Kinematic indicators and mineralization on the Elgoibar faul (Basque-Cantabrian Basin)

Indicadores cinemáticos y mineralización en la falla de Elgoibar (Cuenca Vasco-Cantábrica)

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Abstract

The Elgoibar fault is interpreted the western prolongation of the Leitza fault, wich has been usually considered the boundary between Iberia and Europe plates. Based on new structural data from a mineralized fault zone near Elgoibar, sinistral strike-slip faulting and synkinematic hydrothermal mineralization are inferred. Although no dating is presently available, several regional suggest a probable Late Albian-Late Cretaceous age, i.e. syn-drift of Iberia, for the tectonic and mineralizing episode.

Resumen

La falla de Elgoibar se localiza en la prolongación occidental de la falla de Leitza, la cual ha sido considerada habitualmente como el límite entre las placas ibérica y europea. Basándose en nuevos datos estructurales procedentes de la zona de falla mineralizada próxima a Elgoibar, se ha deducido un fallamiento de desgarre senestro y una mineralización hidrotermal sincinemática. Si bien actualmente no se dispone de dataciones, diversos criterios sugieren una edad probable Albiense superior-Cretácico superior (sin-deriva de Iberia) para el episodio tectónico y mineralizador.

Key words: *Kinematic indicators, strike-slip fault, paleostress, hydrothermal mineralization, Basque-Cantabrian Basin.*

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Introduction

The Elgoibar fault separates the NW- to W-trending North-Biscay Anticlinorium and Biscay Synclinorium (Basque Arch, Basque-Cantabrian Basin) (Agirrezabala and García-Mondéjar, 1994) (Fig. 1a). This fault has been interpreted as the northwestern prolongation of the Leitza fault (EVE, 1995) (Fig. 1a), which is considered the western expression of the North Pyrenean Fault (e.g. Engeser and Schwentke, 1986). Stratigraphic and sedimentologic data suggest that the Elgoibar fault was left lateral and controlled the development of depositional systems during the Aptian-Albian (e.g. Agirrezabala and García-Mondéjar, 1992, 1994) and the Late Cretaceous (e.g. Mathey, 1986). In spite of its importance, published structural data on this shear zone are very scarce (Ábalos, 1989). In this work we describe and interpret new structural data from the Elgoibar fault and from its associated hydrothermal quartz deposits. These data provide oportunity for establishing the kinematics (direction and sense of slip) of the Elgoibar fault during the mineralization event.

Mineralized fault zone

The study site is located in the shear zone of the Elgoibar fault near the town of Elgoibar (Fig. 1a). Here, a NW-trending sub-vertical fault zone separates folded turbiditic sandstones and lutites (Middle-Upper Albian) in the northeast, from unfolded SW-dipping marls and lutites (Upper Albian-Cenomanian) in the southwest (Fig. 1b). The fault zone is characterized by fault breccias with quartz cement and a complex quartz vein system (Fig. 2a). The mineralized fault zone is about 8 to 20 m wide, extends up to 200 m along strike, and shows five quartz-rich masses inside (Fig. 1b). Contacts of the quartz-rich masses with host-rocks are striated fault planes.

The fault zone shows five kind of structures related with faulting and mineralization:

Shear veins: They are NW-trending, sub-vertical veins (N130, 84NE), 0.2-1 m thick and up to 20 m in strike length (Figs. 2a,c and 3a). They are often filled with massive, barren quartz (Fig. 2a) and fault breccia of wallrock and quartz fragments up to 35 cm long cemented by quartz (Fig. 2b). The filling breccias usually occupy the central region of the shear veins. Contacts of shear veins with host rocks or fault breccia are NW-trending, sub-vertical strike-slip fault-planes with pervasive subhorizontal striation and crystal fibers (see below).

