

Subhorizontal shear zones and their relation to nappe movements in the Cantal and Miñarros units. Eastern Betic Zone (Spain)

F. Alvarez

Departamento de Geomorfología y Geotectónica, Universidad de Salamanca, 37008-Salamanca, Spain

Received 21 October 1986; accepted in revised form 6 March 1987

Key words: Betic Cordillera, Horizontal ductile shear zones, Microfabrics, Mylonites

Abstract

The Cantal and Miñarros units, two of the tectonic units that belong to the Internal Zone of the Betic Cordillera, bear evidence of a ductile shear deformation which led to the development of mylonites.

In the Cantal unit, the mylonitic deformation began during the last part of a second penetrative deformation phase; it is restricted to the unit and is unrelated to its present-day position over the Palomas unit on which it has been emplaced later, under much more brittle conditions. In contrast, the mylonitic deformation observed in the Miñarros unit extends for a few metres into its relative autochthon (Lomo de Bas unit) where it affects third phase folds; these observations allow us to establish a direct relationship between the shear deformation and emplacement of the Miñarros unit over the Lomo de Bas unit.

The distribution of the stretching lineations in the shear zones considered and the study of the preferred crystallographic *c*-axis orientation of quartz in the associated mylonites show that the direction of movement within the Cantal unit was from WSW to ENE, and that the Miñarros unit was emplaced from S to N.

Introduction

In the southwestern part of the province of Murcia, in the region of Aguilas and Mazarrón, rocks belonging to the Riff-Betic Orogen are exposed which have been studied from different perspectives by several authors (Durand Delga et al., 1962; Fernex, 1964 a & b, 1965; Corbella-Martí, 1969; Espinosa Godoy et al., 1974 a, b, c & d; Kozur et al., 1980, 1985). On the basis of their stratigraphy and metamorphic histories Alvarez (1984) and Alvarez & Aldaya (1985) distinguished a number of tectonic units that belong to the three complexes of nappes in which the tectonic units of the Internal Zone of the Betic Cordillera have traditionally been grouped. In ascending order these are, the Nevado-Filábride, the Alpujarride and the Malá-

guide complexes (Egeler & Simon, 1969; see also Fig. 1).

The stacking of the units in most cases is due to late thrusting phases which affected an early pile of nappes, a phenomenon well known from the rest of the mountain range (Paquet, 1974; Campos et al., 1984; Cuevas & Tubia, 1984). The thrust structures developed under relatively brittle deformation conditions and their development often obscures the initial contacts between the various units.

However, in two of the units of the region studied, the Cantal and Miñarros units (Alvarez & Aldaya, 1985), mylonitic structures are observed which point to the existence of early ductile shear zones. The study of these structures and the analysis of the petrofabrics of some tectonites allowed us to accurately determine: (1) the direction and sense

