Do the Layered Schists of Cumbres Calchaquíes (NW Argentina Andes) Represent Mylonitic Zones?

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RESUMEN — "Los esquistos bandeados de las Cumbres Calchaquíes (Andes del norte argentino): ¿zonas miloníticas?". El cinturón de esquistos bandeados que forma parte del basamento Proterozoico de los Andes del norte de Argentina, se caracteriza por una conspicua foliación (S_1) definida por la alternancia de folias micáceas y cuarzosas de pocos milímetros hasta 2 cm de espesor. Éstas están intensamente microplegadas. Se reconoce un clivaje de plano axial (S_2) que acompaña al microplegamiento y que varía entre un clivaje espaciado y un bandeamiento tectónico. El origen de S_1 es controvertido, algunos autores lo consideran una estructura primaria. En este trabajo se presentan los resultados obtenidos sobre el análisis microscópico de secciones delgadas orientadas perpendiculares a S_1 y paralelas a la lineación de estiramiento que contiene. Las folias ricas en cuarzo tienen microfábrica granoblástica y las biotíticas, lepidoblástica. En éstas, las micas desarrollan sigmoides y están imbricadas a lo largo de las superficies de cizalla, definiendo estructuras C' típicas de milonitas. También se reconocen pliegues asimétricos, con plano axial paralelo a S_1. Estas son estructuras relícticas, reconocidas generalmente en cinturones miloníticos. Las estructuras C' y los pliegues asimétricos indican movimiento de cizalla dextral. Según los resultados obtenidos, el bandeamiento (S_1) de estos esquistos tiene origen tectónico y está relacionado con una faja regional de cizalla dúctil, dextral y de alto ángulo.

PALABRAS CLAVE: Esquistos bandeados, Cinturón milonítico, Noroeste argentino.

ABSTRACT — The layered schists belt (esquistos bandeados) in the Proterozoic basement of the northern Argentina Andes shows a conspicuous layering (S_1) marked by alternating mica rich layers with quartz layers. They are few millimeters thick up 2 cm thick and intensively microfolded. The axial plane cleavage (S_2) accompanying the microfolding ranges from spaced cleavage to a tectonic layering. The origin of the layering (S_1) is controversial, for some authors is a primary structure. Here we present the results of the microscopic study in oriented sections perpendicular to S_1 and parallel to the stretching lineation into S_1. The quartz rich layers show granoblastic microfabric and the biotite rich lepidoblastic fabrics. In the biotitic layers the crystals show sigmoidal forms and are imbricated along shear surfaces, showing a C' structure typical of the mylonites. Otherwise there are asymmetric folds vein with the axial plane surface parallel to the main foliation (S_1). They are relictic structures recognized in the mylonitic belts. The C' structures and the asymmetric folds are indicators of dextral shear movements. According to the results of this study the layering of these schists has tectonic origin and is related to a major dextral steep dipping ductile shear zone.

KEYWORDS: Layered schists, Mylonitic belts, NW Argentina.

INTRODUCTION

The north part of the Central Cratón of Argentina comprises an external zone of low-grade schists and a westward contiguous metamorphic zone composed by a layered schists belt "esquistos bandeados" (González Bonorino, 1950) extending along a significant part of the north Sierras Pampeanas (figure 1). Excellent outcrops, with a spectacularly developed crenulated layering, along Los Sosa River creek allow the structure to be examinated in detail and sampled. Los Sosa River structures were compared with other sections to obtain a regional picture of the layered schists belt. They represent a significant area to understand the structural evolution of the Proterozoic basement of this portion of the NW Argentina.