Striation: Slickensided fault surfaces of quartz shear veins show widespread subhorizontal striae or slickenlines (mean plunge: 8° to NW; Fig. 3a) of different sizes (Fig. 2b,c). Most are millimeter-deep striae, but

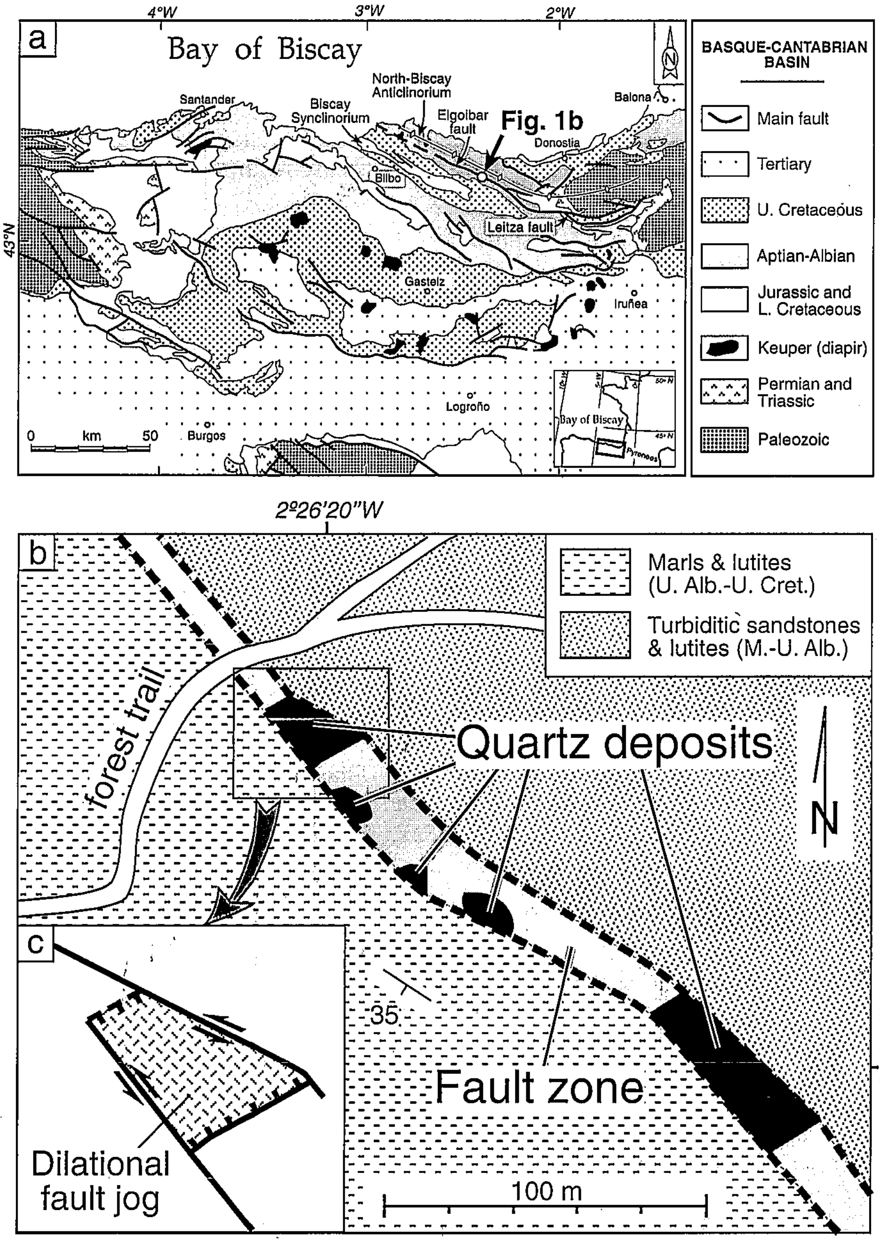

Figura 1. (a) Mapa geológico de la región Vasco-Cantábrica, con indicación del área de estudiio. (b) Mapa geológico esquemático del área de estudio. (c) Detalle de la distribución de las fallas de un "jog" de falla de dilatación.

Figure 1. (a) Geologic map of the Basque-Cantabrian region, with location of the study site. (b) Schematic geologic map of the study area. (c) Detail of the fault pattern of a dilational fault jog.

grooves up to 15 cm deep, 42 cm wide and 27 m long are also found.

Crystal fibers: Several fault-planes of shear veins present sets of crystal fiber growths or slickenfibers (Fig. 2d). They are subhorizontal quartz fibers (parallel to striation, Fig. 3a) that grew perpendicular to asperities and on their lee sides. These fiber accretions show congruous steps (riser facing towards the movement of the missing block) suggesting left-lateral slip.

