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TECTONIC AND PETROGRAPHIC ASPECTS OF AN AREA SW OF THE LALIN UNIT (PROV. ORENSE AND PONTEVEDRA, NW SPAIN)

BY

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ABSTRACT

In a schist area south of the Lalín Unit in the provinces of Orense and Pontevedra, a lithostratigraphy has been established. The disposition of some stratigraphic horizons shows the existence of a large-scale synformal F_2-structure.

Metamorphic porphyroblasts have grown mainly between the two main folding phases F_1 and F_2. Special attention has been given to the garnet porphyroblasts. Probably two types of garnet are present: a Hercynian garnet and an earlier garnet. There are some indications of a tectonic contact within the schists. Probably schists of Lower Palaeozoic age are overlain by older, polymetamorphic schists.

INTRODUCTION

The investigated area is situated between Avión (S) and Forcarey (N), and can be found on the sheets 186 (Puente Caldelas) and 153 (Cerdedo) of the 1:50.000 map published by the 'Instituto Geográfico y Catastral', Madrid, Spain.

A general outline of the geology of the NW part of the (Hercynian) Hesperian massif of the western Iberian peninsula has been given in several publications (den Tex & Floor, 1972; Capdevila, 1969; Matte, 1968; Ribeiro, 1970).

The central Galician schist area is roughly situated between Forcarey (NW), Lalín (NE), Carballino (SE) and Avión (SW) in the provinces of Orense and Pontevedra. The schists are bounded in the East by a migmatitic complex, in the South-East by the post-tectonic, calcalkaline Ribadavia granite, in the South by the alkaline, K-feldspar megacrystal-bearing Avión granite, and in the West by the alkaline western granite. To the North the schists are tectonically overlain by the Lalín Unit (Hilgen, 1971).

Petrographically, the rocks are mainly quartz-rich biotite-muscovite or muscovite-sericite schists, sometimes rich in albite porphyroblasts, with intercalations of micaceous or impure quartzites, graphite-bearings schists or quartzites, amphibolites, ortho(?)gneisses and paragneisses. The porphyroblasts are chlorite, albite, biotite, garnet, staurolite and andalusite.

The area discussed is part of the central Galician schist area (Fig. 1). Preliminary results of the investigation of this area have been given by van Meerbeke, Hilgen & Floor (1973)**. In the present paper some further results of a tectonic and petrographical study are given, based on unpublished work by Roos (1974) and the present author.

