GEOLOGY OF TORNAFORT AREA, CENTRAL PYRENEES, NOGUERA DE PALLARESA, PROV. DE LERIDA, SPAIN

by

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INTRODUCTION

A small area limited in the north by the Boca del Cantó, in the west by the Pallaresa river and in the south by the crest of the Montaña de Bahent and reaching westwards as far as the village of Feixa was surveyed in detail. Previous work by Prof. de Sitter and some of his pupils had revealed that in the steep southern slope of the Boca del Cantó several recumbent folds occur with Ordovician shales in the anticlinal cores and Devonian in the synclines. The work was carried out on the topographical base of an 1:25.000 enlargement of the official 1:50.000 map, sheets 214, Sort and 215 Seo de Urgel, which proved to be far from satisfactory. Aerial photographs were not available.

The Tornafort area is limited in the north by an important fault, which runs practically in the bed of the Boca del Cantó. This fault forms the southern limit of the axial zone of the Pyrenees, north of it we find the Lower Triassic conglomerates, sandstones and shales covering unconformably strongly microfolded non metamorphic Ordovician. Near the mouth of the Boca del Cantó this clastic Trias is covered by the evaporite facies of the Keuper, with ophites and muschelkalk floats. The latter formation forms also the western boundary of our region on the lower slopes of the Tornafort hill towards the Pallaresa river, again separated from the Paleozoic by a north-east trending fault. Thus the Tornafort area forms the northern border zone of the Nogueras zone as it has been defined by Peter Misch (1934). This Nogueras zone is known to have been strongly deformed by alpine orogeny because a little further south and west we see that the paleozoic has been folded together with the Triassic. A section by de Sitter (1957) crossing the Pallaresa river just west of our region shows a Devonian anticlinal core with Trias in the flanks. Our Tornafort region, however, is separated from the structure given by this section by a thrust along which the Devonian with Silurian at its base has been thrusted on the Triassic. This thrust forms the southwest boundary of our map, and the Tornafort structure does not seem to be connected with the just mentioned anticline, as has been done by de Sitter in his section, where the Tornafort structure is drawn as the core of a second anticline further south.

STRATIGRAPHY

Ordovician

The oldest rocks exposed in the area, in the cores of the anticlines and only in the lower part of the slope belong to the Upper-Ordovician. The

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rocks are similar to those described in other places in S. Pyrenees (De Sitter, 1956 and 1957): a monotonous series of lime-free fine-clastics, from shales to argillaceous-micaceous sandstone of subgraywacke type. In the upper horizons pure quartz-sandstones are more abundant. A large ortho-quartzite lenticular body is exposed some 800 m WSW of Soriguera. Limestone lenses of different sizes were observed close to the upper boundary. A well-rounded quartz-conglomerate marks in places the top of the Ordovician, in particular west of the village of Tornafort but in most of the cases the Ordovician-Silurian boundary is transitional, the rocks becoming more shaly and limy upwards, and changing into the black shales of the Silurian.

The Ordovician here, as well as all the overlying formations are not affected by metamorphism. Microfolds are abundant. Bedding is usually easily identifiable. Fossils are rare. Two brachiopods have been found. Of a more common occurrence are some small, pitted spheroidal to oval cavities (cistoidae?), which were found in the Ordovician only.

The greasy outlook, as well as the polyhedral weathering, aid to the identification of the Ordovician outcrops.

Silurian

Silurian is represented here by the typical black shales, as well as by well-bedded Orthoceras-limestone, brownish-pink shales, and a massive dark gray-blue crystalline limestone, composed entirely of crinoidal remains (calcaire à entroques), with many large irregular calcite veins. This limestone is not persistent and of a biohermal appearance, is markedly different from the above-lying Devonian limestone. Crinoids and orthoceratites are abundant. The graptolite-shales, however, were not encountered here. The upper boundary was arbitrarily chosen as the base of the massive dull-gray limestone of the Devonian which is an easily discernible horizon for mapping purposes.

