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Geological setting of the Roses granodiorite (E-Pyrenees, Spain)

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SUMMARY

The Hercynian-aged Roses Granodiorite displays a heterogeneously developed gneissic-mylonitic foliation, developed along bands ranging in width from a few centimeters to about 500 meters. The foliation bands have anastomosing and fanning dispositions, such that the poles to the foliation planes are spread along great circles although a quite regular orientation of the associated mineral elongation lineation is maintained.

The grandiorite was emplaced cutting across a regional schistosity in the probable Ordovician-aged metasedimentary host rocks. Both rock types were then deformed together during the main late-Hercynian folding phase in the region. The different mechanical properties of the rocks as they underwent this late phase of deformation resulted in the formation of crenulation folds in the metasediments and shear zones in the granodiorite.

RESUMEN

La granodiorita hercínica de Roses está heterogeneamente afectada por una foliación gneiso-milonítica, que se desarrolla en bandas cuyo espesor varía desde el orden centimétrico hasta el hectométrico. Las bandas adoptan disposiciones anastomosadas que condicionan la dispersión de los polos de los planos gneiso-miloníticos según círculos máximos. La lineación de elongación asociada, por el contrario, mantiene una orientación considerablemente regular.

El emplazamiento de la granodiorita es posterior a la formación de la esquisitosidad regional de los metasedimentos encajantes de probable edad Ordovicica. Sin embargo todo el conjunto fue deformado durante la fase tardía principal de plegamiento. Los pliegues con crenulación asociada y las zonas de cizalla se interpretan como resultado del distinto comportamiento mecánico de la grandiorita y los metasedimentos respectivamente, frente al episodio de deformación tardío.

INTRODUCTION

The Roses Granodiorite forms a small enlogated body (about 5 km long and 2 km wide) of heterogeneously foliated granodiorite of Hercynian age, and constitutes the easternmost outcrop of intrusive granitoids along the Pyrenean Axial Zone (fig. 1). The granodiorite is mainly bounded on its northeast margin by knotted phyllites, quartz-phyllites and metagreywackes.

This granodiorite, like most other Hercynian granitoids, has usually been considered as a late intrusion cutting across the last folds produced during the Hercynian orogenic event. On the Geological Map of the Pyrenees, edited by Zwart (1972), these granodiorites are erroneously figured as "metavolcanics, mainly rhyolitic". Carreras (1973) desagrees that the Roses granodiorite intrusion post-dates the late-Hercynian folds. A few other granitoid bodies of the Axial Zone are also considered to have intruded during, or shortly before, the late folding phase, e. g. the Mont Lluis Grandiorite (Autran 1964, Autran *et al.* 1970) and the La Jonquera Granodiorite (Llac 1973). The Querigut Massif in particular has been interpreted by Aparicio (1975) to have been emplaced during the main Hercynian deformation phase that was responsible for the formation of the dominant schistosity in the enclosing metasediments.

The Roses granodiorite, along with the nearby Roda granodiorite (Carreras 1973) and the La Jonquera Granitoids, displays a well but inhomogeneously developed planar fabric achieved by deformation under greenschist facies conditions. The foliation is developed along bands, giving rise to mylonitized or gneissified granodiorite.