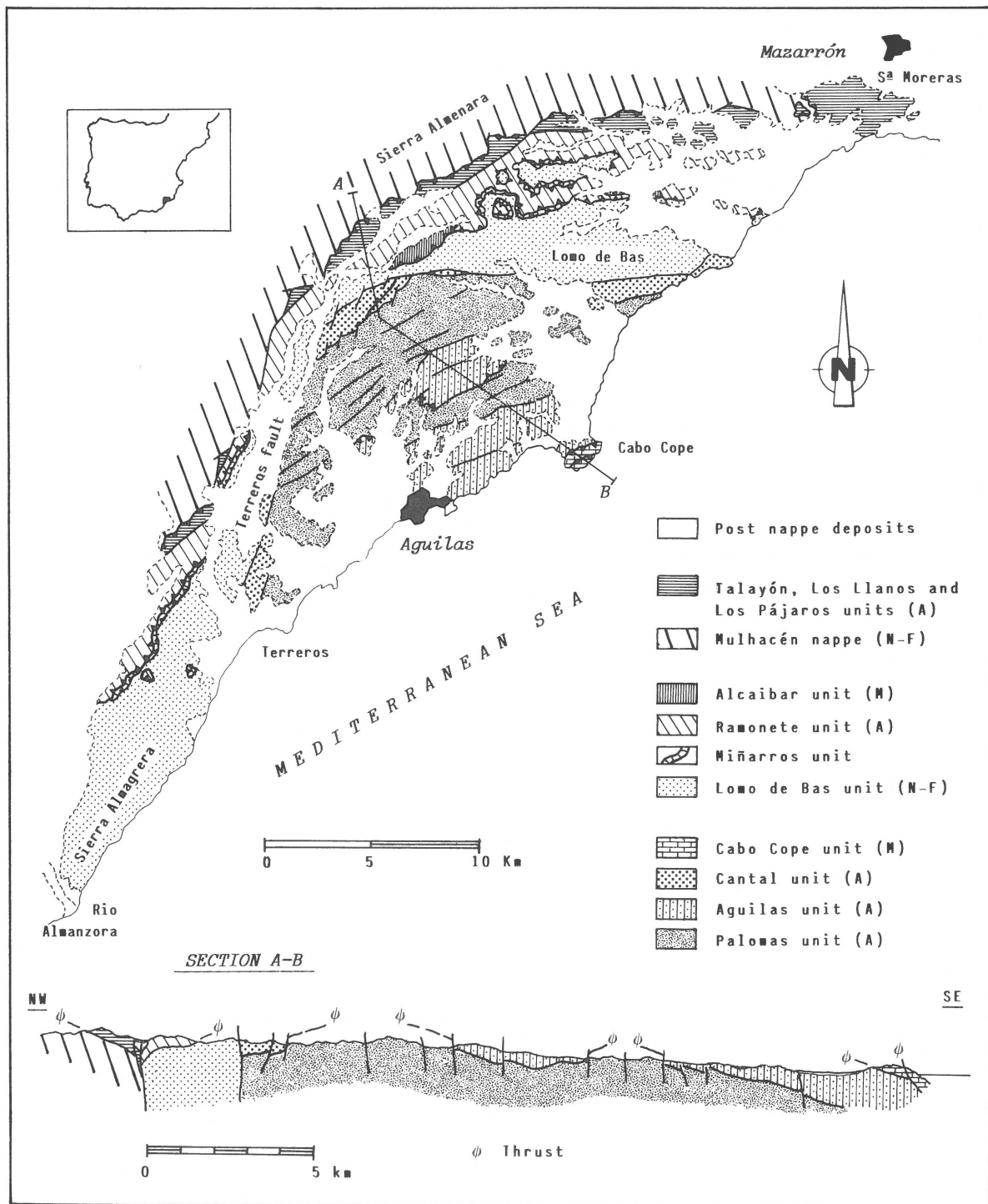


Fig. 1. Simplified geological map and cross section of the Aguilas, Eastern Betic Zone, SE Spain. (N-F), (A) and (M) mean that each unit belong to Nevado-Filábride, Alpujárride and Maláguide complex respectively.

of early movement within the Cantal unit; (2) the direction and sense of emplacement of the Miñeros unit over the Lomo de Bas unit; (3) the prevailing deformation mechanisms during mylonitization; and (4) the timing with respect to the main deformation phases. These petrofabric studies are of great use for the determination of the kinematics of flow in the shear zones and they have recently been applied to the study of the Betic Cordillera with positive results (Behrmann & Platt, 1982; Tubia, 1984; Gonzalez-Lodeiro et al., 1984; Platt & Behrmann, 1986; Tubia & Cuevas, 1986; Orozco, 1986).

The two shear zones considered here show different features and may even correspond to different deformation phases and will therefore be analyzed separately.

The Cantal unit

The Cantal unit is an Alpujárride unit, similar to the Almijara Group (Aldaya et al., 1979), and is mainly composed of medium-to-high grade metamorphic, staurolite- and garnet-bearing schists and quartzites, among which locally a few intercalations of marbles and amphibolites appear; towards the base the unit contains schists with kyanite and/or sillimanite, gneisses and migmatitic gneisses.

Some levels of the lower part of the metamorphic sequence show a penetrative mylonitic foliation; this is particularly evident in the quartzo-feldspathic rocks. The mylonites exhibit a very prominent plano-linear fabric corresponding to a mylonitic foliation (Sm) and a mineral lineation (Lm) which is interpreted as a stretching lineation. The former is subparallel to the S2 schistosity, which developed during the second deformation phase (D2). Both the S2 schistosity and the mylonitic foliation have been folded by the third deformation phase (D3). The mylonitic foliation generally dips towards the NW (Fig. 2) and in the proximity of the lower boundary of the unit it runs parallel to the contact with the footwall. However, the mylonitization did not affect the relative autochthon, so that, together with other metamorphic and structural criteria, the current stacking of the units can be safely inter-

preted to be due to later phases of thrusting.

The mineral lineations are also affected by the third deformation phase (D3); however, since the mineral lineations are largely parallel to the axes of the folds produced during D3 phase, the dispersion of lineations is not very pronounced. Their trends are mainly between N50° E and N70° E (Fig. 2), except in the vicinity of the Terreros fault (Fig. 1) where, owing to the drag along this fault, they trend in a N-S direction.

The mylonites of the Cantal unit were studied in thin sections of quartzitic tectonites that are cut perpendicular to the foliation and parallel to the mineral lineation (i.e. parallel to the inferred XZ section of the finite strain ellipsoid). The most common microstructures observed include ribbons (Boulier & Bouchez, 1978) and elongate mosaic microstructures (Bouchez & Pecher, 1981). Some tectonites exhibit microstructures similar to the type S-C mylonites of Lister & Snoke (1984). Other microstructures characteristic of intracrystalline plastic deformation, such as lamellae and deformation bands, are also observed (Fig. 3).

In c-axis diagrams of quartz made from XZ sections, the quartzitic tectonites can be observed to have a distinct preferred crystallographic orientation. The c-axis pole figures vary from fabrics in which the c-axes are concentrated in two symmetric girdles with respect to the XY plane, to fabrics in which a single girdle of monoclinic symmetry is observed (Fig. 4). In the former, one of the girdles consistently shows a greater concentration of poles than the other, pointing to a non-coaxial nature of the deformation (Lister, 1977; Nicolas & Poirier, 1976; Lister & Williams, 1979; Bouchez et al., 1983). In the single-girdle fabrics, asymmetry with respect to the XY plane is more evident and a common finding in these are skeleton branches of the kind which characterize the type I girdles of Lister (1977). The crystallographic preferred orientations correspond to different degrees of shear deformation (Carreras et al., 1977; Burg & Laurent, 1978), such that the shear component is much greater in those presenting monoclinic symmetry. In this latter fabric type, a decrease may be noted of the angle between the inferred shear plane and the mylonitic foliation. This is in accordance with mod-

