



Strain variations in thrust belts. Insights from Talas Ala Tau (Kyrgyz Republic)

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Abstract: Computational strain analysis methods developed at University College of Cork have been used to analyse several samples taken from Talas Ala Tau, Kyrgyz Republic. These methods are more accurate and faster than manual methods. This study has revealed that the finite strain measured in Talas Ala Tau rocks (principally high quartz percentage feldspatic sandstones and feldspatic graywackes) is independent of lithology and the general strain trend in this fold and thrust belt.

Keywords: Tien Shan, Talas Ala Tau, SAPE, MRL, DTNNM.

Strain determination using approximately elliptical objects is a very useful technique for understanding the processes and products of deformation of the Earth from the micro- to macro-scales (Mulchrone *et al.*, 2005). Ramsay (1967) first presented the idea of measuring finite strain from randomly oriented populations of deformed objects, commonly referred to as the R_f/ϕ method for strain analysis. Subsequently, many different methods have been developed (Dunnet, 1969; Elliott, 1970; Dunnet and Siddans, 1971; Matthews *et al.*, 1974; Borradaile, 1976; Shimamoto and Ikeda, 1976; Robin, 1977; Lisle 1977, 1985; Peach and Lisle, 1979; Yu and Zheng, 1984; Mulchrone and Meere, 2001; Mulchrone *et al.*, 2003). There also exists an alternative class of methods based on object-object separations. The nearest neighbour method of Ramsay (1967) has not been used much due to problems of labour intensity associated with it (Erslev, 1988). The Fry method (Fry, 1979) and related methods such as the Normalised Fry Method (Erslev, 1988) and the enhanced Normalised Fry Method (Erslev and Ge, 1990) are typically graphical in nature and have been used

much more extensively. More recently, Mulchrone (2003) borrowed Delaunay triangulation from computational geometry and applied it to the nearest neighbour method of strain analysis, achieving a faster and objective method.

Geological setting

Tien Shan was uplifted because of the Cenozoic collision between India and Eurasia. The uplift and subsequent erosion of these mountains has led to the exposure of rocks belonging to previous orogenic events that were responsible for the building and amalgamation of Asia (Abdrakhmatov *et al.*, 1996; Bullen *et al.*, 2001; Abad *et al.*, 2003a).

The main orogenic process involved in the Tien Shan range is the Upper Paleozoic Uralian-Mongolian (equivalent to Variscan), which consists in the collision between the Kipchac island arc and the Karakum-Tarim continent (Sengör *et al.*, 1993; Sengör and Natal'in, 1996). This orogenic process is responsible for the folding of Paleozoic rocks and the

intrusion of granites. The Tien Shan mountain range is usually divided into North Tien Shan, Central Tien Shan and South Tien Shan (Fig. 1).

Talas Ala Tau, which is located in the Kyrgyz Republic, is one of the most important Precambrian out-

crops in North Tien Shan. It mainly consists of sedimentary rocks of Cryogenian to Ediacaran age (Korolev and Maksumova, 1980; Kiselev and Korolev, 1981) which crop out in two domains separated by a thrust zone. The Uzunakhmat sheet (in the SW) is greater than 3 km thick and is composed of a