The incompetent Silurian is missing in many places between the Ordovician and the Devonian, for the same tectonical reasons as elsewhere in the Pyrenees. In some outcrops it appears completely slickensided.

The black graphitic shales, or the crinoidal limestone, the land-slide topography, and the presence of springs, are the characteristic landscape-features of the Silurian.

Some of its non-typical limy shales, however, are similar to some of the non-typical Carboniferous shales.

Devonian

The Devonian is predominantly calcareous. Its lower part consists of a gray, hard massive, crystalline limestone. Some pink to dark brown hard calcareous shales were encountered. Badly preserved fossils (fragments of crinoids and corals) are revealed by weathering.

The upper part of the Devonian is composed chiefly of the griotte-limestone. A definite boundary between the lower massive complex and the upper well-bedded griotte-limestones could not be defined; nor was it possible to determine the thickness of these two units. The boundary, therefore, was not mapped, but wherever the presence of the griottes was certain, this was marked on the map.

The griotte-limestone is sometimes quite shaly and ferruginous. This and its comparatively thin and sharp bedding could explain that most of the tectonic transport within this formation was done along the bedding planes,

whereas in the Lower Devonian massive limestone cleavage predominates. As a rough estimate the thickness of the Devonian here would be 300—400 m.

Carboniferous

The boundary between the Devonian and Carboniferous (Visean) is in some places sharp: fine grained conglomerate (quartz — or lydite —) passing upwards into grits, micaceous sandstone, sandy shales, shales. The predominant colour is dark gray. In some places, however, the transition from the Upper Devonian griottes into the Carboniferous clastics is gradual, being marked by an alternation of griottes, cherts and shales.

The Carboniferous clastics are easily discernible from the Ordovician, on account of their comparatively large and abundant mica flakes, as well as their slate-like bedding and absence of microfolds. Fossils were not found and the top is not exposed.

Trias

Fringing the area all along its southern and western boundary, the Triassic was beyond the scope of this survey.

Tertiary and Quaternary

The terrace of Tornafort is covered in many places by a thick overburden of drift.

A brownish limestone, sometimes of large brown rhombohedral calcite crystals, was found here and there in small sporadical outcrops. Some of them would point to a secondary Karstic or to a hydrothermal origin.

A consolidated talus breccia is well-developed above Soriguera.

IGNEOUS BODIES

Igneous bodies occur in three outcrops:

1. 500 m SE of Puigfornin, on the right hand of the road, an igneous body is exposed in the wall facing the road and inside the gully running from SE. Its top contacts are concordant with the uplifted limestone, plunging down to the W. Its contact with the Ordovician in he East runs in the gully and is covered by alluvium. The rock at the base of the exposure is an aphyric biotite-quartz-microdiorite, passing gradually towards the top into a quartz-free- to biotite-hornblende-meladiorite (field-determination only). The contact with the above-lying limestone is sharp, the latter being recrystallized to a thickness of 3—4 m (fig. 1).

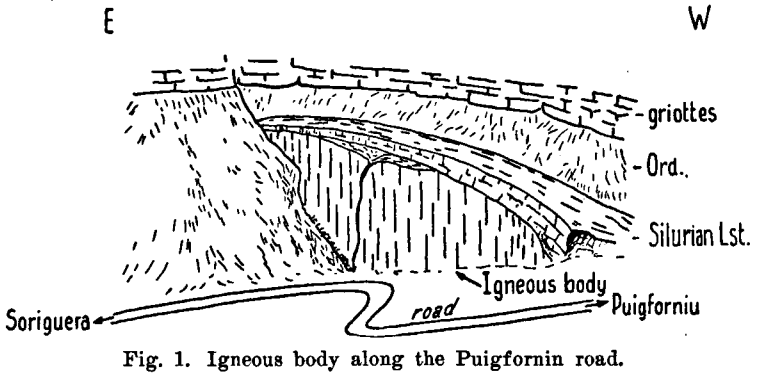

Fig. 1. Igneous body along the Puigfornin road.

