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KINEMATIC INTERPRETATION OF THE MINOR AND MESOSTRUCTURES IN THE ABRA DE LA VENTANA AREA, SIERRAS AUSTRALES, BUENOS AIRES, ARGENTINA

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ABSTRACT

Microstructures are described from an overturned fold in quartzites of the Ventana Group exposed in the neighborhood of Abra de la Ventana, Sierras Australes. Fractures belonging to a secondary fault system related to the Abra de la Ventana Fault were developed in a tensional stress field. Based on the relationships between minor structures, folding and faulting, a tectonic kinematic interpretation is proposed for this domain.

RESUMEN

Se describen las microestructuras de un pliegue volcado en las cuarcitas del Grupo Ventana en las cercanías del Abra de la Ventana, Sierras Australes. Las fracturas pertenecientes a un sistema secundario con relación a la Falla Abra de la Ventana se han desarrollado en un campo tensional. En función de las relaciones entre las microestructuras, plegamiento y fracturación se propone un esquema de interpretación cinemática para este dominio.

I. Introduction

In the arcuate fold belt of the Sierras Australes of the Province of Buenos Aires, extending from the village of Puan to the southeast of Estomba, the Paleozoic sequence is exposed showing a 5000 m folded clastic sequence of Silurian to Permian age (Harrington, 1947). Further east in the offshore of the Colorado basin part of a similar sequence has been drilled (Lesta *et al.,* 1979). (See location map. fig. 1).

The Paleozoic sequence overlies granites and rhyolites, Precambrian according with new isotopic age studies (Varela and Cingolani, 1975). Very thin Miocene conglomerates are located at high altitudes in the Sierra de la Ventana and Sierra de Bravard. Harrington (1970) considered the Sierras Australes as a composite aulacogenic chain with an

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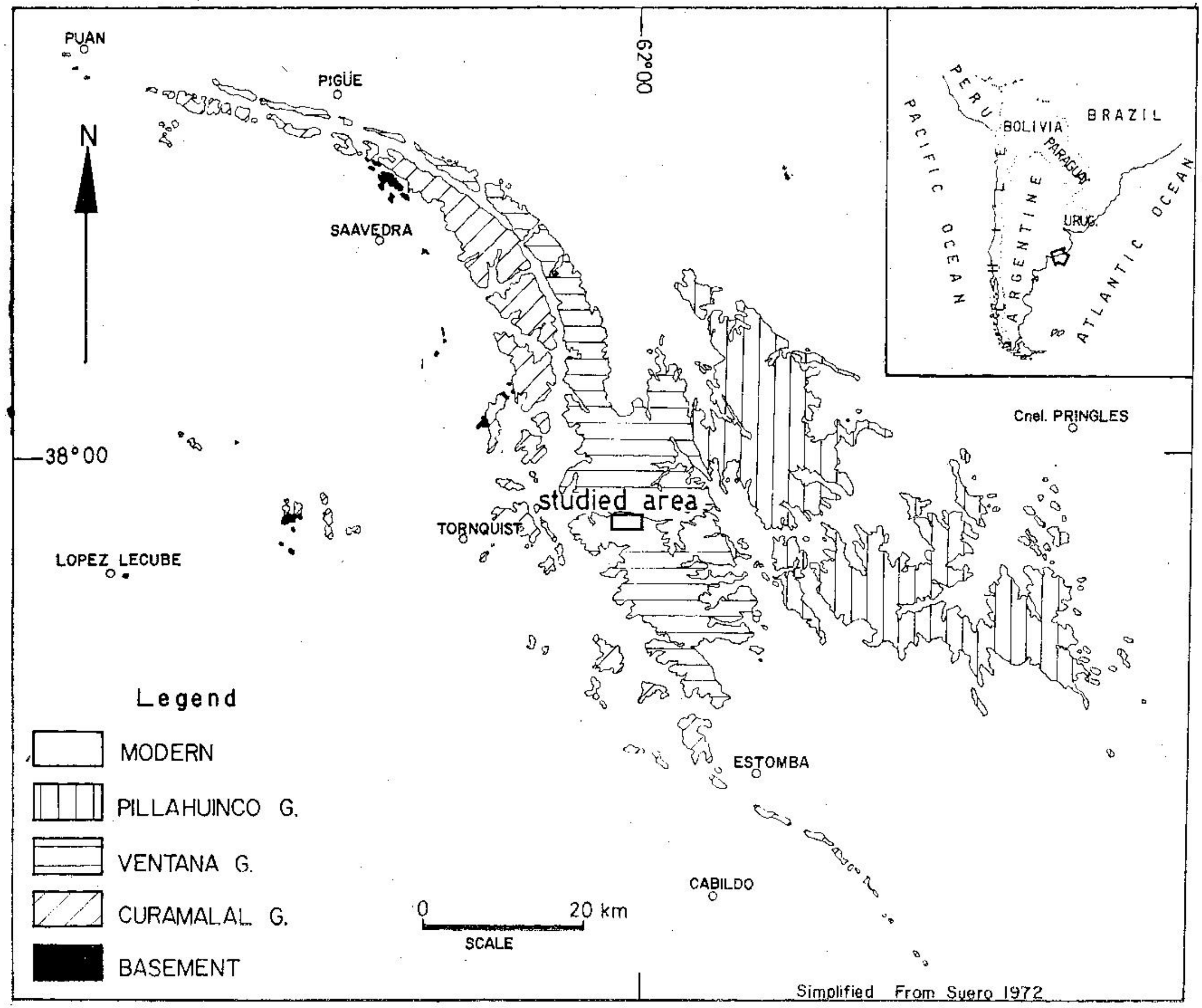

Simplified From Suero 1972

Fig. 1. — Location map. Sierras Australes. Province of Buenos Aires

unique pure folding style, although tear faulting has been proposed by Amos and Urien (1968). Du Toit (1927) regarded the Sierras Australes as the western end of the "Samfrau geosyncline", an idea that has recently been reviewed following the similarity of rocks and folding style with the Cape Fold Belt of Southern Africa.

In spite of the very detailed work carried on by Harrington the relationships between minor structures and several order folding of the Ventana Group have not been studied. The present paper is an initial contribution to elucidate the progressive deformation in the neighborhood of the Abra de la Ventana, a wind gap about 23 km east of Tornquist village. A kinematic interpretation is proposed for the deformational sequence and time-depth relationships based on folding and other structures.

