Albian sediment-filled fissures on an Urgonian carbonate platform as kinematic indicators of extension, Westernmost Pyrenees

Fisuras albienses rellenas de sedimento en una plataforma carbonatada urgoniana como indicadores cinemáticos de extensión, Pirineo occidental

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RESUMEN

Numerosas fisuras albienses rellenas de sedimento se sitúan en el techo de una plataforma carbonatada urgoniana de edad Aptiense superior-Albiense inferior entre los pueblos de Andoain y Hernani, en el margen noreste de la Cuenca Vasco-Cantábrica. Dichas fisuras muestran contactos planares a subplanares y están rellenas de brechas calizas autoclásticas y areniscas y calcarenitas arenosas marinas someras. Aunque los procesos de disolución (kársticos) modificaron las fisuras previas, la medición de 181 fisuras muestra una orientación preferente NW-SE, lo cual indica una extensión albiense NE-SW.

Key words: *Sediment-filled fissures, Albian, extension, Basque-Cantabrian Basin, western Pyrenees.*

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Introduction

A fissure is a fracture or crack across which there is a significant separation of the wall rocks (Bates and Jackson, 1980). When fissures have a tectonic origin, they maintain a preferred orientation associated with the regional tectonic regime and may therefore be used as palaeostress indicators (e.g. Dunne and Hancock, 1994). Fissures may be filled with material from above, usually sandstone, and are therefore termed neptunian dikes (Bates and Jackson, 1980). In this work we describe and interpret a large number of