The controversial origin of the layering is the main concern of this paper. It was described as a primary sedimentary structure by González Bonorino (1950), Toselli (1990). Otherwise Willner (1983, 1990), Mon and Hongn (1991) argued for a tec-

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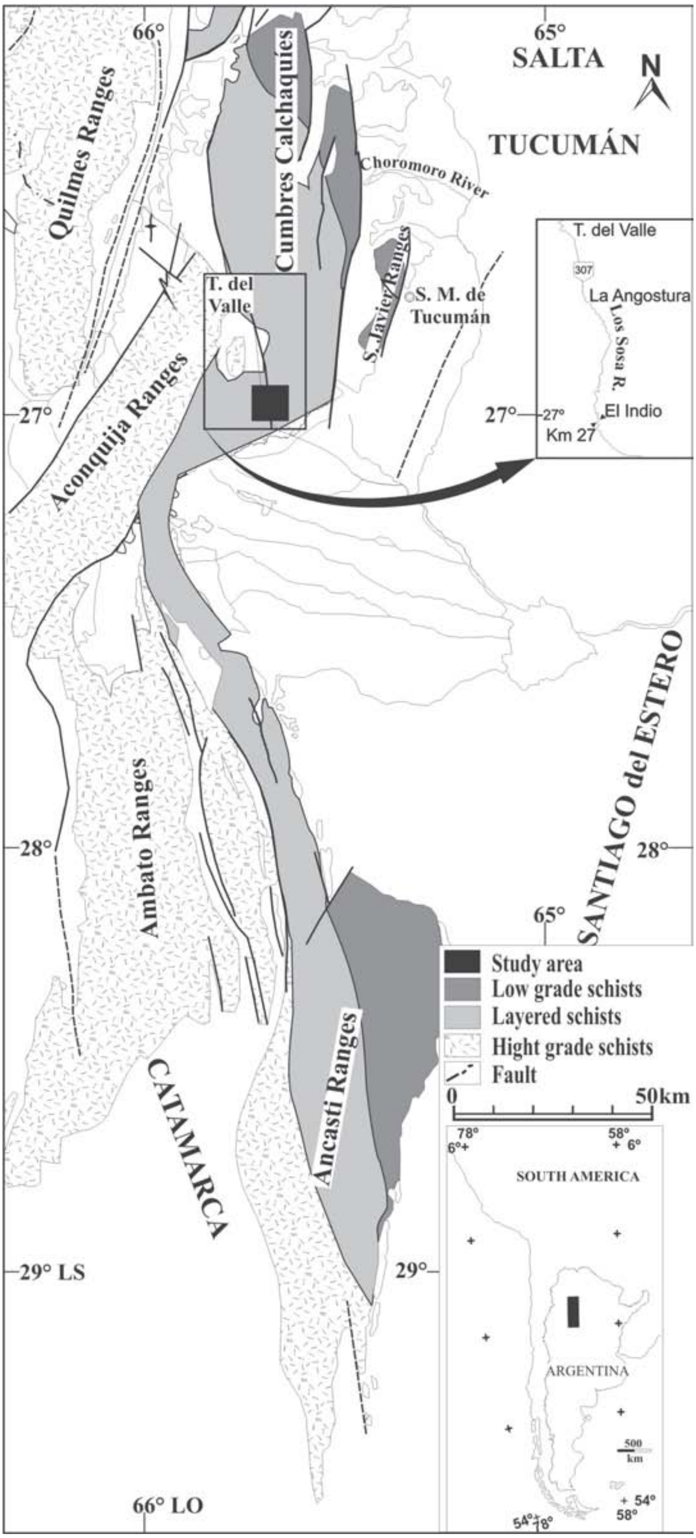

Figure 1. Location map of the study area and regional distribution of the layered schists in NW Argentina.

tonic origin. According the results presented in this paper, based in the microstructural analysis of several oriented thin sections, the layering of the "esquistos bandeados" is a deformation induced structure.

GEOLOGICAL SETTING

The layered schists exposures consist of an extended belt of quartz - biotite - muscovite schists intruded by tonalites and granodiorite bodies (figure 1). They have undergone polyphase folding as result of the Neoproterozoic – Lower Cambrian Tilcaric deformation phases (Turner and Méndez, 1975; Toselli, 1990; Mon and Hongn, 1991). Main folding phases F_1 and F_2 are related to D_1 and D_2 deformation episodes. The differentiated cleavage producing the tectonic layering, discussed in this paper, is related to D_1 deformation. Shear indicators were observed on the microscopic scale within the zones of differentiated cleavage.

