VALIDATION OF DIGITAL TERRANE MODELS OF ASTER SENSOR ON THE STUDY OF GEOMETRY AND STRUCTURAL EVOLUTION OF THE NW SIERRAS PAMPEANAS OF ARGENTINA

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Abstract: This paper presents the results of an interpretation of ASTER products and structural data in the investigation of suture zones of cordilleran-type orogenic belts. These results have been interpreted under the light of structural analysis, isotopic and metamorphic geology, to investigate the history of tectonic evolution of the Cuyania Terrane. The capacity of ASTER sensors to acquire visible and thermal infrared data, not supported only field work, but also allowed the distinction between different rock types as well as the reinterpretation of lineaments, something not always possible using conventional cartographic methods. Following a brief description of the main pervasive fabrics recorded by rocks of this area, we present the integration of DTM and colour composite of ASTER images showing a three-dimensional view of some of the main structures of the area, in particular the large-scale F3 folds, and discuss their role in the evolution and structural geometry of the rocks. We shall demonstrate the advantages of using DTM models for structural mapping in areas of difficult access such as NW Sierras Pampeanas of La Rioja, Argentina.

INTRODUCTION

The NW Sierras Pampeanas of Argentina are located in the southern-central Andes and comprise a sequence of crystalline rocks uplifted by movement along inverse faults to ca. four thousand meters since the Tertiary. Fast uplift and desertic climatic conditions have favored preservation of structures such as large scale isoclinal intrafolial folds whose geometries and attitudes, despite impossible to be observed in the field, can be easily seen in ASTER images. Field control provided by structural traverses and Sm/Nd ages from the sierras de Maz-Espinal, Umango and Las Ramaditas indicate that rocks cropping out in these areas were affected by several episodes of deformation under high-grade metamorphic conditions with ages spanning from mesoproterozoic (Greenville) to carboniferous times. Deformational episodes recorded by these rocks gave rise to flat-lying composite fabrics with well-developed stretching and mineral lineations. These fabrics and the few observed large scale shear zones ascribed to the fabric-forming deformation episodes recognized in this region were affected by several sets of younger upright folds and faults that control their attitudes across the area.

As age of fabrics are impossible to be distinguished on metamorphic grade or structural grounds and considering the purposes of the present discussion, penetrative fabrics older than the up-right F3 folds were grouped under the denomination “composite banding”, irrespectively of their absolute ages. Therefore, kinematic interpretation of the main deformation episodes refers only to the ductile structures older than the upright folds (‘F3s’) that show N/NE - S/SE trends in Sierras de Umango and Espinal and N-S in the Sierra de Maz. The latter are the major folds that control the outcrop pattern of the sierras and seem to be affecting paleozoic and mesozoic sequences alike.

Following a brief description of the main pervasive fabrics recorded by rocks of this area, we present DTM of some of the main structures of the area, in particular the large-scale F3 folds, and discuss their role in the evolution and structural geometry of the rocks. We shall demonstrate the advantages of using DTM models for structural mapping in areas of difficult access such as NW Sierras Pampeanas of La Rioja, Argentina (Figure 1).

DESCRIPTION OF STRUCTURES

The composite banding, as recognized in most rock types of this area, includes the lithological succession, representing the original and a metamorphic segregation banding (Figure 2a) or a schistosity (depending on the rock-type and metamorphic conditions), as well as two sets of tight to isoclinal folds (Figure 2b). The composite banding was the only structure that could be correlated between exposures with some degree of confidence due to the complex geometry controlled by several sets of late folds and faults (Porcher et al., 2004). The general geometry of this banding can be observed with some detailed in exposures at several scales, including the 15m resolution Aster images here hinge of isoclinal (F1-F2) folds can be observed in large cliffs. This fabric shows, in addition to isoclinal folds (F1+F2), boudins and pinch-and-swell structures in almost all observed rocks, particularly in calc-silicate rocks containing marbles and amphibolites, where the viscosity contrast is high as indicated by shape of boudins (Figure 2a). Igneous rocks represented by bodies of several sizes and composition ranging from amphibolites, diorites to sienogranites intrude the composite banding.