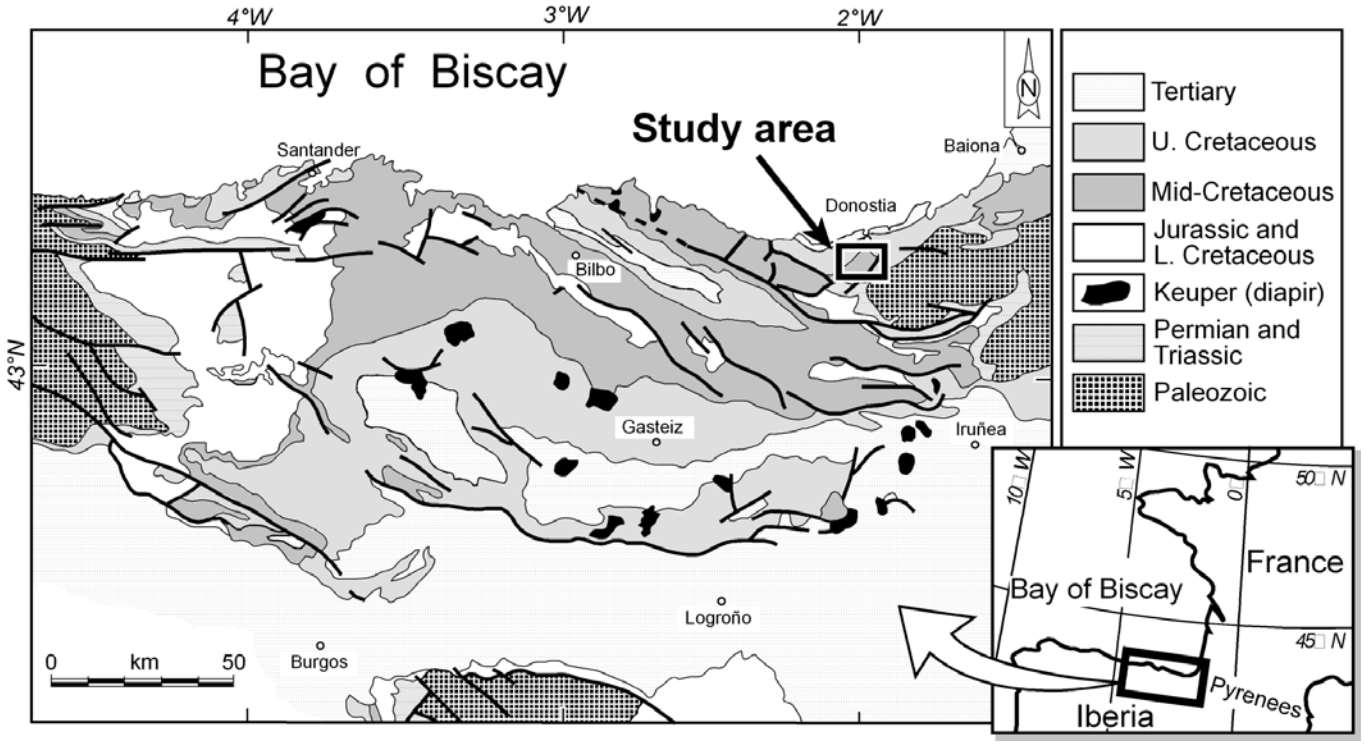

Fig. 1.- Geological map of the Basque-Cantabrian Basin with location of the study area.

Fig. 1.- Mapa geológico de la Cuenca Vasco-Cantábrica y localización del área de estudio.

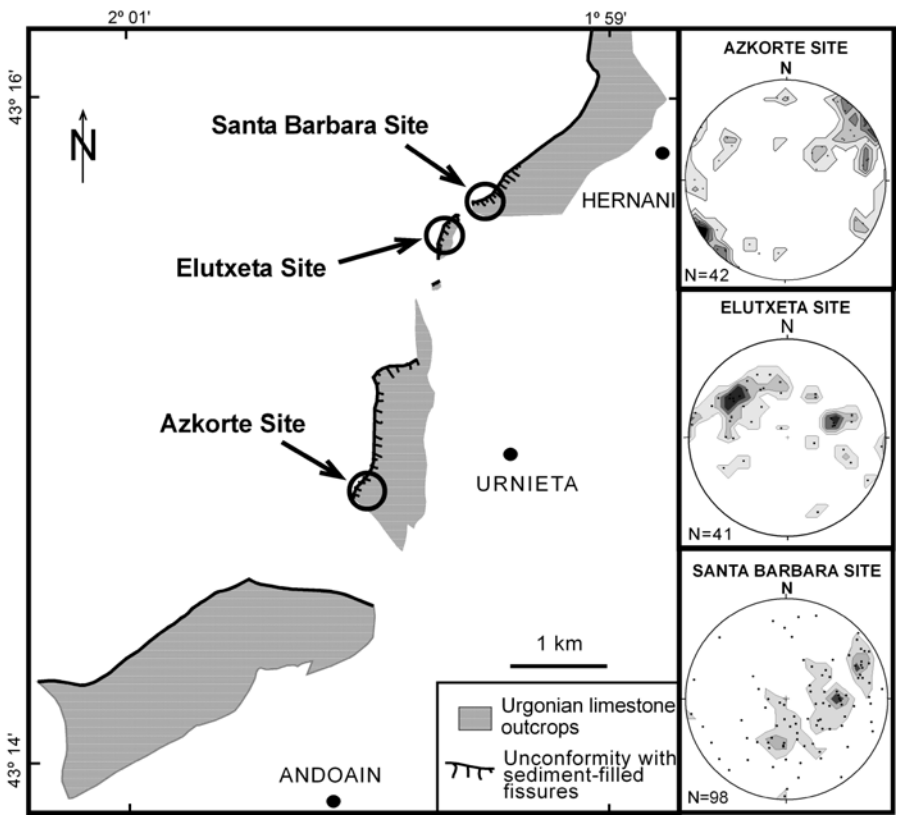

Fig. 2.- Outcrop map of Urgonian platform limestones and location of the Azkorte, Elutxeta and Santa Barbara sites. Detail shows equal area density contour plots of sediment-filled fissures after removing of bedding dip (Confidence Index: 2.0%/1% area).

Fig. 2.- Mapa de afloramientos de calizas urgonianas y situación de las localidades Azkorte, Elutxeta y Santa Barbara. Los recuadros representan contornos de densidad (igual área) de las fisuras rellenas de sedimento después de abatir la estratificación (Índice de Confidencia: 2.0%/1% área).

fissures. Nevertheless, preferred orientation of the fissures can be used as kinematic indicators of extension and may allow us to calculate the paleostress which caused the formation of the fissures.

