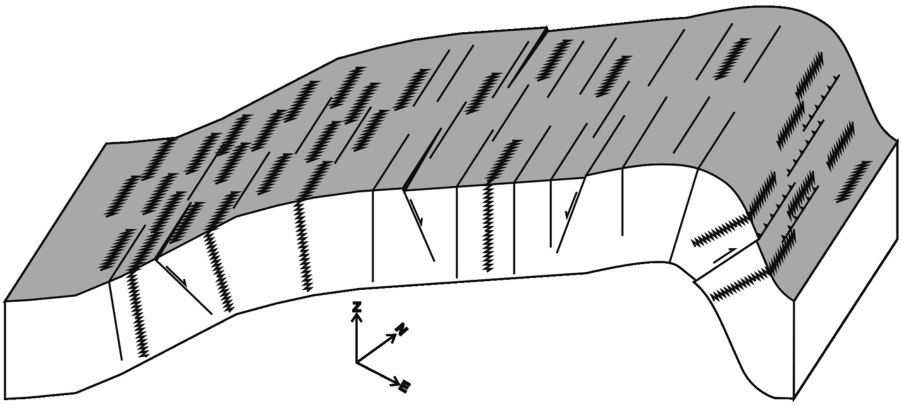

Figure 4. Schematic distribution of longitudinal fractures in the Fiastrone anticline.

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