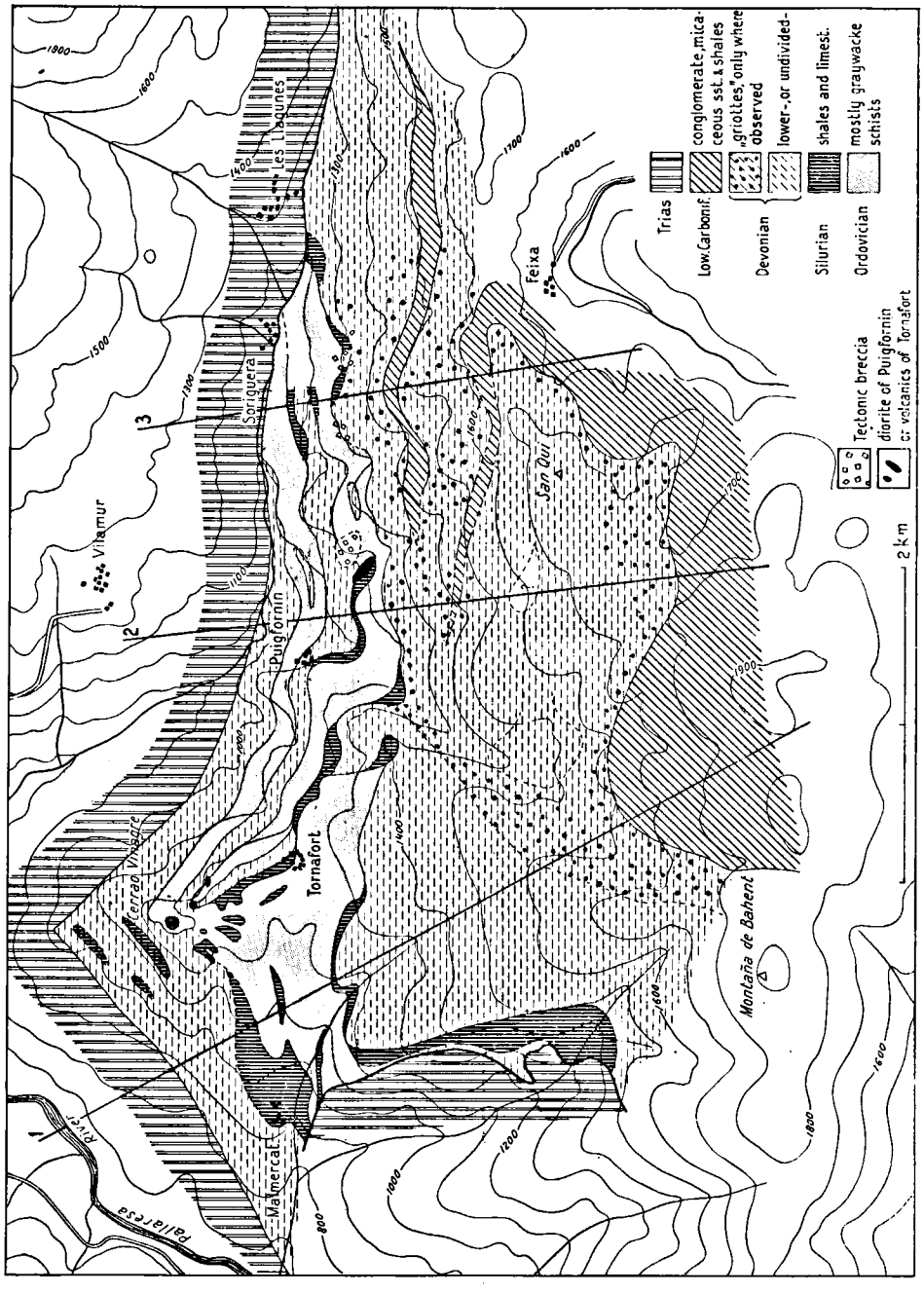

Fig. 2. Map of the Tornafort area, Upper Pallaresa valley, with section lines.