Geological Setting

The study area is located in the north-eastern margin of the Basque-Cantabrian Basin, in the westernmost Pyrenees (Fig. 1). This Mesozoic-Early Tertiary basin constituted a pericratonic rift related to the Bay of Biscay opening and Iberian plate drift. The Lower Cretaceous Urgonian carbonate platforms and related deposits of the basin formed in a pulsating extensional/transtensional regime, allowing the accumulation of very thick sequences. In the study area, between the towns of Andoain and Hernani, Upper Aptian-Lower Albian Urgonian platform carbonates crop out along the NE-trending «Buruntza ridge» (Lamare, 1936). The top of these carbonates constitutes an important unconformity where studied fissures occur. Overlying siliciclastics of the Supra-Urgonian Complex (Rat, 1959) infiltrated downward and filled the previously formed fissures. Preliminary data from deposits of the lower part of this complex allow us to interpret them as deposited in an estuarine to shallow siliciclastic platform environment.

Sediment Filled Fissures

The sediment-filled fissures occur on the top of an Urgonian carbonate platform and exhibit an irregular areal distribution. The highest concentration of fissures occurs in three localities, which are adjacent to sinsedimentary fault traces: Azkorte, Elutxeta and Santa Barbara (Fig. 2). Most of the data herein correspond to these sites. The fissure-containing limestone interval is up to 40 m thick and measured individual fissure lengths vary from few centimetres to 8 m. Their widths range from 1 mm to 70 cm. The fissures generally have planar to subplanar contacts that are vertical to moderate dipping steeply (Fig. 3a). However, many of them show a more irregular geometry, particularly at Elutxeta and Santa Barbara sites where up to 3 m wide subcircular sediment-filled cavities occur.

Fissure fills

Fissures can be classified into three groups according to the fill type. Nevertheless, many fissure-fills present a mixed or transitional character (Fig. 3).

Sandstone fills (Fig. 3a,c,d): They are composed of fine- to medium-grained quartz arenites. They show a grain-supported texture with subangular to subrounded grains of quartz and polycrystalline quartz and also scarce micas and recrystallized bioclasts (Fig. 3c-d). Cement consists of microsparitic calcite, fibrous calcite and minor syntaxial quartz overgrowths. Fibrous calcite cements occur on grain faces subparallel to the fissure contacts and calcite fibres are normal to them (Fig. 3c-d). Fibre growth indicates that extensional opening normal to the fissures continued during sandstone cementation. Some sandstone fills appear slightly mineralised with iron oxides.

Limestone breccia and sandstone fills (Fig. 3b): They consist of disorganised, monomictic, heterometric limestone breccia and sandstone in variable proportions. Usually, sandstone (above described) constitutes the matrix of clast-supported breccia (Fig. 3b). Limestone clasts are composed of red algae-rich wackstone to packstone facies, very similar to the host limestone. Texturally, clasts exhibit a very angular shape and often their margins can be matched with the walls of the fissures. They are interpreted as autobreccias formed by host rock fracturing and *in situ* deposition (or with minimum transport) and subsequent downward sand infiltration and filling of interclast spaces.

Sandy calcarenite fills: These minor fills are composed of sandy bioclastic calcarenites with variable proportions of siliciclastics and bioclasts. Two types can be distinguished in base to internal organisation: disorganised and laminated sandy calcarenites. The latter is composed of alternating, several milimeter thick sand-rich and calcarenite-rich laminae, which onlap fissure contacts or adjacent clasts. Usually, calcarenite-rich laminae are recrystallized and bioclasts (echinoderms, benthic foraminifera, rudists, red algae) exhibit a ghost-like appearance.