STRUCTURE

The earliest recognizable deformation D_1 corresponds to a zonal cleavage characterized by alternating quartz-rich domains and mica-rich domains. It is displayed in outcrops and microscopically in thin sections. On mesoscopic scale the main schists structure is a compositional layering determined by alternating quartz and micaceous layers. They are no more than 2 centimeters thick and they are enhanced by color variations from white to dark greenish grey.

The folding of the layering (S_1) during D_2 generated many fold orders from 0,01m to 600 m wave length have been described (Marini, 1988, Mansilla, 1990). The folds are accompanied by an axial plane cleavage (S_2), ranging from a spaced cleavage to a differentiated crenulation cleavage.

The samples for microstructural studies were collected in exposures where the layering (S_1) is steeply dipping (N 70°O/ 80° N) with subhorizontal stretching lineation and the second one is not significantly developed.

MICROSTRUCTURE DESCRIPTIONS

The alternation of mica-rich bands and quartz-rich bands define a compositional layering, smooth, parallel and discrete, according to the morphological classification of Passchier and Trouw (1996).

Microscopic foliation is parallel to the macroscopic layering. In the quartz-rich domains there are platy minerals aligned parallel to the S_1 layering into the axial microfolded quartz vein. Muscovite is also intergrown with quartz as symplectites. Mica domains show imbricated biotite plates (figures 2) determining sigmoidally structures and related to thin slender fibrolites (figures 2a and b).

This fabric resembles the S-C fabric observed in mylonites. The surface contact (S_1) between quartz and mica domains corresponds to C and imbricated mica crystals sigmoidally curved represent S foliation. A C‘ surface can be inferred by the platy minerals inflections oblique to the border bands, cutting them at a small angle in opposite sense than that of the S surfaces (figures 2c and d).

In the quartz-rich bands, tight asymmetric intrafoliated microfolds were identified

