Some misleading boudin-like structures

Ciertas estructuras confusas por su semejanza con boudins

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RESUMEN

Las estructuras de boudinage *son indicadoras de extensión paralela a las capas. Sin embargo, existen estructuras que poseen un alto grado de similitud con los boudins pero cuyo origen no está relacionado con un estiramiento significativo paralelo a las capas, venas o diques aparentemente boudinados. En el presente trabajo se discuten dos de estas estructuras:* shear bands *y venas en fracturas en zigzag. Las fallas o* shear bands *pueden cortar una capa separándola en bloques o «*boudins*» (de ahí el término* clivaje de crenulación extensional*). Sin embargo, en determinadas circunstancias, estas estructuras pueden formarse en capas paralelas al plano de no estiramiento en cizalla simple, pudiendo así dar un impresión falsa de extensión de la capa. Un segundo tipo de «falsos* boudins*» lo constituyen las venas formadas por la abertura de grietas a lo largo de una fractura, dando lugar a una ristra de cuerpos elongados cuya geometría presenta gran semejanza con los* boudins *reales formados por estiramiento.*

Key words: boudinage, dique, grieta dilatante, shear band, vena.

Geogaceta, 41 (2007), 31-34
ISSN: 0213683X

Introduction

Boudinage, which produces boudins, is a well-known process in tectonics since its original definition by Lohest (1909). Since then, many workers have reported on the formation of boudins, based on field observations, theoretical, experimental, and numerical studies (for an incomplete selection, see Cloos, 1947; Ramberg, 1955; Rast, 1956; Ramsay, 1967; Strömgård, 1973; Smith, 1975; Lloyd et al., 1982; Goldstein, 1988; Mandal and Karmakar, 1989; Mandal and Khan, 1991; Passchier and Druguet, 2002). Boudins are structures that form by the extension of layers or rods to form a string of individual lenses or blocks, because they are mechanically more competent than the adjacent material or «matrix». Boudins are useful structures for tectonic analysis, since they can give an estimate for the amount of extension of the boudinaged layer or rods (Hossain, 1979; Ramsay and Huber, 1983). Furthermore, boudins commonly display asymmetric structures that can be used as markers of the bulk sense of shear (Hanmer, 1986; Passchier and Druguet, 2002; Goscombe and Passchier, 2003).

To correctly determine extension from boudins, it is of course important that the structures are correctly interpreted as true boudins that formed by extension.

Apparent boudinage related to dissecting shear bands or faults

Shear bands or faults are zones of localised ductile or brittle deformation. Slip along such structures will necessarily lead towards the eventual separation of a dissected layer. In simple shear, synthetic and antithetic shear bands will produce a pattern that suggests that shear-plane parallel layers were stretched. However, shear-plane parallel planes do not stretch, nor shorten, in simple shear. Good examples of such «false boudins» are found at Mas Rabassers de Dalt in the Cap de Creus Variscan massif (Carreras, 2001; Druguet, 2001). Here, a quartzite layer with distinct laminations is sheared in dextral, layer-parallel simple shear during the last (D_3) deformation event (kinematics determined by Gomez-Rivas et al, this volume). Small faults formed at an initially high (~80°) angle to the foliation and subsequently rotated towards the shear plane (Fig. 1). Slip along these faults produced the extension-like features and reverse drag of the lamination (Exner et al. 2004). These structures were termed «flanking folds» by Grasemann and Stüwe (2001) and Passchier (2001). However, the sections between the faults are shortened to compensate the stretching caused by slip along the faults, giving a net result of zero stretching of the layers. Care should therefore be taken in interpreting these structures, because they can, but must not be associated with real stretching.

Apparent boudinage related to opening of jogs in fractures

Perhaps the most misleading boudin-like structures are those that formed by magmatic or mineral veins that formed by the opening of jogs in fractures. Slip along a non-straight fracture surface can lead to opening of the fracture in extensional jogs. Such opening jogs can be filled by minerals that precipitate from a fluid, or by crystallising melt. The result is a string