II. Geologic setting

Chart 1 indicates the regional stratigraphic sequence exposed in the Sierras Australes shown by location map (fig. 1). In this area only the Napostá, Providencia and Lolén Formations are exposed. The first two are formed of light coloured thickly bedded metaquartzites and forming rounded 3rd order folds. The Providencia Formation forms an alternating sequence of fine and coarse grained beds, meanwhile the Lolén Formation is composed of micaceous metasandstones with predominantely angle shaped folds contrasting strongly with the other older formations. The contact plane between the Lolén and Providencia Formations is well exposed south of Route 76 as shown in figs. 2 and 3.

CHART 1. — *Stratigraphic sequence*

Age	Stratigraphic units	
Miocene		Conglomerado Abra
		Angular Unconformity
Permian Upper Carboniferous?	Pillahuincó Group	Tunas Fm. Bonete Fm. Piedra Azul Fm. Sauce Grande Fm.
		Regional Unconformity
Devonian	Ventana Group	Lolén Fm. Providencia Fm. Napostá Fm. Bravard Fm.
		Regional Unconformity
Silurian?	Curamalal Group	Hinojo Fm. Trocadero Fm. Mascota Fm. La Lola Fm.
		Uncoformity
Precambrian		Granites and rhyolites

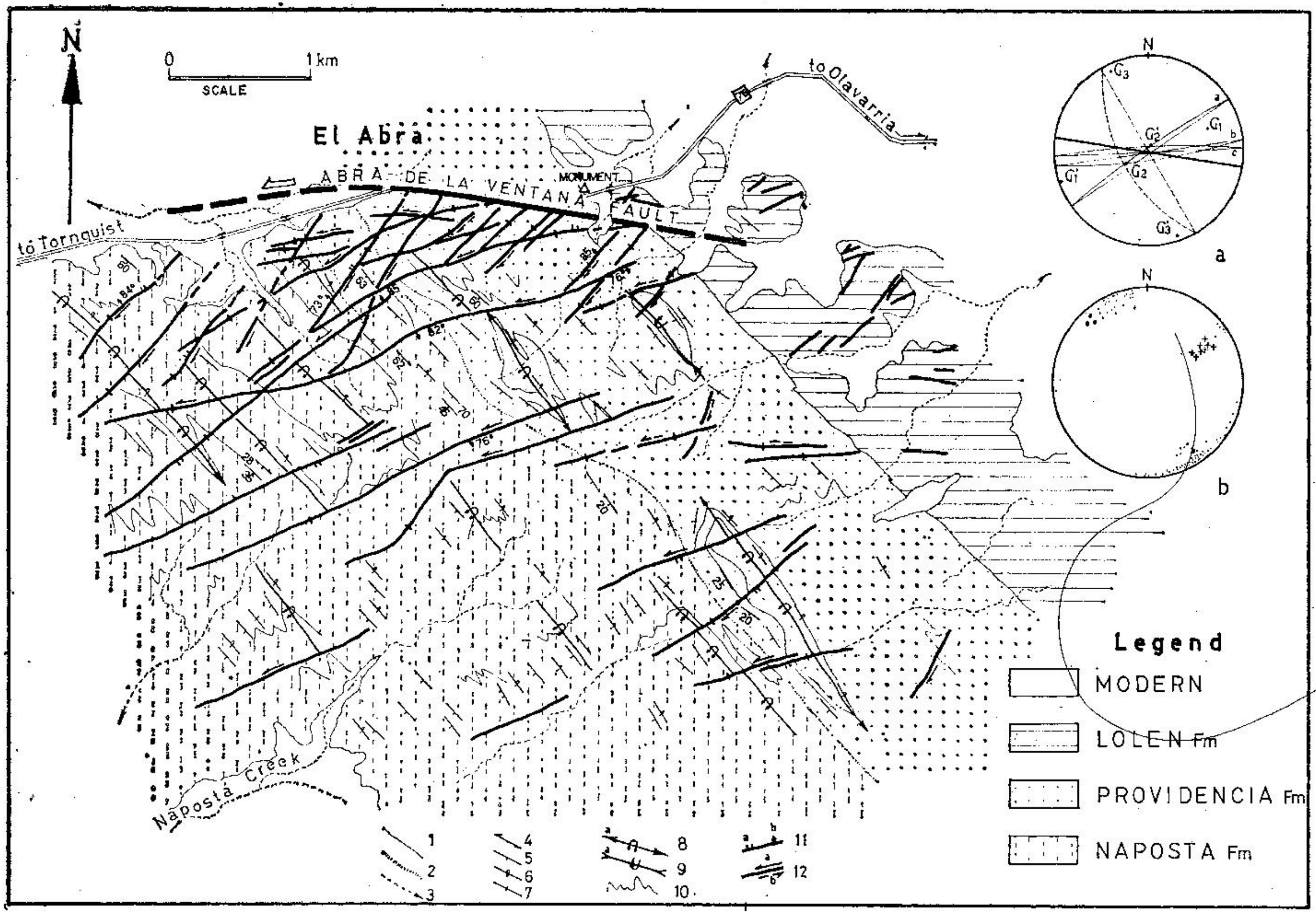

FIG. 2. — Geological map of Abra de la Ventana. *1.* contacts; *2.* inferred contacts; *3.* stream; *4.* cleavage; *5.* normal bedding; *6.* reverse bedding; *7.* vertical bedding; *8.* axis, overturned anticline *a*: plunge; *9.* axis overturned syncline *a*: plunge; *10.* guide bed contacts; *11.* fault *a*: footwall, *b*: dip; *12.* fault *a*: relative movement; *b*: inferred.
a: Faulting relationships (diagram): - - - - axial plane; ╲ Abra de la Ventana fault; ╲ a,b,c: second order fault sets.
b: Napostá and Providencia Fms. Plot of mesostructures (π diagram): crosses axial plane cleavage; dots joints; circles fold axis.