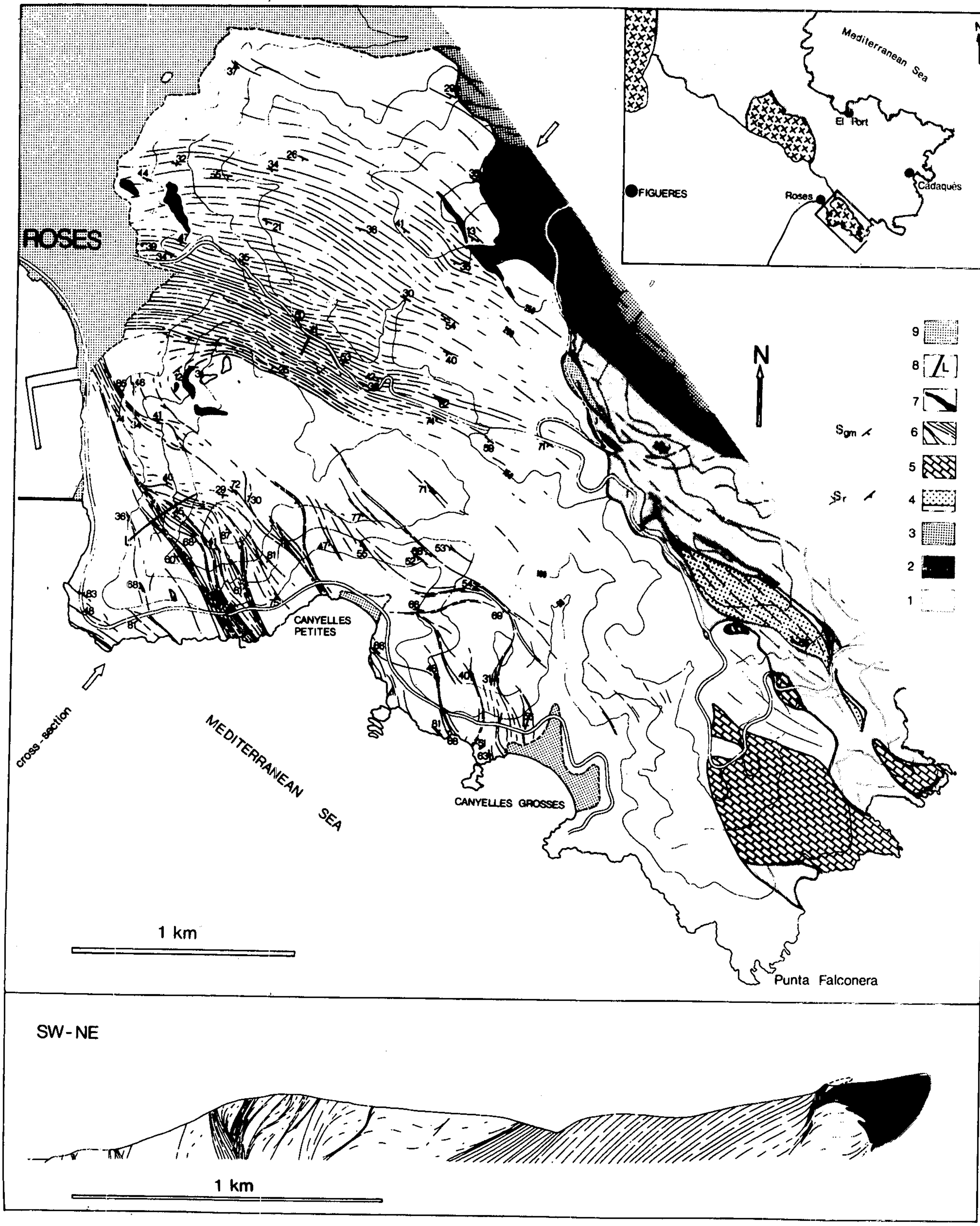

Fig. 1.–1A: Geological setting of the mapped area. 1B: Geological map of the Roses Granodiorite and the enclosing metasediments. 1: Rhythmic phyllites and quartzites; 2: Black phyllites; 3: Microconglomerats and muscovite rich phyllites; 4: Amphibole bearing gneisses; 5: Marbles; 6: Granodiorite and gneissic-mylonitic foliation trace; 7: Quartz dykes; 8: Lamprophyre dykes; 9: Recent detritical materials. Sr: Regional foliation, Sgm: Gneissic-mylonitic foliation. 1C: Cross-section as indicated in Fig. 1B.

These bands range in width from a few centimeters up to about 500 meters in belts of rather homogenously foliated granodiorite.

The mylonites are throught to belong to the Late-Hercynian mylonite belt which deforms the crystalline rocks of the Axial Zone of the Eastern Pyrenees (Carreras et al. 1980). However, there is no general agreement on the age of the mylonites in these deformed granitoids. For instance, mylonites cutting across the granitoid rocks of the Neoville Massif in the Central Pyrenees, have benn interpreted as Alpine in age (Lamouroux 1976, Lamouroux et al. 1980). There are two main reasons for considering the mylonites in the Roses Granodiorite to be of Hercynian age: firstly, the mylonites are cut by undeformed basic dykes attributed to the late Triassic-early Jurassic (Fig. 2), and secondly, the mylonites show microstructural and mineralogical features indicative of deformation under greenschist facies conditions (Carreras et al. 1980), unknown for Alpine deformation in that area.

