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INTERPRETATION OF SOME STRETCHING FABRICS: A MODEL

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RESUMEN.— En el presente trabajo se intenta construir un modelo idealizado para explicar el origen de determinadas fábricas de estiramiento (L-tectonitas), asociadas a las zonas centrales de la Cadena Hercínica Ibérica. Varios hechos tales como la disposición espacial de las L-tectonitas consideradas, la asociación con zonas de mayor metamorfismo regional y su relación con las estructuras regionales, inducen a pensar en un origen diferente de los ya propuestos por otros autores para otros cinturones de plegamiento. Las L-tectonitas consideradas en este trabajo, se interpretan como originadas por un estiramiento progresivo en dirección paralela al eje del cinturón, relacionado por un lado, con la posible distribución de esfuerzos en profundidad, en un régimen compresivo; y por otro lado, con el aumento de la capacidad de flujo de las rocas con el grado de metamorfismo.

SUMMARY.— This work tries to construct an idealized model to explain the origin of certain stretching fabrics (L-tectonites) associated with the central zones of the Iberic Hercynian Chain. Various events such as the spacial arrangement of the considered L-tectonites, the association with zones of major regional metamorphism, lead, one to think of a different origin than those already proposed by other authors for other folding belts. The L-tectonites considered in this work, are interpreted as being originated by a progressive stretching in a direction parallel to the axis of the belt, related, on one hand, with the possible distribution of stresses in depth in a compressive state; and on the other hand, with the increase of the rock flow capacity along with the metamorphic grade.

I. INTRODUCTION

The existence of stretching fabrics, L-tectonites, frequently associated with orogenic belts in concrete zones, has been, in the last years, object of various more or less complex interpretations. However, it is necessary to consider the different types of occurances in which they have been described and interpreted in a certain folding belt and not to claim a generalized model.

There are many examples described in geologic literature. Most of the investigators propose a simple shear model to explain certain stretching fabrics. In this way, ESCHER et al. (1974), NICOLAS et al. (1977) interpret the stretching lineation (axis X of the finite strain ellipsoid) as the direction of the flow of the shears, being the planar fabrics, usually less developed, the shearing plane arranged horizontally; being the lineation perpendicular to the front of the belt and the megastructures. Being able to occur, in zones of major deformation, a reordering of the fold axes that tend to become parallel in the stretching direction (SANDERSON, 1973; WILLIANS, 1978; MARTINEZ—CATALAN, 1981).

On the other hand, it is possible to develop stretching lineations in relation with vertical simple shear zones with ductile behaviour (IGLESIAS, 1981; ibid, in press), although, in this case the stretching is a local phenomenom in the proximities of the shear zone, and its magnitude depends on the intensity of the deformation or the proximity to the shear (CARRERAS et al. 1977).

However, there exists certain zones characterized by the presence of stretching lineation, extraordinarily accentuated until the point of being the only fabric that the rock possese. These L-tectonites arrange themselves horizontally and are usually associated with amphybolite facies metamorphism in the orogen central zones, being the direction of stretching parallel to the axis of the chain; they can present a faintly marked planar fabric arranged horizontally or subhorizontally.

The L-tectonites that have been utilized as base of the proposed model, are situated in the nucleus of an antiformal structure (Castellanos antiform) between the Avila and Salamanca provinces. They consist of femic gneiss, leucocratic gneiss and schists with intercalated pegmatoids (Alamo Series), conglomerates, porphyroids, etc. (See FIGUEROLA y FRANCO, 1975; FRANCO, 1980).

II. FIELD OBSERVATIONS

Various observations in this zone lead one to review the established models for the origin of the L-tectonites; (1) in the first place, we have that the direction of the lineation is parallel to the megastructures and to the axes of the minor folds; (2) if the lineation was in relation with thrusting faults, its vergence would be SE or NW, and the described thrusts in close zones would have the front parallel to the megastructures in the NW-SE direction, developing a perpendicular lineation to its front; (3) there exists a clear relation between the metamorphic grade and the linear fabrics, in such a way as to be more marked in rocks with mineral assemblages of the highest grade; (4) there exists a gradual transition from the slightly or non-metamorphic zones, that at the very most, present a mineral lineation in the foliation plane, to zones of greater metamorphic grade with a strong development of linear fabrics.