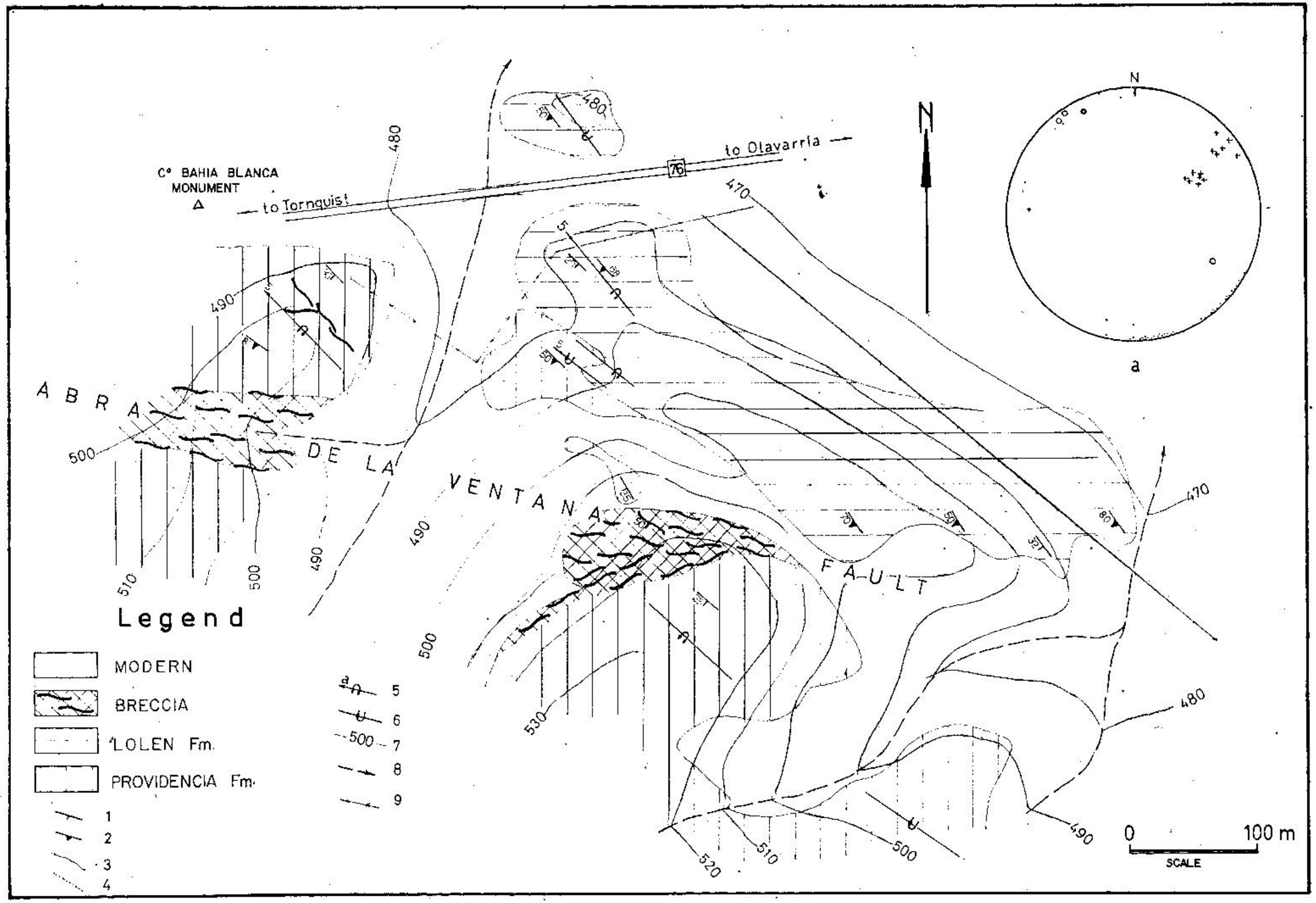

Fig. 3. — Mesoscopic structures map southeast of Abra de la Ventana. *1.* bedding; *2.* cleavage; *3.* boundary; *4.* transitional boundary; *5.* anticlinal axis, *a*: plunge; *6.* syncline axis; *7.* contour lines; *8.* creek; *9.* fence.

a: Mesostructures (π diagram): dots joints; circles fold axis; crosses axial plane cleavage.

III. Description ot structures

The primary and secondary structures observed in the Napostá, Providencia and Lolén Formations, some of them described already by Massabie and Rosello (1984 a), will be discussed in relation to a tight 3rd order asymmetric fold with normal SW and inverted NE limb of an anticline with NE vergence (fig. 4) in order to stablish the relationships between the minor structures and folding.

A. ATECTONIC

1. *Bedding (ss)*

Well marked in beds from 0,5 to 1 m thick, with neat contact, no internal structures, homogeneous and considered excellent guide horizons. The Napostá Formation are regularly metaquartzitic beds of 0,5 m thick meanwhile the Providencia Formation is also metaquartzitic with alternate thinner beds in the order of 0,5 m of finer grain size. The Lolén Formation is composed on micaceous metasandstones bedded in 0,4 m to 0,2 m thick without outstanding guide planes. ss planes are usually in the N 40° to N 50° W direction dipping between 25° to 35° SW (fig. 4 a).

2. *Cross Lamination (cl)*

Minute laminae of less than 1 cm thick in some beds of the Napostá, Providencia and Lolén Formations are well marked. This structure is used frecuently to check normal or inverted limbs.

3. *Worm-like tubes* (wt)

Small 10 cm long and 1 cm diameter tubes lying normal to ss planes, specially in the quartzitic beds of the Napostá Formation are present. In planes normal to ss these tubes are observed as half barrels showing a weak lineation.

B. TECTONIC

1. *Folds (Fo)*

Folds of several orders are exposed in the area covered by figure 1. Generally asymmetric, closed to tightly folded, overturned with NE vergence and axial planes dipping 60° to 70° SW, crest lines subhorizontal plunging about 5° to NW and SE, *b* axis trending N 30°-40° W (figs. 2, 3 and 4). These folds have a strong control on the relief, crests forming highs and troughs depressions. Crest lines produce culminations and depressions with slight displacements of axial structures due probably to local wrench faulting. In the Napostá and Providencia Formations folding of the 3rd order is very common with a 500 to 700 m wavelenght and 150 m amplitude.