Fig. 2. Underformed lamprophyre dyke cutting across the mylonitized granodiorites.

This paper presents the results of a study to determine the internal geometry of the deformation structures in the Roses Granodiorite, and to establish their relationship to the enclosing metasediments.

INTERNAL STRUCTURES IN THE UNDEFORMED GRANODIORITE

The Roses Granodiorite is rich in micro-quartz-diorite enclaves which occasionally form accumulations up to about 50% by volume of the rock. The undeformed rock is usually quite isotropic although locally a preferred orientation of the enclaves and magmatic schlieren is thought to represent a primary igneous flow texture. Xenoliths and septae of hornfelsed metasediments are also locally observed within the igneous body, any foliation within these inclusions being clearly cross-cut by the granodiorite. A suite of aplite dykes cuts across the granodiorite. More leucocratic granitoids are common along the border zone of the granodiorite intrusion and form apophyses that invade the surrounding country rock. Granodiorite dykes cutting across the metasediments are also frequently observed.

In thin-section, the undeformed biotite-hornblende granodiorite consists of quartz, oligoclase-andesine, K-feldspar, biotite and hornblende (fig. 4A). Epidote, clinozoisite and allanite are common accessory minerals. Biotite frequently contains oriented needles of rutile (sagenite).

INTERNAL STRUCTURES IN THE DEFORMED GRANODIORITE

The granodiorite shows a strong and penetrative foliation (Sgm) in a broad zone close to its northern boundary (fig. 1B). Towards the south, the foliation is restricted to gneissic-mylonitic zones that range in width from a few centimeters to tens of meters. These zones form a sub-parallel set, predominantly trending NW-SE and dipping steeply towards the SW (fig. 3A). Vertical or even north-easterly dips occur occasionally reflecting a fan-like disposition of the foliation planes. Anastomosing bands of foliated rock surround and isolate lozenge-shaped bodies of weakly deformed granodiorite (Simpson 1981). Within less deformed areas of the granodiorite, narrow mylonitic zones have a more variable orientation and conjugate sets of shear zones have been observed. Locally, a weak, penetrative, flat-lying foliation is observed to be deflected into the later, discrete, steeply-dipping mylonite zones.

The mylonitized granodiorite exhibits a marked mineral elongation lineation, sub-parallel to the displacement direction in the rocks. The orientation of the lineations is quite regular, plunging at a few degrees towards the southeast and forming a maximum located almost perpendicular to the girdle of poles to foliation planes (fig. 3B). The mylonitic foliation is itself sometimes folded and/or crenulated; the axes of these folds are parallel

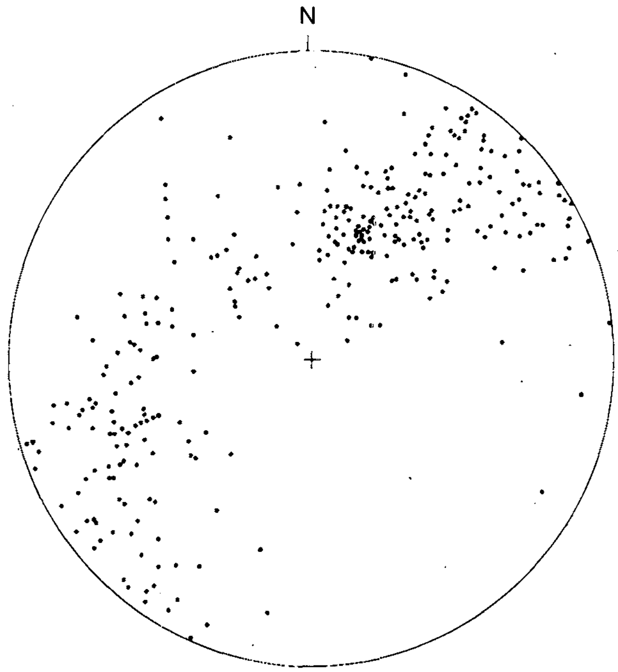

Fig. 3A.- Lower hemisphere stereoplot of poles of the gneissic-mylonitic foliation (Sgm), 304 poles.