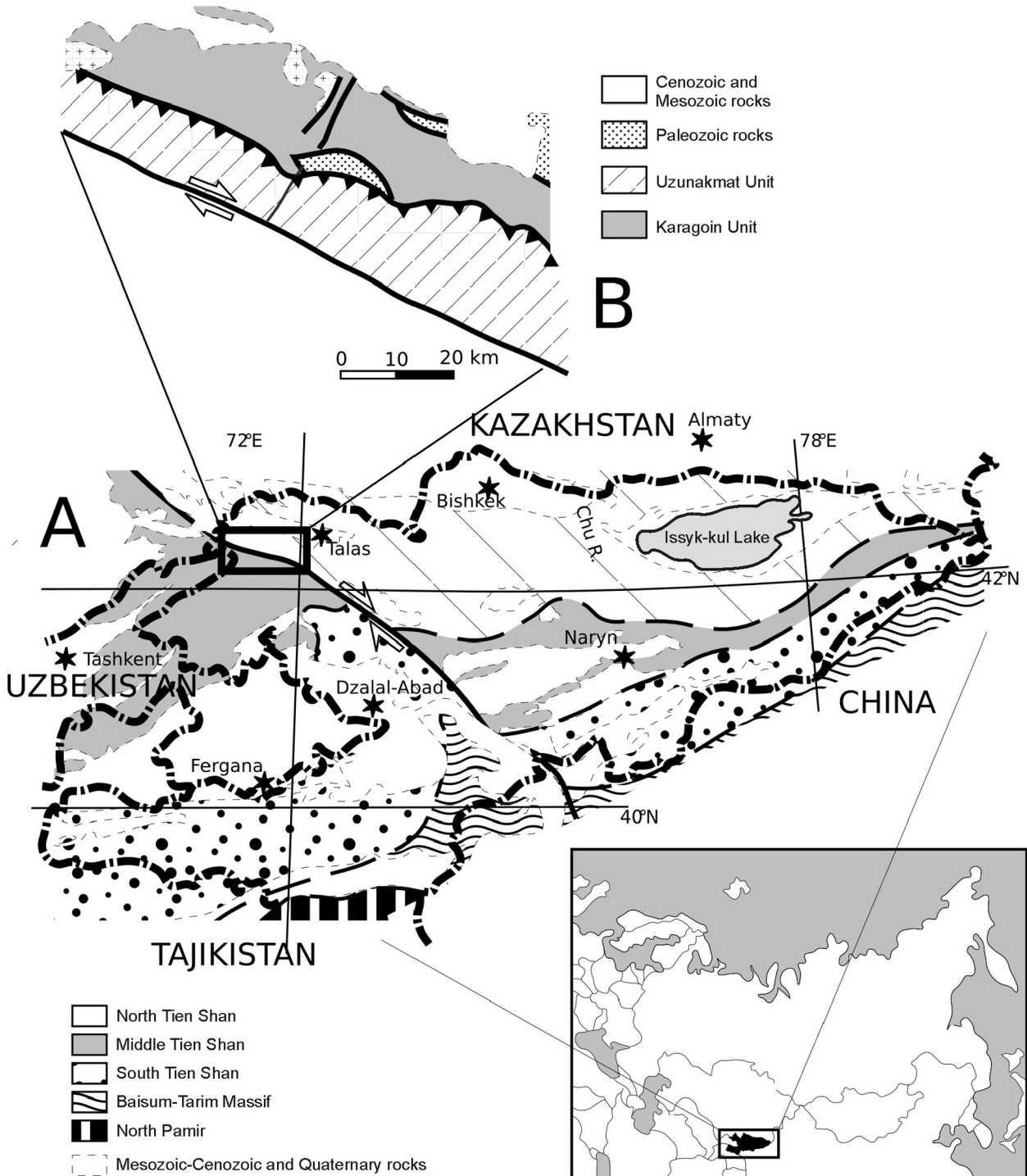


Figure 1. (a) Location of the main geological domains within the Tien Shan belt in the Kyrgyz Republic, (b) general geological map of the Talas Ala Tau, depicting the two main sheets based on Abad *et al.* (2003a).

