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# ADDITIONAL GEOMORPHOLOGICAL DATA ON THE RIA AREA OF WESTERN GALICIA (SPAIN)

BY

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## ABSTRACT

The geomorphology of western Galicia is reconsidered in the light of Nonn's monograph (1966), and an envelope map of the relief, as defined by Stearns (1967) and Pannekoek (1967), and an interpretation of the latter are also presented. The envelope map shows more clearly than an ordinary contour map that the major relief features are not controlled by the lineations of the Hercynian basement but by late- or post-Hercynian faults, some of which may have been reactivated in Tertiary times.
Concerning the geomorphological evolution, the author agrees with most of Nonn's conclusions, although there is some divergence on minor points. The isolated mountain massifs, capped by remnants of older pediplains, already existed in Upper Miocene times. The depressions between these massifs, including the long median depression, are, much more than was previously presumed, the result of erosion along pre-existing fault lines, first during the Miocene and then during the Pliocene: only a few are bordered by post-Pontian fault scarps.
Finally, tentative reconstructions of the Upper Miocene and the Pliocene topography are given.

## SUMARIO

*Datos geomorfológicos adicionales sobre la región de las rias de Galicia occidental*

La geomorfología de la Galicia occidental es vuelta a ser enfocada tomando en consideración la monografía de Nonn (1966). Igualmente se presenta un mapa "envolvedor" del relieve, tal como ha sido definido por Stearns (1967) y Pannekoek (1967), dándose una interpretación del mismo. El mapa "envolvedor" muestra mas claramente que un mapa de contornos ordinario, que las características principales del relieve no son contraladas por las alineaciones del basamento hercínico sino por fallas de origen hercínico tardío o posthercínico, alguna de las cuales pueden haber sido reactivadas durante el Terciario.
En lo que se refiere a la evolución geomorfológica, el autor esta de acuerdo con la mayoría de las conclusiones de Nonn, aunque si hay alguna divergencia en puntos menos importantes. Los macizos montañosos aislados, cubiertos por restos de "pediplain" mas viejos, existían ya en el Mioceno superior. Las depresiones entre estos macizos, incluída la depresión media alargada, son, mucho mas que previamente fue supuesto, el resultado de una erosión a lo largo de líneas de falla preexistentes, primero durante el Mioceno y consecutivamente durante el Plioceno. Solamente unas cuantas depresiones son bordeadas por escarpas de fractura de origen post-Pontiense.
Finalmente, se dan reconstrucciones tentativas de la topografía del Mioceno superior y del Plioceno.

## RÉSUMÉ

*Données supplémentaires sur la géomorphologie de la région des rias dans la Galice occidentale (Espagne)*

La géomorphologie de la Galice occidentale est passée en revue par l'auteur, compte tenu des résultats de la monographie de Nonn (1966). En outre, une carte de l'enveloppe du relief, dans le sens de Stearns (1967) et Pannekoek (1967), est présentée (fig. 1), ainsi qu'une interprétation de celle-ci (fig. 2). Elle montre, d'une façon plus claire qu'une carte ordinaire, que les traits majeurs du relief ne sont guère déterminés par les linéations hercyniennes mais par des failles et fractures fini- ou post-hercyniennes, dont quelques-unes ont rejoué au Tertiaire.
Quant à l'évolution du relief, l'auteur se range aux principales conclusions de Nonn (fig. 3), bienqu'il y ait des divergences sur quelques questions secondaires. Les massifs montagneux, couronnés par des fragments de pédiplaines, existaient déjà au Miocène supérieur. Les dépressions entre ceux-ci, y compris la grande dépression médiane, sont dans une plus large mesure qu'on ne l'avait supposé jadis, le résultat d'érosion suivant des failles et fractures préexistantes, d'abord pendant le Miocène, ensuite pendant le Pliocène: seules quelques-unes des pentes rectilignes sont des abrupts de faille.
Enfin l'auteur donne des reconstructions très conjecturales de la topographie miocène supérieur (fig. 4A) et de la topographie pliocène (fig. 4B).

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## 1. INTRODUCTION

There are two reasons for reconsidering the geomorphology of the area around the Ría de Arosa in western Galicia, described in my earlier paper in this volume (Pannekoek 1966a, see also 1966b). The first is the publication of H. Nonn's monograph on the