III. INTRODUCTION TO THE PROPOSED MODEL

This model deals with seeking a mechanism capable of explaining the simultaneous development of different structures in different levels of the crust, in function of the quantitative variations of the principal stresses with the depth, and the differential rheologic behaviour defined by the conditions of pressure, temperature, concentration of fluids, mineralogic composition, etc.

The influence of the fluid concentration on the rock flow capacity has been studied from different points of view, as much as for the metamorphic rocks as for the igneous, (FYFE, 1972; ELDER, 1969; CORRETGE y MARTINEZ, 1978; LOPEZ—PLAZA, 1981). Taking into account the fluid liberation during the metamorphism (VERNON, 1976; HARKER, 1974), one could consider the major or minor flow capacity consequence of a certain state in the pressure and temperature conditions for a determined composition, conditions that stay recorded on the rock by a certain mineral paragenesis; COWARD, (1981) speaks of a greater ducti-

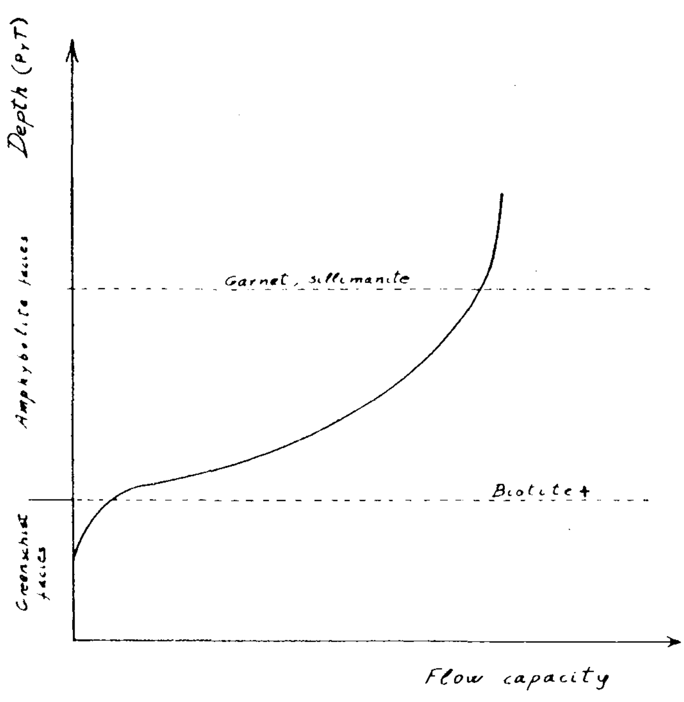

Fig. 1.- Progressive increase of the flow capacity with the metamorphic grade in a compressive state; (For pellitic rocks).

lity in amphybolite facies. Taking this into account, and in a dynamic state (compressive state), the rheologic behaviour differences would stay recorded on the rock by different types of internal fabrics. Figure 1 proposes an approximate relation between the flow capacity and the grade of metamorphism. For a determined composition (pellitic), a progressive increase of the flow capacity would be produced from the biotite + isograde, until the appearance of garnet and sillimanite; from here, the fluid concentration could be constant.

On the other hand, one will consider the possible variation of the magnitudes of the principal stresses (σ_1, σ_2, σ_3) along with the depth in a compressive state, with which, for an idealized model we have to: (1) the direction of the principal stresses does not vary substantially with the depth. (2) It is considered with exceptional importance the establishment of a vertical stress σ_v, whose magnitude increases with the depth due to the increase of the crustal load pressure, which in turn, will increase while the deformation increases given the progressive swelling of the crust in the orogenic central zones. Implying vertical pushes in depth is not necessary in this case. (3) The magnitude of the major compressive stress, σ_1, (perpendicular to σ_v) will be aproximately constant in the different crustal levels, becoming equal to the vertical stress in a determined depth, where the minor stress will be distensive. (4) The deformed material is considered anisotrope as a whole, anisotropy fundamentally due to the bedding planes and to the general layered structure of the crust, (FOUNTAIN & SALISBURY, 1981; SMITHSON & BROWN, 1977) which definitly constitutes subhorizontal litological discontinuities which will be responsible for the appearance of a vertical stress, σ_v, that increases progressively with the depth. However, each litological level is considered isotrope and homogenous in itself, hence the direction of the stress ellipsoid axes, will coincide with the direction of the principal axes of the incremental strain ellipsoid (RAMSAY, 1977). This second consideration should not be taken in a rigorous sense; it is done with the only purpose being to simplify the model and to be able to represent the incremental strain ellipsoid instead of the stress ellipsoid (Fig. 2)