Extensional veins: These are ENE-trending sub-vertical veins which occur in groups throghout fault breccias and host-rocks of the fault zone (Figs. 2a,c and 3a). They merge into the shear veins, usually show a sigmoidal pattern and form en echelon arrays parallel to shear veins. They are 0.5-3 cm thick and are filled by stright quartz crystals subperpendicular to the vein walls, suggesting continuous growth of open fractures.

Dilational fault jogs: The best outcrop of massive quartz in the fault zone is located northwesterly, in an along-strike overstep (Fig. 1c). It is bounded by two NW-trending right-stepping strike-slip faults (shear veins with subhorizontal striation) and by an ENE-trending normal fault (pitch of slickenlines: 82°). Fault arrangement suggests a NW-trending sinistral strike-slip movement that promoted local extensional opening and consequent quartz mineralization. This structure is similar to other dilational fault jogs described for many fault-controlled hydrothermal mineralizations (e.g. Sibson, 1989).

Kinematic indicators and paleostress analysis

Many structures of the described Elgoibar fault zone can be used as kinematic indicators (Fig. 3), suggesting that sinistral strike-slip movements took place during mineralization. Pervasive subhorizontal striation and crystal fibers on subvertical shear veins indicate subhorizontal slip. In addition, crystal fiber accretion on the lee side of asperities indicate left-hand shear-sense. In other wise, sigmoidal, sub-vertical extensional veins form oblique to shear veins; both, the acute angle between these kinds of veins and the sigmoidal shape of the extensional veins are indicative of sinistral strike-slip too. Finally, the dilational fault jog is congruent with a left-lateral sense-of-shear as well.

Geometric relationships among these structures provide opportunity for paleostress analysis. As Figure 3 shows, a) extensional veins form normal to the minimum principal stress (σ_3), b) intersection between extensional veins and shear plains defines the direction of the intermediate principal stress (σ_2), and c) the maximum principal stress (σ_1) is parallel to extensional veins and normal to the σ_2-σ_3 plane. Therefore, maximum and minimum principal stresses σ_1 and σ_3 are subhorizontal, and the intermediate principal stress σ_2 is sub-vertical. Under simple shear ideal conditions instantaneous extensional veins and σ_1 direction are usually oriented at 45° to the shear planes, but in the case of the Elgoibar fault they form 58°. This higher angle can be explained in two manners: 1) progressive rotation of the extensional veins in the direction of the shear sense during deformation; and 2) addition to the simple shearing of a component of compression normal to the shear zone (transpression) (e.g. Sanderson and Marchini, 1984). The sigmoidal extensional