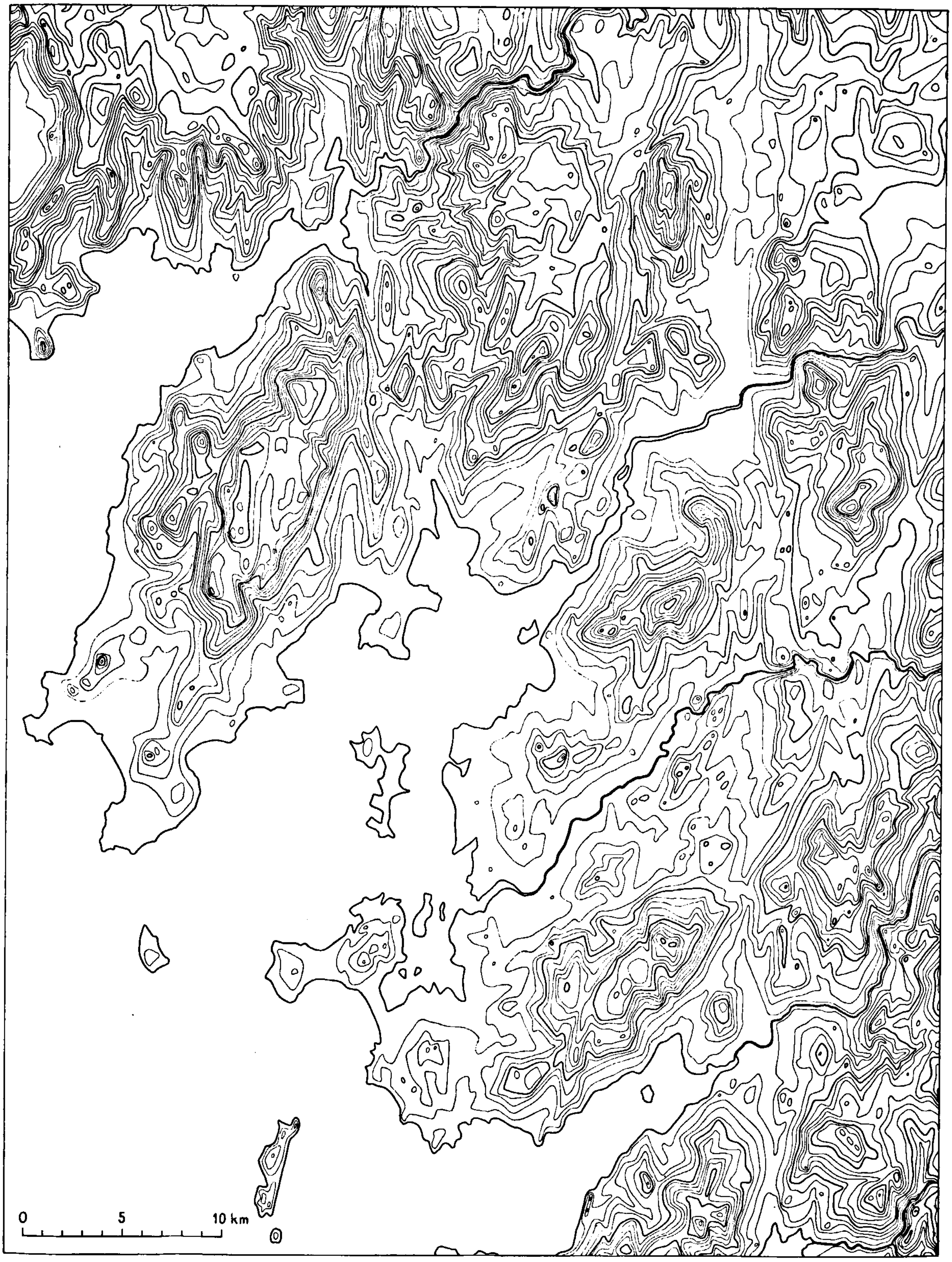


Fig. 1. Envelope map of part of western Galicia. Scale 1:300,000. Contour interval 40 m.

geomorphology of the whole of western Galicia (Nonn 1966, summarized in Nonn 1969), which, besides lengthy descriptions, contains a wealth of information and important conclusions on the evolution of the relief in the area under consideration. The second reason is the completion of an "envelope"

