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TECTONIC ANTECEDENCE OF VARISCAN GEOLOGY IN BELGIUM

by S. C. MATTHEWS † (*)

In Memoriam

On May 5th, 1983, Dr. S. C. MATTHEWS died suddenly. A few days before he sent us the manuscript of the talk he was expected to give at the meeting that the Société belge de Géologie organized to honour their Past-President and General-Secretaries Ir. A. DELMER et Dr. R. LEGRAND. Unfortunately, because of illness, he was unable to attend the whole meeting and did not present his contribution.

S. C. MATTHEWS was born at Muirkirk (Scotland) on 23rd May, 1936. He first attended Glasgow University were he got his B. Sc. Then he was awarded a Shell Studentship and proceeded to the University of Bristol, where he first became Assistant Lecturer in 1960 and was promoted Lecturer in 1963. He got his Ph. D. in 1965. He left the University of Bristol in 1982 for the Department of Paleobiology of the University of Uppsala (Sweden) where he died suddenly and unexpectedly following a heart attack.

His scientific carrer was quite eclectic and productive. Indeed, he managed with equal mastery work in three different fields :

- Devonian and Carboniferous conodont faunas, mainly in Southwest England;
- Studies of early Cambrian skeletal fossils. This involving exploration of some of the earliest examples of mineralized organic tissues;
- Geology of the southwestern part of the British Isles in its European context.

Being a perfect polyglot (Crosbie MATTHEWS conducted his business equally well in English, French and German and had a working knowledge of Swedish and Russian) and a great traveller, he was the right person to make a synthesis of the abundant new information, making it possible to re-assess the character of the Variscan fold-belt in Central and Western Europe.

His main publishing activity for the last few years was in this field and only three years ago he gave for the members of the Société belge de Géologie a conference on "Les principaux traits structuraux de l'Europe. Commentaires de la structure paléozoïque de la Belgique".

The Société belge de Géologie is proud to publish one of the last manuscripts of this great erudite.

Eric GROESSENS.

ABSTRACT. - There is a reason to ask whether geological purposes are well served if we continue to apply terms such as "Caledonian" and "Variscan" to Palaeozoic tectonism in Belgium. Questions can also be raised concerning the state of the late Precambrian in Belgium, particularly whether any resemblance to Precambrian geology in the Armorican Massif is likely to exist. It appears improbable that "Caledonian" metamorphism is developed to any worthwhile degree in the region. "Variscan" tectonism is interpreted as including two effects in the Ardennes and regions to the east. Each is evident first as a heating which induced modifications of basin form then later as more penetrative deformation. One is attributed to heating in the Ardennes - Ebbe Anticline neighbourhood ("Ardennes effect"). The other is heating advancing northwestward from a source in Central Europe ("Saxothuringian effect"). The two interfere with one another. The Ardennes heating, and a consequent doming, is compared with heating in southwest Ireland. The cause in each of these two cases may be suggested to be mantle delamination precipitated

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by the closure of the Iapetus Ocean. Pre-existing, essentially late Precambrian features of major structure may have played a part in determining the sites of delamination. The argument suggests that "Variscan" intraplate tectonism may be explained as a consequence of "Caledonian" processes.

INTRODUCTION.

The matters involved may be introduced by posing three questions :

- What is the justification for applying the name "Caledonian" to tectonic effects in the Lower Palaeozoic rocks in Belgium ?
- What are our reasons for applying the name "Variscan" to later Palaeozoic tectonism in Belgium ?
- What is the nature of pre-Devillien (approximately pre-Cambrian) geology in Belgium and adjacent regions ?

The first two questions require accounts of a wide range of information patiently accumulated over many years. We agree that those who introduced these terms to Belgian geology were putting the best interpretation they could contrive on the information available in their time. We should ask whether we, by continuing usage of these terms, are making the best employment possible of the fund of information available to us.

The third question is different in kind. We are not richly well informed on pre-Devillien geology in Belgium. We may nevertheless approach a solution to the question, which is of considerable interest, by less direct means.

It should be said that this exploration of ideas is offered in amity by an observer who has for a number of years and for a variety of reasons had cause to be involved with Belgium sources of geological information, but who has always found it difficult to digest published interpretations of tectonic relationships between Belgium and other regions.

THE CALEDONIAN QUESTION.