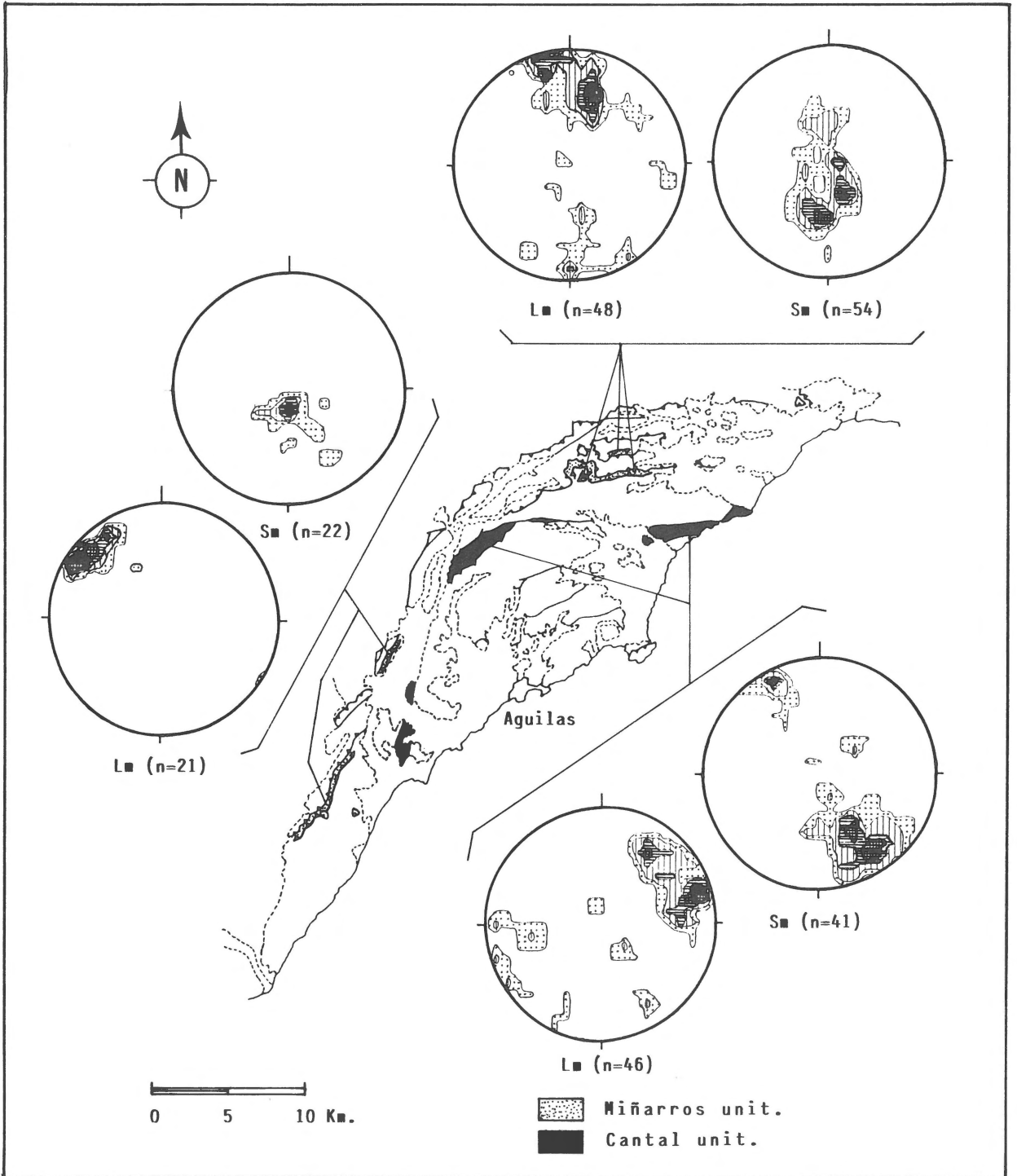


Fig. 2. Lower hemisphere equal-area orientation plots showing the distribution of the mylonitic foliation (Sm) and stretching lineations (Lm) in the shear zones of the Miñarros and Cantal units.

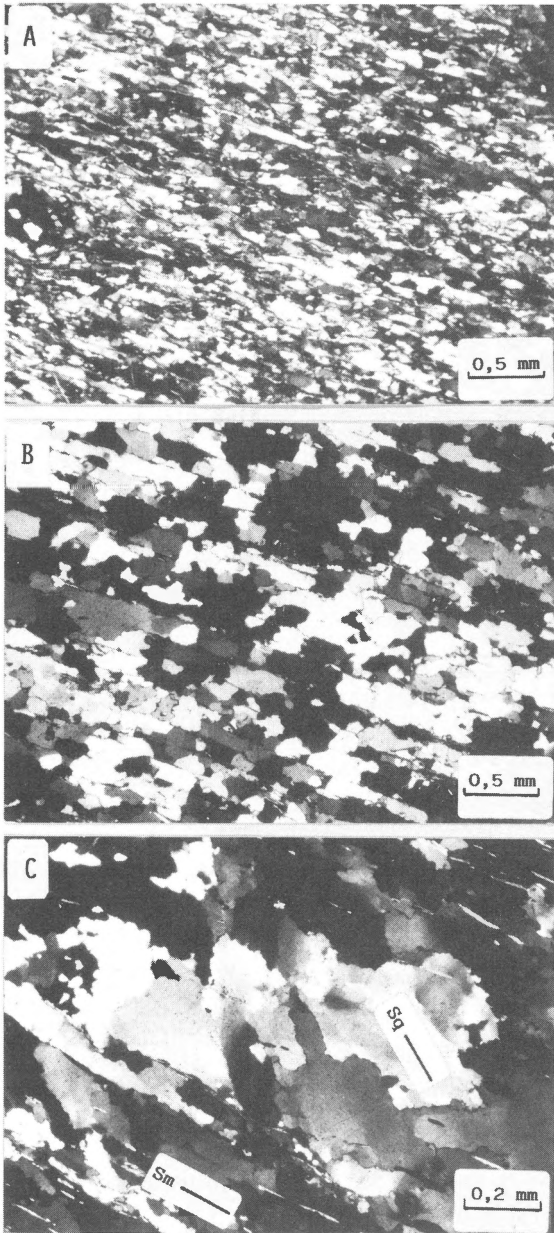


Fig. 3. Photomicrographs of the most common microstructures observed in the quartzitic tectonites collected from the mylonitic layer of the Cantal unit (Section XZ). (A) Ribbon microstructure. (B) Elongate mosaic microstructure. (C) S-C mylonites: elongate quartz grain defining a foliation (Sq), oblique to the general foliation (Sm).

els proposed by several authors (Hudleston, 1978; Lister & Williams, 1979; Bouchez et al., 1983; Behrmann & Platt, 1982).