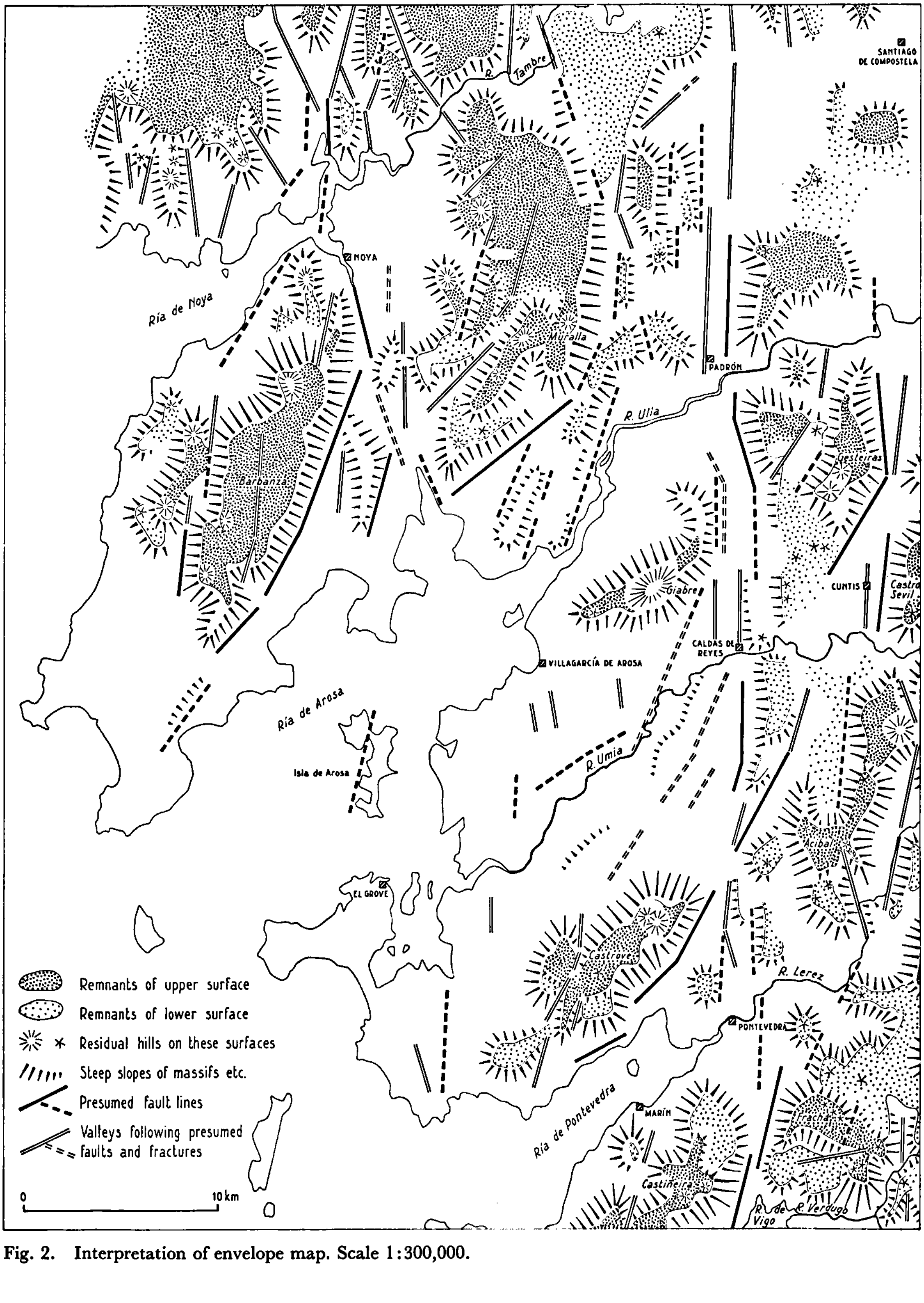


Fig. 2. Interpretation of envelope map. Scale 1:300,000.

or "enveloping surface" map of part of western Galicia (Fig. 1) and of an interpretation of the latter (Fig. 2), from which additional information can be derived and which will be considered in the light of Nonn's conclusions.
The enveloping surface map will be dealt with first.

## 2. THE ENVELOPE MAP

The construction of an enveloping surface, or envelope, can be done by generalizing contours in such a way that the effect of dissection of the relief by small valleys is eliminated (Pannekoek 1967, Stearns 1967). This is accomplished by connecting the points of a contour lying at the outward edges of the spurs between the minor valleys, thus obtaining a generalized contour. This new contour is thus tangent to the actual surface and "jumps" across valleys[2]. It shows much more clearly than the original contour map the major relief features, as it were the relief before it was dissected by minor valleys (although such a situation need not have ever existed), but it intentionally obliterates other aspects of the relief, such as the detailed drainage network and its adjustment to the lithology.
The envelope map of western Galicia clearly shows how the relief, formed upon crystalline rocks, consists of isolated mountain blocks, mostly capped by a rather flat surface and bounded by steep, often rectilinear slopes. These mountains are separated by low hilly areas and wide depressions, into some of which the sea penetrates deeply to form the well-known west-Galician "rias".
The same features can, of course, be seen on an actual, ungeneralized contour map, but the generalized, or envelope, map shows more clearly the straightness of many mountain slopes, the flat top areas, and the general arrangement of the major relief elements.

## 3. INTERPRETATION OF THE ENVELOPE MAP

The second map (Fig. 2), which gives an interpretation of the envelope map, is kept very simple. It distinguishes:
(a) the flat, plateau-like upper surfaces of the mountain blocks, differentiated into (a1) a higher level, roughly above 400 m, and (a2) a lower level (between 200 and 400 m)[3] separated by a steeper slope. Also, the main residual hills on these surfaces are shown by a symbol;
(b) the steep, often rectilinear slopes of the mountain masses, which may in many cases be related to faults or fractures;
(c) faults or fractures, which are drawn tentatively along the foot of such slopes, although, since they cannot be observed directly, their actual positions may be different;
(d) some straight valleys, which are presumably also controlled by faults or fractures.
It should be stressed that the straight mountain slopes, if controlled by a fault, need not be fault scarps. They may equally well be valley-slopes which have strongly retreated by back-wearing and which remained straight because the original valley followed a straight fault or fracture. Consequently, there is no essential difference between what is shown on the map as presumed faults (c) and as straight valleys controlled by a fault or fracture (d).
The elimination of the smaller valleys has at the same time caused the almost complete obliteration of the influence of the older Hercynian structures on the relief. This becomes obvious when a map showing the lineation of the metamorphic rocks (Floor 1968) is compared with the maps of Figs. 1 and 2. There is hardly a single major relief feature that follows the NNW-SSE trending Hercynian structure (some exceptional cases are a few valleys, too wide to be eliminated, on the flanks of Mt. Castrove and near Noya, following weak schist zones).
Many of the mountain blocks, for instance, consist of alternations of different types of rock (mica schists, gneisses, oriented and un-oriented two-mica granites; Floor 1968), the boundaries of which run obliquely across these massifs. The outlines of the massifs thus bear no relation to the rock differences, and the same applies to the wide depressions between these mountain blocks, in particular the median depression running through western Galicia from N to S.
In the area there is, however, one important exception to the independence of the gross topography from rock differences: the extension of the late-Hercynian intrusive Caldas-granite, a coarse-grained biotite granite, coincides with a low undulating topography with rounded residual hills and with some plateau remnants belonging to the lowest level (SE of Caldas de Reyes, 263 m). This situation is largely the result of the intense and rapid weathering of this granite. We will return to this point later (section 8).
Otherwise, the topography is largely controlled by faults and fractures running in new directions (particularly N-S and N 30° E) and belonging to a later phase; and some of which, as we shall see, were reactivated in late Tertiary times. Some of these faults have been found during geological surveys (and are accordingly shown on Fig. 2 in Floor 1968), but the presence of many more can only be assumed from topographic evidence. Their age is not known. They may date from a time directly after the Hercynian orogeny when, as in so many orogenic structures, tensional movements had succeeded compression. They could also date from the Mesozoic, and it is tempting to imagine a relation with the presumed opening of the Atlantic Ocean rift, or with the rotation of the Iberian peninsula and the formation of the Bay of

[2] Stearns limits the distance over which the new contour can run in the air between two points of the actual topography to a fixed maximum value, e.g. 2000 feet, 2 miles, depending on the scale. I have used more arbitrary distances.