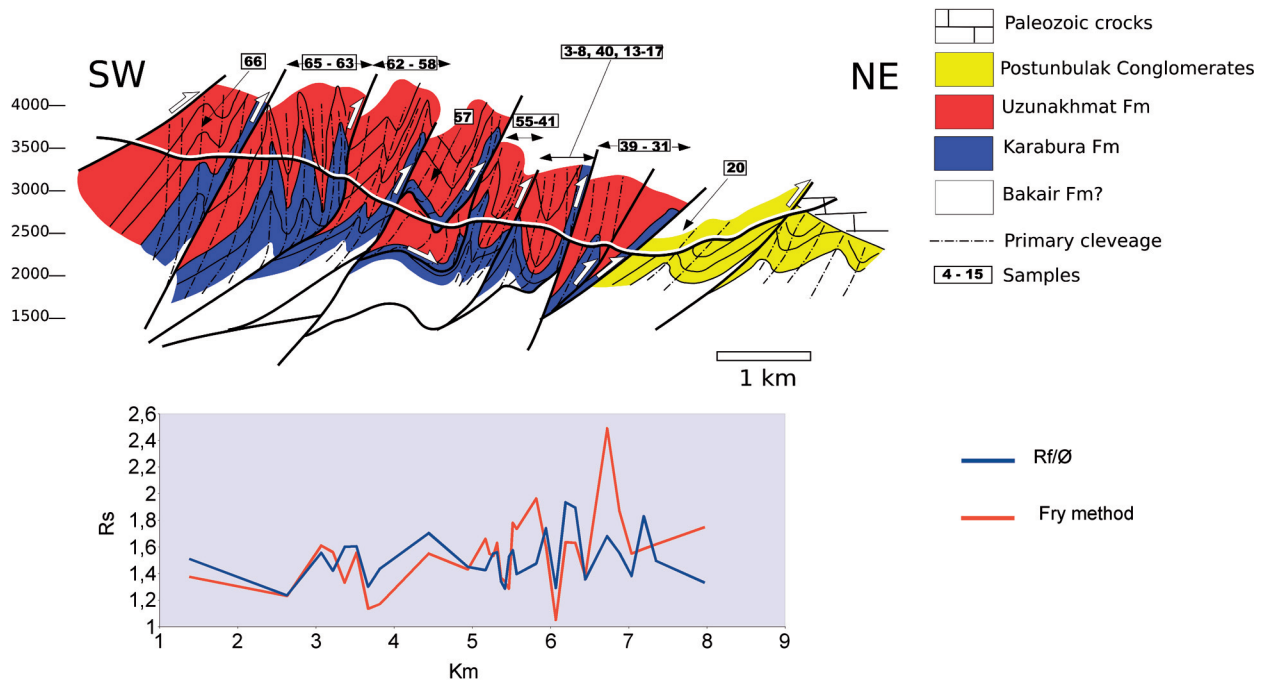


Figure 2. Postunbulak Valley cross section based on Abad *et al.* (2003a), with the strain variations observed across it.

sequence including the Baikair, Karabura and Uzunakhmat formations (Maksumova, 1980). The Karagoin sheet (in the NE) is made up of the Karagoin group which contains the Chondzol,

Tagyartau, Chydygolot, Birbulak, Umaral, Chokutash and Kzyzbel formations (Maksumova, 1980). Lithologically, the Baikair, Karabura, Uzunakhmat and the Karagoin groups are composed