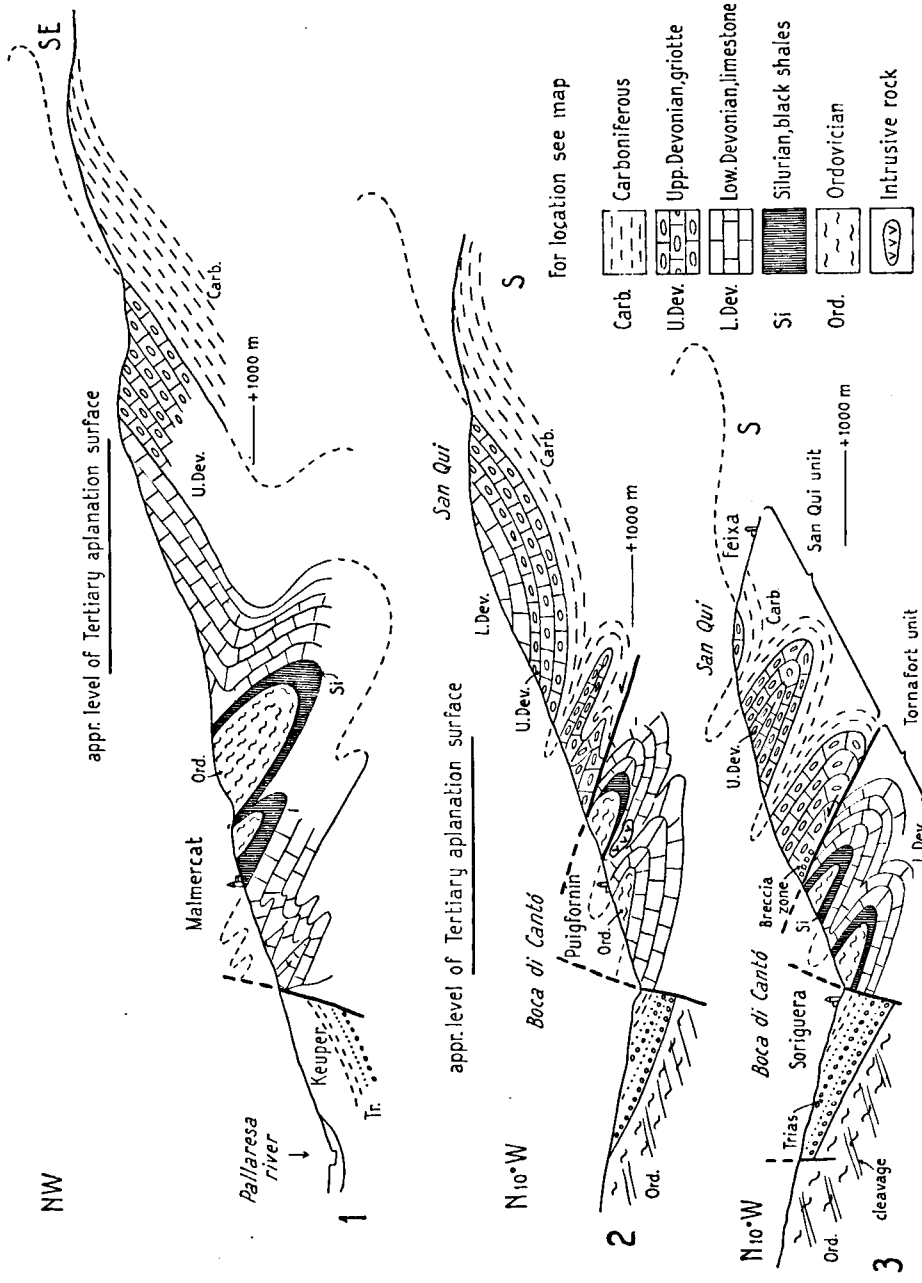

Fig. 3. Three cross sections through the recumbent folds of the Tornafort area (see map, fig 1).