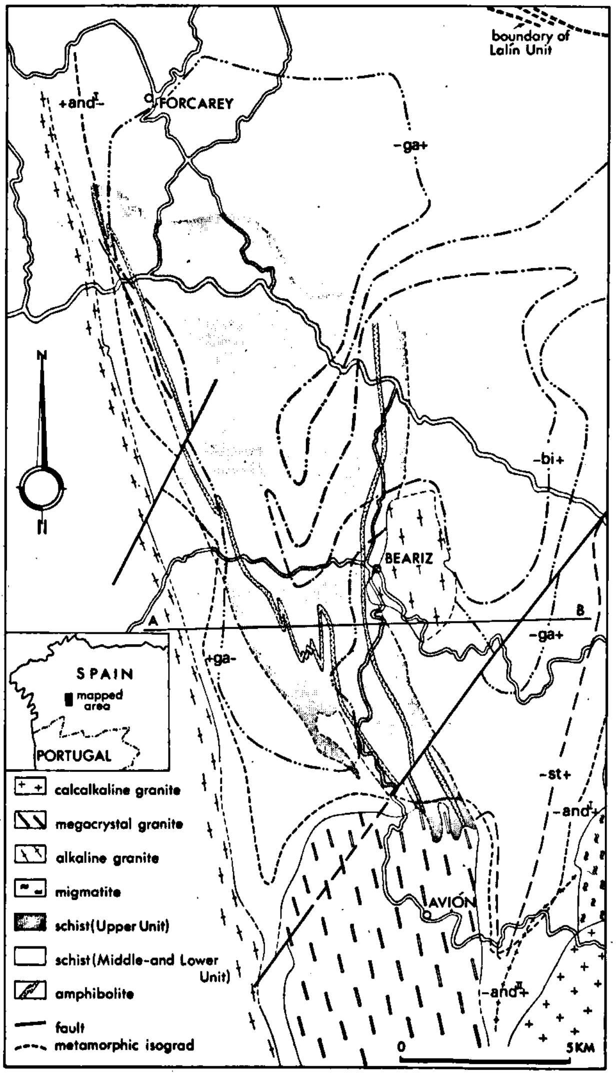

Fig. 1. Simplified geological map showing the location of the schists of the Upper Unit (Metamorphic isograds slightly modified after van Meerbeke, e. a., 1973) (after Minnigh, 1974, and Roos, 1974).

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** After this paper was sent to the printers, a series of papers appeared of R. Castroviejo, entitled 'Estudio Geológico y Metalogénico de la Zona de Beariz (Orense) y sus Yacimientos Minerales de Sn-W' (Boletín Geológico y Minero, 85, pp. 528–548, 1974; 86, pp. 142–166, and pp. 262–276, 1975). He has described some geological aspects near the Beariz granite, with special reference to the mineralizations.

LITHOSTRATIGRAPHY

A lithostratigraphic column is given in Fig. 2. Subdivision of rock types is mainly based on the percentage and the grain size of quartz. Attention is also given to the occurrence of albite porphyroblasts. A Lower-, Middle- and Upper Unit has been established.

The rocks are mainly schistose. The schists of the Lower Unit have a groundmass of quartz, muscovite-sericite and chlorite. All these minerals are homogeneously distributed and are fine-grained (<0.5 mm). The quartz content is often higher than 50%. Within these schists some graphite-bearing schists, graphite-bearing quartzites and mica-bearing quartzites are present. These layers are discontinuous in the field, probably due to boudinage, or to discontinuous deposition.

The schists of the Middle Unit have a lower percentage of quartz. The groundmass is composed of the same minerals as the underlying schists. Also black schists and quartzites are present. Near these layers, reddish weathered schists crop out. In a few places albite porphyroblasts are present. The schists of this sequence have a pelitic appearance.

The Upper Unit consists of schistose greywackes. The quartz is coarse-grained (0.5–1.5 mm) and also albite porphyroblasts are present. Sometimes the albite porphyroblasts become so abundant that the rock acquires a gneissic appearance. Quartz and albite are easily recognized in hand specimen. These metagreywackes weather easily and give a good soil for agriculture; this property is well seen on aerial photographs. The micas in these rocks are muscovite, biotite and sometimes chlorite. Near the contact of this unit with the underlying pelitic schists, a succession of a mica-bearing white quartzite, some amphibolite layers and a probable orthogneiss crops out within a space of approximately 20 m. The micas in the quartzite are concentrated in thin, sparse films parallel to the main schistosity S_1, causing a platy cleavage. There are in the South five or six thin amphibolite layers, each about 15 cm thick, while in the North-West three layers, each about 1 m thick crop out. The rock is composed of green hornblende, plagioclase (35–40% An) and epidote and variable amounts of albite, actinolite, quartz, biotite and sphene.

A light-coloured gneiss overlies the amphibolites. It contains quartz, inclusion-rich albite, microcline, biotite, sphene and sometimes garnet and green hornblende. It is an almost massive rock with hardly any schistosity. There is a striking resemblance with the orthogneisses of the Lalín Unit and the blastomylonitic 'Graben' of western Galicia (Hilgen, 1971; e. g. den Tex & Floor, 1967). Normally schists are found between the amphibolites and the gneiss, but in some localities there is simply a gradual transition between the two; this is seen in the field as well as in thin section. It varies in thickness from 1 m in the South to approximately 10 m near Forcarey in the North-West (the thickness there is probably due to F_2-folding), and is locally absent, due to boudinage.