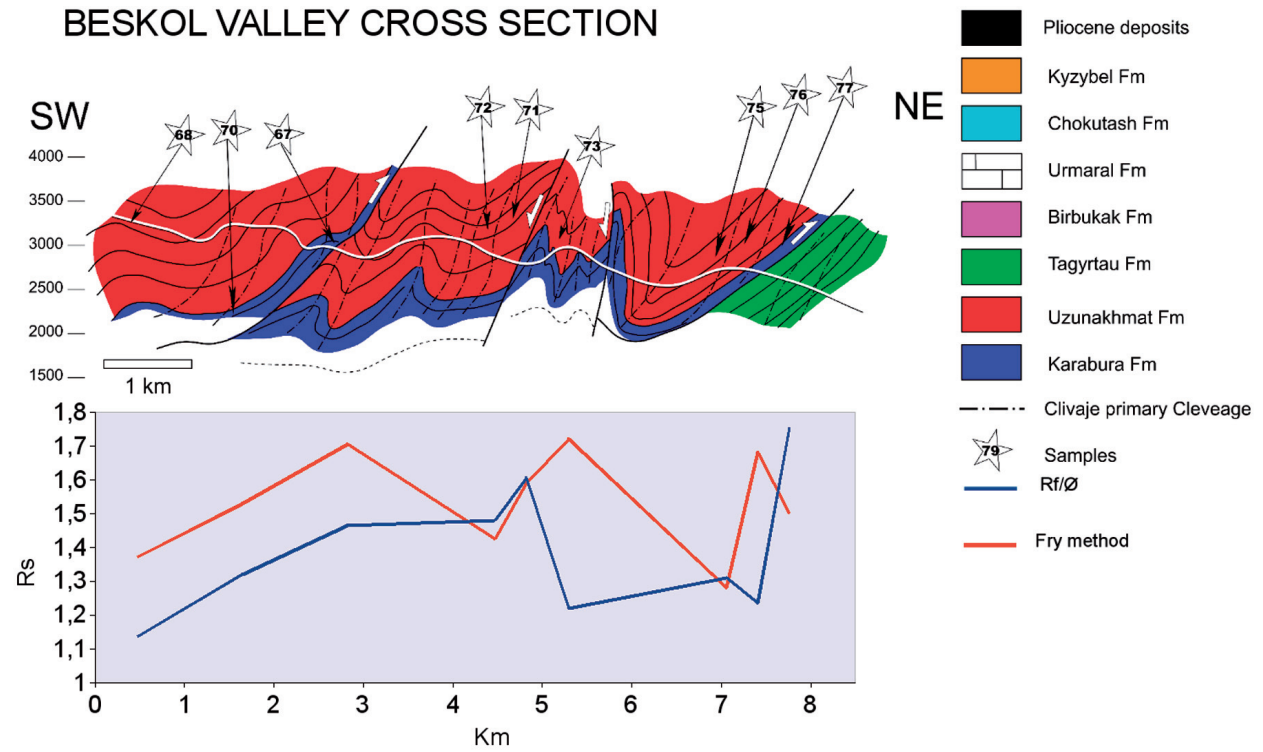


Figure 3. Beskol Valley cross section based on Abad *et al.* (2003a); beneath it the observed strain variation is plotted.

Karabura Valley Cross-section

SW

NE

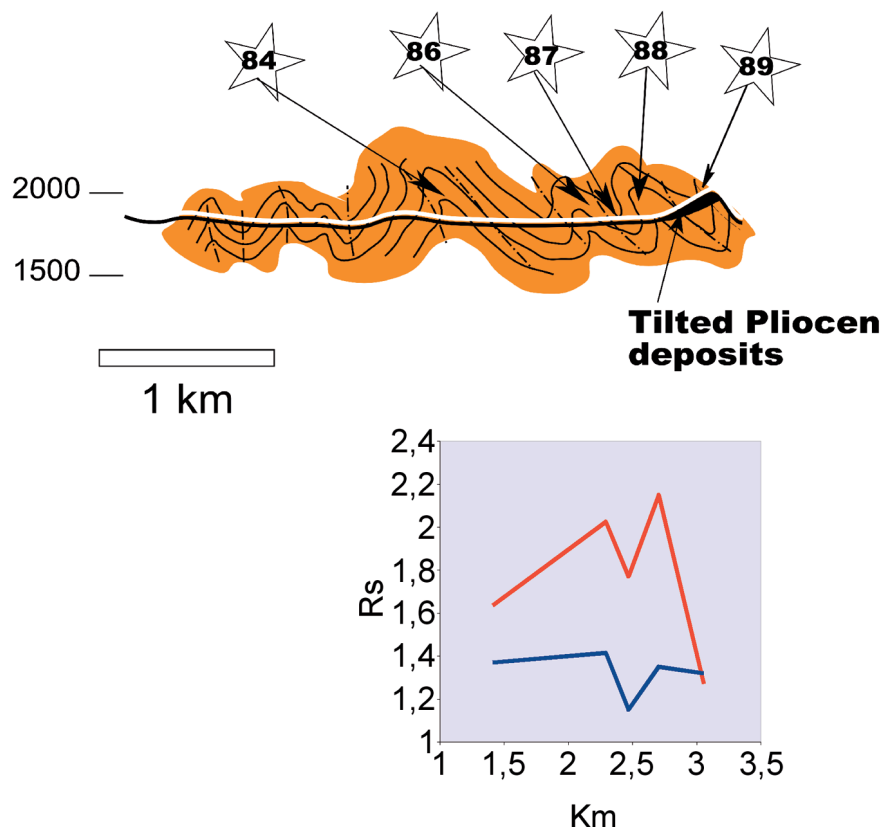


Figure 4. Karabura Valley cross section based on Abad *et al.* (2003a), below it the measured finite strain variation plot. Legend is shown in figure 3.