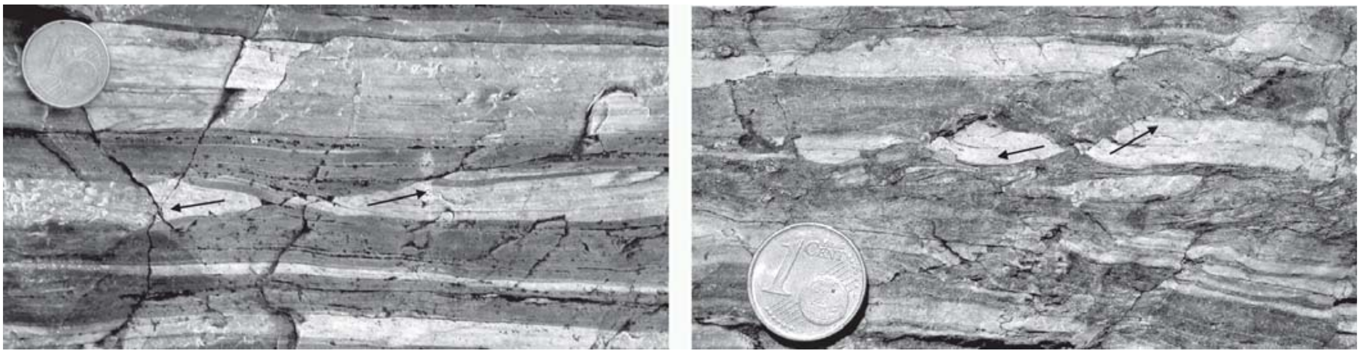

Fig. 1.- Antithetic shear bands in a quartzite layer at Mas Rabassers de Dalt, Cap de Creus (NE Spain). The shearing (arrows) suggests a significant layer-parallel extension (boudinage). However, the quartzite bed has been subjected to dextral simple shearing with probably no significant layer-parallel stretching. Coin for scale 15 mm.

Fig. 1.- Shear bands antitéticos en un nivel cuarcítico en Mas Rabassers de Dalt, Cap de Creus (NE de España). El cizallamiento (flechas) indica extensión paralela a las capas (boudinage). Sin embargo, el nivel cuarcítico ha sido sometido a cizalla simple destral, probablemente sin estiramiento significativo paralelo a las capas. Tamaño de la moneda como escala: 15 mm.