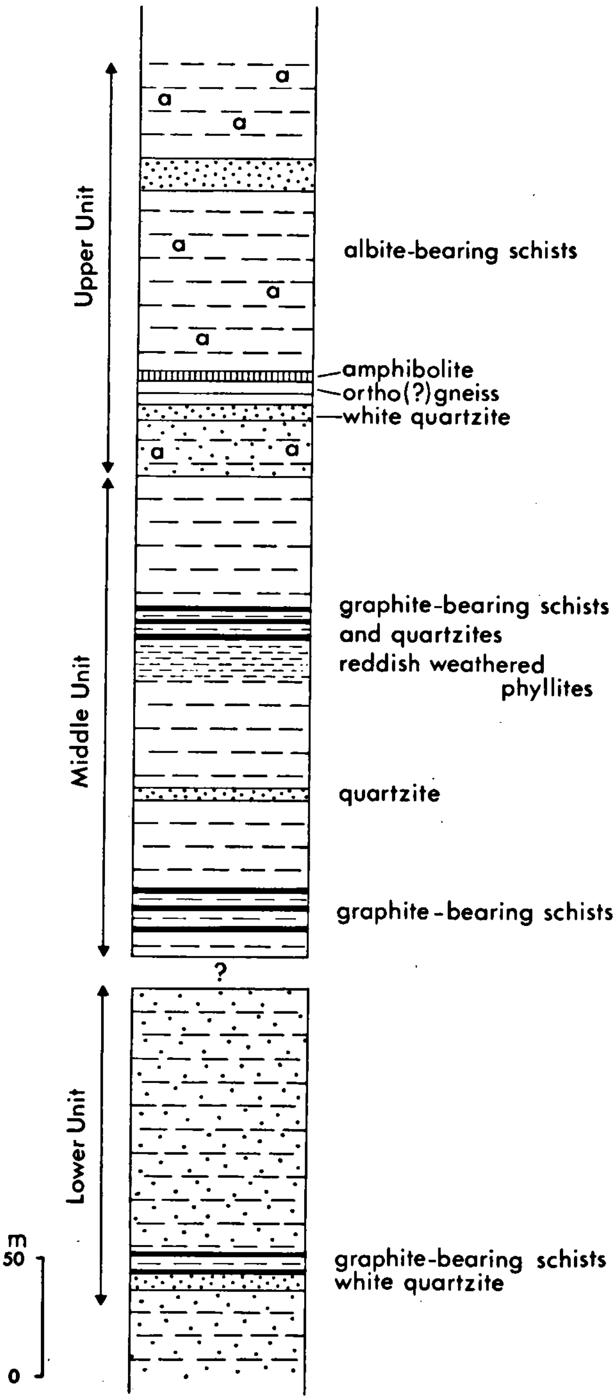

Fig. 2. Schematic lithostratigraphic column (after Roos, 1974).

STRUCTURAL ASPECTS

At least two folding phases are present. The first phase has generated a schistosity plane S_1, which is in general the main schistosity in this area. It has a NNW–SSE strike and normally dips to the West. The S_1-schistosity is mostly a fracture cleavage in the sense of Ramsay (Ramsay, 1967, p. 177). An alternation of muscovite-sericite layers with quartzrich layers, each about 1 mm thick, is clearly visible in thin section. Van Meerbeke et al. (1972) give some examples of an S-surface older than S_1, which is only visible in thin section; they call this surface S_0. S_0 occurs as polygonal arcs of muscovite and chlorite in areas where S_1 is a crenulation cleavage.

In the field F_1-folds are very rare. The few F_1-fold axes observed, plunge approximately 30° NNW. In thin section evidence of F_1 exists as:

a) polygonal arcs of S_0,
b) small isoclinal folds with S_1 as axial plane.

However, both features are rare.

The influence of the second folding phase F_2 is visible throughout the area, but the western part is folded more intensely than the eastern part.

The angle between the limbs of the F_2-folds varies from 40°–90°. The folds are asymmetric and the axes are subhorizontal with a NNW–SSE trend. The axial plane varies from vertical to a steep easterly dip in the West, to a westerly dip of approximately 50° in the East.

On a microscale, S_1 is commonly crenulated by F_2. The crenulation varies from more or less symmetric to strongly asymmetric. In rare cases a new crenulation cleavage S_2 has formed. However, more often only the direction of the F_2-axial plane is indicated by a preferred orientation of coarse-grained muscovite. Randomly grown muscovites have been reoriented parallel to S_2 due to the F_2-deformation (van Overmeeren, 1973).