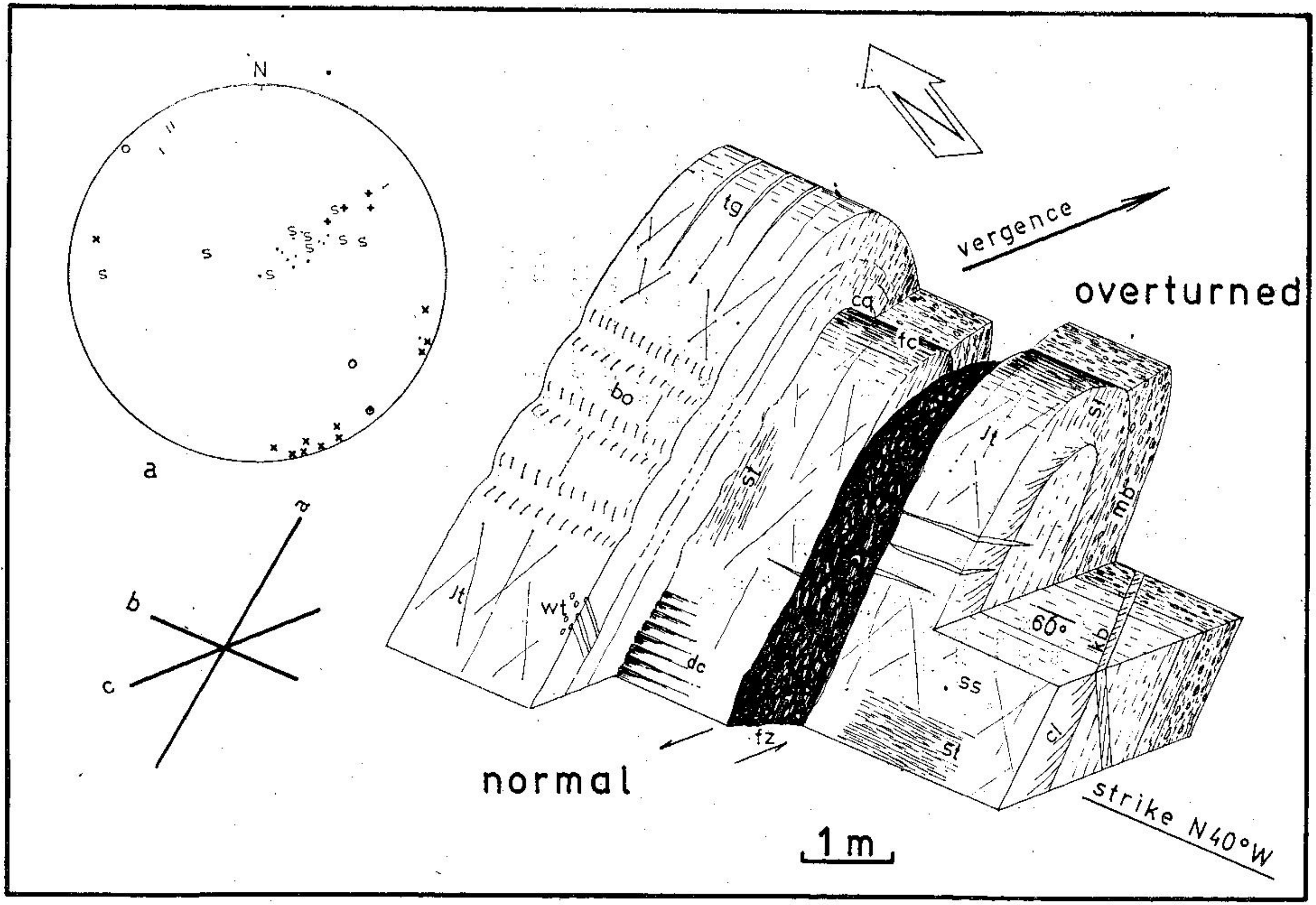

FIG. 4. — Geometrical relationships between folding and minor structures. *ss.* bedding; *cl*: cross lamination; *wt*: wormlike tubes; *st*: striation; *sl*: foliation; *bo*: boudinage; *mb*: mylonitic bands; *fc*: flow corrugation; *dc*: drag corrugation; *cq*: interstratal cleavage and quartz rods; *tg*: "en échelon" tension gashes; *jt*: joints; *kb*: kink bands; *fz*: shear zones.
a: Plot of microstructures; \\: bedding striation; *s*: faulting striation; *o*: drag corrugation; *x*: kink bands; *crosses*: foliation; *cicles*: boudinage; *dots*: bedding.

Di Nardo and Dimieri (1984) have described 1C folds slightly to the west of this area (Ramsay, 1967) with *b* axis with a slight helicoidal trajectory with 46 % shortening. They proposed a lithologic contrast plus consolidation and pore fluid pressure variation for their geometry. The effective stress and variation of water accumulation in particular ss levels is proposed as the main mechanisms for this particular fold geometry.

Undoubtedly the folding geometry depends on lithology in different formations. Three principal types can be recognized: a) concentric folding in the Napostá Formation by flexural folding, as beds are rather uniform in thickness. However, flexural flow can be observed in some metaquartzites; b) in beds of higher ductility contrast such as in the Providencia Formation, folds are of a similar type with thinning of lims, sometimes showing accordion-like refolding or chevron. However concentric folds are sometimes present in this sequence. There is a cigar shaped anticline 1,500 m long with *b* axis lying horizontally (fig. 2); c) beds of the Lolén Formation develop similar folds with acute anticlinal crest (fig. 3) like those described by Rosello and Massabie (1981) near the Sauce Grande-Lolén boundary.

Falcate cavities in the Napostá and Providencia Formations are very common in antiformal folds developed in metaquartzitic beds (fig. 4). They vary in extent from a few centimeters to several meters such as in the Cueva del Toro near the Abra de la Ventana. The origin is attributed to weathering and erosion of the ductile material which preserve the thickness near the hinge and thinn out towards the limbs. Previous authors have attributed these cavities to detachment between metaquartzitic beds (Schiller, 1930; Llambías y Prozzi, 1975).

Undoubtedly the types of folds developed in this area and the mechanisms that took place have a strong lithologic dependence, specially when comparing in detail the Lolén Formation style of folding, essentially similar, with that of the Napostá Formation, mainly concentric with local thinning of limbs.

2. *Striae on bedding planes (st)*

Two sets were observed, one parallel and the other transverse to *b* (Fig. 1a). These sets may show shear movements specially in normal limbs and between thick beds of relative different composition. The sets are 10 to 20 cm long, 1 or 2 mm deep on fine grained white milky quartz.

3. *Foliation (sl)*

This is of the most persistant structure through out the area trending about N 40° W, parallel to fold axis and dipping about 60° SW (Fig. 4). In the Napostá and Providencia Fms. quartzites this structure pass to wider spaced cleavage or develops mylonitic quartzites with cataclastic foliation most common in inverted limbs. In the Lolén Fm. foliation is well developed and closely spaced, showing a "pasteboard" aspect due to alignment of dimensional minerals. In some weathered exposures they seem like "fans" or "leaves of books" gliding downslope.

4. *Boudinage (Bo)*

In some normal limbs of folds, extension structures in beds normal to *b* axis (fig. 4) show pinch and swell, and when strong ductility contrast is present, boudins with their long axis parallel to *b* are observed. In the northern part of the Abra, and in beds of the Providencia Fm., boudins 60-70 cm wide and 30-40 cm thick and 1 m long dipping 5° towards W are in contact with green foliated micaceous beds. Where these boudins thin-out minor fractures parallel to *b* filled up with milky quartz are present.