of high quartz percentage feldespatic sandstones or feldespatic graywackes. The thrust that separates the domains is called the Kumyshtak thrust; its absolute displacement is unknown but is estimated to be more than 10 km (Abad *et al.*, 2003a). At the southern limit of Talas Ala Tau is the Talas-Fergana fault (Burtman *et al.*, 1996), which is a dextral strike slip fault with a displacement larger than 220 km. Evidence for the existence of a Precambrian or Cambrian deformation event is provided by the unconformable juxtaposition of Ordovician limestones over all of the other Talas Ala Tau formations.

Abad *et al.* (2003a) studied metamorphism in Talas Ala Tau using phyllosilicates (white mica) developed during the Baikalian event deformation. The study shows that these phyllosilicates formed under very low temperature (below 300 °C) and high pressure (at least 8 kbar) conditions. This is not in agreement with usual fold and thrust belt interpretations and we pro-

pose a subduction-related geodynamic environment for the deformation and the origin of the main structures in this region.

There is only one previously reported strain analysis study in Talas Ala Tau (Khudoley, 1993). In that contribution a few samples were studied using the Fry and R_f/ϕ methods and the results ranged between 1.2 and 6.2.

Methodology

Sixty three thin sections of detrital sedimentary rocks with matrix ratios between 0% and 45% were cut normal to fold axis from samples collected along four cross sections of the Uzunakhmat and Karagoin sheets (Postunbulak Valley, Karabura Valley, Urmara Valley and Beskol Valley, figures 2, 3, 4 and 5) and were analysed two or three times per thin section with each of the methods used. Twelve of these samples were cut

normal to the first thin section in order to check the strain ellipsoid 3D shape using the Flinn graph (Flinn, 1956). The finite strain ellipsoid tends to exhibit a mainly flattened shape.

Strain analysis of the selected samples was carried out with the package of computer programs for strain analysis developed at University College, Cork, Ireland. Semi-Automatic Parameter Extraction (SAPE) (Mulchrone *et al.*, 2005) was used for extracting strain parameters of the markers from digital images. At least 150 clasts were selected from each thin section, as Meere and Mulchrone (2003) recommend. The finite strain was calculated using two methods:

On the one hand, Mean Radial Length (MRL) (Mulchrone *et al.*, 2003) is used to calculate the finite strain from the shape and orientation of objects. This method is based on the conceptually simple fact that the mean radial length of a set of randomly oriented ellipses in the unstrained state evaluates to a circle, so that after strain the mean radial length equates to the strain ellipse. It has been demonstrated that error

bounds can be made smaller than those of other methods (Mulchrone, 2003, 2005).

On the other hand, Delaunay Triangulation Nearest Neighbour Method (DTNNM) (Mulchrone, 2002) has been used to measure the bulk strain using the spacing between objects. However, DTNNM has to be used cautiously with loosely packed rocks (Mulchrone, 2002, 2005). For this reason, DTNNM has been used as an intermediary for the Normalised Fry Method (Erslev, 1988) in this study due to the petrographic characteristics of the Talas Ala Tau rocks, which are typically poorly to very poorly sorted greywackes with a large percentage of matrix.