Megastructures

The sequence of white quartzite, amphibolite layers and gneiss situated in the lower part of the Upper Unit (stratigraphic column Fig. 2) was used for mapping large-scale structures. In Figure 3 this sequence indicates a fold-structure. The asymmetry of small parasitic F_2-folds indicate that it is an asymmetrical synform. The axis of this synform has a NNW–SSE trend with a plunge of approximately 15° to the North. This axis runs from the Avión granite in the South, west of the Beariz granite to Forcarey in the North.

The short western limb of the synform is situated east of the western two-mica granite. This limb is subvertical and contains many parasitic F_2-folds. The hinge zone of the synform is characterized by symmetrical parasitic folds. The eastern limb, which is the long limb contains parasitic F_2-folds near the hinge, but these become less common to the East.

METAMORPHISM AND ISOGRADS IN RELATION TO TECTONIC EVENTS

The metamorphism varies from greenschist facies to lower amphibolite facies. Several metamorphic zones have been mapped by van Meerbeke (van Meerbeke, 1972; van Meerbeke, Hilgen & Floor, 1973). These zones are indicated by isograds (Fig. 1) which are based on the first appearance of biotite, garnet, staurolite and andalusite. Schists below the biotite-isograd occur mainly in the center of the area, while schists of a higher grade of metamorphism surround this center.

The groundmass of the schists of the Lower- and Middle Unit becomes coarser with the increase of metamorphism;

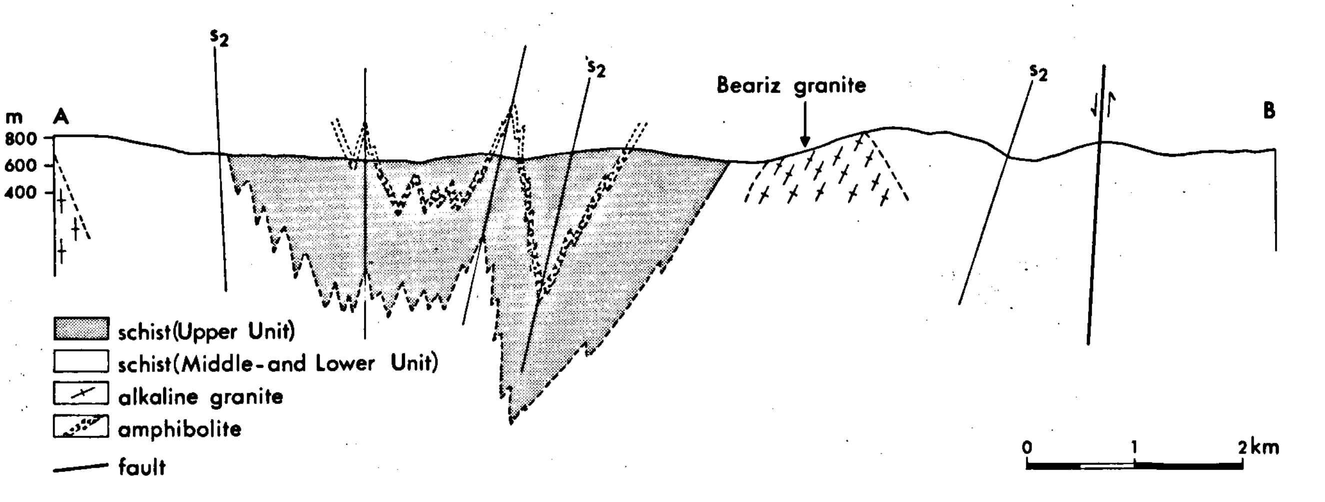

Fig. 3. E–W profile (A–B in Fig. 1) showing a synformal F_2-structure.

however, this is a minor feature. In schists of the Upper Unit the groundmass of quartz, biotite, muscovite and chlorite is coarse-grained. Quartz is often recrystallized. The micas are fine to coarse-grained and define the S_1-foliation.