The asymmetry observed in all diagrams may be interpreted as an indicator of the sense of shear (Bouchez & Pecher, 1976; Carreras et al., 1977; Bossiere & Vauchez, 1978; Lister & Williams, 1979; Behrmann & Platt, 1982). A shearing sense is inferred which is consistent with that deduced from the pressure shadows adjacent to some rotated porphyroblast in the mylonites (Simpson & Schmid, 1983). In both cases the sense of shear points to an important movement within the Cantal unit from WSW to ENE, presumably during the last part of the second deformation phase.

Miñarros unit

The Miñarros unit is a strongly mylonitized structural element that separates the Lomo de Bas unit, belonging to the Nevado-Filábride complex, from the overlying Maláguide and Alpujárride complex. The parallelism existing at regional scale between the mylonitic band and the contact between the formation of the upper Alpujárride unit (Ramónete unit) allows one to assume that it is a mixture zone related to the emplacement of the Alpujárride complex over the Nevado-Filábride complex.

The Miñarros unit is composed of a thin sequence (< 15 m.) of calc-schist and light and dark-coloured banded marbles, with intercalated feruginous calcareous mylonites, layers of mylonitic quartzites, and light-coloured phylonites.

Between these rocks and metapelites of the Lomo de Bas unit there is a layer, about 12 m thick, of schist and heavily mylonitized dark quartzites. Towards the top of this layer there appears to be a gradual transition into the above-described rocks of the Miñarros unit. Moreover, down into the layer the mylonitic character disappears gradually, although it is not possible to observe a distinct contact between mylonitic rocks and metapelites of the Lomo de Bas unit. A ductile shear zone in the upper part of the Lomo de Bas schist which separates rocks of different lithology leaves no doubt that the Miñarros unit is an allochthonous tectonic

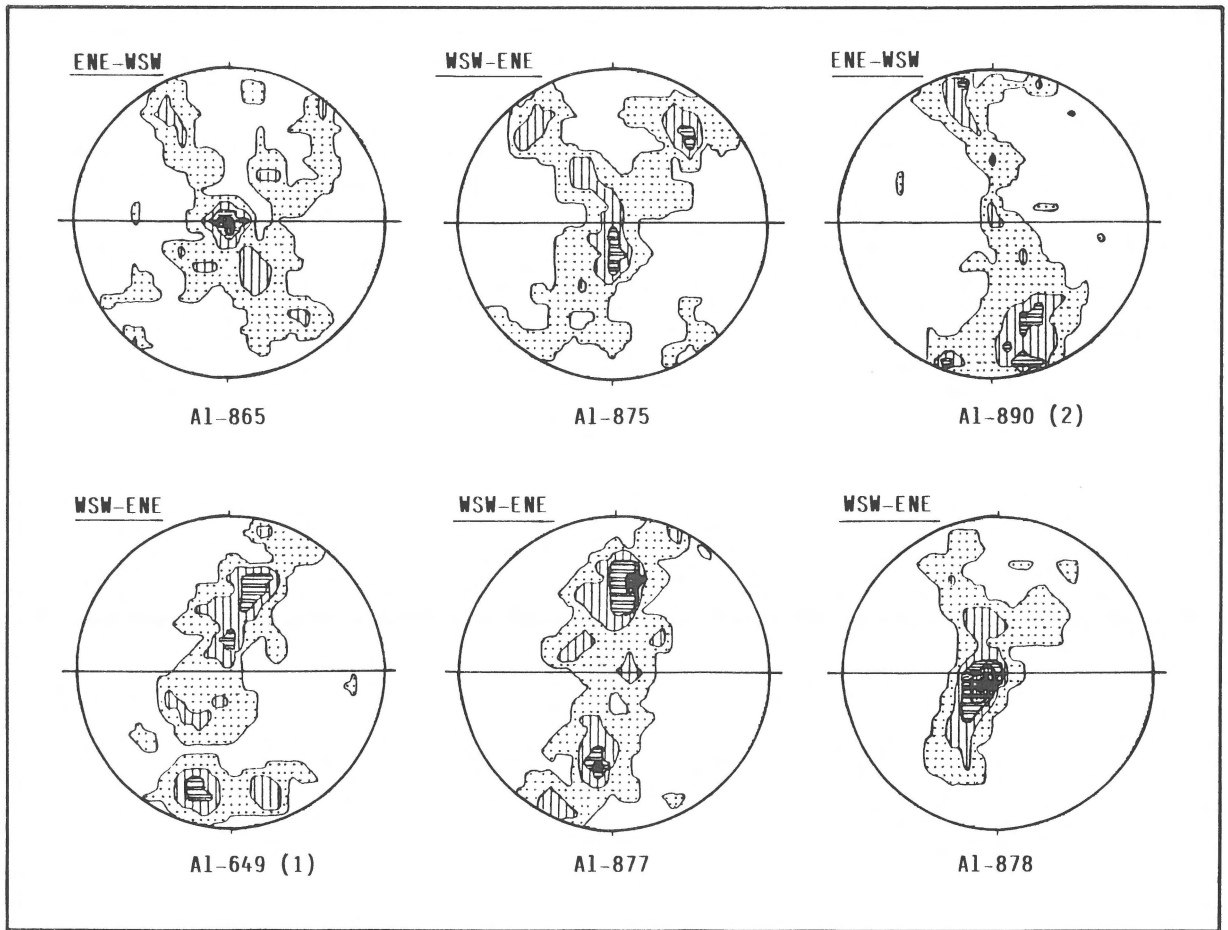


Fig. 4. Diagrams showing quartz c-axes preferred orientation in mylonites from the Cantal unit. Section XZ. Equal-area projection, lower hemisphere. Intervals of 1, 3, 5, 7, 9 and 11%, except for samples A1-878, of which the intervals are 1, 4, 7, 10, and 16%. 150 measurements per diagram. The orientation of these diagrams is approximated.

unit, although it is difficult to determine a precise limit between the two units.