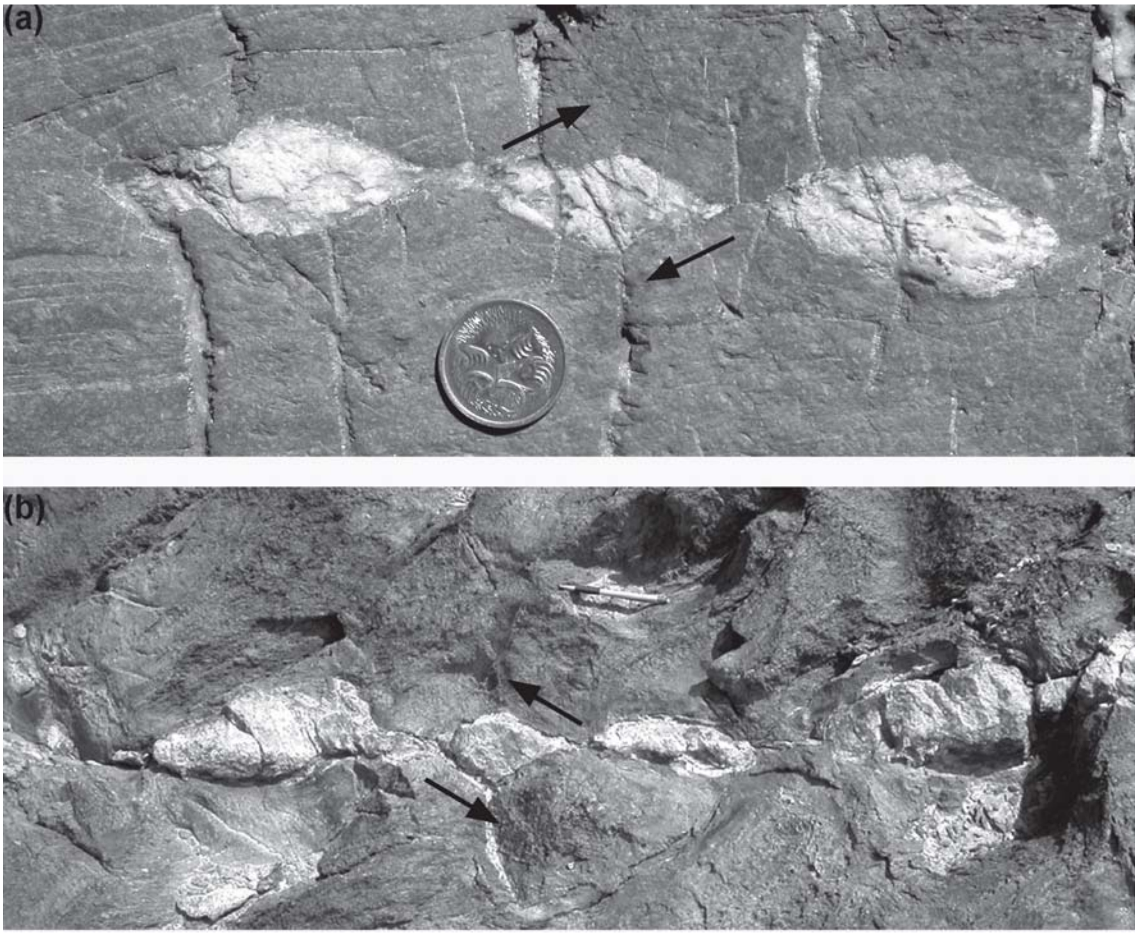

Fig. 2.- (a) Boudin-like structures in carbonate veins in metapelites from Yudnamutana (South Australia). Calcite precipitated in pull-aparts formed by dextral sliding (arrows) along a fracture with jogs. The structure could easily be mistaken for a boudinaged vein. Coin for scale 19 mm. (b) Similar structure in a quartz vein in metasediments from Cap de Creus, NE Spain. Arrows indicate the sinistral sliding direction on the fracture. Subsequent deformation rotated the foliation in the host rock by over 45° clockwise, and probably modified the pseudo-boudin structure, making it more difficult to distinguish from true boudins. Pencil for scale 15 cm.

Fig. 2.- (a) Estructuras semejantes a boudins desarrolladas en venas carbonáticas en metapelitas de Yudnamutana (Sur de Australia). La calcita precipitó en pull-aparts formados por deslizamiento dextral (flechas) a lo largo de una fractura escalonada. La estructura podría fácilmente confundirse con una vena boudinada. Tamaño de la moneda como escala: 19 mm. (b) Estructura similar a la anterior perteneciente a una vena de cuarzo en metasedimentos del Cap de Creus (NE de España). Las flechas indican deslizamiento senestral a lo largo de la fractura. La deformación subsecuente produjo una rotación de unos 45º en sentido horario de la foliación en los metasedimentos, y probablemente modificó la estructura original de pseudo-boudin, dificultando la distinción entre estas estructuras y los verdaderos reales. Tamaño del lapiz como escala: 15 cm.

of lozenge-shaped pods that may bear a striking resemblance to real boudins (Fig. 2), especially if subsequent (minor) deformation modifies the shape of the pods somewhat. Figure 2 shows examples of such pull-apart jogs in carbonate veins in the Tindelpina Shale Member near Yudnamutana in South Australia and in quartz veins in the Cap de Creus schists at the Lighthouse. The structures resemble extensional boudinage, but in both cases there is at the very most only minor vein-parallel stretching. The quartz vein at Cap de Creus (Fig. 2b) may even be slightly shortened, because a nearby parallel vein of probable similar age shows minor folding. We suggest that the apparent boudins in pegmatite bodies, also found around Cap de Creus (Bons et al., 2004), may have formed by a similar mechanism.

Conclusions

Boudinage is a common, well-understood and straightforward process. Boudins are an important tool in strain analysis in deformed rocks and can often indicate the sense of shear in non-coaxial deformation. However, we here pointed out that boudin-like structures should be carefully scrutinised to assess whether they really indicate stretching of a layer or vein (Fig. 3a). Shear bands and faults that bound apparent boudins should be considered with care, especially if the offset layer displays reverse drag. In case of apparently boudinaged veins or dykes, one should always consider the possibility that these formed in dilatant jogs and not as an initially continuous sheet (Fig. 3).

Acknowledgements

We thank Gijs Brecht, Marlina Elburg, Ilka Hamann, Cees Passchier, the participants of the First TecTask field workshop on Structural Analysis, and our fellow MIET members for ideas, suggestions and discussions that helped us to develop and focus our ideas. This work was financed by the Spanish Ministry of Education and Science (project CGL2004-03657/ BTE).