The typical metamorphic minerals of the Hercynian metamorphism in this area: biotite, garnet, staurolite and andalusite, generally have a porphyroblastic habit. Albite and muscovite also occur as porphyroblasts. The different properties and relationships to tectonic events of these porphyroblasts are as follows:

Biotite exists as two generations: light-coloured, sometimes boudinaged small flakes parallel to S_1, and a coarse-grained dark biotite, often with numerous inclusions indicating a straight fabric. S_2-micas are bent around the latter, therefore this generation must have grown before F_2; the straight S_i represents the unfolded S_1. The small, light-coloured biotites are associated with F_1, for they are oriented parallel to S_1.

Garnet porphyroblasts occur in two different types. These types have great similarities with the type I- and type II-garnets of the Lalín Unit (Hilgen, 1971). For that reason the different types of garnet will be mentioned in this paper also as type I and type II. Schematically the different properties of the two types are given below.

	Type I	Type II
size	commonly < 1 mm	1–3 mm
shape	commonly round	idiomorphic
corrosion	present	never found
inclusions	few	common
'dusty' cores	sometimes present	never present
alteration products	chlorite	limonite

In general the size of a porphyroblast is not an indication of two different types. In thin section one can see several stages of crumbling apart of the garnets of type I. So, originally garnets of type I were large and in that case they have 'dusty' cores, but at present these garnets are mostly broken into more or less rounded grains (Fig. 4). The type I-garnets only occur in the albite-bearing schists. There are a few examples of garnets of type I occurring within albite porphyroblasts, but the type II-garnets are never found as inclusions.

The relationships between the different garnets and the several S-surfaces are not always clear, especially for type I. Because the type II-garnets have straight inclusions