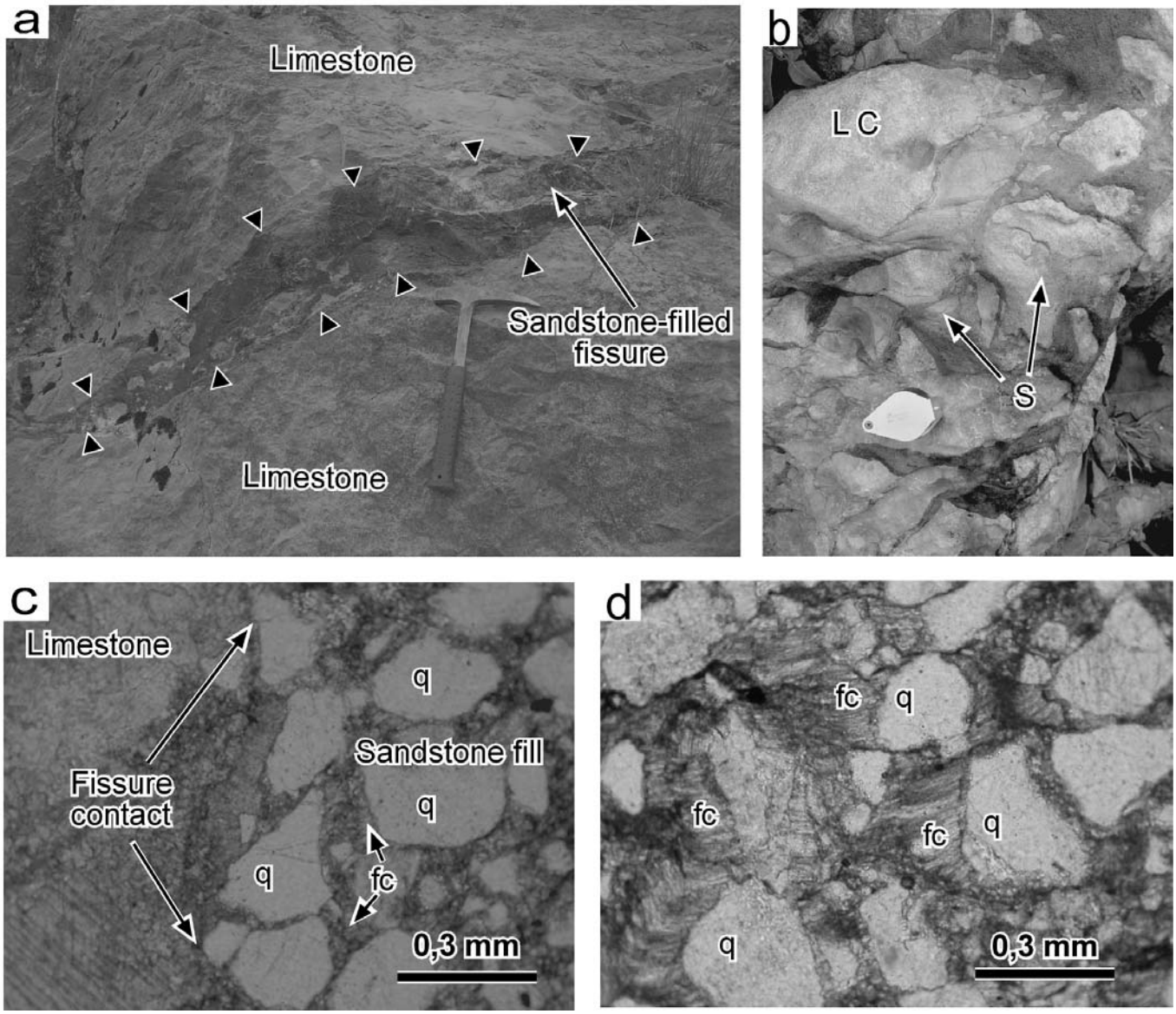

Fig. 3.- (a) Common aspect of sandstone-filled fissure; (b) Limestone breccia and sandstone fill (LC: limestone clast; S: sandstone); (c) Microphotograph of host limestone fissure contact and sandstone fill (fc: fibrous calcite; q: quartz); (d) Microphotograph of sandstone fill showing fibrous calcite cements (fc: fibrous calcite; q: quartz).

