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High-resolution rotational kinematics in fold-and-thrust belts; what is new and what is left to do?. The experience from the Southern Pyrenees

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The Southwestern Pyrenees are an excellent natural laboratory to study the evolution of fold-and-thrust belts (FAT belts). Together with outstanding outcropping conditions of syntectonic materials, the geometric and diachronic kinematic setting has produced a rotational FAT belt characterized by a complete catalogue of complex structures that includes superposed folding, conical and plunging folds, oblique thrust ramps, etc.... The application of paleomagnetic techniques in the Southwestern Pyrenees during the last decades has followed two complementary ways of research; on the one hand the highly dense characterization of rotations magnitudes (more than 2000 points) and, on the other side, the dating of synsedimentary piles and deformation processes by means of magnetostratigraphic studies (more than 85 km of series). Both techniques have been lately assembled together to characterize the rotational kinematics providing the first rotation speed values of single thrust sheets in FAT belts. Thrust sheets (as deduced from their associated anticlines; Pico del Aguila, Boltaña and Balzes) may rotate at rates reaching 20°/Ma although moderate magnitudes are more frequent around 10°/Ma. These kinematic data open a new way of understanding FAT belts in 4D (particularly the severe space problems).

On the other hand, paleomagnetic vectors can now be used to restore complex folded geometries in 3D. A new method recently launched considers the paleomagnetic information to obtain more reliable reconstructions of the underground (Ramón et al., 2012-J. Struc. Geol.). In the External Sierras front two structures (Sto. Domingo and Balzes anticline) fulfilled the basic requirements to be restored using this methodology; they represent complex geometries (conical and curved geometries respectively), both have undergone important rotations and they are characterized by hundreds of paleomagnetic vectors evenly distributed and they are provided by high resolution magnetostratigraphic studies that have yield an accurate dating of the stratigraphic sequences and the recorded folding, thrusting and rotation times and rates.

Despite this large, dense, detailed and reliable dataset some problems have arisen and should be tackled in the near future. The first one is related to the resolution and reliability of the datasets; how many data are needed to obtain a reliable vector in a portion of the FAT belt?, which criteria should be used to filter the noise at the sample, site and thrust sheet scales?. The second issue is related to the management of errors; apart from inclination flattening or non-dipolar records of the magnetic field, some sources of error (like the overlapping of vectors, internal deformation and incorrect restoration of vectors to the paleo-horizontal) are related to the geometry of folding (and thrusting). Some of them have been already studied in structural or paleomagnetic works but a thorough and comprehensive method to unravel at once all these systematic errors is still to be done. A comprehensive quantitative integration of structural and paleomagnetic data could change our view of the FAT belts in the future if these issues are satisfactorily resolved.