[3] i.e. the „intermediate surface" of our 1966 paper.

Biscay before or during the lower Cretaceous (van der Voo 1969, Jones & Funnell 1968).
The median fault zone running through western Galicia from N to S follows, for a certain distance, an older direction (den Tex & Floor 1967) and may have been the site of transcurrent movements in Hercynian times. It was reactivated during and after the Miocene (see section 8), but there is as yet no evidence that these later movements were of a transcurrent nature: where a river is offset by a N-S fault, it may simply have followed a pre-existing fault for some distance; the offsets are, moreover, in both directions.

## 4. DATING OF THE TERTIARY SURFACES

Nonn (1966) distinguishes in the plateau covering extensive areas in northern Galicia (Fig. 3), three pediplain-levels of decreasing altitude and age:
(1) a highest level, bearing still higher residual hills, mountains, and even mountain-ranges;
(2) a second level, lying mostly between 440 and 480 m, i.e. some 80—100 m lower than the highest one and separated from it by a strongly indented slope;
(3) a third level at heights varying between 200 and 320 m and occurring mainly along the major valleys.
For dating these levels, he made use of various Tertiary deposits, in the first place those of Puentes de García Rodríguez (southeast of La Coruña). These deposits consist of an alternation of mainly kaolinitic clays and lignites with a total thickness of 220 m, probably deposited in a subsiding basin, and warped and faulted after their deposition. According to their plant remains, the ages of the lignites range from Tortonian to Pontian; they are underlain by clays of probably Aquitanian age and composed of attapulgite and illite. On the basis of their position in relation to the surrounding pediplain levels, Nonn correlates these lower clays with the second level, which is thus approximately dated as Aquitanian. The highest level must be older, and is referred to as "Eogene" (i.e. Paleogene). The third level is presumed to date from about the Tortonian, because lignites and clays (containing montmorillonite) of this age indicate a somewhat dryer climate favourable for the formation of pediments and pediplains. Personally, I am inclined to leave open the possibility that they continued to be formed till the end of the Miocene, like so many pediplains ("fini-Pontian surface") of the Iberian peninsula.
After the Pontian, the deposits were faulted and warped, which movements must also have affected the surrounding relief. The deposits thus reveal the existence of at least two Tertiary tectonic phases, the first marked by the subsidence of the basin (pre-Aquitanian, but continuing afterwards), the second at the end of the Pontian or beginning of the Pliocene. The latter may correspond chronologically with the post-Pontian tensional movements that led to the subsidence of the western Mediterranean basin.

## 5. THE DATINGS APPLIED TO THE RIA AREA

How these datings apply to the area of the West-Galician rias can best be seen on the geomorphological map accompanying Nonn's work (Fig. 3 shows a part of this map on a greatly reduced scale). The difficulty with such interpretational maps is that a relief feature has to be assigned to either one or another group distinguished in the legend, and doubts or transitional cases can only be expressed with difficulty (interrogation marks, transitional symbols, etc.). Actually, the events will have taken place more gradually, and any distinction of separate phases is a gross, although inevitable, simplification.
It will be clear that for a limited area, in which only small patches of the high surfaces have been preserved, there is no direct proof for their assignment to distinct levels. Such assignment was mainly done on the basis of their height, although this criterion neglects the possibility that the height may have changed owing to unequal uplift. Only where there is a definite step in such a high surface remnant, as on the Mt. Castrove, is there any justification for attributing both parts to different levels.
The two highest pediplain surfaces have, moreover, been subdivided by Nonn on his geomorphological map according to their preservation [4]. He distinguishes:
(a) well-preserved surfaces;
(b) degraded (i.e. lowered) parts of these surfaces;
(c) relief features derived from these surfaces, comprising rounded mountains which, as indicated by their heights, may originally have been part of such a surface.
Comparing Nonn's geomorphological map with our Fig. 2, we find that most of the "high surfaces" of the latter have been assigned by Nonn to his highest, or Eogene, level, as for instance those of the Castrove, Acibal, Gesteira, Castro Sevil, Muralla, and Barbanza massifs, most of which bear still higher residual hills; others, such as the Fracha, Domayo, and Giabre mountains, have been classified as "derived from the Eogene surface".
The "Aquitanian" level is represented by somewhat lower extensions of the Castrove, Fracha, Acibal, and Giabre mountains and by some larger plateaus, especially those on both sides of the Ulla River upstream from the median depression, those situated north of Muralla Mountain, and north of the Ria de Noya.
The third, Tortonian, level of Nonn's map, coinciding with our "lower surface", is found in small patches around the afore-mentioned mountain massifs, and in large areas (larger than we are inclined to attribute to this level) on both sides of the Umia River upstream from the median depression, and equally large areas on both sides of the median depression more to the north.
On the whole, there is a fair amount of agreement between his map and ours.