to the mineral elongation lineations. Separate deformation events could not be established for the formation of the varions linear features and it is assumed that progressive deformation was responsible for the generation of all the observed structures. Progressive deformation has also been suggested for the formation of fold axes parallel to

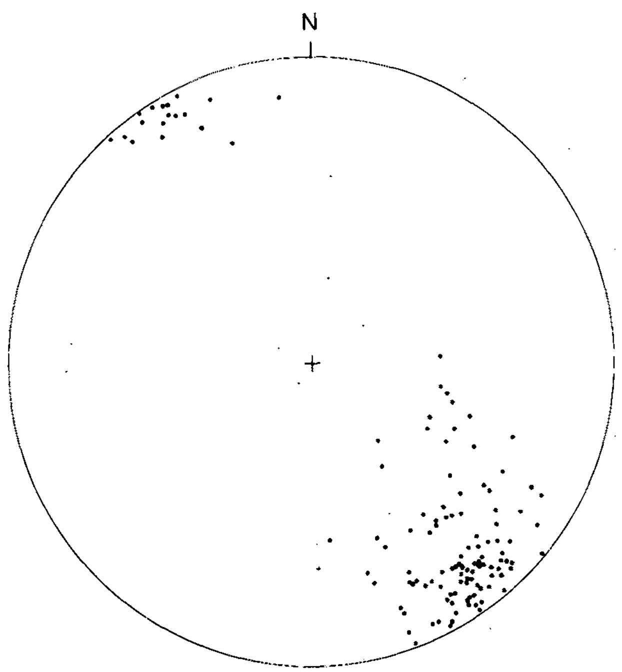

Fig. 3B.- Lower hemisphere stereoplot of stretching lineations, 121 lineations.

mineral lineations in other mylonitic belts (Dalziel and Bailey 1968, Bryant and Reed 1969, Carreras and Santanach 1973, Berthé and Brun 1980, Cobbold and Quinquis 1980) Simpson (1981) considers that during an initial stage of homogeneous deformation, a weakly penetrative foliation may develop under an irrotational regime, followed by an inhomegeneous simple shear deformation, concentrated along narrow shear zones that deform the earlier weak foliation.

Mylonitization of the granodiorite is always accompanied by a microstructural change marked by a drastic grain refinement (Fig. 4B and C), and by a partial mineralogical change seen as a new growth of chlorite, epidote, muscovite and albite. In some cases chemical transformations may also be significant; the most marked is the development of quartz-depleted chlorite-albite mylonites (Fig. 4D).

THE DEFORMATIONS PHASE IN THE METASEDIMENTS AND THEIR RELATION TO THE GRANODIORITE EMPLACEMENT

The metasedimentary host rocks of the granodiorite comprise two distinct sequences: (i) a lower, rather monotonous series of rhythmic phyllites and quartzites, overlain by black phyllites, and (ii) a upper sequence of heterogeneously interbedded micro-conglomerates, muscovite-rich phyllites, metagreywackes and amphibole-bearing feldspathic rocks of possible volcano-sedimentary origin, overlain by an upper series of sandy-wackestone marbles and massive dolomitic marbles.

The upper sedimentary sequence is similar to series of Upper Ordovician age described from Paleozoic terrains in the NE of the Iberian Peninsula and the Pyrenees (Cavet 1957, Hartevelt 1970, Santanach 1972, Llac 1973 and Barnolas et al. 1980). For this reason it is assumed that the metasedimentary rocks surrounding the Roses Granodiorite are probably also of Upper Ordovician age.

The sedimentary rocks described above show a low grade regional metamorphic imprint. Those rocks nearest to the granodiorite exhibit a contact metamorphism which causes the development of spotted phyllites and hornfelses.