IV. VARIATION OF THE RELATIVE MAGNITUDES OF THE INCREMENTAL STRAIN ELLIPSOID AXES WITH THE DEPTH

Figure 2 schematically represents the different deformation styles as answer to a distribution differential of the strain ellipsoid in depth. From the case a) to c), all possible intermediary steps exist. The vertical stress is represented by σ_v; the two extreme terms are cosidered from that $\sigma_v = \sigma_2$, until that $\sigma_v = \sigma_1$, (σ_1 = constant).

The changes in the incremental strain ellipsoid geometry not only become conditioned by the progressive increase of σ_v, but also by the differential rheologic behaviour of the deformed material.

In case a) of figure 2, we have an «oblate» type ellipsoid, with X = Y > Z, K = O (FLINN, 1962). The most viable deformation mechanism would be the development of foliation (flow foliation) with vertical axial plane folds, being able to consider the direction of «flow» in a perpendicular direction to the axis «b» of the folds («a» kinematic axis), although in the theoretic case the «flow» is possible in whatever direction perpendicular to Z of the incremental strain ellipsoid.

In case b) (Fig. 2), the σ_v stress is incremented with respect to the above case. The considered depth would correspond approximately to the bathograde 1 (CARMICHAEL, 1978) with values of P T in order of 2Kb and 600°C. In this situation, the material is more ductile than the case before, and the flow capacity of the deformed material would therefore be larger; but, the posibility of the vertical flow is less, given the increase of σ_v. In these conditions, it is obvious that the