5. *Mylonitic bands (mb)*

These are parallel to axial planes of folds and predominantly seen on inverted limbs and crests. However some are developed on normal limbs, also parallel to foliation. They are formed of quartzitic protomylonites (Higgins, 1971) with porphyroclasts of quartzites and quartz crystals up to 3 mm long, lenticular with their long axis parallel to general foliation, in a base of crystalized mortar quartz and thin muscovitic bands parallel to mylonitic foliation. A strong planar anisotropy somewhat irregular is present that control partitioning of the rock. Porphyroclasts are parallel to *ba* plane making a strong lineation together with mylonitic foliation which sometimes are transitional and other neat with intercalations bands are thicker (about a few meters) mostly in beds of the Napostá and Providencia Fms. but not in the Lolén Fm. However obliterated by these bands ss planes are clearly seen (fig. 4).

6. *Corrugations*

These structures are related to the presence of mylonitic bands in the Napostá and Providencia Fms. and are observed on ss planes, or near the hinge of folds. (Fig. 4). Corrugations are irregular and are parallel to *b* of the major fold, usually about 5 cm wave length and several decimeters long producing interdigitation of beds.

They may be formed by short displacements of mylonitic fillets between the metaquartzites of the Napostá and Providencia Formations. They are indicated as (fc) in figure 4.

Other corrugations are similar to ripple marks with axis parallel to *b*, but with anastomosing and bifurcating branches when the micaceous metaquartzites are more ductile. They may be produced by drag (dc) along succesive beds. Associated striations are common trending normal to *b* axis of folding.

In the southern part of the Abra, near Route 76 corrugations (dc) plunging 30° SE are observed with wave lenghts of about 5-10 cm and amplitudes of 1 to 2 cm on curved surfaces transected by fault subvertical breccia bands that produced drag.

7. *Interstratal cleavage and quartz rods (cq)*

This foliation is developed in lens like 10-40 cm thick fine schistose dark beds intercalated between metaquartzitic beds in the Napostá and Providencia Fms. normal limbs sl or mylonitic bands can be observed transposed by latter cleavage producing a sigmoidal geometry. With the later curving, rods and tablets of milky quartz are associated (Wilson, 1953).

8. *En échelon tension gashes (tg)*

Two types of gashes from a few centimeters to at least 1 m are distinguished mainly in the Napostá and Providencia Fms. filled up of fine grained crystals of quartz arranged in two sets: one normal to *b* axis and parallel to *a* and *c*, and another parallel to *b* and in the *bc* plane (fig. 4). Both sets show syntectonic extension with fl folding both with *b* and *a* directions. Locally at hinge zones gashes filled with milky quartz are aproximately parallel to the *ba* plane.

9. *Joints (jt)*

Several sets of joints are arranged according to Billings (1957): (fig. 2, 3). a) extension joints normal to *b* axis, trending N 20-60° E, sometimes distributed in a step manner and filled with quartz. Plumose structures are seen on the joint surfaces; b) relief joints parallel to (sl) cleavage and mylonitic bands trending N 40° situated on hinges; c) conjugate joint sets are oblique to symmetry axis of folding. These joints are comparable to the ones described by Amos and Urien (1968), Llambías and Prozzi (1975); Rossello and Massabie (1981) and Massabie and Rossello (1984b) in several exposures of the Ventana Group.

10. *Kink bands (kb)*

Centimetric kinks are common in the Napostá Fm. in planar anisotropic planes produced by mylonitic foliation (Fig. 4 and 4a). These are irregular and sinuose kink planes with no evidence of silding, dextral or sinistral rotation, trending N 60° E to N 30° E and subvertical. This spatial arrangement is coincident with those described by Rossello and Massabie (1981) in the lower beds of Sauce Grande Fm. near the junction of Route 74 and 76.

11. *Faults (f)*

Although faulting is a rather common feature in this area no important offsets are observed in the Napostá and Providencia Fms. They form narrow gorges crossing anticlinal hinges. The faults are about 500 m to 3 km long. (fig. 2) with subvertical fault zones (fz) and variable thicknesses of breccia between 1 and 10 m, including horses, can be up to 80 m as in the largest fault described by Amos and Urien (1968) at the Abra de la Ventana (figs. 2 and 3).

In the larger faults surfaces are ondulating, with breccia thickness up to 10 m in the secondary faults with offsets in the order of ten meters. Thinn sections of the material in the fault zones show that in the earliest stage of faulting, bands of cataclastic isotropic rocks with primary cohesion (hemiclastites according to Zeck, 1974, cataclasites and microbreccias according to Higgins, 1971) were formed. (Massabie and Rossello, 1984a). These are acompanied by solution of quartz and concentration of opaque iron minerals in the matrix and precipitation of quartz with minute inclusions in tensional microfractures and fractures. The latter have porphyroclasts of quartzitic mylonites disposed longitudinally essentially sinkinematic with fo_1 folding.

These faults zones were reactivated later as shown by textural relations in the Abra de la Ventana fault with vertical offsets as indicated striae. (fig. 3a). Red fault breccias formed from cataclastic rocks with no flow structure, cemented by silica and accompanied by iron oxides, recrystalized into quartz as secondary growth from fragments of quartz crystals that are idiomorphic by free growth and preservation of cavities.

No doubt the Abra de la Ventana is the main fault of the area with a minimun 80 m thick breccia, crossing the central part of the Sierras Australes in an E-W direction to N 105° in the eastern slope. The secondary faulting sometimes are splays from the main fault. The secondary faults, as shown in Fig. 1 and 1b, are exposed in three principal sets of parallel and oblique faults to the main folding. The first *(a)* is N 60° E, subvetrical or dipping more than 75° NW, and with breccia zones that transect the main Abra de la Ventana fault in Route 76. A second set (*b*) is N 75° E, dipping 90° to 70° SE; and a third set (*c*) N 85° E dipping 90° to 75° NW. Another unconspicous set is parallel to the main fault. Field data shows that the main Abra de la Ventana fault apparently does not continue eastwards in the Lolén Fm. as fold axis and ss planes are not offset by the supposed continuation of the fault to the SSE of Bahía Blanca Historical Monument (fig. 3). However a weak lineation is observed at that point with stronger fracturation and increase in quartz veinlets in the Lolén Fms. Furthermore the secondary faults do not affect the Providencia-Lolén Fms. boundary. According to the features described the fault system belongs to a transcurrent sort. Amos and Urien (1968) suggested a tear fault.

a) *Tectonic setting of the faulting*

We propose that the secondary fault system near the Abra de la Ventana is a consequence of the main fault traversing from a fragile (Napostá and Providencia Fms.) (fig. 1) to a ductile behaviour in the

Lolén Fm., the ocurrence of this secondary faulting is enhanced at this particular transition. The secondary faults are to be expected as shown by Chinnery (1966a and b). Sets *b* and *c* are second order faults forming a smaller angle with the main fault (about 15°) with the same relative displacement (sinistral) as the main fault. Set *a* on the other hand is a complementary second order with an angle of 75° (dextral) and displacements contrary to the main fault as shown by McKinstry 1953), Moody and Hill (1956), Chinnery (1966a and b) and Casey (1980). Figures 2, 2a and 3 show the distribution of faults and the relative measured displacement which agrees very well with the classical theoretical model. However as second order faults have at least a postomous activity a vertical or inclined displacement component, not only along strike as shown by the striation (fig. 4a), in some particular cases they may not agree with the general relative movements of the fault system.