Fig. 3.- (a) Aspecto común de las fisuras rellenas de arenisca; (b) Brecha de caliza y relleno de arenisca (LC: clasto de caliza. S: arenisca); (c) Microfotografía del contacto entre la roca caliza encajante y el relleno de arenisca (fc: calcita fibrosa; q: cuarzo); (d) Microfotografía del relleno de arenisca, mostrando los cementos de calcita fibrosos (fc: calcita fibrosa; q: cuarzo).

Fissure orientations

The attitudes of 181 sediment-filled planar to subplanar fissures were measured at the three study sites and were then rotated to the original state by removing regional bedding. Density contour plots of data for the sites show diverse results (Fig. 2). The plot of the Azkorte site data exhibits a high concentration of fissures with a mean NW-trending vertical orientation. Elutxeta site plot denotes a higher dispersion of data with two maxima corresponding to NE- and NNW-trending fissures. Finally, the plot of the Santa Barbara site also shows a high data dispersion although NW- and N-trending fissures dominate. Despite the high dispersion of the data from the Elutxeta and Santa Barbara sites, collectively fissures exhibit a preferred NW-trending vertical attitude (Fig. 4).

Interpretation and discussion

The fissures of the study area are interpreted as formed by Albian tectonic extension, in accordance with the following characteristics: planar shapes, preferred orientation, matching of walls of some fissures, concentration close to sinsedimentary faults, and calcite fibre growth normal to fissure walls. Similar characteristics have been documented elsewhere (Smart et al., 1988; Blendinger, 1986; Wall and Jenkyns, 2004; Schlische and Ackermann, 1995; André *et al*., 2004). As tectonic fissures formed normal to minimum principal stress (s_3) (e.g. Dunne and Hancock, 1994) preferred orientation of fissures indicates that minimum principal paleostress axis (s_3) is 239/03 (Fig. 4), which is a NE-SW extension. This is consistent with contemporaneous NW-trending normal faults of the study area.

The irregular shapes of several sediment-filled fissures and their high trend dispersion at Elutxeta and Santa Barbara are interpreted as the result of dissolution (karstification) processes that enlarged and modified previous fissures