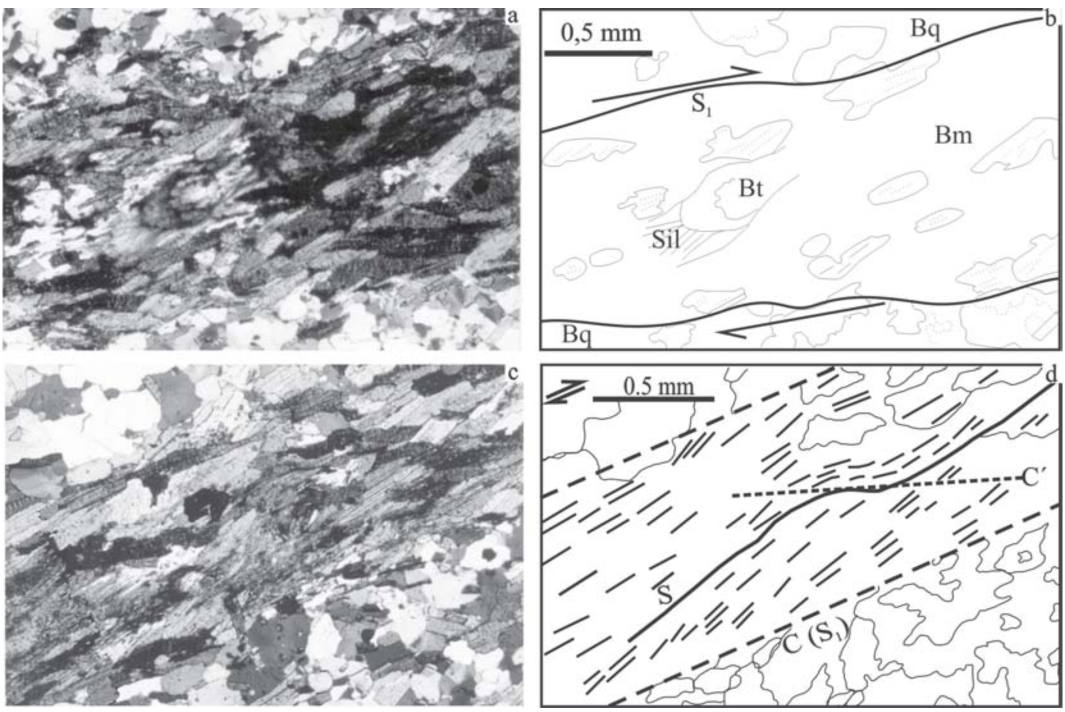

Figure 2. Layered schists sections views normal to the (S_1) foliation and parallel to the mineral alignment: (a) photomicrograph of the sigmoidally biotite microstructure (Bi) showing fibrolite sillimanite (Sil) ends and imbricated mica plates within the lepidoblastic band (Bm) (cross nicols). (b) Schematic section representing figure 2a. The foliation (S_1) is in the same direction to the dextral shear sense. (c) Photomicrograph of the shear band type C‘ within the cleavage domain or mica rich band (Bm). The foliation (S_1) is in the same direction to the shear sense. S and C‘ are oblique to borders band (crossed polars). (d) Schematic section representing figure 2c.

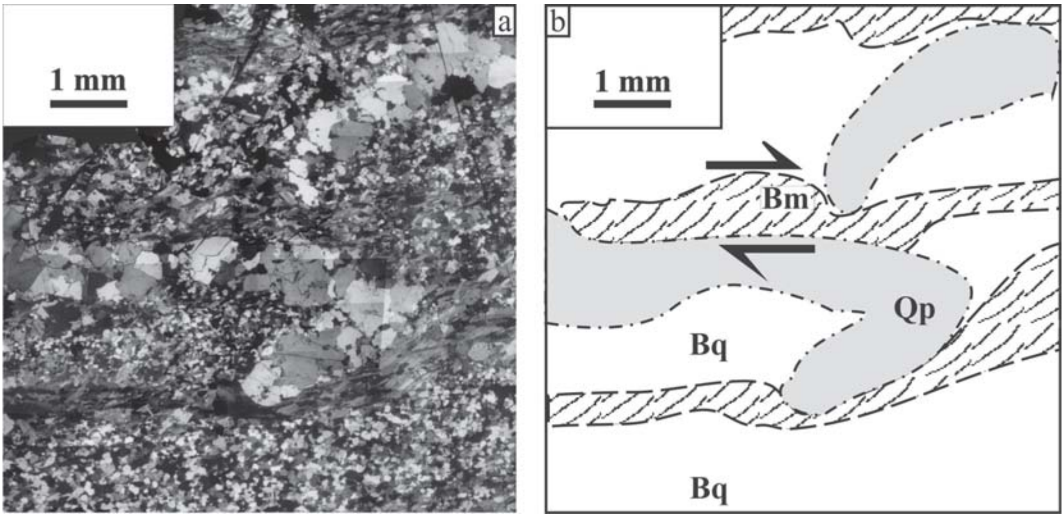

Figure 3. Layered schist view: (a) photomicrograph of the first foliation, showing an intrafolial quartz (Qp) fold, platy minerals bands (Bm) and quartz rich bands (Bq). Section view normal to the (S_1) foliation and parallel to the mineral alignment (crossed polars). (b) Schematic section representing figure 3a.

(figures 3a and b). They are indicating the same shear sense as the S-C fabric.

The second deformation episode D_2 is represented by a crenulation cleavage (S_2) which lies at high angle to S_1 foliation. S_2 is a differentiated crenulation cleavage due to microfolding of S_1 foliation; its mica domains are built up by thin biotite and muscovite aggregates parallel to the microfolds axial planes.