FOURMARIER (e. g. FOURMARIER, 1931, 1954), whose opinions on tectonism in Belgium have carried great authority, sought a relationship between Caledonian tectonism in Belgium and Caledonian tectonism in Wales. A larger view of the problems involved was presented by von GAERTNER (1960), who offered two alternative interpretations of the setting of the several massifs which produce Lower Palaeozoic outcrop in Belgium and northern France : either (von GAERTNER's first possibility, which he regarded as providing the better accomodation of the Belgian evidence) the Brabant and Ardennes massifs are included in a Caledonian belt which swings from Wales through Belgium and in its course farther eastward subsumes Caledonian geology (as von GAERTNER took it to be) in the West Sudeten and the Lysa Gora, or (von GAERTNER's second possibility, which is more in keeping with the preferences of a number of more recent commentators on these matters - see, for example, ZIEGLER 1978, 1982) the Central European "Caledonides" are to be thought to be associated with a Caledonian belt which runs from the neighbourhood of Stavanger in Norway southeastward through Europe. On this interpretation one regards the Belgian "Caledonides" a as special development on the south flank of an isolated "Zwischenmassif" which could include the older geology of Central England, and one suspects that where the Zwischenmassif ends in the east (as the interpretation requires that it do), "Caledonian" tectonism of the character seen in the Ardennes must also end. KREBS (1976, 1978, 1982) has treated pre-Devonian geology in the Rheinisches Schiefergebirge, especially the evidence revealed in the Soest-Erwitte borehole, in a manner largely in keeping with von GAERTNER'S (1960) second possibility. DUNNING and WATSON (1977) made a closer examination of the scattered information on the character of the older geology of central England (the Zwischenmassif) and offered an interesting distinction between a London Platform (treated as a continuation of the Brabant Massif) and an older Midland Craton to the northwest of it. But they found it difficult to suggest what might have been the continuation of these two elements southward into regions where the stamp of later, Variscan tectonism is assumed to dominate the character of the pre-Mesozoic geology. DUNNING (1980) later touched on AUTRAN and GUILLOT's (1977) suggestion of a Caledonide belt extending from the Massif Central to Newfoundland and the Appalachians and ventured the thought that any eastward continuation of such a belt toward the Bohemian Massif (i. e. a belt such as von GAERTNER's 1960 possibility 1 would prescribe) "must constitute some kind of 'Pan-African'-type internides to all the external Caledonian fold-zones to the north, that is, Brabant, Ardennes and Rügen-Pomerania". DUNNING's (1980) inclination was in favour of an interpretation that would be consistent with von GAERTNER's (1960) possibility 2. He, like FOURMARIER before him, found it difficult to identify concrete connexions between the geology of the Brabant Massif and the geology of the Caledonides in the western and northern parts of the British Isles.

It is evident that the problems of choice presented to the 1960 International Geological Congress by von GAERTNER were still extant when DUNNING wrote on the occasion of the 1980 International Geological Congress, and this in spite of the fact that the intervening twenty years had brought the influence of plate tectonic thinking to discussion of questions of these kinds. Plate tectonics has, if anything, done more to expose the isolated state of "Caledonian" tectonism in Belgium and northern France than to explain it. If one accepts an interpretation of the Caledonides of the kind advanced first by DEWEY (1969) and recently redeveloped (DEWEY, 1982), what bearing does it have on "Caledonian"

tectonism in the Ardennes and the Brabant Massif ? Which sources of energy were tapped in order to drive tectonic processes there in pre-Devonian time ?

Caledonian relationships within Belgium and northern France (GEUKENS 1950; LEGRAND 1968; MICHOT 1976, 1978, 1980; BEUGNIES, DUMONT, GEUKENS, MORTELMANS and VANGUESTAINE, 1976; WALTHER 1978, 1980) involve the problem of understanding why an Ardennes basin failed (so that that area has no representation of a sequence between mid Ordovician and low Devonian) in what is regarded as an early Caledonian effect and thus presents a contrast with the Brabant Massif, where the Lower Palaeozoic sequence continues later and the tectonic effect is regarded as late Caledonian. MICHOT (1978) makes the point that farther to the west, in the Liévin area for example, no such break is developed and he infers that there was a certain "bombement" (doming), fading westward, in the structural relief. VANGUESTAINE (1973, 1974) has brought new palaeontological information to discussion of these problems and it is now established that mid Ordovician ages are represented in the higher part of the Salmien succession. It therefore becomes clear that the Lower Palaeozoic succession in the Ardennes includes an earlier sequence (comprising a major part of the known thickness) which is dominantly of shallow water character, and a later part, ranging into the Ordovician, in which there are minor amounts of what may be flyschoid sediments. Any suggestion that a Caledonian geosyncline is represented does little to penetrate the character of the geology. Indeed, given the balance of sedimentary character in the succession and the lack of any significant volume of basic igneous rocks, such a suggestion might be entirely inappropriate. A possibly more fertile thought is that the Devillien, Revinien, Salmien accumulation in the Ardennes may show something of the character of an inversion structure. It is, however, readily recognized that these are a geologically unobliging set of rocks, and the present lack of information on the exact form of the Lower Palaeozoic basin is understandable.