All the metasediments display at least one penetrative foliation (Sr) developed during the regional metamorphic event. This foliation is often folded and a crenulation cleavage is frequently associated with the folding. Minor folds and crenulation are especially marked in NW-SE trending zones, i.e. the crenulation planes are subparallel to the Sgm foliation seen in the granodiorite. In some cases

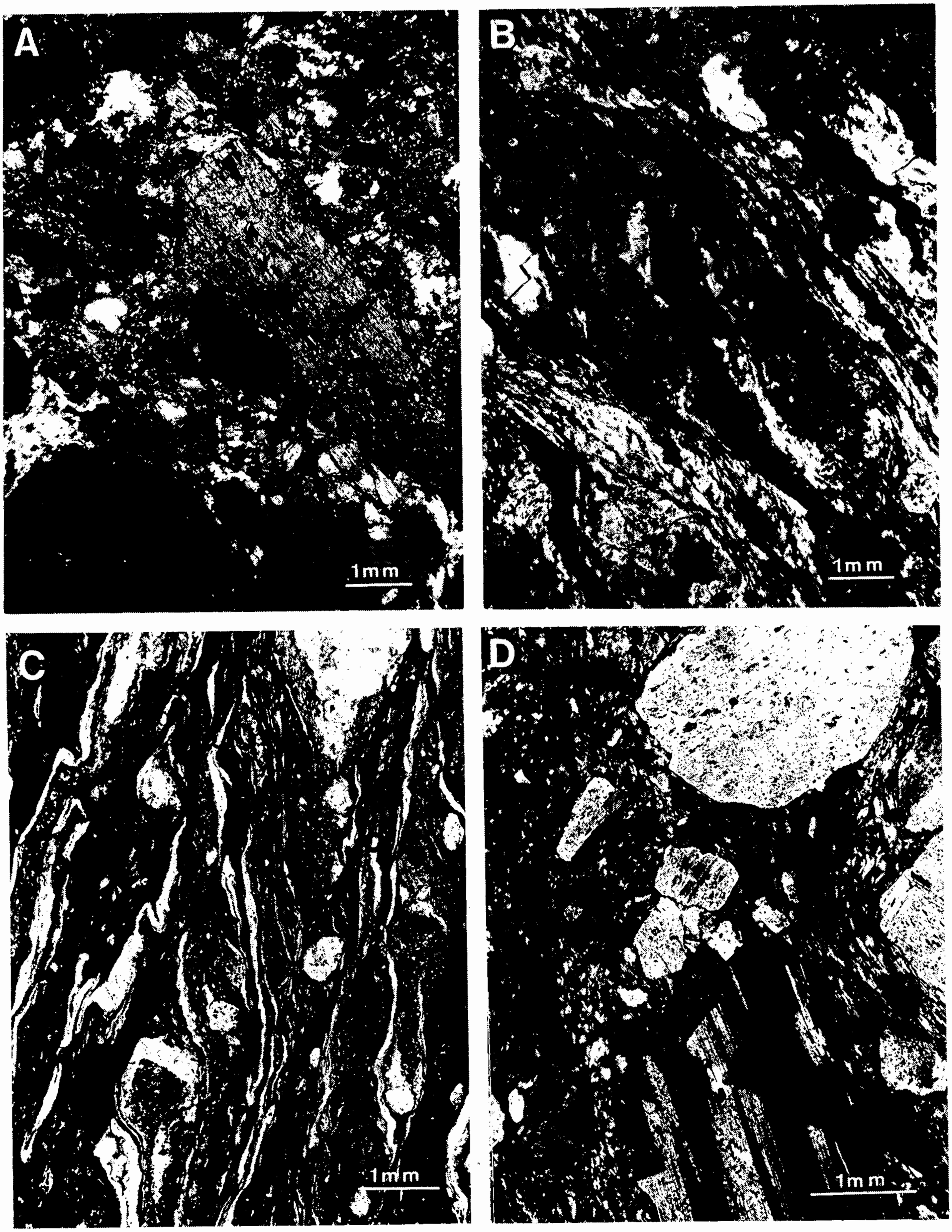

Fig. 4.- PHOTOMICROGRAPHS OF GRANODIORITES AND THEIR MYLONITIZED EQUIVALENTS. 4A Underformed granodiorite, 4B Sheared granodiorite mylonitic foliation is defined by elongated quartz and a phyllosolicate matrix. 4C. Higly strained granodiorite shear bands and folds affect the quartz ribbons. 4D. Albite-chlorite mylonite. In these rocks quartz is absent. Subhedral albites are wrapped by chlorite and withe micas.