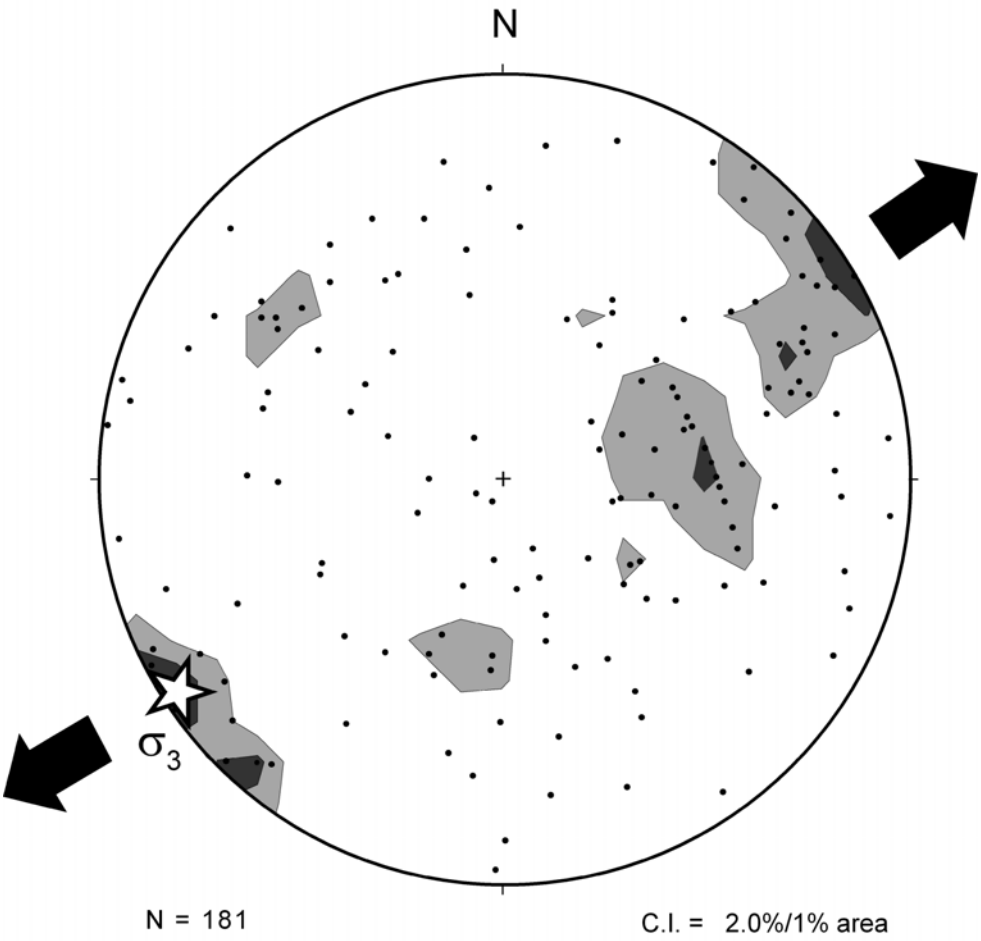

Fig. 4.- Equal area density contour plot of the Azkorte, Elutxeta and Santa Barbara sites fissure data. Star indicates minimum principal palaeostress axis and the arrows extension direction.

Fig. 4.- Proyección de contornos de densidad de todas las fisuras de las localidades Azkorte, Elutxeta y Santa Barbara. La estrella indica el eje de esfuerzo mínimo principal y las flechas la dirección de la extensión.

and even formed several meter wide karstic cavities. Limestone breccia fills would have been formed by host rock fracturing during fissure opening process. Subsequently, sandstone and calcarenites deposited in both empty fissures and interclast open spaces of the previously formed breccias. The presence of marine bioclasts in those fills indicates that their deposition took place in a shallow-water marine environment. During the cementation process of sandstones, the NE-SW extension and opening of previous fissures continued, as indicated by fibrous calcite cement.

Conclusions

1. In the north-east margin of the Basque-Cantabrian Basin, Albian sediment-filled fissures are common on the top of an Urgonian carbonate platform and adjacent to contemporaneous normal faults.
2. Fissure-affected host limestone interval is 40 m thick; the fissures have planar to subplanar walls; range in width from 1 mm to 70 cm and show lengths up to 8 m; are filled with limestone breccia, sandstones and sandy calcarenites.
3. The fissures formed as a result of extension of Urgonian limestones; limestone breccia (autobreccia) fills formed by rock fracturing and fissure opening; locally, karstification processes enlarged and modified previous fissures.
4. Shallow-water marine sandstones and sandy calcarenites filled fissures completely from above, postdating fissure formation.
5. Sediment-filled fissures show a preferred NW-SE orientation, indicating a minimum principal paleostress axis s_3=239/03, that is a NE-SW extension, which is consistent with contemporaneous NW-trending normal faults present in the study area.

Acknowledgements

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References

André, G. et al. (2004). *Bull. Soc. Géol. Fr*., 175, 595-605.

Bates, R.L. and Jackson, J.A. (1980). *Glossary of Geology*. American Geological Institute, Washington, D.C., U.S.A. 416pp.

Blendinger, W. (1986). *Sedimentology* 33, 159-183.

Dunne, W.M. and Hancock, P.L. (1994). In: *Continental Deformation* (Hancock, P.L., Ed.) Pergamon Press, 101-120.

Lamare, P. (1936). *Mémmoires de la Société Géológique de France*, 27, 464pp.

Rat, P. (1959). *Tesis Doct*. Univ. Dijon, 525pp.

Schlische, R. W. and Ackermann, R. V. (1995). *Journal of Structural Geology*, 17, 987-996.

Smart, P.L., Palmer, R. J., Whitaker, F. and Wright, V. P. (1988). In: *Palaeokarst* (James, N. P. and Choquette, P.W. eds). Springer-Verlag, New York, 149-163.

Wall, G. R. and Jenkyns, H. C. (2004). *Geol. Mag.*, 141, 471-504.