So that one large fault of the second order (set *c*) forms a characteristic intersection with another well developed of set *b* SW of the Abra fig. 2 and 2a) regarded sinistral within an early stage. However it has an apparent sinistral displacement in its eastern end and an apparent dextral displacement in its western end. This fault (with striations 45° in a NE direction) is geometrically a pivotal fault (Donath, 1962).

There are also some differences with the theoretical orientation of second order faults as proposed by McKinstry (*op cit.*) and Casey (*op cit.*). There are two distinct sets *b* and *c* (fig. 2a) that correspond —independently of the sense of relative movement— to second order faults that form a smaller angle and the same sense of relative movement as the principal. This can be interpreted as local variations of the tensional field in relation with changes within the main Abra de la Ventana fault. The latter can be assumed as phases of progresive extension to the E of the main fault similar to the mechanism proposed by Chinnery (1966b) for other fault systems. If this irregularity is discarded and a mean value is adopted for *b* and *c* sets (fig. 2a) or if they are considered independently, the angle between the strike of these and the complementary second order, *a* (fig. 2a) is sustantially lower to the theoretical, in the order of 60°. This can be explained considering the regional tensional field of initial faulting. In this sense according to the cataclasites and breccias with primary cohesion (Higgins, 1971) and the characteristical development of extension and relief joints (Billings, 1957) filled frequently with quartz (fig. 2b and 4) a favourable tensional state for the development of extension shear would have existed. Murrell (1977) indicates angles of 0° to 22° 30' (angle between normal to the fault plane and direction of maximun principal stress). On the other hand Chinnery (1966a) has shown that second order faulting is possible in areas where stress invariant is positive (tension), contrary to areas in which is negative (compression) after the development of the main fault.

The stress field from second order faulting according to the intersection *a b* or *a c* define the principal stresses σ_1, σ_2, σ_3 and σ'_1, σ'_2, σ'_3, (fig. 2b). Both intersections defining the principal stress directions suggest a rotation of the maximun stress direction towards the main Abra de la Ventana fault according to stress trayectories (Chinnery 1966a, b). On the other hand if the geometry of the folding with a NE vergence together with the faulting (fig.s. 2, 3, 4) is considered having a genetic relationship-at least in the initial phases of deformation-with a late folding phase of the Sierra de la Ventana, we conclude that a σ_1, σ_2, and σ_3 is a rather more compatible explanation for the local stress distribution. This means that set *a* is complementary of the second order set *b*, but not of *c*. The latter could be related with an earlier stage of development of the main fault as recorded by at least two deformation events in the shear zone of the main Abra de la Ventana Fault.

IV. Relationships between the tectonic structures

Based on genetic and spatial relationships, the structures are included in three main assemblages produced by equivalent deformative episodes. The first belongs to a continous deformation: folding with secondary associated structures (Massabie and Rossello, 1984a). The second is mainly a discontinous deformation characterized by cohesive faulting. And a third episode is a noncohesive faulting. The kinking common in several formations-included the lower part of the Pillahuincó Group (Upper Carboniferous)-is formed in a strong planar anisotropy foliation as has been shown by several authors.

Although this mesostructure is a continous deformation, it represents a relative higher fragile condition with respect to the first folding assemblage. A relationship with the noncohesive faulting is probable.

As shown in Figure 2 faults are transverse to fold axis in three well developed sets considered as second order with respect to the main Abra de la Ventana fault. Further to their spatial relationships a suite of cataclastic rocks, with and without flow structure and primary cohesion, show a temporal succesion of generating events that implicity lead to a correlation of several environmental conditions as shown by Higgins (1971), Sibson (1977) and Grocott (1977). These rocks show definite relationships with metamorphic conditions under which they were generated (Higgins, 1971; Beach, 1980; Belliere, 1982) and are depth markers according to their textures, with implications in their faulting mechanism (Sibson, *op cit.*).

The longitudinal shear showing flow structure or mylonitic foliation were formed from pure quartzites, and are characterized by a quartz-muscovite paragenesis which is not critical for metamorphic grade determination. It can only be shown that it has overcome the very low grade by the effective presence of muscovite (Winkler, 1974). If the textural relationships that cataclastic rocks have between them are regarded, a logical sequence can be shown between the early formation of