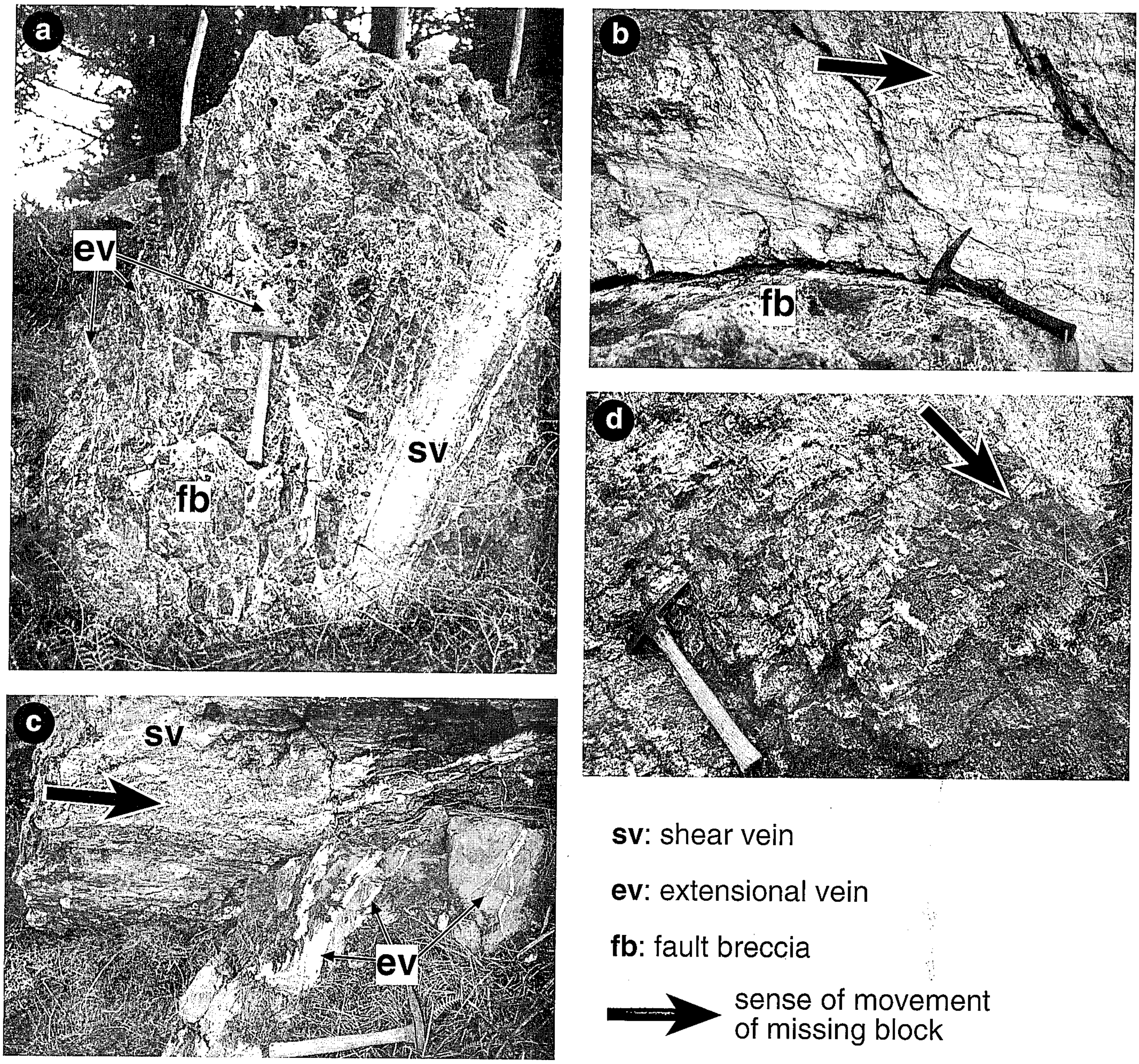

Figura 2. (a) Aspecto habitual de la zona de falla, mostrando la relación entre venas de cizalla, venas de extensión y brechas de falla (el color blanco corresponde al cuarzo hidrotermal). (b) Estriación subhorizontal en una vena de cizalla vertical y brecha de falla adyacente. (c) Relación entre una vena de cizalla vertical con estrías horizontales y venas de extensiónsubverticales adyacentes. (d) Crecimiento de fibras de cuarzo subhorizontales sobre un plano de cizalla, mostrando escalones congruentes con un movimiento siniestro.

Figure 2. (a) Common aspect of the fault zone, showing relationships among shear veins, extensional veins and fault breccias (white color corresponds to hydrothermal quartz). (b) Subhorizontal striation on a vertical shear vein and adjacent fault breccia. (c) Relationships between a horizontally striated, vertical shear vein and adjacent sub-vertical extensional veins; (d) Subhorizontal quartz fiber growth on a shear plane, showing congruous steps with left-lateral movement.

veins suggest their progressive rotation in some grades, but transpression tectonics is not completely ruled out.

Faulting and mineralization age. Discussion

Fills of extensional veins and crystal fiber growth indicate that hydrothermal mineralization took place simultaneously to the slip of the fault. Moreover, quartz fragments in the fault breccia and slickensides on quartz veins suggest more than one slip phase. Faulted and mineralized rocks of early Late Albian age predate both the slip and the hydrothermal event, indicating a maximum age for these of early Late Albian. Although no precise dating is available yet, the geology of the region strongly suggests that the age of faulting and mineralization is Late Albian to Late Cretaceous (not Tertiary). This hypothesis is based on the following four arguments: 1) Albian-Late Cretaceous sinistral strike-slip has been proposed for NW- to E-trending faults of the Pyrenean realm (e.g. Choukroune, 1992) and the Basque-Cantabrian region (e.g. García-Mondéjar et al., 1996), associated with Cretaceous southestward drift of the Iberian plate; 2) Tertiary NW-trending movements in the Basque-Cantabrian Basin had a dextral (not se-