Despite showing various structural relations with respect to the main fabric, most of these rocks where plastically deformed present the same N-NW trending stretching lineation ubiquitous in deformed rocks of this area. In the few high-strain zones recognized, structures such as foliation fish, shear bands, and lithoclasts are very common being typical of non-homogeneous ductile progressive deformation with a component of simple shear (Figure 2d). Microstructures and kinematic indicators observed in these rocks include asymmetric sigma-type recrystallization tails in feldspar porphyroclasts and prismatic subgrains in quartz, confirming the high-T conditions of the principal deformation, as determined by thermobarometric studies (see below). Foliation-fish and mica-fish are common in mylonites developed from marbles and metasediments (Figure 2d). Kinematic indicators show conflicting sense of movement (top-to-N and S). This might be controlled by tight folds and many other factors whose confirmation should be checked by detail geometric studies. However, in high-T major shear zones with relatively simple geometry, such as the one at Cerro Cacho (NW of Sierra de Umango), a top-to-North sense of movement parallel to the NW-N trending stretching lineation could be determined with confidence. Linear structures include boudins, fold mullions, stretching and mineral lineations, usually marked by amphibole.

Two sets of folds older than the upright F3s are observed in most exposures. The F1 folds observed in exposures are generally small (cm to dm) and present high amplitude/wavelength ratios (~10). They are marked mainly by felsic bands in aluminous and quartz-feldspathic gneisses and mafic bands in the calc-silicatic sequences. The hinges are thickened and the limbs are often attenuated characterizing them as rootless intrafolial folds of class 2 and 1C geometry (Figure 2c).

Large-scale F1and F2 folds are only distinguished on ASTER images where they mark the composite banding on large cliff sides. The F2 folds are isoclinal and tight with thickened hinges, developing 1C and 2 geometries and intermediary amplitude/wavelength ratios (~5). These folds are generally intrafolial (Figure 2b) and are usually acylindrical showing wide variation of hinges within the composite banding. It is very hard to distinguish them from structures that were labelled as F1 folds in exposures where only one generation of folds is present. The F3 folds are concentric, open normal (subvertical axial plane) to inclined double plunging folds with axial planes of N/NE-S/SE direction. Their trends change from NE in sierras de Umango and Espinal to NW in the Sierra de Maz, making up a pattern of an open "S" at the regional scale (Figure 1). The axial plane foliation is marked by crenulation cleavages where features of pressure solution are common in more schistose rocks and a spaced cleavage in more siliceous units. Faults are commonly associated with these low-T folds (Figure 2c). Ridges and other positive topographic features commonly coincide with hinges of F3 antiforms, so that they were baptized as "Casa de Piedra" or "La Puntilla Sierra de Cacho" in the terrain. The F4 folds present a more NE-SW trends and are particularly well developed in the SW limb of Sierra de Maz (Figure 1). Axial-planar cleavage in metapelites is a zonal crenulation. Despite being upright flexural folds and the other late major set of folds that control the 'egg-box' geometry, they differ from the F3s not only by trends but also for presenting smaller amplitudes and localized development.

From observation of DTM models they seem to be better developed along the limbs of large F3 folds (Figure1). Analysis of orientation diagrams shows that stretching and mineral lineations of the main pervasive deformations present N-NW/S-SE trends and low plunges (cf. stereonets in Figure1). They were not strongly reoriented by the young NE-SW trending flexural folds in most of the area since the F3 folds present the same trends and the F4 are of localized development. The same happens with the main fabrics whose general attitude was sub-horizontal if the effects of late (F3 & F4) flexural folds are restored. This seems to be true for measurements taken from rocks of all sierras, including Las Ramaditas, where the highest temperature fabric recognized in the area yielded carboniferous ages (Porcher et al. 2004).

DISCUSSION

Aster images and digital terrain models are unvaluable tools to understand the geometry of structurally complex areas of difficult access. With the help of field data they provide essential elements to constrain interpretations of the geological evolution of terranes of polyclyclic evolution based on isotopic, thermobarometric and geophysical data as presented in this and related papers.

REFERENCES

Porcher, C.C.; Fernandes,L.A.D.; Vujovich,G.I.& Chernicoff, C.J.(2004a). Thermobarometry, Sm/Nd ages and geophysical evidence for the location of the suture zone between Cuyania and the western proto-Andean margin of Gondwana. *Gondwana Research* ***58 (4)*** Special Volume *"Cuyania: an exotic block to Gondwana*" (in press).