[4] This subdivison has been omitted in Fig. 3, the scale of which is five times smaller than the original. Many other details are also left out.

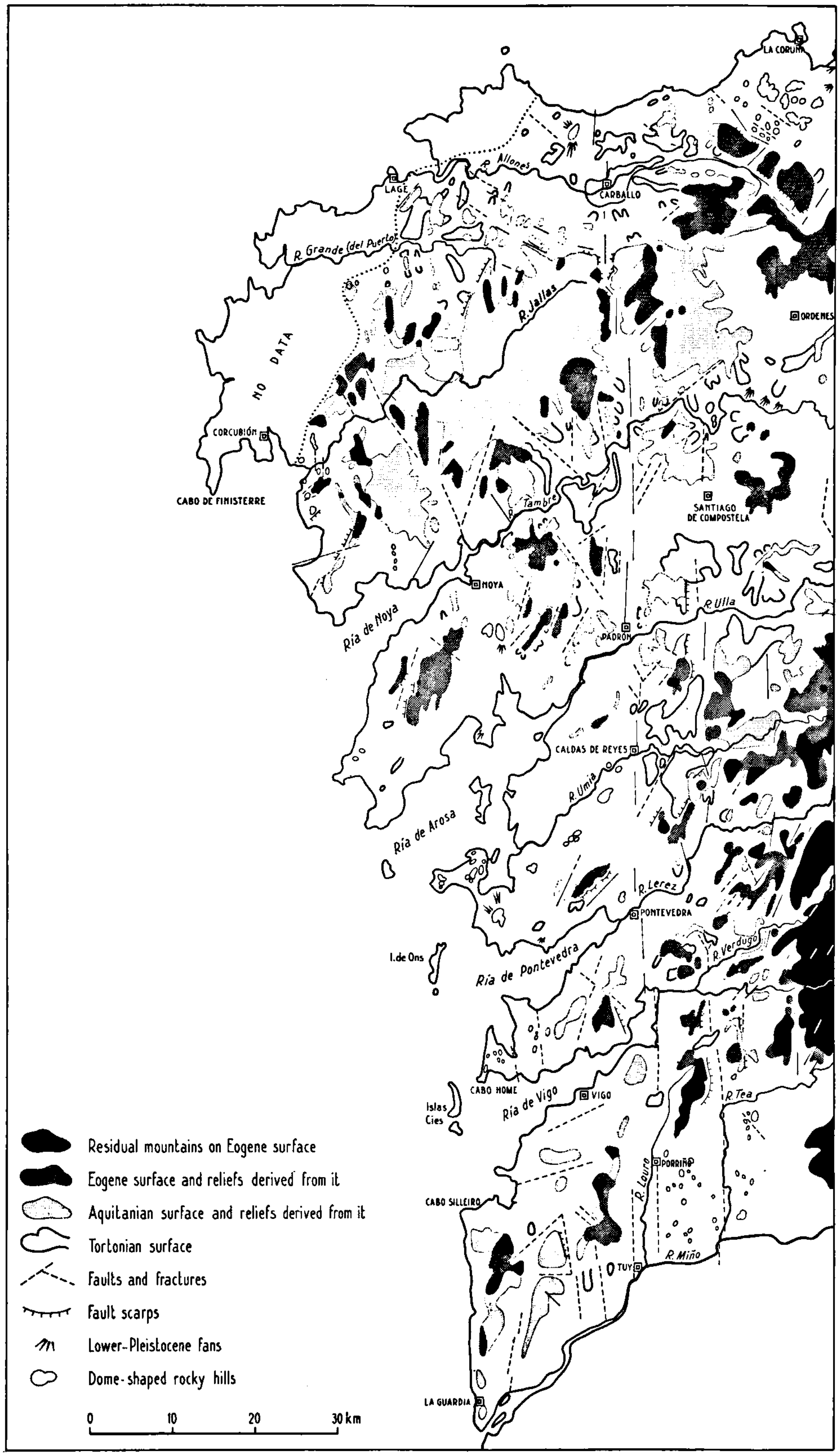


Fig. 3. Tertiary erosion surfaces in Western Galicia. Simplified after Nonn 1966. Scale 1:800,000.

Two more questions concerning the high surfaces require brief mention. First, we must realize that at the time of their formation in a tropical climate (although probably one with a dry season), the high pediplains were covered by a mantle of weathered material, the top of which was slowly being washed away as the base, the weathering front, moved downward. The rivers of that time must for long distances have flowed on top of this weathered layer, and the residual hills were partly buried by it. It was only in Quaternary times that much of this cover was removed and the underlying rock surface was partially laid bare; in this sense all high surfaces are „degraded".

The second point is the tilting assumed by Nonn for some of the mountain blocks whose upper surface has a faint slope, as e.g. the Castrove. If such a mountain block represents a "horst" (a question to be discussed below), such tilting during the uplift cannot be excluded. It should, however, be kept in mind that even a subtropical pediplain (a "*Spülpediment*" or surface-wash pediment, as defined by Büdel) has an initial slope, however weak, or rather consists of weak slopes in varying directions. In my opinion, there is as yet no definite proof for the alleged tilting of some of the mountain massifs.