2. A small outcrop of a green aphanitic rock, 200 m SE of Malmercat on Ordovician-Silurian boundary. Field relations were difficult to establish.

3. An altered lava or tuff outcropping both N and S of the Tornafort ridge in what seems to be the top of Ordovician.

Although all the above-mentioned igneous bodies were found at the same stratigraphical horizon, it was not possible to find any petrological analogy in the field or correlation of date of intrusion.

STRUCTURE

The Tornafort area is built up of a series of flat lying and overturned recumbent folds, with a more or less Southern direction of movement refolded in a later stage along a NE—SW axis.

Two distinct units can be distinguished. The topographically lower part, the Tornafort unit, consists of a series of at least three folds, having Ordovician in their anticlinal cores and lower Devonian limestone in the synclines. At the center, between Tornafort and Puigfornin, the axes have an E—W trend, they plunge both east and west. In the east they are cut-off by the Bco del Cantó fault. Towards the west their plunge becomes quite steep, the folds fan out (northwest of Tornafort, between Malmercat and Cerrao Vinagre) and are cut-off by the Pallaresa fault. In the southwest, they are truncated by Triassic (S of Malmercat) along a thrustfault, the front-line of the latter cutting across the axes of the former.

The topographically higher part, the San-Qui unit, consists of a series of at least three folds, developed in the eastern part only, having Devonian in the anticlinal cores and Carboniferous in the synclines. The axes run E—W. From a line running N—S, approximately from Les Llagunes to Feixa, the synclinal cores of Carboniferous pinch out towards the west.

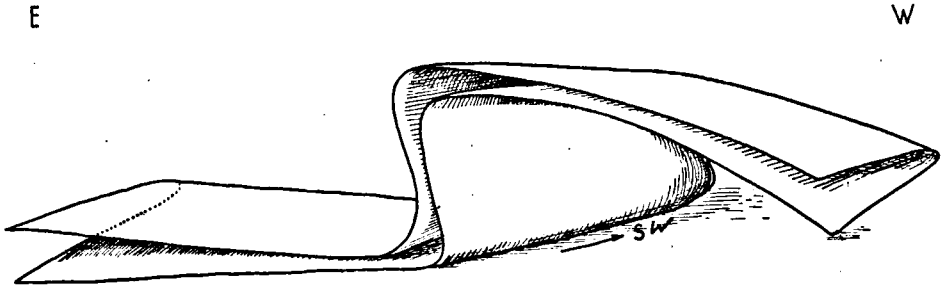

Fig. 4. Refolding of one of the recumbent folds.

Refolding

The element, which makes the structure of this area complicated, is the refolding of the above-mentioned folds along a NE—SW axis, running roughly parallel to the canyon south of Puigfornin. Its SE flank is vertical to overturned and can be studied along the NW wall of the canyon. Here, one can see the refolded griotte-mass cascading down in flat-lying secondary folds. The latter have a SW to WSW axis, plunging mostly SW but some of them also NE. (fig. 5) This superimposed structural element accounts for the knick in the outlines of the outcrops on the map. The amplitude of this

NE—SW fold is quite large, but no other fold, having the same direction, was found in the area between Malmercat and Soriguera.

The breccia zone

The boundary between the Tornafort and San-Qui units is marked by a zone having the following characteristics:

1. Starting from a point just above the source of Puigfornin and down to a point between Soriguera and Les Llagunes in the west, the Silurian or Ordovician are overlain directly by griottes and not by the massive limestone of the Lower Devonian.
2. Wherever good exposures allow it, one can see the well-bedded griottes assuming a different position from the underlying Ordovician. For instance, above the Puigfornin source, well-bedded, shaly, ferruginous griottes, dipping 60°/ N 70°W lie on Ordovician sandy shales, dipping gently to the SSW.
3. In some of the good exposures in the canyons, these griottes can be seen thrown into cascade folds with an average axis trending NW.

