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Folded onlap geometries: implications for recognition of syn-sedimentary folds

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Abstract

Growth strata are usually analysed from geological maps, outcrop geometry or seismic sections. Many growth folds have been defined from geological maps, especially in areas where plunging structures allow the syn-tectonic sequence to be displayed at the surface. The geometrical arrangement of these syn-tectonic sequences can also be defined from the relationships between pre-growth and growth strata, as obtained from geological maps. In this paper, from theoretical models and natural examples from the southern Pyrenees, we argue that some cartographic patterns of strata associated with variably plunging folds, traditionally ascribed to syn-tectonic sedimentation with thinning of sedimentary units toward the anticlinal hinge zone, can be explained as completely post-sedimentary folds of sedimentary units lapping onto an inclined bedding surface, and linked to basin margin, or downlap geometries on the basin floor. We conclude that 3-D analysis of syn-tectonic structures, combining data from independent sources (i.e. geological maps and seismic reflection profiles) is essential to determine relationships between sedimentary units and structures.

Keywords: Growth strata; Geometry; Fold; Syn-sedimentary structures; Pyrenees

1. Introduction

Analysis of growth strata is a very important tool for determining the kinematics of folds at shallow crustal levels (Suppe et al., 1992). Geological maps, outcrop views and analysis of seismic reflection profiles help to determine the geometry of growth strata above pre-growth units (see e.g. Vergés et al., 2002, and references therein). In many cases, larger scale structures post-dating folds exhume the pre- and syn-growth sequences, allowing pseudo-3-D analysis of growth structures to be performed (Millán et al., 1994; Poblet et al., 1997).

The outcrop pattern of syn-tectonic strata is often the main tool for defining their relationships with their substratum, especially in areas (such as the southern Pyrenees) where a complete sedimentary record is preserved and the outcrop conditions are good. Thinning of units in the hinge zone of anticlines is usually considered as evidence of coeval fold growth and sedimentation (Millán et al., 1994). The stratigraphic series can then be divided into a pre-growth sequence (with constant thickness) and a syn-growth sequence (with variable thickness) from which the velocity and growing rates of folds can be obtained (Suppe et al., 1992; Millán et al., 1994; Poblet et al., 1997; Storti and Poblet, 1997), provided that rocks of the syn-tectonic sequence can be dated. Unless a significant post-folding palaeotopography is preserved, the 'post-growth' sequence will not show significant changes of thickness related to the hinge zone of folds. Nevertheless, it can be deformed by subsequent re-activation of the same folds, after deposition of the whole sequence (Millán et al., 1994).

In our analysis we have considered that the cartographic pattern of hinge-thinning strata can be achieved either by: (i) coeval folding and sedimentation, with a 'real' thinning of beds belonging to the syn-growth sequence onto the active hinge zone of the anticline, or (ii) by sequential sedimentation and folding, the 'apparent' thinning of the sequence onto the hinge zone due to a combined geometrical effect of onlap (or downlap) of the syn-onlap

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sequence onto the top beds of the pre-onlap sequence. Later folding of this sedimentary arrangement in a direction perpendicular or oblique to the pinchout line would lead to a cartographic pattern with the sequence apparently thinning onto the hinge zone (Fig. 1). This means that folding post-dates the hypothetical growth-strata, and can be contemporary with the rotation of the whole structure around a horizontal axis in a direction perpendicular or oblique to folding (Fig. 1). Our aim is to develop this second hypothesis in order to finally establish criteria to distinguish between this model and actual syn-sedimentary folds.