## 6. THE RIA AREA IN QUATERNARY TIMES

Pliocene deposits being absent, the next younger chronological evidence, although very approximate, is given by the fan and slope deposits, which were first described from the Ria de Arosa area (Nonn 1964, Pannekoek 1966a) and are now known to occur (Nonn 1966), together with "*glacis*", on numerous lower slopes in western Galicia. At various places along the rias they continue below the present sea-level. These are the first deposits containing coarse pebbles and boulders, and are attributed to the advent of Quaternary climatic conditions. The fans are certainly older than the Mindel-Riss interglacial (Nonn 1964), and Nonn is now inclined to assign them to either the Upper Villafranchian or the Günz glacial. In the former case they would, according to him, be correlatable with the *raña* deposits of Portugal and the Spanish meseta.

These fan deposits could easily form since the slopes were then still covered by a mantle of Tertiary weathering debris (Nonn 1966, p. 335) and only began to be "cleaned" at that time (Nonn p. 297) by the sheet wash and occasional floods of the cool and possibly semi-arid climate during the older cold phases of the Quaternary.

The wide-spread occurrence of these bedded fan deposits on the lower slopes implies, to quote Nonn's words, that "already in the older Quaternary erosion had accomplished its main work" (p. 266) and that later on "even the cold episodes of the Quaternary have not too much disfigured the relief" (p. 455).

The relief now rising up before our eyes is in its broad outlines the relief that already existed at the turn of Tertiary times, or, as expressed by Nonn, "Galicia is a region privileged by the persistence of subtropical landscapes. . . . in which kaolinite could continue to be formed during the Pliocene" (p. 475). I am inclined to go one step further: there are indications that at least on the coarse-grained Caldas granite it continued to be formed in Quaternary times and is perhaps formed even today (Bisdom 1967).

## 7. EROSIONAL PHASES

From the approximate datings just referred to, it follows that erosion since the Middle Miocene in the downstream parts of the major wide valleys of western Galicia must have taken place in at least three phases, the first and second dating from the Upper Tertiary, and a third phase from the Lower Pleistocene.

The first Upper-Tertiary phase is evidenced by Nonn's third ("Tortonian") level, occurring along the main valleys and also, in small patches, along the rias (granting that these patches really belong to this level). If it is assumed that Nonn's dating is correct (although there is no direct proof), it implies that in about Middle Miocene times not only the main valleys, bordered by wide pediments, but also the main mountain blocks were already in existence (Fig. 4A), since in various places the mountain flanks rise up from these "Tortonian" pediments and pediplains[5].

In various shallow upstream parts of the main valleys, the rivers still flow on the Upper-Miocene surface and higher up on even older surfaces. Nearer to the sea, the valleys, including the major part of the median depression, have subsequently been deepened, so that there the supposed Miocene surfaces, wherever preserved, are found high above the early Quaternary and present valley floors.

A second erosional phase (or series of subphases or epicycles) follows from the fact that the early Quaternary valley floors, foot-slopes, and areas of low undulating relief were formed on deeply weathered rocks at a level some 200 to 300 m below the "Tortonian" surface. Although the post-Tortonian weathering will have penetrated to considerable depth, a depth of 200—300 m seems too much even for the Mio-Pliocene. It is, therefore, reasonable to assume a second erosional phase, followed by a period of deep weathering, after the Miocene (Fig. 4B). This second erosional phase may have been activated by the post-Pontian tectonic movements, the Pliocene being the time when the slopes became again deeply weathered and receded to their early Quaternary positions.

[5] Nonn assumes, at least for the upper Ulla valley (p. 198), some downwarping of the pediplain, and these movements would have determined the situation of this and perhaps of the other main drainage systems. This may be so, but no proof is available. In my earlier paper (1966a) I considered the main river courses to have been inherited from the upper pediplain surface and their directions to be in accordance with the original slope of the latter towards the ocean of that time.

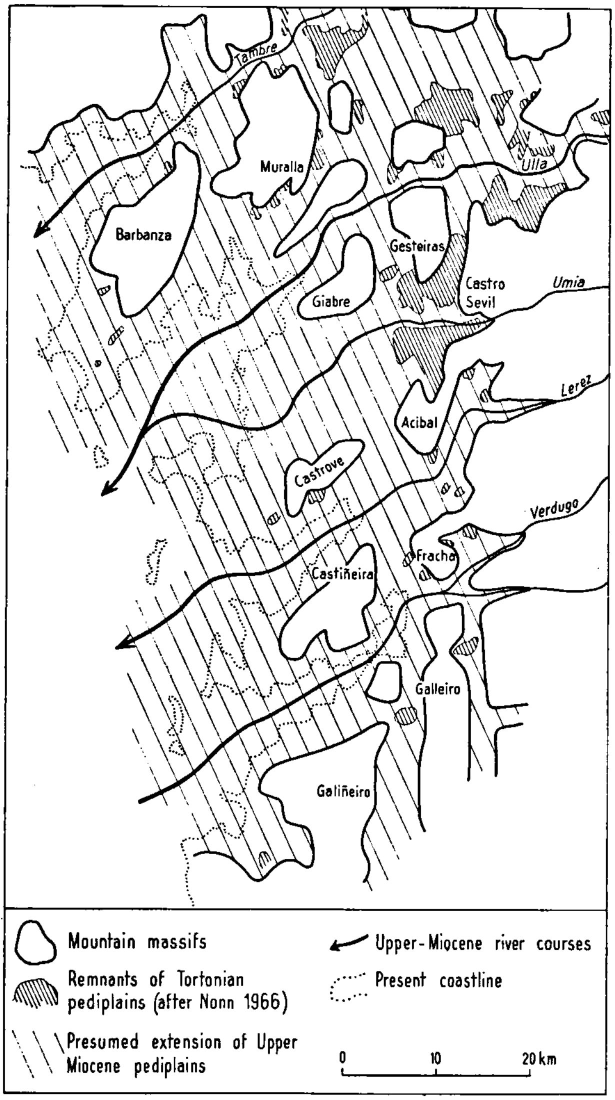


Fig. 4A. Tentative reconstruction of part of western Galicia during the Upper Miocene.