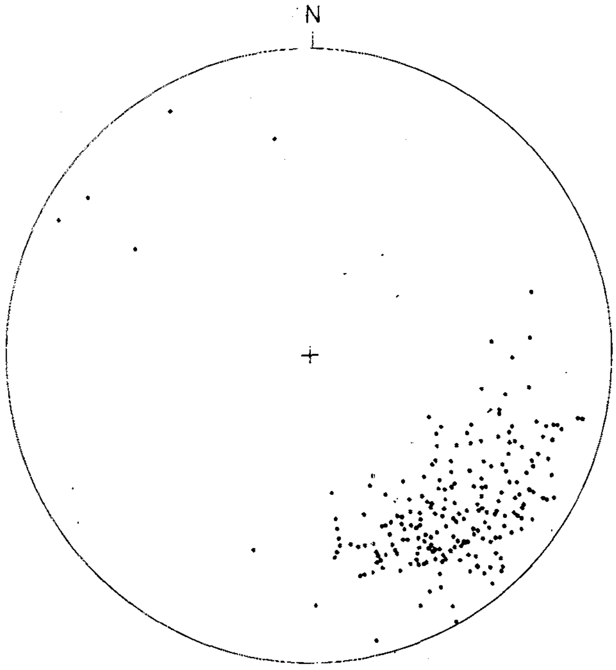

Fig. 5. - Lower hemisphere stereoplot of crenulation lineations in the enclosing metasediments, 210 lineations.

Fig. 6.– Spotted phyllite. Nodular porphyroblast acting as buckling instability for microfold development during the late major fold event.

the crenulation cleavage becomes sufficiently penetrative to cause the transposition of the earlier regional foliation, Sr. The minor fold axes have a N 140º E trend and a moderate plunge towards the southeast (fig. 5).

The granodiorite intruded the metasediments at different stratigraphic levels and clearly cuts across the regional foliation, Sr. However, the late minor folds and crenulations in the metasediments appear to post-date the intrusive event. Crenulation folds wrap around the nodular porphyroblasts that developed in the phyllites of the contact aureole. Furthermore, these nodular porphyroblasts frequently act as sites of buckling instability, to produce disharmonic microfolds (fig. 6). Sericitized porphyroblasts are sometimes folded, and muscovites and biotites in the hornfelses are often kinked. Small granodiorite veins that cut the metasediments are in some instances folded with axes parallel to those of the late folds and crenulations in the phyllites (fig. 7). Mineral elongation lineation in quart-zrich dykes close to the granodiorite-metasediments boundary, and in foliated regions of the main granodiorite body, are also parallel to the latestage fold axes in the metasediments.

Fig. 7. - Intrusive granitic vein affected by the late folding. Spots in the hornfelsed phyllite are deformed and mainly elongated parallely to the crenulation cleavage.

CONCLUSIONS

Although the Roses Granodiorite is thought to be a late intrusion of Hercynian age since it cuts across the regional chistosity in metasediments of presumed Ordovician age, it was emplaced prior to a later fold and crenulation Hercynian-aged event. During this post-emplacement deformation event the granodiorite itself was strongly and heterogeneously deformed. Deformation structures in the granodiorite range from a regular gneissic foliation, to strong mylonitization along discrete, narrow shear zones. Crenulation folds develop in the less competent metasediments. All of the post-intrusive fold axes, regardless of rock type, are subparallel to a mineral elongation lineation that developed synchronously with the mylonitization. The anastomosing and fan-like attitude of gneissic-mylonitic foliation planes results in a spread of Sgm poles along a grat circles, a distribution commonly seen in sheared granitoids (Ramsay and Allison 1979, Simpson, 1981). The mineral elogantion lineation plot closely parallel to the pole to this grat circle, i.e. the intersection line of the mylonite foliation planes.

The main late deformation event, of Hercynian age, described above is in contrast to the post-tectonic emplacement of the majority of Hercynian granitoids in the NE Iberian Peninsula and Pyrenees.

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