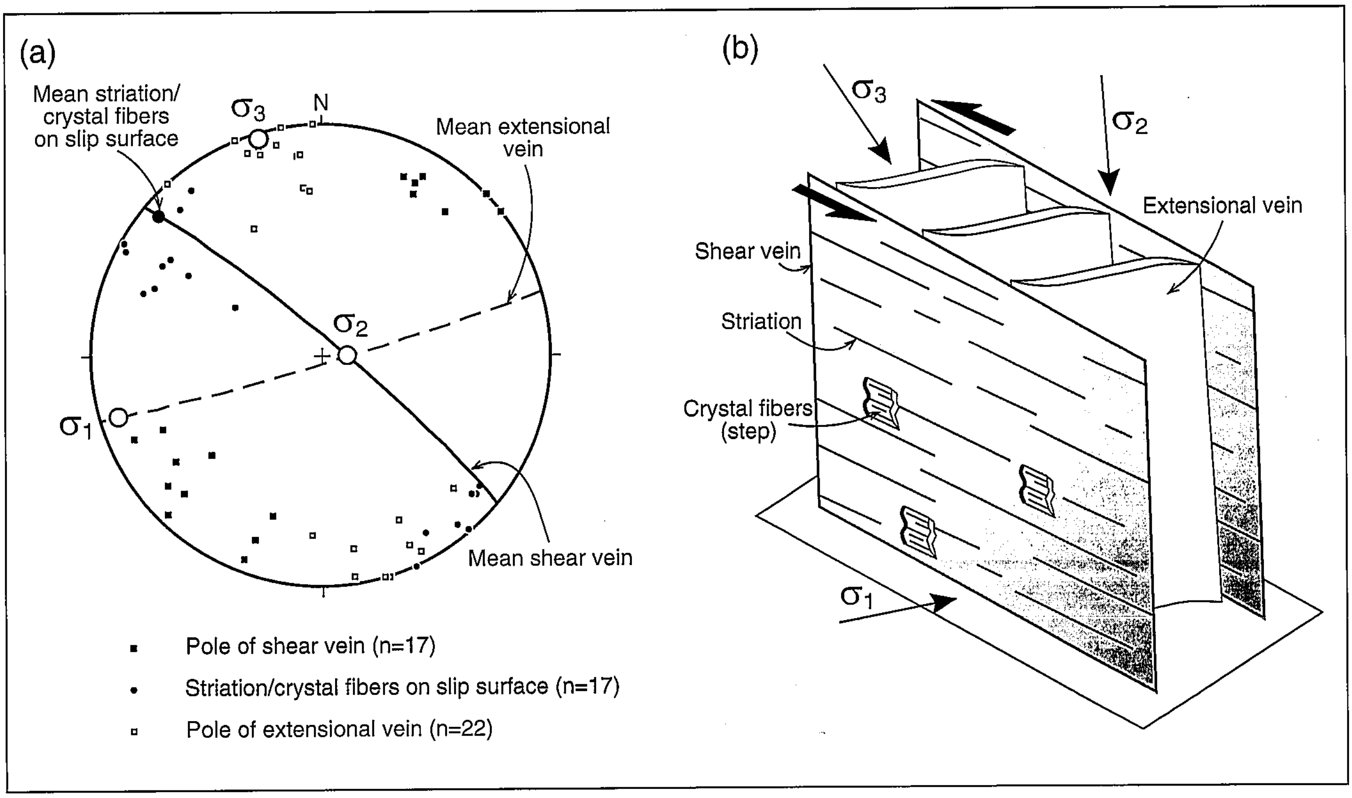

Figura 3. (a) Datos de orientación de las estructuras de la zona de falla de Elgoibar e interpretación de las orientaciones principales de esfuerzo en el área (los datos están representados en el hemisferio inferior de una plantilla equiárea). (b) Diafragma esquemático mostrando la relación entre diversas estructuras y el campo de esfuerzos.

Figure 3.(a) Orientation data of the structures of the Elgoibar fault zone and interpretation of the principal stress orientations in the area (data are presented on an equal-area lower hemisphere stereoplot). (b) Schematic diagram showing the relationships between different structures and the stress field.

nestral) strike-slip component (Cámara, 1989); 3) hydrothermal fluids most probably originated from the important volcanic activity developed just to the south of the Elgoibar fault during Late Albian-Santonian (e.g. Rat, 1959); 4) other Basque-Cantabrian fault-controlled hydrothermal ore deposits have also been related with Late Cretaceous volcanism, rather than with the Tertiary inversion phase (e.g. García-Mondéjar, 1989).

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