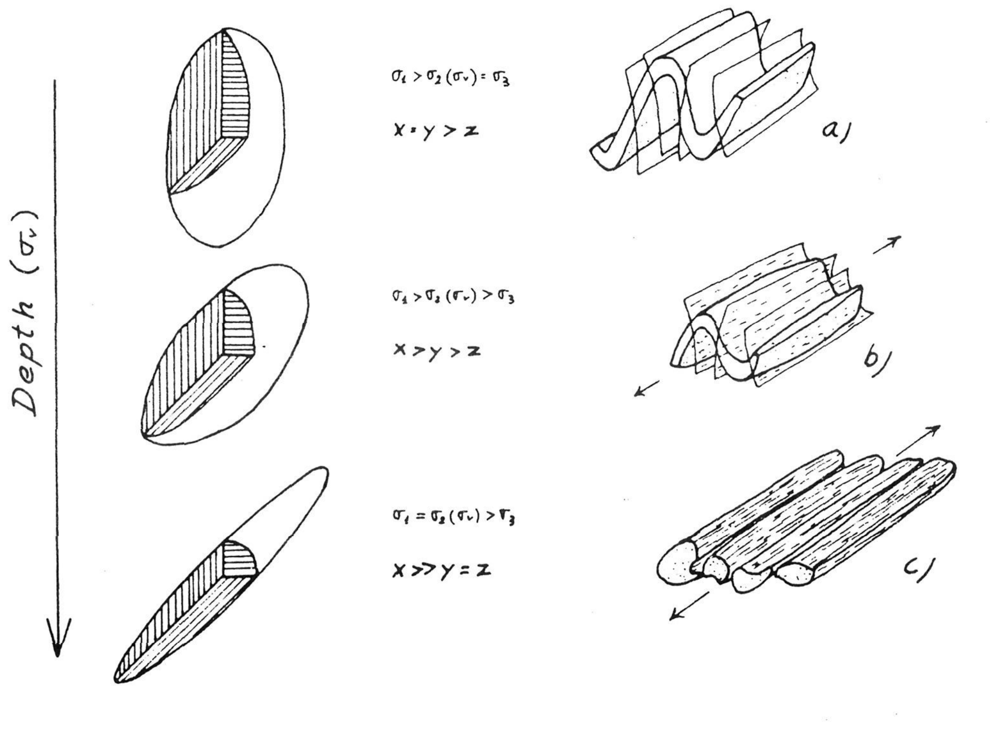

Fig. 2.- Evolution of the incremental strain ellipsoid with the depth and associated structures. See text for explanation.

style of deformation is going to be different than the case before. It will develop axial plane folliation, but with horizontal stretching parallel to the axes of the folds, what results is the appearance of a mineral lineation in the foliation plane, and a stretching lineation that will manifest with greater or lesser importance in function of the different flow capacity of the deformed material, but in whatever case, with greater development of planar fabrics.

In case c) (Fig. 2). The vertical component (σ_v) becomes equal to σ_1; the strain ellipsoid that would be attained, would be «prolate» type with $X \gg Y = Z$, $K = \infty$; at the same time that σ_v increases, therefore, it increases the metamorphic grade, according to what was earlier shown; we would find ourselves in close conditions to the sillimanite isograde, the flow capacity would be high and the direction of it parallel to the X axis, that is arranged subhorizontally. The style of deformation would be netly different from case a), appearing a strong stretching that results in the development of linear fabrics fundamentally (L-tectonites). The direction of the lineation would therefore be parallel to the axes of the folds and in general, parallel, to the chain megastructures. In the studied zone, the L-tectonites are fundamentally developed from gneiss, conglomerates and porphyroids, those that the lineation arranges subhorizontally and with direction varying between E-SE and SE. Figure 3 shows the development of a L-tectonite on a level of conglomerates intercalated in less competent rocks.

V. DISCUSSION

It would be very extensive to analyze the differences between the proposed idealized model and the complex structure of a folding chain; however, the model is fundamentally based on field observations realized in different zones of the central sector of the Iberic-Hercynian Chain. Said observations refer mostly to the metamorphism and the constant association, in this zone, of L-tectonites in amphibolite facies; however, it is necessary to make some abstractions to apply such a simple model. The existence of various phases of deformation in the Hercynian Chain is well known, but there does not yet exist a clear correlation between metamorphism, plutonism and deformation, since the number of data that are actually arranged is still insufficient to establish a generalized model.

The possible complications that could have added to the particular model proposed here would be practically innumerable, but it only tries to explain the origin of certain stretching fabrics in the context of the general structure of the chain. Certain facts, such as the existence of subhorizontal planar fabrics associated with the L-tectonites require greater attention and a detailed study for its interpretation, since such an association can lead one to think, in principle, of a