PHYSICAL CONDITIONS

These schists show Qtz + Bt + Mu + Pl (mineral symbols after Kretz, 1983) mineral assemblages indicating low- to medium- grade metamorphism on pelitic sedimentary rocks, under nearly 2.5 kbars of pressure and 450° C of temperature conditions (Toselli and Rossi de Toselli, 1984).

The fibrolite aggregates can not be included in this paragenetic mineral association because they were originated at expense of micas (figure 2a). The fibrolite is a good indicator of concentration pressure zones where porphyroblasts and aggregates of micas could be developed accompanying them (Vernon and Flood, 1977; Vernon, 1987). Fibrolite in the biotitic layers is typical of mylonites and mylonitic processes (Grambling, 1981, Flöttmann 1991).

Considering these intergrowth structures as originated by pressure, when the first controlling factor is a deformational episode, quartz-muscovite symplectites are indicators of pressure concentration zones (Simpson and Wintsch, 1989).

DISCUSSION

The layering of the schists of Los Sosa River valley were interpreted as sedimentary structures enhanced by recrystallization and induced by magmatic injection by González Bonorino (1950). Layered schists similar to those of Los Sosa River were described by Willner (1983) in Ancasti Ranges and in Cumbres Calchaquíes (Willner, 1990). According this author in both areas the layering is parallel to bedding. In the case of Cumbres Calchaquíes he postulates that the layering coincides with a transposed stratification where most of the primary structures are obliterated.

Between the low-grade schists of the Choromoro belt and the layered schists (figure 1), there is a gradual transition. The axial plane cleavage of the Choromoro belt grades westward into well developed tectonic layering (Mon and Hongn, 1991). Therefore according these authors the layering corresponds to an axial plane cleavage, completely independent of any sedimentary structure.

In Los Sosa River section and along the whole Cumbres Calchaquíes layered schists belt field studies and detailed investigations of thin sections have not revealed sedimentary structures. These rocks show the effects of two ductile deformation episodes, the first one generated the layering (S_1) and the second one the intense microfolding accompanied by a crenulation cleavage (S_2).

Sigmoidal microstructures between imbricated plates represent pressure concentration points, favorables to fibrolite generation.

The microscopic cinematic indicators described above, accompanying S_1 layering show dextral movement evidences. The limbs displacement of the intrafoliated asymmetric microfold confirms the dextral movement evidences. This microfold corresponds to a quartz vein generated before the layering. This chronological relation is confirmed by mica bands inflections around the microfold axis, because a progressive deformation effect. These intrafoliated folds could be the only relict structures in mylonitic rocks which commonly seem to be not deformed (Spry, 1969). The schists show recrystallization signs but they are not unmistakable evidences to be dynamic, specially from quartz. Static recrystallization could extend after the stresses dissipation masking some deformation structures as undulated extinction. Non oriented muscovite plates are related to later thermal episodes.

These posthumous episodes could obliterate some structures belonging to the first deformation episodes.

The “esquistos bandeados” layered schists do not show any mesoscopic scale evidence of mylonitization. Only the microstructural analysis of grain-scale processes allowed recognizing fabrics typical of mylonites. Similar Precambrian rocks were described in mylonitic belts of north Brazil (Hippert and Tohver, 1999) and in western India (Mamtani *et al.*, 1999).

CONCLUSIONS

The layering of the “esquistos bandeados” belt is a shear related structure. Microestructures analyzed prove the action of shear components parallel to the layering S_1 showing dextral displacement along a steep dipping shear zone, N 70°O/ 80° N. The preserved microstructures correspond to mylonites generated during this processes. The whole “esquistos bandeados” belt could correspond to several shear zones, representing major structures of the Proterozoic basement of north Argentina Andes. The results of this work allow a new scope for the tectonic research of the wide exposures of layered schists of the Precambrian basement of the Sierras Pampeanas of Central Argentina, where significant mylonitic belts could be exposed.

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