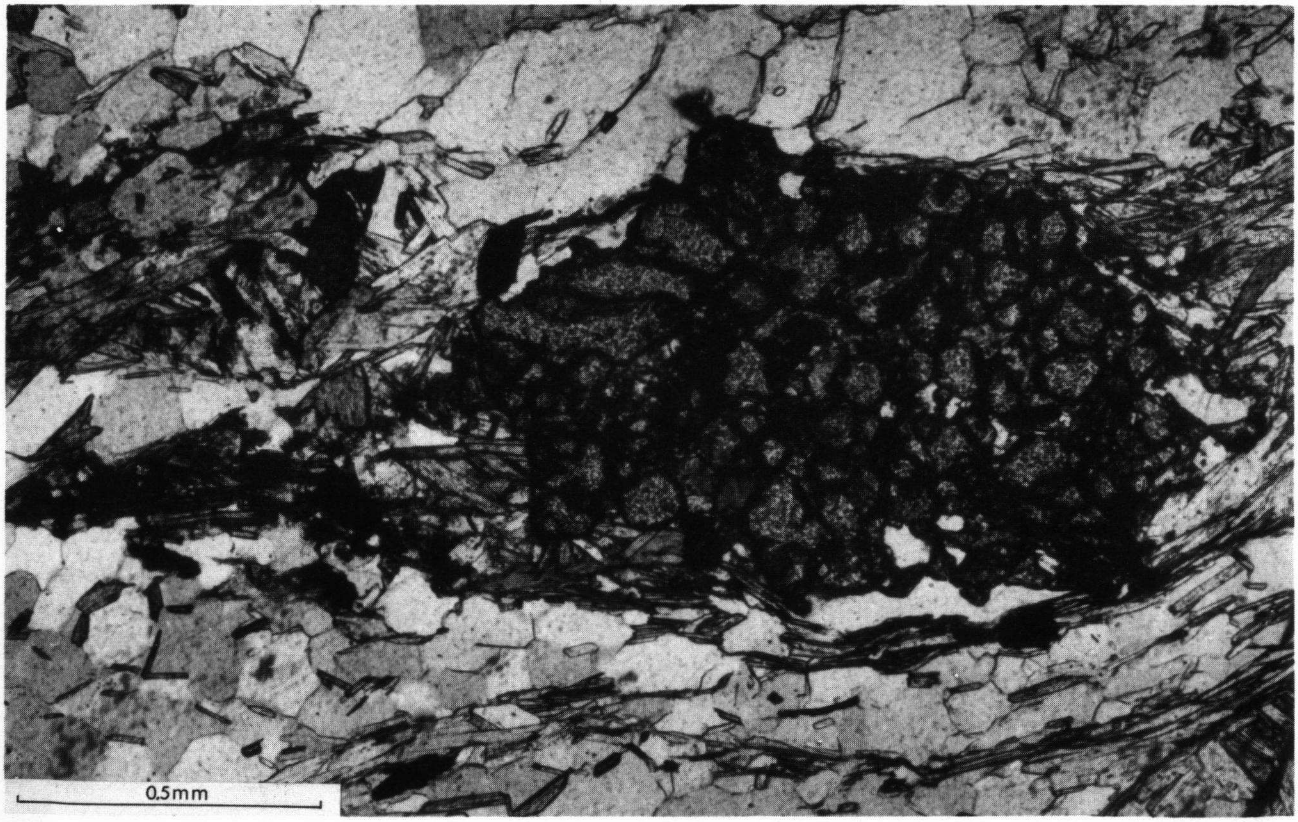

Fig. 4. Type I-garnet broken into more or less rounded grains. Garnet-, albite porphyroblast-bearing biotite-muscovite schist; specimen M-47-186 D_2 (polarizers at 110°).

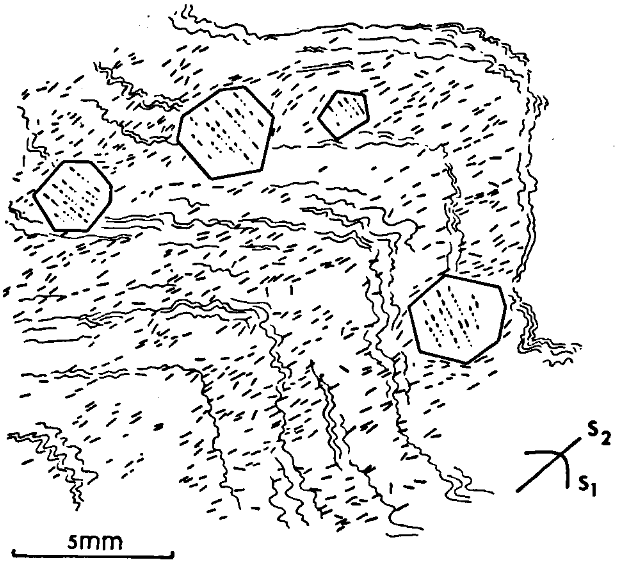

Fig. 5. Idiomorphic garnet porphyroblasts of type II with straight Si. F_2-fold crenulating S_1 with the formation of muscovite flakes parallel to S_2. S_1-micas bend around the garnet porphyroblasts. Garnet porphyroblast-bearing muscovite-chlorite schist, specimen M-171/186 E_1. (Fig. 3a from van Meerbeke e.a., 1973).

($S_i=S_1$), and S_2-micas bend around them (Fig. 5), they are believed to have formed between F_1 and F_2.

There are several striking similarities between the type I-garnets and the pre-Hercynian garnets found in the metasediments of the blastomylonitic and polymetamorphic 'Graben' in western Galicia (Floor, 1966; den Tex & Floor, 1967; Arps, 1970) and in the Lalín Unit (Hilgen, 1971). However, there is no proof that the type I-garnets in the area studied are pre-Hercynian.

Staurolite porphyroblasts are rich in inclusions. The inclusions form a straight fabric and S_2-micas bend around the porphyroblast, so staurolite have formed between F_1 and F_2. Sometimes garnet (type II) and biotite is found enclosed in staurolite; the reverse has never been observed.

Andalusite is strongly related to the several granites in and around the present area; it is only present adjacent to these granites. Two generations of andalusite have been observed. The inclusions in the older generation (andalusite I) form a straight fabric ($S_i=S_1$), therefore the formation of these andalusites was between F_1 and F_2. These andalusites are associated with the western granite, the Beariz granite and the Avión granite. The andalusites related to the Ribadavia granite and the migmatitic complex south-east of the area (andalusite II), are post-F_2, for these porphyroblasts have helicitic inclusions, and they are often oriented randomly (van Meerbeke, 1972; Roos, 1974).