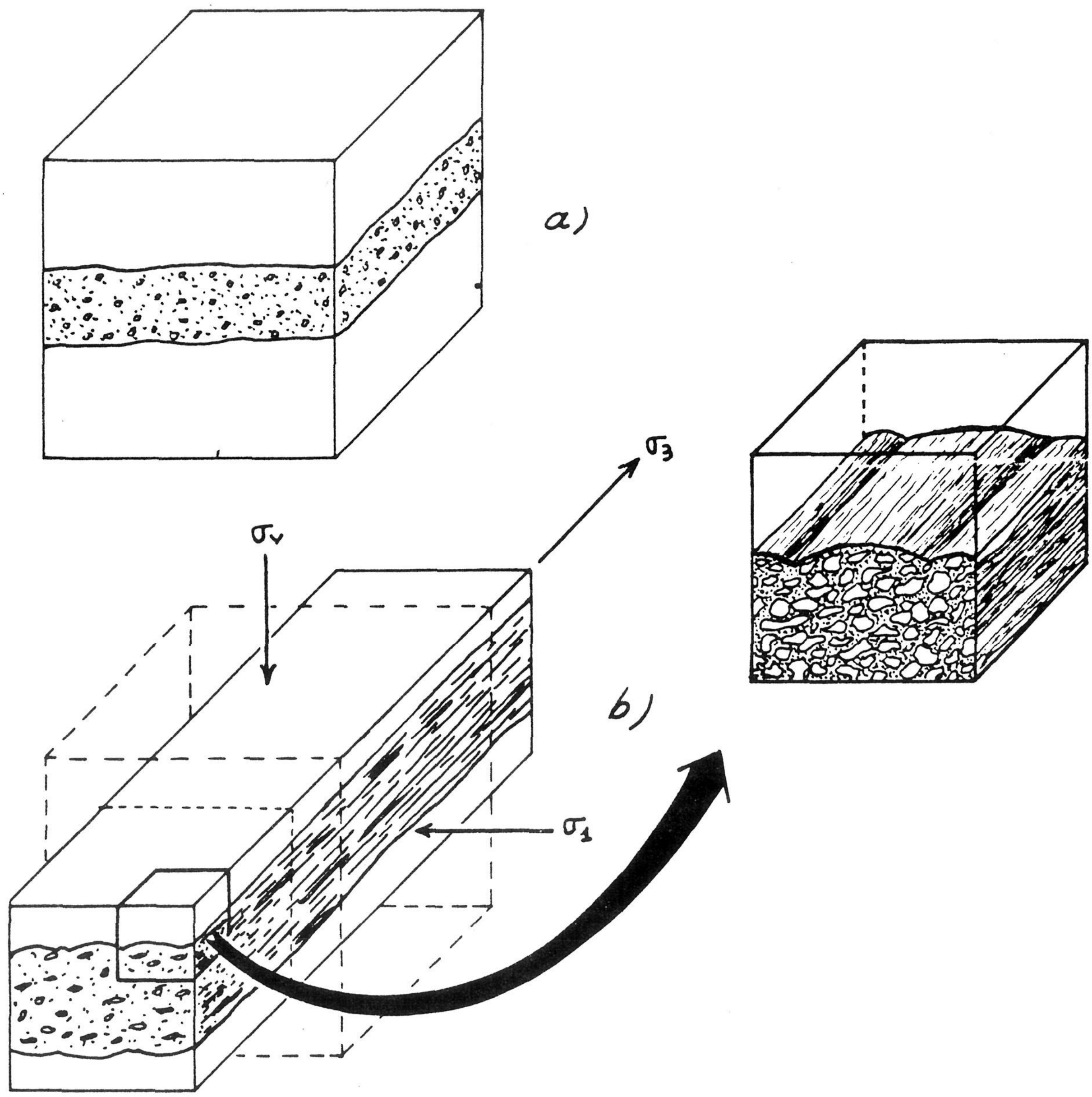

Fig. 3.- Probable mechanism for the development of a L-tectonite.
a) Level of conglomerate intercalated in less competent rocks.
b) Arrangement of the principal stresses and stretching in direction of σ_2; $\sigma_1 = \sigma_v$ (see text).

subhorizontal simple shearing model as was explained in the introduction of this work. But such a scheme is inaplicable here, given the spacial arrangement of the considered L-tectonites with the regional structures. In our scheme, the subhorizontal planar fabric, generally subparallel to the bedding, would be produced as consequence of the differential stretching of the different lithological levels that compose the series; in other words, because of the different rheologic behaviour of compositionally different materials in the same pressure and temperature conditions; said differential stretching would induce the sliding of some levels over others, developing subhorizontal simple shearing zones, that would locally produce planar fabrics.

While one proposes for deep zones a progressive stretching parallel to the axis of the belt, in more superficial zones, the structural complexity is greater, existing various superposed folding phases, often homoaxials (QUIROGA, 1981) very difficult to correlate in depth with more than just one phase (stretching), and from here, the necessity of a model of this type.

REFERENCES

CARMICHAEL, D.M. (1978) Metamorphic bathozones and bathograds: a measure of the depth of post-metamorphic uplift and erosion on the regional scale. *Am. J. Sci.* 278: 769-797.