The upper limit of the unit is an abrupt tectonic contact through which the filites and quartzites of the Ramonete unit run; these do not show mylonitic deformation.

The regional importance of this mylonitic band, in which the upper carbonatic and quartzitic mylonitic layers should also be included, not only lies in the great thickness of the deformed zone, but also in the large lateral extent over which the rocks occur, with identical characteristics over the entire region studied (Fig. 2). It should also be noted that its prolongation towards the W has been observed at different localities in the northern part of the

Sierra Cabrera and the Sierra Alhamilla, where similar rocks occupy a similar structural position (Navarro-Vila et al., 1984). In this sense it is comparable to the mylonitic band that separates the Alpujarride units from the Nevado-Filábride units south of Sierra Alhamilla (Behrmann & Platt, 1982; Platt et al., 1983), and to the one reported by Platt et al. (1984) in the region of Cartagena and in other localities of the Sierra Nevada, Sierra de los Filabres and Sierra Cabrera.

In the quartzitic mylonitic layer of the Miñarros unit there is a pronounced plano-linear fabric corresponding to a mylonitic foliation (S_m) parallel to the contact between the two units, and a mineral lineation (L_m) which is mainly represented in the

quartz-rich layer, although it also occurs in the carbonatic materials. The lineations to the North of the Lomo de Bas unit trend approximately N-S, whereas in the western part of the area, they were rotated 30–60 degrees anticlockwise in consequence of the drag along the Terreros fault (Fig. 2).

The N-S orientation contrasts with that of the mineral lineations that developed in the Lomo de Bas schist during the second deformation phase which ranges between N60° E and N100° E. The N-S lineations associated with the shear zone are superimposed on previous lineations in the schist, such that the latter become less obvious when approaching the mylonite zone, in which they finally disappear. Another significant fact to be taken into account is the reorientation of the axes of the third phase folds in the Lomo de Bas metapelites that is observed in the proximity of the shear zone. It may thus be inferred that the ductile shear zone that separates the Miñarros and Lomo de Bas units developed during the third deformation phase or later, and that it affected preexisting structural and metamorphic features.

The mylonitization gave rise to a strong reduction in grain size as well as to numerous microstructures which point to the plastic nature of the intracrystalline deformation. This is in contrast to the pressure dissolution mechanisms which characterize the deformation in the schist underneath. The microscopic fabric exhibited by the mylonites is very similar in all samples examined. Consistently, a strongly developed ribbon microstructure is observed similar to that of the type I described by Boullier & Bouchez (1978); the size of the ribbons is very small (< 50 μm in length) and within them subgrains and undulose extinction can be seen (Fig. 5).

The quartz *c*-axis diagrams reveal pronounced preferred crystallographic orientations. All diagrams obtained show a monoclinic symmetry with a principal girdle (Fig. 6) similar to the type I fabric of Lister (1977), and that reflects a very important non-coaxial deformation. The intensity of this shear deformation is also reflected in the small angle, usually less than 25 degrees, that can be observed in all diagrams between the inferred shear plane and the mylonitic foliation.

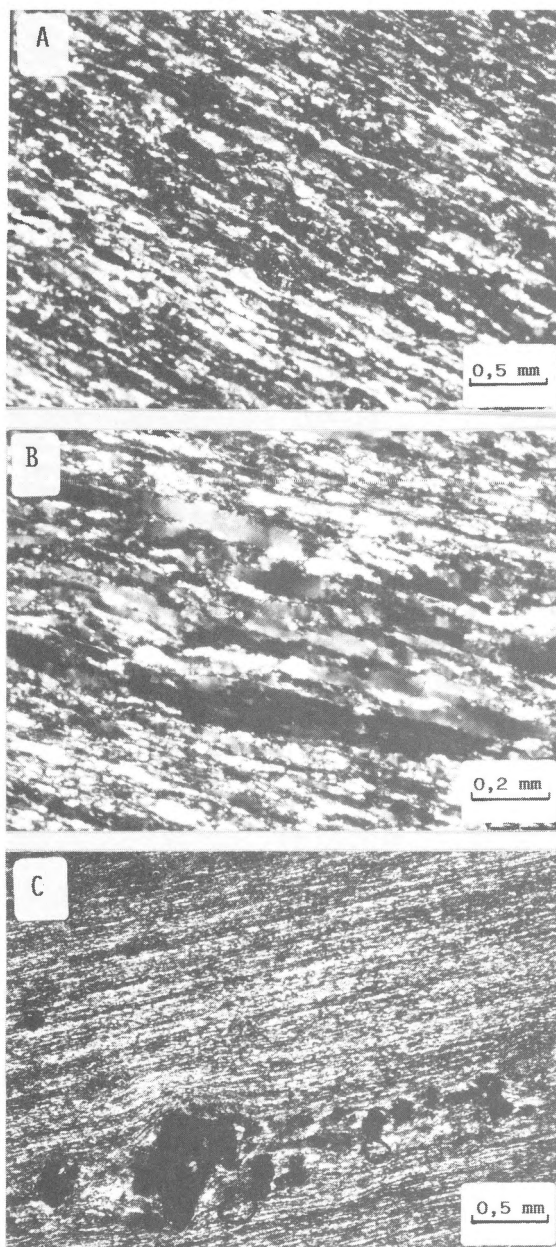


Fig. 5. Photomicrographs of the quartzitic tectonites collected in the mylonitic band of the Miñarros unit (Section XZ). The ribbon microstructures (A) observed point to a strong deformation with a pronounced grain size reduction. The sense of shear can be deduced from the obliquity between subgrains in the quartz-ribbons and the mylonitic foliation (B), and from the asymmetry of the pressure shadows around some porphyroblast (C).