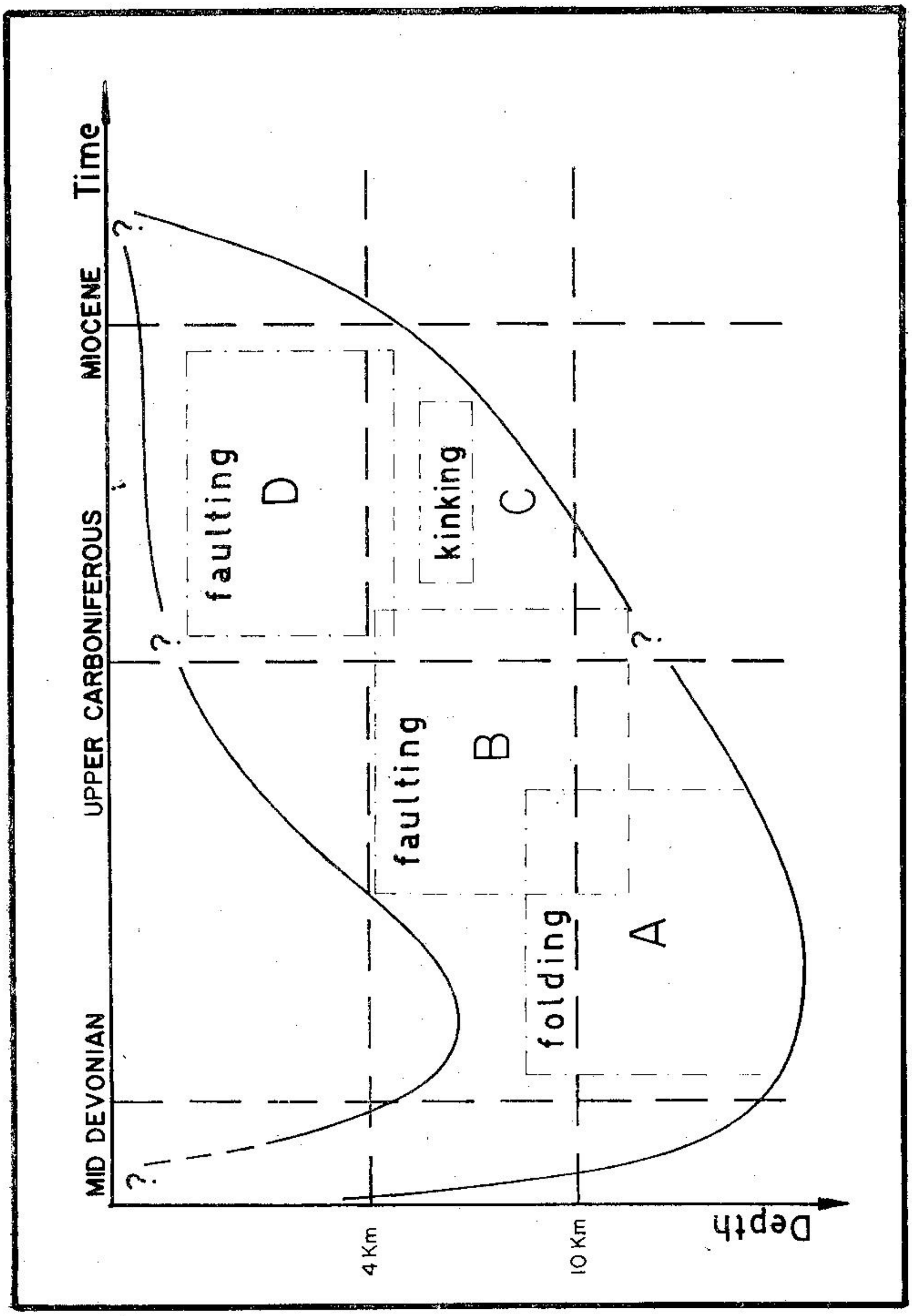

Fig. 5. — Time-space relationships between structures.

metaquartzites with mylonitic foliation, cohesive cataclasites with clasts of previous mylonitic quartz, and finally non-cohesive cataclastic rocks or cemented fault breccias. If this sequence is compared with that shown by Sibson (1977), the cemented fault breccias could have been formed at very shallow depth, not deeper than 4 km, the isotropic cohesive cataclastic rocks between 4 and 10 km, and the metaquartzites with mylonitic foliation at depths between 10 and 15 km.

In Fig. 4 a time-space relationship is proposed that shows the tectonic evolution of the Abra de la Ventana area.

V. Final considerations and discussion

Some points discussed above can be emphasized.

a) *Folding and faulting.*

It was stated above that it was not the aim of this paper to favour a pure folding or a folding and faulting model for the Sierras Australes. However some observations are important in the light of the above information. Schiller (1930) has shown that overthrusting is a frequent structure associated with folding deformation of the Sierras Australes. However Harrington (1947) considered that the Sierras are a case of pure folding.

Recently Cucchi (1966) mentions longitudinal faults in the Cerro del Corral and Cerro San Mario, while Amos and Urien (1968) discuss the transverse Abra de la Ventana fault and later Massabie and Rossello (1984a) show transverse faults south of the Abra as breccia zones.

The information in former pages clearly show that faults of restricted extension with thick breccias transverse to fold axis only developed in the Napostá and Providencia formations does not alter the general model of pure folding.

On the other hand it is important to discuss the contact between the Providencia and Lolén Formations in relation to the longitudinal faulting, specially in the eastern side of the Abra. In this part Keidel's (1916) map (1 : 25,000 scale) and Harrington (1947) clearly show a normal contact. However Schiller (1930) suggested an overthrust. We agree that the relation between both units in a normal folded contact following the general style and no evidence of thrusting is present. This invalidates the role of the temporal upper boundary of transcurrent faulting for this contact as there are no evidences of a discordant boundary. Therefore it is an important mechanical boundary for the development of this faulting to the east, as a lithological controlling factor between more brittle quartzitic rocks with lesser intercalated fillites (Napostá and Providencia Fms.) and the foliated metasandstones of the Lolén Fm. relatively more ductile.

b) *Zones of ductile shear in the Napostá and Providencia Fms*

Ductile shear zones several meters thick parallel to axial plane folds and intimately linked with their development, formed from quartzites of the Napostá and Providencia Fms. develop metaquartzites with typical mylonitic foliation (mb). These zones are absent in the Lolén Fm., which has a tight foliation.

Again it is evident that the developing process is sensible to a lithological control as the different microstructures developed in the Napostá and Providencia Fms. on one side and Lolén Fm. on the other are esentially due to lithological contrasts.

c) *Cataclastic rocks relationships with the major structure and their significance*

Zones of cataclastic rocks formed from metaquartzites are grouped from a texture point of view in those with flow structure (mylonitic foliation) anisotropic, and cataclasites with no flow structure and isotropic. The first related with transcurrent fault breccias that intersect folding and mylonitic quartzites. The latter were formed in deeper parts, meanwhile isotropic cataclasites at shallower depths.

d) *Time space relationships between structures*

Within the first folding stage controlled by the rheological conditions the following structures are included: striation on ss planes, foliation, mylonitic bands, corrugations, interstratal cleavage, quartz rods, en echelon tension gashes, and joints. Several of the microstructures such as en chelon tension gashes, extension joints in hinges, striae en ss planer normal to fold axis, foliation and kink bands have been described by Hiller and Snowden (1983) south of Steytlerville in the Cape Fold Belt of South Africa which are undoubtedly similar to the Sierras Australes in the Abra de la Ventana area. However the smaller thrust causing disruption and isolated noses in the Konga Fm., were not observed.

A second event can be interpréted as late to post kinematic with folding related to reactivations that produced transcurrent type faulting such as Abra de la Ventana fault, and second order faulting resposible of breccia zones. The local stress field from this second order faulting has a maximun stress σ_1 dipping 32° N 66° E, intermediate σ_2 dipping 58° S 64° W and a minimun σ_3 dipping 03° N 24° W (Fig. 2a) consistent with the general structural setting.

The kink band sets are probably related with this last faulting deformative event or perhaps with another later and independent, dextral and sinistral. They are well developed in several formations of the Sierras Australes, included the Upper Carboniferous Sauce Grande Formation (Rosello y Massabie, 1981).