Albite porphyroblasts are mainly restricted to the schists of the Upper Unit. The An-percentage varies between 4–8 with an average value of 5%. Large porphyroblasts (up to 1.5 mm) are rich in inclusions. Opaque ellipsoid 'patches', muscovite, biotite, chlorite, tourmaline, graphite, quartz 'droplets', rutile, zircon, apatite(?) and occasionally garnet (type I) are the inclusions. In general these inclusions indicate a straight fabric ($S_i=S_1$). The appearance of the albite porphyroblasts in thin section is very much the same as that of the albite found in the paragneisses in the blastomylonitic 'Graben' (e.g. Floor, 1966; van Zuuren, 1969; Arps, 1970); the quartz 'droplets' are especially typical. In addition to the special type of garnet (I), this is another similarity with the older, polymetamorphic rocks of Galicia.

Since S_2-micas bend around the albite, albite is believed to have grown before F_2.

After the second folding phase a retrogradation has given rise to chlorite. There is some primary chlorite in pressure-shadows, and as radiating aggregates, but this mineral is mostly of secondary origin. It is commonly replacing biotite, which retrogresses to a mixture of chlorite and rutile (sagenite).

The mineral growth in relation to the several folding phases is given in a schematic form in Fig. 6.

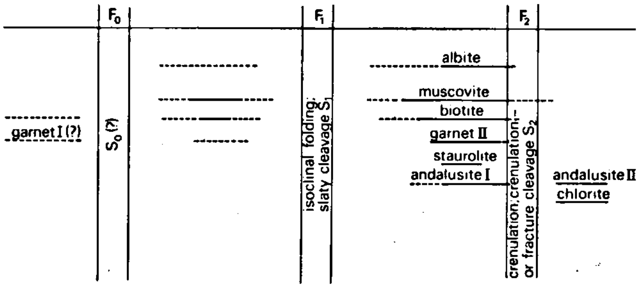

Fig. 6. Relation between the folding phases and mineral growth.

An interpretation of the structural pattern of the isograds is given in the next chapter.

CONCLUSIONS AND DISCUSSION

1. The rocks of the area are folded into a large asymmetric F_2-synform.
2. Since most porphyroblastic minerals have grown before F_2, isograds must also have been folded by F_2 (van Meerbeke, et al., 1973). The disposition of the isograds is consistent with this interpretation. The disposition of the isograds east of the Beariz granite suggests another synform, but structural evidence for this has not been found.
3. Two different types of garnet have been found, type I and type II. The garnets of type II are the same as the Hercynian garnets elsewhere in Galicia. On the other hand great similarities between the type I-garnets and the garnets found in the polymetamorphic areas in Galicia, have also been observed. The type I-garnets occur only in the albite-bearing schists, which occur at the top of the lithostratigraphic column.

Also lithologically there is a great resemblance between the rocks of the Upper Unit and the paragneisses of the Lalín Unit (Hilgen, 1971), and the polymetamorphic paragneisses elsewhere in Galicia, which suggests a similar age and geological history for the former as well.

4. The older rocks of the Lalín Unit are lying on top of younger rocks (Hilgen, 1971). In the present area the same situation has been found.

Several explanations can be envisaged for this:

a) the complete sequence has been inverted,

b) there is a tectonic contact between the albite-bearing schists and the underlying pelitic schists,

c) a combination of a) and b).

According to a) and c) the sequence should be interpreted as the overturned limb of a large subhorizontal, isoclinal F_1-fold. However, the hinge zone of such a megafold has not been found in the investigated area. If, on the other hand, there is a tectonic contact between the albite-bearing schists and the pelitic schists, the former could have been thrust upon the latter. A recent preliminary investigation by Hilgen gives some indications of the presence of a thrust plane between the ortho(?)gneiss and the white quartzite (Fig. 2) (oral comm.). Since there is no discontinuity in the F_1-structures between the two types of schists, the thrust plane must be older than F_1. E–W structures, common for pre-Hercynian rocks (e. g. Engels, 1972; Hilgen, 1971), however, have not been found in the albite-bearing schists.

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