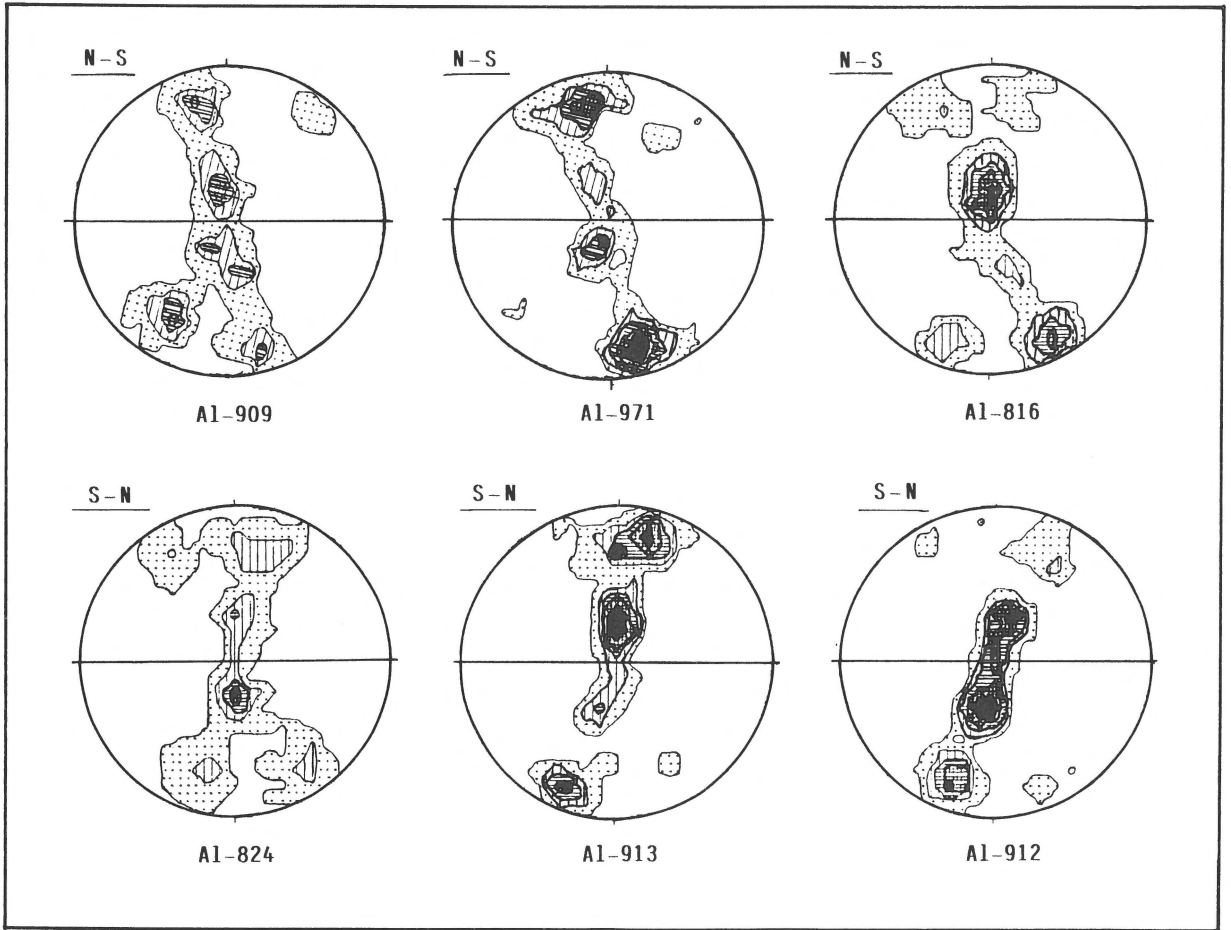


Fig. 6. Quartz c-axis preferred orientation patterns in mylonites at the contact between the Miñarros and Lomo de Bas units. Section XZ. Equal-area projection, lower hemisphere. Intervals of 1, 3, 5, 7, 9 and 11%. 150 measurements per diagram. The orientation of these diagrams is approximated.

The sense of shear deduced from the asymmetry of the c-axis diagrams, together with the data concerning the orientation of the lineations discussed above, show that the Miñarros unit was displaced from the South towards the North, with the Lomo de Bas unit as its relative autochthon. Another criterion that supports this sense of movement is deduced from the extensional crenulation cleavage structures (Platt & Vissers, 1980) which overlie the mylonitization and which may be interpreted as a product of shear under more brittle conditions.

Discussion and conclusions

The mylonites in the Cantal and Miñarros units were produced by ductile shear with intracrystalline plastic deformation, strong recrystallization and pronounced grain size reduction. The structures and petrofabrics of the rocks reveal the kinematics of flow in the emplacement of the Miñarros unit over the Lomo de Bas unit and of the shear zones within the Cantal unit.

In the Cantal unit it is possible to observe a mylonitization which reflects differential movement in an ENE direction during the last part of the second deformation phase. This movement is unrelated to its present-day position over the Palomas

unit, and it allows one to surmise that during D2 a differentiation of an independent tectonic unit had already begun. Regarding this, it should be noted that for the western sector of the Cordillera, Tubia (1984) has described thrusting between the Alpujarride units of medium-to-high grade metamorphism that is due to the D2 phase; the direction and sense of emplacement that Tubia deduced from the mylonitic zones that separate these units, indicates movements from WSW to ENE. Similarly, several authors have reported the existence of a stretching lineation associated with the D2 phase in some units of the Nevado-Filábride complex (Martinez, 1984), and from petrographic studies they deduced senses of movements towards the ENE (Gonzalez-Lodeiro et al., 1984; Orozco, 1986).