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VII. References

Amos, A. J. & Urien, C. M., 1968. La falla "Abra de la Ventana" en las Sierras Australes de la prov. de Buenos Aires. *Asoc. Geol. Arg., Rev. XXIII* (3): 197-206.

Anderson, E. M., 1951. The dinamics of faulting and dyke formation with applications to Britain. *Oliver & Boyd.* Sec. Ed. p. 206.

Beach, A., 1980. Progressive metamorphic processes in shear zones with special reference to the Lewisian complex. *Jour. Struc. Geol.*, V. 2,1/2: 257-263.

Belliere, J., 1982. Structure of mylonitic and blastomylonitic rocks in relation with the (T, P) conditions of their genesis. *Int. Conf. Plan. Lin. Fab. Def. Rocks, ETH.* Zurich, Abstracts.

Billings, M. P., 1957. Structural Geology. 2nd Ed. *Prentice-Hall.* Inc.

Casey, M., 1980. Mechanics of shear zones in isotropic dilatant materials. *Jour. Struct. Geol.*, V. 2, 1/2 143-137.

Chinnery, M. A., 1966a. Secondary faulting I. Theoretical aspects. *Can. Jour. Earth Sci.*, V. 3: 163-174.

— 1966b. Secondary Faulting. II Geological Aspects. *Ibidem:* 175-190.

Cucchi, R. J., 1966. Petrofábrica del conglomerado de la Formación La Lola. Sierras Australes de la prov. de Buenos Aires. *Asoc. Geol. Arg., Rev. XXI* (2): 71.

Di Nardo, L. R. y Dimieri, L. V., 1984. Posibles mecanismos de deformación de la masa rocosa en las formaciones Napostá y Providencia, Sierras Australes, prov. Bs. As. *Act. 1º Reunión de Trab. Grupo Microt.* UBA.

Donath, F. A., 1962. Analysis of basin-range structure, South Central Oregon. *Bull. Geol. Soc. Am.*, V. 73: 1-16.

Du Toit, A., 1927. "A geological comparison of South America with South Africa. With a paleontological contribution by F. Cowper Reed". *Carnegie. Inst. Wash.* Washington, Pub. 381.

Grocott, J., 1977. The relationship between Precambrian shear belts and modern fault systems. *Jour. Geol. Soc. Lon.*, V. 133, part 3: 257-261.

Harrington, H. J., 1947. Explicación de las Hojas Geológicas 33m y 34m, Sierras Curamalal y de la Ventana. *Serv. Nac. Min. y Geol.*, Bol. 61.

— 1970. Sierras Australes de Buenos Aires: cadena aulacogénica. *Asoc. Geol. Arg., Rev. XXV* (2): 151-181.

Higgins, H. W., 1971. Cataclastic rocks. U. S. *Geol. Surv. Prof., Pap.*, 687: 1-97.

Hiller, N. & Snowden, P. A., 1983. Structural and stratigraphical relationships in the Cape Fold Belt, South of Steytlerville. *Trans. Geol. Soc. S. Afric.* (86): 263-271.

Keidel, J., 1916. La geología de las Sierras de la provincia de Buenos Aires y sus relaciones con las montañas del Cabo y los Andes. *An. Min. Agric. Nac., Secc. Geol. Mineral y Min., Buenos Aires,* Tomo XI (3): 1-76.

Lesta, P., Mainardi, E. & Stubelj, R., 1979. Plataforma continental argentina. *II Simposio Geol. Reg. Arg., Acad. Nac. Cs. Cba.*, Tomo 11: 1577-1602.

Llambías, E. J. & Prozi, C. R., 1975. Ventania. *IV Cong. Geol. Arg., Relatorio.* B. Blanca: 79-101.

Massabie, A. C. & Rosello, E. A., 1984a. Estructuras deformativas del Abra de la Ventana y adyacencias, Sierras Australes de Buenos Aires. *Act. 1º Reunión de Trab.* Grup. Microt. UBA.

— 1984b. La discordancia pre-Formación Sauce Grande y su entorno estratigráfico, Sierras Australes de Buenos Aires. *Acta IX Cong. Geol. Arg.*, V. I., S. C. de Bariloche: 337-352.

McKinstry, H. R., 1953. Shears of the second order. *Am. Jour. Scie.*, V. 251: 401-404.

Moody, J. D., & Hill, M. J., 1956. Wrench-fault tectonics. *Bull. Geol. Soc. Am.*, V. 67: 1207-1248.

Murell, S A. F., 1977. Natural faulting and the mechanics of brittle shear failure. *Jour. Geol. Soc. Lon.*, V. 133, part 3: 175-189.

Ramsay, J. G., 1967. Folding and fracturing of rocks. *McGraw Hill.*

Reinoso, M., 1968. Paelocorrientes en la Formación Providencia, Devónico, Sierras Australes de la provincia de Buenos Aires. *Asoc. Geol. Arg., Rev. XXIII* (4): 287-295.

Rosello, E. A. & Massabie, A. C., 1981. Micro y mesoestructuras en las Formaciones Lolén y Sauce Grande y sus implicancias tectónicas, Sierras Australes de Buenos Aires. *Asoc. Geol. Arg., Rev. XXXVI* (3): 272-285.

Schiller, W., 1930. Investigaciones geológicas en las montañas del sudoeste de la prov. de Bs. As., *An. Mus. La Plata, A (Serie 2)*, La Plata: 9-101.

Sibson, R. H., 1977. Fault rocks and fault mechanisms. *Jour. Geol. Soc. Lon.*, V. 133, part. 3: 191-213.

Suero, T., 1972. Compilación geológica de las Sierras Australes de la prov. de Buenos Aires. *Serie II, 216, LEMIT* (Ed. J. Ulibarrena).

Varela, R. & Cingolani, C. A., 1975. Nuevas edades radimétricas del basamento aflorante en el perfil del Cerro Pan de Azúcar, Cerro del Corral y consideraciones sobre la evolución geocronológica de las rocas ígneas de las Sierras Australes, prov. de Bs. As. *Act. VI Cong. Geol. Arg.*

Wilson, G., 1953. Mullion and rodding structures in the Moine Series of Scotland. *Proc. Geol. Ass. Lon.*, V. 64: 118.

Winkler, H. G. F., 1974. Petrogenesis of metamorphic rocks. *Springer-Verlag.*

Zeck, H. P., 1974. Cataclastites, hemiclastites, holoclastites, blasto-ditto and myloblastites-cataclastic rocks. *Am. Jour. Sci.*, V. 274: 1064-1073.