Rolim, S.B.A.; Fernandes, L.A.D. 2003. Response of terrane accretion based on ASTER remote sensing: the example of Cuyania Microcontinent, NW-Sierras Pampeanas of Argentina. *Terrane Processes at the Pacific Margin of Gondwana (TAPMOG).* 2003, Cambrige. **TAPMOG** Cambrige: British Antarctic Survey. 2003.

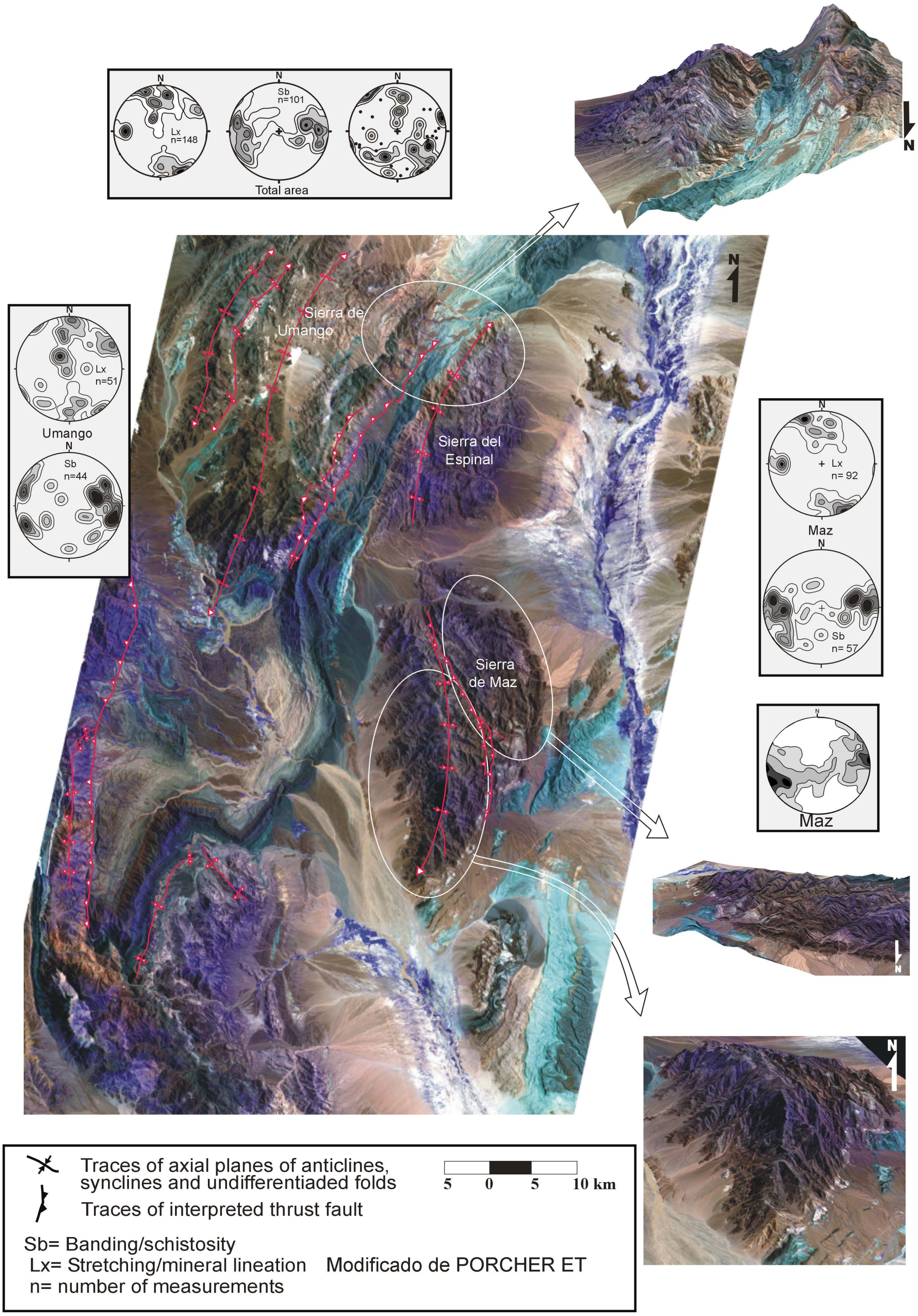

Figure 1 - NW Sierras Pampeanas of La Rioja, Argentina