The emplacement of the Miñarros unit over the Lomo de Bas unit took place during or after the third deformation phase observed in the footwall schist. Its transport direction, deduced from the crystallographic fabric and the superimposed extensional crenulation cleavage, was from S to N. The characteristics of this unit allow one to consider it as a mylonitic band comparable to those described from other parts of the Cordillera with respect to northward emplacement of the Alpujarrides units over those of the Nevado-Filábride complex (Platt, 1982; Behrmann & Platt, 1982; Platt et al., 1983; Konert & van den Eckhout, 1983; Platt et al., 1984).

From the foregoing, it may be deduced that the mylonitic deformations observed in both units correspond to different deformation phases with different directions of movement.

The change in orientation of the lineations near the Terreros fault may be interpreted to be the result of the sinistral movement of this fault which is in fact a subvertical brittle-ductile shear zone of post-serravalliense age that led to anticlockwise rotation in the pre-existing structures.

Acknowledgements

This study was carried out during a research project entitled: 'Cinámica de los mantos Béticos-Rifeños, reconstrucción del paleomargen sudibérico y

naturaleza de las manifestaciones básicas', auspiciado by the C.S.I.C. and C.A.I.C.Y.T.

References

- Aldaya, F., V. Garcia-Dueñas & F. Navarro-Vilá 1979 Los Mantos Alpujarrides del tercio central de las Cordilleras Béticas. Ensayo de correlación tectónica de los Alpujarrides. *Acta Geol. Hisp.* 14: 154-166
- Alvarez, F. 1984 Las Unidades Alpujarrides y Nevado-Filábrides en el Sector Aguilas-Mazarrón (Cordilleras Béticas Orientales). In: J. Lopez-Ruiz (ed.) *El borde mediterráneo español: Evolución del Orógeno Bético y geodinámica de las depresiones neógenas*. C.S.I.C., Granada: 30-32
- Alvarez, F. & F. Aldaya 1985 Las Unidades de la Zona Bética en la región de Aguilas-Mazarrón (Prov. de Murcia). *Estudios Geol.* 41: 139-146
- Behrmann, J.H. & J.P. Platt 1982 Sense of nappe emplacement from quartz c-axis fabrics; an example from the Betic Cordilleras (Spain). *Earth Plan. Sci. Lett.* 59: 208-215
- Bossiere, G. & A. Vauchez 1978 Deformation by ductile shear of a granite in the Western Great Kabylia, Algeria. *Tectonophysics* 51: 57-81
- Bouchez, J.L., G.S. Lister & A. Nicolas 1983 Fabric asymmetry and shear sense in movement zones. *Geol. Rdsch.* 72: 401-419
- Bouchez, J.L. & A. Pecher 1976 Plasticité du quartz et sens de cisaillement dans quartzites du Gran Chevauchement Central himalayen. *Bull. Soc. Geol. France* 18: 1377-1385
- Bouchez, J.L. & A. Pecher 1981 The Himalayan Main Central Thrust pile and its quartz-rich tectonites in central Nepal. *Tectonophysics* 78: 23-50
- Boullier, A.M. & J.L. Bouchez 1978 Le quartz en rubans dans les mylonites. *Bull. Soc. Geol. France* 20: 253-262
- Burg, J.P. & P. Laurent 1978 Strain analysis of the shear zone in a granodiorite. *Tectonophysics* 47: 15-42
- Campos, J., V. Garcia-Dueñas, F. Gonzalez-Lodeiro & F. Aldaya 1984 Direcciones de traslación y apilamiento de unidades en los Mantos Alpujarrides centrales y orientales. In: J. Lopez-Ruiz (ed.) *El borde mediterráneo español: Evolución del Orógeno Bético y geodinámica de las depresiones neógenas*. C.S.I.C., Granada: 15-17
- Carreras, J., A. Estrada & S. White 1977 The effects of folding on the c-axis fabrics of a quartz mylonite. *Tectonophysics* 39: 3-24
- Corbella-Martí, J.H. 1969 Etude géologique de la Sierra de las Moreras (Prov. de Murcia, Espagne). Thesis, Univ. Paris: 159 pp
- Cuevas, J. & J.M. Tubia 1984 Existencia de una banda blastomilonítica asociada a las peridotitas de Sierra Alpujata (Alpujarrides occidentales). In: J. Lopez-Ruiz (ed.) *El borde mediterráneo español: Evolución del Orógeno Bético y geodinámica de las depresiones neógenas*. C.S.I.C., Granada: 9-10
- Durand Delga, M., P. Escalier des Orres & F. Fernex 1962 Sur