THE VARISCAN QUESTION.

The literature records a history of controversy as to what is Caledonian and what Variscan in the structure and metamorphism in the Ardennes. It is not in doubt that more than one generation of structure is represented (see, for example, PLESSMANN 1959; KRAMM 1982) and it is not in doubt that an unconformity separates the basal Devonian from the pre-Devonian rocks. But the tenor of recent findings (SCHREYER 1975; BEUGNIES, 1976; BEUGNIES, CHAVEPEYER and MERCIER, 1981; DANDOIS 1981; KRAMM 1982) appears to favour the view that the metamorphism took place within the range of age represented by the succession above the unconformity. SCHREYER'S (1975) study of garnet growth in pebbles contained within Gedinnian conglomerate is critically important. So, too, is KRAMM'S (1982) observation that chloritoids within Salmien clasts in Gedinnian conglomerate resemble chloritoids in the matrix both in morphology and in details of their internal fabric and likewise his observation that cleavage in pre-Devonian slates within Gedinnian conglomerate does not exert any control on the shape of the clasts but is disposed in the same attitude in adjacent clasts whatever their shape. The onus is now on anyone who insists on a Caledonian metamorphism in the Ardennes to demonstrate a metamorphic effect peculiar to the pre-Devonian rocks.

The polyphase structures in the Ardennes are therefore suspected to post-date the development of the basal Gedinnian unconformity. More obscure is the meaning one should then attach to any suggestion that earlier and later phases of Variscan deformation should be distinguished.

A set of rocks which, in spite of the apparently small total area occupied at outcrop, is of some significance in any attempt to unravel the geological history of the Ardennes, is the Venn intrusions (SCHERP 1959; KRAMM 1982). These porphyritic tonalites and associated dolerites outcrop among the pre-Devonian rocks in the core of the regional structure. They are themselves affected by metamorphism, which appears to have its best development in the south flank of the regional structure. KRAMM (1982), who has contributed an impressive amount of new information and intelligent insight, disposes of earlier suggestions (e.g. STAINIER 1930; KREBS and WACKENDORF 1974) that metamorphism in the Ardennes is contact metamorphism in the neighbourhood of such intrusions. He comments that the layout of grade-boundaries is more in keeping with a pattern of regional metamorphism, a view which is consistent with evidence of geothermal gradients commonly of the order of 60°/km in the Hohe Venn, the Givonne Massif (BEUGNIES 1976) and in the Bastogne area (de BETHUNE 1980). If they are affected by regional metamorphism and if the metamorphism post-dates the Gedinnian conglomerates, the Venn intrusions cannot be regarded as Caledonian. The rocks available at exposure are deeply affected by weathering (SCHERP 1959) and relatively little is known about their chemistry - for example, there has been no special study of the carbonate component of the tonalites reported by VAN WAMBEKE (1955) and SCHERP (1959).

The intrusions are metamorphosed. They are also cleaved. All that can be said of their age is that they are demonstrably post-Salmien, arguably (by reference of the metamorphism) post-Gedinnian, and that they predate some part of the history of development of what is regarded as Variscan cleavage. A further comment on their possible significance appears below.

These interesting and insufficiently well understood intrusive rocks could be labelled "intra-Variscan"; but any reference to Variscan (or Hercynian : see MATTHEWS and FORD (in press) in Belgium and northern France immediately requires qualification. The reason is that several of the characteristic features of

Variscan geology in the Reinisches Schiefergebirge to the east do not occur here - there is no comparable development of basinal ("herzynische") facies in the Devonian and there are none of the strata-bound ore deposits (e.g. Meggen, Rammelsberg) that are present in Germany. Belgium and northern France have no worthwhile representation of the basic volcanism that is prominent in the Middle Devonian and Lower Carboniferous in the Rheinisches Schiefergebirge. Further, there is no equivalent of the Carboniferous turbidite influx ("Kulmgrauwacke"). These are absent in Belgium, and yet they are all represented again farther to the west in southwest England (MATTHEWS 1977). This interruption of basin development does nothing to encourage acceptance of ZIEGLER's (1978, 1982) proposal of a Cornwall-Rhenish Basin.