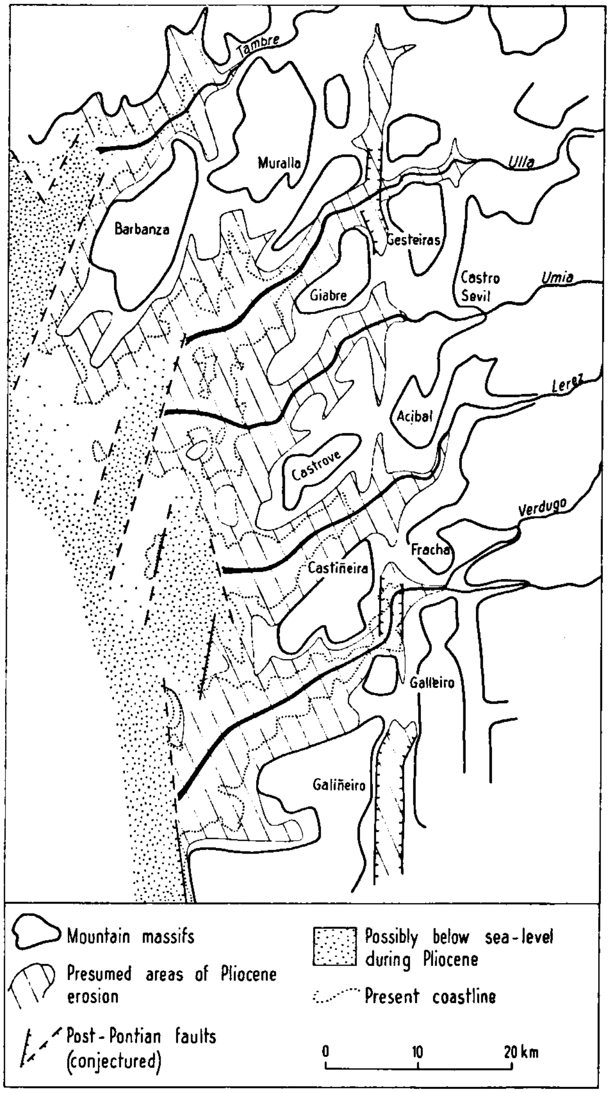


Fig. 4B. Tentative reconstruction of part of western Galicia during the Pliocene.

The third erosional phase may then have occurred during the first cool phases of the early Quaternary, when the valleys were eroded down to their present depth, whilst the lower slopes were partially stripped of their weathering debris and transformed into *glacis* with here and there alluvial fans.

The rias may have been in existence during all the interglacial stages. If so, the oldest coastal terraces must have been removed by Quaternary slope processes; the oldest existing ones probably date from the Sicilian (Nonn 1966, Arps & Kluyver 1969).

## 8. TECTONIC CONTROL OF MAJOR RELIEF FEATURES

Various rectilinear slopes of mountain massifs and main depressions seem to be controlled by faults and fractures, as is clearly shown by Figs. 1 and 2. However, as has already been pointed out, these straight slopes need not be, and in many cases are not, fault scarps but slopes of valleys, the river of which followed a pre-existing fault zone weakened by deep weathering.

To approach the problem of whether any slopes were actually produced by late- or post-Miocene tectonic movements, we will consider in succession (a) the median depression, (b) the depressions in which the rias are situated, and (c) the rectilinear outlines of some mountain massifs.

(a) Only for the southern end of the median depression, i.e. the Louro valley between Porriño and Tuy (Fig. 3), is there evidence, according to Nonn, of its being a true graben; the valley floor is some 3 km wide and the depression contains Tortonian lignites in a horizontal position but dipping at one of the borders. The lignites lie less than 30 m above the present sea-level, i.e. far below the supposed Tortonian valley floors.

The same may apply to the wide section of the median depression where it is crossed by the Ulla River (near Padrón): at this place lignites were found at one time (Parga Pondal, personal information, also cited by Nonn).

A graben-like depression may perhaps also be suspected for the upper part of the Ria de Vigo (the Ensenada de San Simón), which is situated in the median depression, since it is bordered in the north and south by transverse mountain slopes.

In the Louro graben there are even indications for Quaternary movements, because the terrace gravels of the Miño, which penetrate into this depression, seem to have been deformed along one of the borders (see also Butzer 1967, de Aguirre & Butzer 1967, Sos Baynat 1965). Whether the older terraces of the Miño valley itself were deformed in Quaternary times is still open to doubt, even according to a recent paper by Nonn (1967).

Other sections of the median depression are certainly not grabens but single fault zones, for instance the section south of Pontevedra where the foot-slopes of the Castiñeira and Fracha massifs touch each other, or north of that town between the Castrove and Acibal massifs (Figs. 1 & 2).

The term rift valley, applied in our first paper as well as by many other authors, is therefore not quite appropriate for this feature, and should be replaced by the term median depression. This depression is a complex fault zone, only some parts of which have the character of grabens, other parts being erosional valleys following a fault.