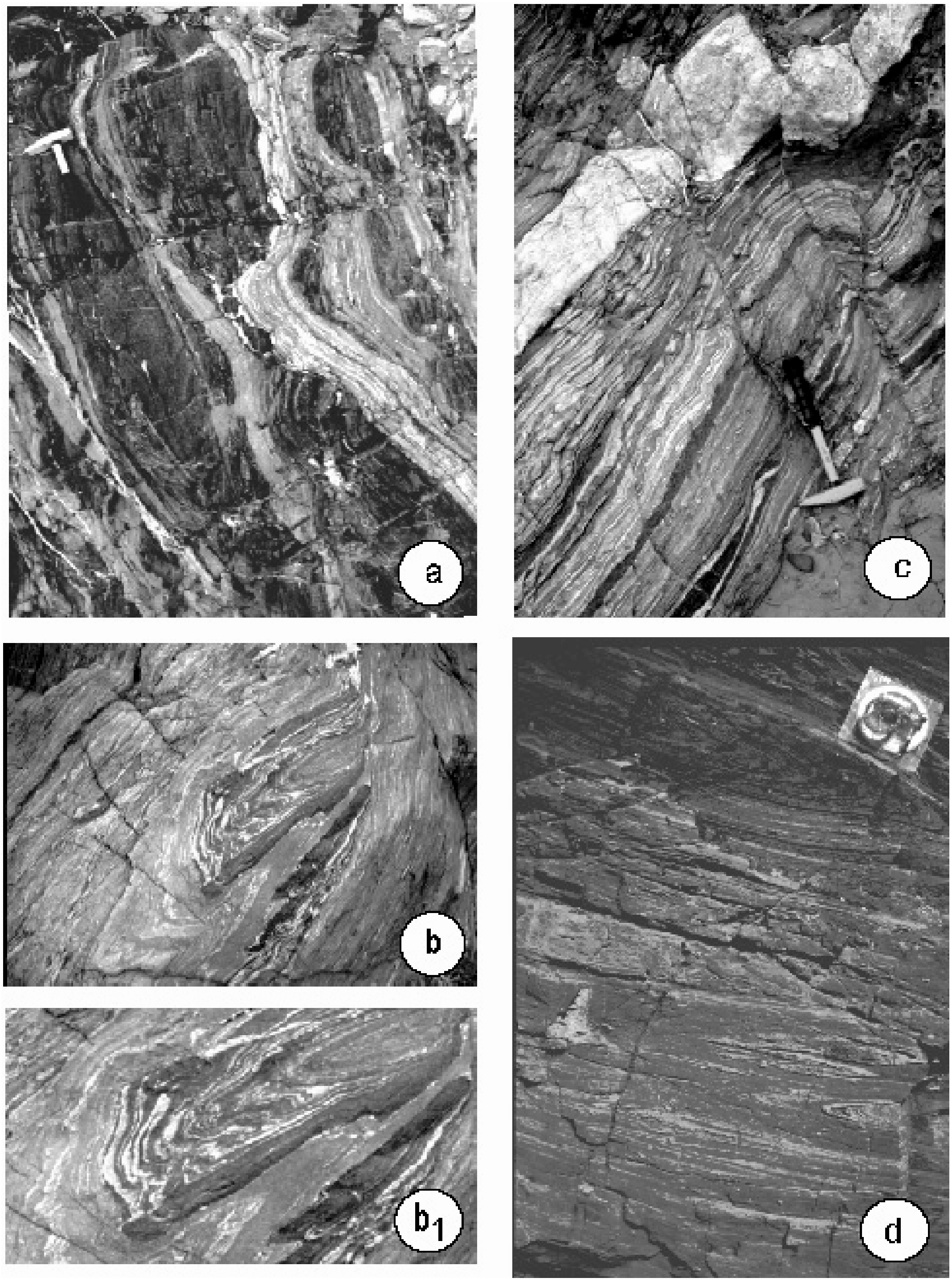

Figure 2 - Mesoscopic-scale structures of the NW-Sierras Pampeanas rocks showing strong boudinage of calc-silicate gnaisses (A), mylonites in marbles (B) and two phases (F1 & F2) of rootless intrafolial folds (C) belonging to the early deformation, all affected by the upright F3 folds (D). The latter are the most obvious structures observed in the Digital Terrain Model using ASTER images.