Results

R_s (the ratio of the principal axes of the strain ellipse) values range between 1.1 and 2.6, with a general increasing trend towards the thrust surfaces in the four cross sections studied. A regional gradient could not be discerned from the data. Petrographic parameters such as grain size, sorting, percentage of matrix, carbonate

URMARAL VALLEY CROSS SECTION

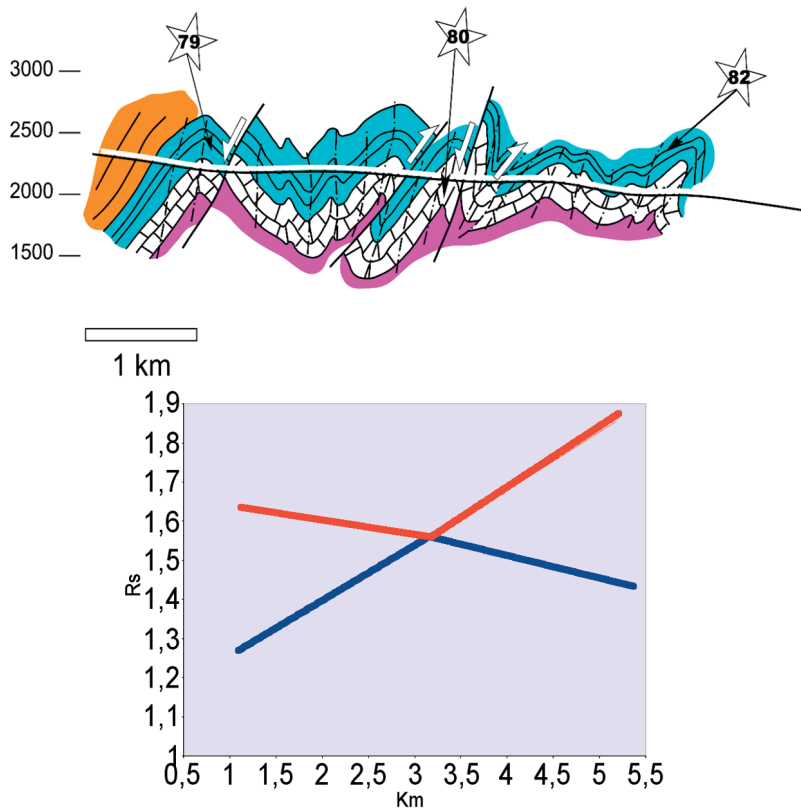


Figure 5. Urmalar Valley cross section based on Abad *et al.* (2003a), beneath the cross section the observed strain variation is shown. Legend is shown in figure 3.

or feldspar content do not exhibit a causal relationship with finite strain values (Pastor-Galán, 2008).

Basic statistical analyses have been performed on the data obtained (Pastor-Galán, 2008), and the results are very similar for the two strain analysis methods. Furthermore, use of both R_f/\emptyset and Fry methods has allowed a comparison between them. The results correlate, although the correlation is not as strong as might be expected due to the Talas Ala Tau rock properties (high percentage of matrix in the greywackes).

Discussion

The use of computer techniques permits the analysis of a large number of samples in a reasonable time frame. A single analysis performed with manual methods, such as Ramsay's R_f/\emptyset (Ramsay, 1967) or Fry's family of methods (Fry, 1979; Erslev, 1988; Erslev and Ge, 1990) may take over an hour, though using computational methods four samples can be analysed in the same time.

The results obtained exhibit no lithology dependence, which implies that analyses from rocks with different percentages of matrix, grain size and mineral composition are comparable. Passive clast behaviour is one of

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- the fundamental assumptions of the R_f/\emptyset family of methods (including MRL) (Ramsay, 1967, Mulchrone *et al.*, 2003). Although MRL and Normalised Fry method were used to measure different things (grain strain and bulk strain), results are very similar and comparable. This strongly suggests that the clasts in these rocks behave passively.
- Strain increases in the hangingwall of the thrust sheets towards the thrust plane. This variation is interpreted as being caused by the increasing levels of simple shear towards the thrust surface. The finite strain measured is larger than expected for rocks deformed under such low metamorphic (anchizone) conditions. This is probably due to the geodynamical conditions proposed earlier. Unfortunately, we cannot evaluate the influence of pressure solution mechanisms which is necessary for a complete deformation picture in this kind of fold and thrust belt. Additionally, we found that fold position (hinge or flanks) appears to have no bearing on the finite strain measured.

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