CARRERAS, J.; ESTRADA, A. & WHITE, S. (1977) The effects of folding on the c-axis fabrics of a quartz mylonite. *Tectonophysics* 39: 3-50.

CORRETGE, L.G. y MARTINEZ, F.J. (1978) Problema sobre la estructura y emplazamiento de los granitóides: aplicación a los batolitos hercínicos del Centro-Oeste de la Meseta Ibérica. *Seminario de est. cerámicos de Sargadelos* N° 27 113-134.

COWARD, M.P. (1980) Shear zones in the Precambriam crust of Southern Africa. *J. Struct. Geol.* 2: 19-27.

ELDER, J.W. (1969) Quantitative laboratory studies of dynamical models of igneous intrusions. In: NEWALL, G. & RAST, N. (editors) Mechanisms of Igneous Intrusions. *Geol. Jour. (Special issuel)* 2: 245-260.

ESCHER, A. & WATTERSON, J. (1974) Stretching fabrics, folds and crustal shortening. *Tectonophysics.* 22: 223-231.

FLINN, D. (1962) On folding during three-dimensional progresive deformation. *Quart. J. Geol. Soc.* 118: 385-433.

FOUNTAIN, D.M. & SALISBURY, M.H. (1981) Exposed cross-sections through the continental crust: implications for crustal structure, petrology and evulution. *Earth Planet. Sci. Lett.* 56: 263-277.

FRANCO, P. (1980) Estudio petrológico de las formaciones metamórficas y plutónicas al norte de la depresión del Corneja-Amblés (Sierra de Avila) Tesis Doctoral. Universidad de Salamanca (impubl.) 273 pp.

FYFE, W.S. & BROWN, G.C. (1972) Granites past and present. *J. Earth. Sci.* 8: 249-260.

GARCIA DE FIGUEROLA, L.C. y FRANCO, P. (1975) Las formaciones infraordovícicas y el borde de las granodioritas al este de Guijuelo (Salamanca). *Est. Geol.* 31: 487-500.

HARKER, A. (1974) Metamorphism. Chapman & Hall. London. 362 pp.

IGLESIAS, M. & CHOUKROUNE, P. (1979) Shear zones in the Iberian Arc. *J. Struct. Geol.* 2: 63-68.

IGLESIAS, M. et RIBEIRO, A. (in press) Position stratigraphique de la formation «Ollo de sapo» dans la région de Zamora (Espagne)-Miranda do Duero (Portugal). *Bol. Serv. Geol. Port.*

LOPEZ-PLAZA, M. (1980) Comportamiento reológico, fuerza ascensional y deformación en el material granítico: Aplicación al Plutón de Ledesma (Salamanca) *Bol. Geol. Min.* 91: 649-660.

MARTINEZ CATALAN, J.R. (1981) Estratigrafía y estructura del Domo de Lugo. Tesis Doctoral. Universidad de Salamanca. (impubl.) 317 pp.

NICOLAS, A.; BOUCHEZ, J.L.; BLAISE, J. & POIRIER, J.P. (1977) Geological aspects of deformation in continental shear zones. In: D. DENHAN (editor) Stress Environement and Displacement at Continental Margins. *Tectonophysics* 42: 55-73.

QUIROGA, J.L. (1981) Estudio geológico del paleozóico del W de Zamora. Tesis Doctoral. Univ. de Oviedo. (impubl.) 210 pp.

RAMSAY, G.J. (1977) Plegamiento y fracturación de rocas. Blume. Madrid 583 pp.

SANDERSON, D.J. (1973) The development of fold axes oblique to the regional trend. *Tectonophysics.* 16: 55-70.

SMITHSON, S.B. & BROWN, S.K. (1977) A model for lower continental crust. *Earth and Plan. Sci. Lett.* 35: 134-144.

VERNON, R.H. (1976) Metamorphic processes. Murby. London. 247 pp.

WILLIANS, G.D. (1978) Rotation of contemporary folds into the X direction during overthrust processes in Laksefjord, Finnmark. *Tectonophysics* 48: 29-40

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