Although the geometry and kinematics proposed may seem an ad-hoc explanation for the geometrical arrangement found in nature, it is important to note that onlap geometries are common at basin margins and that the localisation of deformation runs are usually parallel to

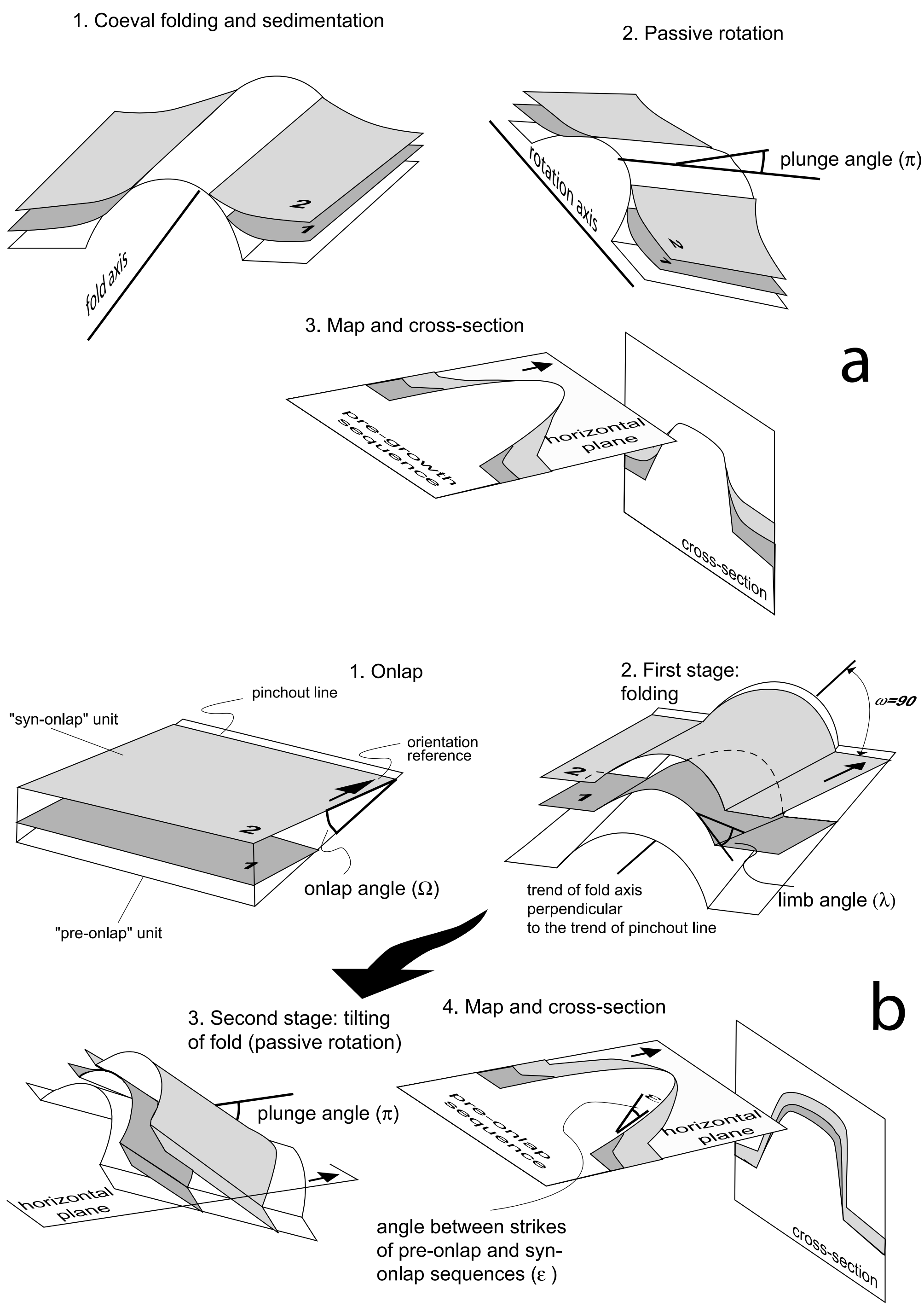

Fig. 1. Sketch showing the geometrical analysis and variables used in this work. (a) Actual growth strata scenario. (b) Model with a folded onlap geometry. See text for explanation.