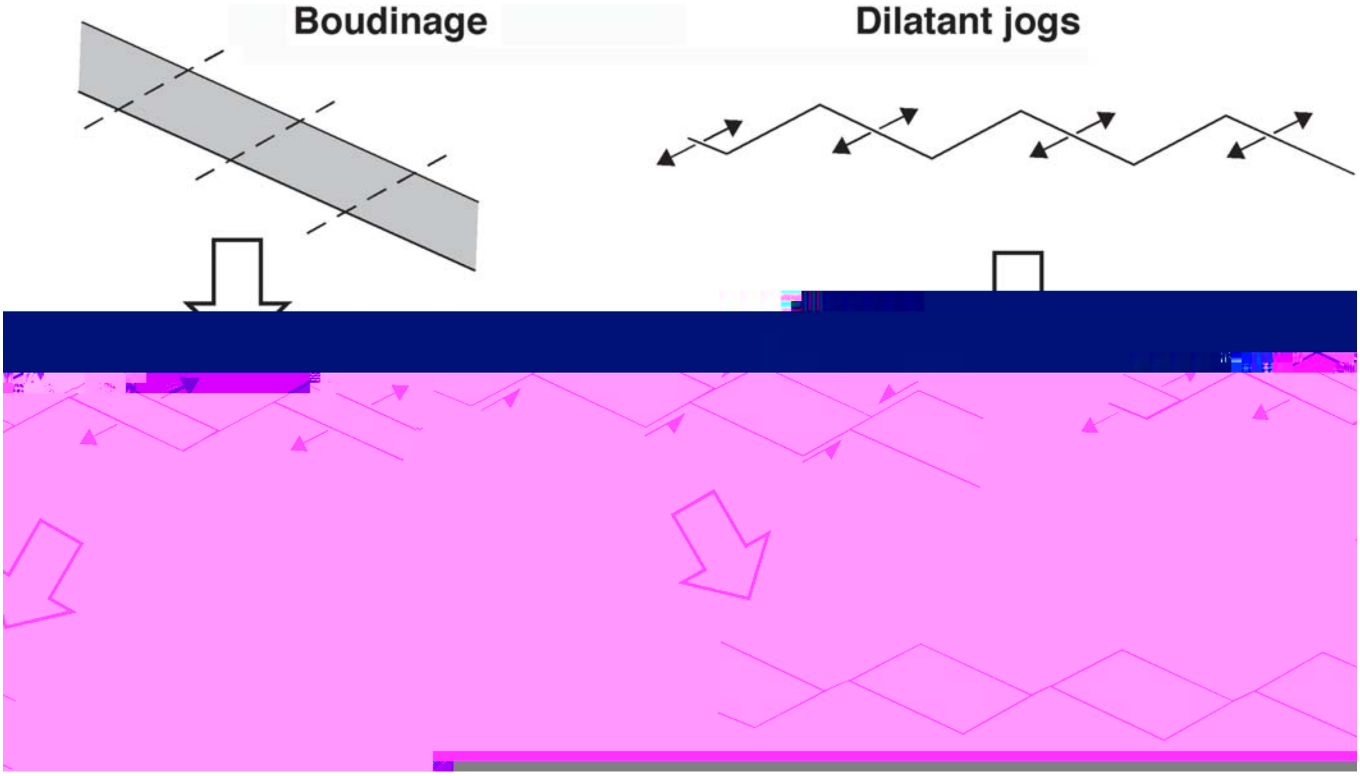

Fig. 3.- Sketch showing how real extensional boudinage (left) and dilatant jogs (right) can produce identical looking structures (bottom).

Fig. 3.- Esquema que muestra como tanto el verdadero boudinage extensional (izquierda), como las grietas dilatantes (derecha) pueden producir estructuras de idéntica apariencia (abajo).

References

Bons, P.D., Druguet, E., Hamann, I., Carreras, J. y Passchier, C.W. (2004). *Journal of Structural Geology*, 26, 625-636.

Carreras, J. (2001). *Journal of Structural Geology*, 23, 1457-1487.

Cloos, E. (1947). *Transactions of the American Geophysical Union*, 28, 626-632.

Druguet, E. (2001). *Tectonophysics*, 332, 275-293.

Exner, U., Mancktelow, N.S. y Grasemann, B. (2004). *Journal of Structural Geology*, 26, 2191-2201.

Goldstein, A.G. (1988). *Journal of Structural Geology*, 10, 707–715.

Goscombe, B. y Passchier, C.W. (2003). *Journal of Structural Geology*, 25, 575–589.

Grasemann, B. y Stüwe, K. (2001). *Journal of Structural Geology*, 23, 715–724.

Hanmer, S. (1986). *Journal of Structural Geology*, 8, 111–122.

Hossain, K.M. (1979). *Tectonophysics*, 60, 279–288.

Lloyd, G.E., Ferguson y C.C., Reading, K. (1982). *Journal of Structural Geology*, 3, 355-372.

Lohest, M. (1909). *Annales de la Société Géologique de Belgique*,

36B, 275–282.
Mandal, N. y Khan, D. (1991). *Journal of Structural Geology*, 13, 349-356.
Mandal, N. y Karmakar, S. (1989). *Tectonophysics*, 170, 151-158.
Passchier, C.W. (2001). *Journal of Structural Geology*, 23, 951–962.
Passchier, C.W. y Druguet, E. (2002). *Journal of Structural Geology*, 24, 1789–1804.
Ramberg, H. (1955). *Journal of Geology*, 63, 512–526.
Ramsay, J.G. (1967). *Folding and Fracturing of Rocks*. McGraw-Hill, New York, 568 p.
Ramsay, J.G. y Huber, M.I. (1983). *The techniques of modern structural geology: Volume 1: Strain analysis*. Academic Press, New York, 307 p.
Rast, N. (1956). *Geological Magazine*, 93, 401-408.
Smith, R.B. (1975). *Geological Society of America Bulletin*, 86, 1601-1609.
Strömgård, K.-E. (1973). *Tectonophysics*, 16, 215-248.