- la présence de Jurassique et d'Oligocene a l'ouest de Carthagene (Espagne meridionale). C.R. Acad. Paris 255: 1755–1757
- Egeler, C.G. & O.J. Simon 1969 Sur la tectonique de la Zone Betique (Cordilleres Betiques, Espagne). Verh. Kon. Ned. Akad. Wetensch. 25: 1–90
- Espinosa Godoy, J.P., S.M. Martin Vivaldi, J.M. Martin Alafont & M. Pereda 1974b Mapa Geológico de España. E: 1 ÷ 50.000 (segunda serie) 26–39, Mazarrón, I.G.M.E., Madrid
- Espinosa Godoy, J.P., S.M. Martin Vivaldi, J.M. Martin Alafont & M. Pereda 1974b Mapa Geológico de España. E: 1 ÷ 50.000 (segunda serie) 26–39, Mazarron, I.G.M.E., Madrid
- Espinosa Godoy, J.P., S.M. Martin Vivaldi, J.M. Martin Alafont & M. Pereda 1974c Mapa Geológico de España. E: 1 ÷ 50.000 (segunda serie), 25–40, Aguilas, I.G.M.E., Madrid
- Espinosa Godoy, J.P., S.M. Martin Vivaldi, J.M. Martin Alafont & M. Pereda 1974d Mapa Geológico de España. E: 1 ÷ 50.000 (segunda serie), 26–40, Cope, I.G.M.E., Madrid
- Fernex, F. 1964a Essai de corrélation des unites betiques sur la transversale de Lorca-Aguilas. Geol. Mijnb. 43: 326–330
- Fernex, F. 1964b Répartition du métamorphisme dans les zones betiques orientales de la transversale de Lorca-Aguilas. C.R. Acad. Paris 258: 5678–5681
- Fernex, F. 1965 L'origine probable de certains éléments structuraux des zones internes des Cordilleres Betiques orientaux (Espagne meridionale). Bull. Soc. Geol. France 7: 511–520
- Gonzalez Lodeiro, F., M. Orozco, J. Campos & V. Garcia-Dueñas 1984 Cizallas ductiles y estructuras asociadas en los Mantos del Mulhacén y Veleta; primeros resultados sobre Sierra Nevada y Sierra de los Filabres. In: J. Lopez-Ruiz (ed.) El borde mediterráneo español: Evolución del Orógeno Bético y geodinámica de las depresiones neógenas. C.S.I.C., Granada: 15–17
- Hudleston, P.J. 1978 Progressive deformation and development of fabrics across zones of shear in glacial ice. In: S. Saxena & S. Bhattacharji (eds.) Energetics of Geological Processes. Springer, Berlin: 121–150
- Konert, G. & B. van den Eeckhout 1983 Data on the tectonic evolution of the Alhamilla unit, Sierra Alhamilla (Betic Cordilleras, SE Spain), with emphasis on the tectonics below moving nappes. Geol. Rdsch. 72: 619–636
- Kozur, H., C. Mulder-Blanken & O.J. Simon 1980 Zawidzkella kampschurri n. gen. sp., a holothurian sclerite from the Triassic of the Betic Zone (southern Spain). Proc. Kon. Ned. Akad. Wetensch. 83: 345–353
- Kozur, H., C. Mulder-Blanken & O.J. Simon 1985 On the Triassic of the Betic Cordilleras (southern Spain), with special emphasis on holothurian sclerites. Proc. Kon. Ned. Akad. Wetensch. 88: 83–110
- Lister, G.S. 1977 Discussion: crossed-girdle c-axis fabrics in quartzites plastically deformed by plane strain and progressive simple shear. Technophysics 39: 51–54
- Lister, G.S. & A.W. Snoke 1984 S-C mylonites. J. Struct. Geol. 6: 617–638
- Lister, G.S. & P.F. Williams 1979 Fabric development in shear zones: theoretical controls and observed phenomena. J. Struct. Geol. 1: 283–297
- Martinez, J-M.M. 1984 Evolución tectono-metamórfica del Complejo Nevado-Filábride en el sector de union entre Sierra Nevada y Sierra de los Filabres, Cordilleras Béticas (España). Thesis Univ. Granada: 198 pp
- Navarro-Vilá, F., F. Alvarez & F. Aldaya 1984 La extensión regional y posición tectónica de la Unidad del Lomo de Bas (Cordilleras Béticas orientales). In: J. Lopez-Ruiz (ed.) El borde mediterráneo español: Evolución del Orógeno Bético y geodinámica de las depresiones neógenas. C.S.I.C., Granada: 26–27
- Nicolas, A. & J.P. Poirier 1976 Crystalline plasticity and solid state flow in metamorphic rocks. Wiley Interscience, London: 444 pp
- Orozco, M. 1986 Fábrica de cuarzo y cabalgamientos hacia el ENE en Sierra Nevada y Sierra de los Filabres. Cordilleras Béticas. Geogaceta 1: 40–41
- Paquet, J. 1974 Tectonique eocene dans les Cordillères Bétiques; vers une nouvelle paléogéographie dans la méditerranée occidentale. Bull. Soc. Geol. France 16: 58–73
- Platt, J.P. 1982 Emplacement of a fold-nappe, Betic Orogen, southern Spain. Geology 10: 97–102
- Platt, J.P. & J.H. Behrmann 1986 Structures and fabrics in a crustal-scale shear zone, Betic Cordillera, SE Spain. J. Struct. Geol. 8: 15–33
- Platt, J.P., J.H. Behrmann, J-M.M. Martinez & R.L.M. Vissers 1984 A zone of mylonite and related ductile deformation beneath the Alpujarride nappe complex, Betic Cordilleras, S. Spain. Geol. Rdsch. 73: 773–785
- Platt, J.P., B. van den Eeckhout, E. Janzen, G. Konert, O.J. Simon & R. Weijermars 1983 The structure and tectonic evolution of the Aguilon fold-nappe, Sierra Alhamilla, Betic Cordilleras, SE Spain. J. Struct. Geol. 5: 519–538
- Platt, J.P. & R.L.M. Vissers 1980 Extensional structures in anisotropic rocks. J. Struct. Geol. 2: 387–410
- Simpson, C. & S.M. Schmid 1983 An evaluation of criteria to deduce the sense of movement in sheared rocks. Bull. Geol. Soc. Am. 94: 1281–1288
- Tubia, J.M. 1985 Sucesiones metamórficas asociadas a rocas ultramáficas en los alpujarrides occidentales (Cordilleras Béticas, Malaga). Thesis, Univ. Paris Vasco: 263 pp
- Tubia, J.M. & J. Cuevas 1986 High-temperature emplacement of the Los Reales peridotite nappe (Betic Cordillera, Spain). J. Struct. Geol. 8: 473–488