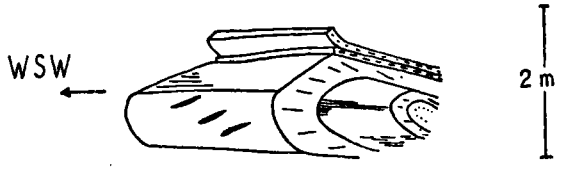

Fig. 5. Griotte limestone folds in Puigfornin canyon.

4. In many places along this zone both the Ordovician and the griottes are brecciated. The degree of brecciation varies from internally fractured beds within the folded griottes to breccia masses, which after a closer study reveal "shadows" of the original bedding. At one outcrop this zone is represented by a 3 m thick layer of coarse-grained calcite rock; the large calcite crystals being in places fractured.

This "breccia zone", starting in the W at the lower hinge of the NE—SW fold, forms a continuous structural terrace towards the ENE, until it reaches the Boco del Cantó fault.

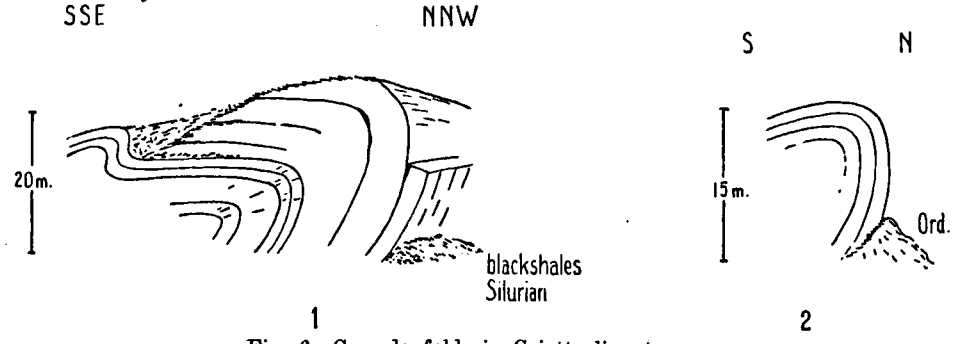

Fig. 6. Cascade folds in Griotte limestone.

Sequence and interrelation of the tectonic elements

The Tornafort and San-Qui folds are most probably of Hercynic age. (The Trias not being involved). Their present steeply-overturned to recumbent position is of a later stage. Whether this later tilting is of a late Hercynic stage or belongs already to Alpine movements, could not be established within the limits of this area and the time spent in the field. The discordant relation between the overthrusted Trias and the Paleozoic folds near Malmercat above, would suggest a late Hercynic tilting of the folds, but a more careful study is required to draw conclusions on this point.

As to the refolding on the NE—SW axis, this belongs evidently to a later stage, but, for the same reasons, its exact age could not be determined.

The "breccia zone" is regarded as a detachment zone caused by stretching and rupture inside an intensely folded body. This could be caused during the first stage of Hercynic folding, but it could as well be attributed to the NE—SW refolding. In this case, the thinning at the limbs of the new fold would explain its presence, as well as the orientation of the cascade folds in the canyon.

MORPHOLOGY

A conspicuous aplanation level occupies the 1700 m elevation. Above these flat-lands the slopes rise steeply to the 1900 m elevation of the crest of the Montaña de Bahent and fall still more steeply to the N and W; the steepest slopes being cut between 1400—1700 m. Twice the slope is interrupted by flat terraces viz.:

1. The Tornafort half-dissected 1200 m terrace is probably a purely morphological feature, i. e. a river terrace as many similar terraces observed at different levels along the Pallaresa.
2. The structural terrace between Puigfornin and Soriguera, mentioned above.

Karst

Between 1400—1700 m fossil Karst-phenomena in Devonian limestone (with preference to griottes)are encountered. Its fossil character is clearly established by the now exposed and partially denudated sink-holes, tunnels, etc. (making the climbing quite dangerous). A beautiful, small, cultivated, hidden valley at 1380 m elevation, above Soriguera, with no drainage, is probably a dolina. It is situated in griottes and its floor is gently inclined to the S towards the high mountain cliff.

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