(b) The same applies to the depressions running in a SW-NE direction and partially filled by the rias. These depressions have been interpreted as grabens by Birot & Solé Sabaris (1954), and as wide, antecedent valleys by myself (1966a, b). Nonn thinks that at least the rias of Vigo, Pontevedra (although with some doubt), and the upper part of the Ría de Noya are wide valleys following a single fault zone; only for the lower part o the latter does he consider the possibility that it could be a real graben.

The position of the Ría de Arosa is different. It is largely surrounded by a zone of low undulating topography, approximately coinciding with the extent of the coarse-grained, post-kinematic Caldas granite, which weathers easily. Parga-Pondal (1968) attributed the lowness of the area containing the wide ria to the weatherability of the granite; Birot & Solé Sabaris (1954) presumed a subsidence of the granite area along faults. Nonn adheres to the latter opinion, although he does not deny lowering through rapid weathering: actually, the whole Caldas granite area is indicated on his map as "low zone in weak or weathered rock (differential erosion)". Faults have never been found along the boundary of the granite, and are not likely to be present where this boundary is sinuous. Personally, I think that rapid and deep weathering fully explains the depressed area.

The Ría de Arosa itself is in the first place a drowned part of this granite topography with a thick weathering mantle between rounded hills and tors. Its great width and indented outline is additionally accounted for by the fact that various rivers, possibly following pre-existing fractures, converge in this low area. During glacial stages these rivers deposited alluvial fans on the ria bottom, which was then dry (Hinz 1969). Although post-Pontian faults are suspected to occur in the open sea (e.g. along the straight coasts of southern Galicia and of some islands) and are shown in a purely conjectural manner in Fig. 4, their presence has not yet been proved by seismic methods.[6]

(c) Thirdly, we have to consider to what degree the mountain massifs themselves are controlled by Tertiary tectonic movements. They have been referred to as "*horsts*" by various authors (Birot & Solé Sabaris 1954, Nonn 1966 p. 117, 267, 271), but this term needs some qualification.

As we have seen, many of the massifs (e.g. Castrove, Barbanza, Acibal, Gesteiras) are surrounded, according to Nonn's map (Fig. 3), on one or more sides by fragments or large parts of the "Tortonian" surface, so that they must have already existed in Upper Miocene times. If they were *horsts*, the faults along which they rose up would date from an early Miocene or older phase, but in many places the scarp separating the two levels is sinuous and does not suggest a fault. The approximately equal height of the mountain surfaces, which has been used as criterion for their identification, also does not support the idea that each mountain block rose up separately as a *horst*; it rather suggests that the upper surfaces once belonged to a continuous pediplain, only slightly deformed by later tectonic movements, and that the present mountain massifs became separated due to Miocene erosion proceeding locally along pre-existing fault lines. Nonn also states (p. 275) that, for instance, the Barbanza massif became already isolated at an early date.

In the more downstream area, nearer to the sea, the second erosional "wave" removed most of the "Tortonian" surface and in many places proceeded as far as the mountain massifs, which thus became bordered by slopes rising up from the bottoms of the large valleys. During the succeeding Pliocene, i.e. since about 7 million years ago, the new slopes could recede further, especially in places with deep weathering (Nonn's "alveoles"), and in the early Quaternary the deeply weathered basal parts of the slopes were once more eroded and transformed into *glacis*.

The main outlines of the mountain blocks, like those of the depressions between them, are thus the result of erosion and slope-recession along pre-existing faults and fractures. Fini-Pontian movements will rather have had the effect of locally retouching the relief; they may be assumed along some fresh-looking scarps, as for example on the eastern flank of the Barbanza massif and continuing towards Noya. They will have been stronger, apart from sections of the median depression, in the coastal zone, for instance along the rectilinear southern coastal section (La Guardia-Cape

[6] Tertiary faults much farther out into the sea have been found on seismic profiles by Stride et al. (1969).

Silleiro) and in the area now occupied by the sea (as suggested in Fig. 4), where stronger subsidence may have initiated the second erosional phase.

## 9. CONCLUDING REMARKS

The wealth of information that has become available through Nonn's work, and some results from the present paper, call for a slight modification of our former conclusions.

The main points involved are (a) Nonn's identification of remains of a late-Miocene surface, which may make it possible to obtain some idea of the topography of that time (Fig. 4A), and (b) the lesser extent of late- or post-Miocene fault movements in the median depression and the greater importance of post-Miocene erosion and slope-recession (Fig. 4B).

In the Miocene, as we have seen, broad valleys were situated at the sites of the present river valleys, and were already flanked by most of the mountain massifs. Near the present coast these valley bottoms were still far above the present sea-level, and it is likely, as we already assumed in our earlier paper, that the land extended much farther out into what is now sea (Fig. 4A).

Subsidence and flooding of these areas at the end of the Miocene, at least partially along faults, and probably also some uplift of the land, caused a new erosional "wave" to penetrate into the downstream parts of the valleys and into the median depression, where its action was enhanced by local deep subsidence of parts of this depression (Fig. 4B). Only the valley parts downstream from these actively subsided sections of the median depression can be regarded as antecedent, a term we used in 1966 for all the downstream valley parts and which Nonn applies to at least the Ulla valley.

Upstream from the median depression, headward erosion proceeded with more difficulty, over distances varying with the capacity of the rivers, as pointed out in our earlier paper.

During the Pliocene these newly-deepened valleys reached, as a result of strong weathering and slope-recession, approximately their present width, after which erosion during the first cool phases of the early-Quaternary brought the main valleys down to their present depth and shaped the lower valley slopes into *glacis*.

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