One may note the large-scale thrusting affecting Carboniferous rocks in Belgium and may take this to justify reference to Variscan tectonism; but this, again, does not promote the idea that Belgium is tectonically at one with Germany, for the northern part of the Rheinisches Schiefergebirge shows no evidence of an eastward continuation of the Belgian style of thrusting. MATTHEWS (1983a) has remarked that the Palaeozoic geology of Belgium provides what some would accept as a clear expression of a Variscan Front, but lacks most of what are taken to be characteristic features of Variscan geology as a whole in the Rheinisches Schiefergebirge or in southwest England. Words like "stability" and "consolidation" regularly arise in response to any reference to the apparently idiosyncratic tectonic behaviour of Belgium and northern France. They acknowledge the existence of some special problem, but do little to make the problem clearer and do nothing to explain it. One wonders what "consolidation" might mean ?

THE PRE-DEVILLIAN QUESTION.

Questions concerning relative "stability" or "consolidation " of the Ardennes region serve to introduce the problem of estimating the nature of the deeper, entirely unexposed geology in Belgium and northern France. Only two matters need to be discussed at this stage of the argument :

1. KLEIN (1978) introduced the idea of a "socle mou". This was his conception of the meaning of polyphase tectonism and since there is polyphase tectonism in both Brittany and the Ardennes he took these two to be examples of tectonic reactivation as he understood it. But the two regions show more of diversity than of unity : it would be wrong to conclude that they have tectonic themes, or phases, in common, and it is to be doubted whether the example of the Massif Armoricain offers us worthwhile instruction on the nature of the pre-Devillien geology in Belgium and northern France. Some differences between the two are already obvious in the exposed geology. It is, for example, clear that whatever interpretation we put on "Caledonian" breaks that interrupt the pre-Devonian succession in the Ardennes and the Brabant Massif, we are seeing something quite different from the Ligérien tectonism (PRUVOST 1949, AUTRAN and COGNÉ, 1980) of Silurian-Devonian time recorded in the geology of south Brittany. Further, our information on Ordovician in Belgium and northern France suggests that the succession includes no representation of the Grès Armoricain which is such a conspicuous feature of Ordovician successions in northwest France and regions wider afield. We have no direct information on the nature of the base of the Devillien and no means of making comparison with relationships near the base of the Brioverian in western France; but the evidence already available should be sufficient to cause one to hesitate before assuming that Belgium is underlain by pre-Brioverian basement of the kind exposed in northwest France and the Channel Islands. MICHOT (1980) has offered an indirect argument in favour of a suggestion that Dalslandian may be an appropriate label for some component of the crust in this region.

2. Any such proposal would be at variance with a suggestion VOLL (1978 and *fide* MURAWSKI 1981) makes on the basis of rock-samples brought from depth in the crust by the Tertiary volcanism in the Eifel region. He is prepared, on that evidence, to contemplate the possibility that the crust sampled may be largerly of Variscan establishment.

We return later to the question of the nature of the pre-Devonian in Belgium and northern France.

EASTWARD FROM THE ARDENNES.

There is brief mention above of suggestions (von GAERTNER 1960; KREBS 1976, 1978, 1982) that Caledonian tectonism may have been active eastward of the Ardennes. Given the difficulty of distinguishing anything that is Caledonian from what is probably polyphase Variscan tectonism in the Ardennes, the significance of an eastward expression of Ardennes-associated tectonism is not immediately obvious - certainly, bland application of the label "Caledonian" does not seem to be justified. Stratigraphic evidence opens up an opportunity of a clearer view of what was involved.

KEGEL (1950) produced a survey of stratigraphic relationships in the Rheinisches Schiefergebirge. It has been complemented by SCHMIDT's (1952) work on the Devonian around the Hohe Venn and has been reconsidered that during three decades in which we have acquired more and more detailed sedimentary information (see, for example, FRANKE, EDER, ENGEL and LANGENSTRASSEN 1978; GOLDRING and LANGENSTRASSEN 1979) the meaning of KEGEL's (1950) maps and their information on variations of thickness have never impressed themselves sufficiently firmly on our thinking.

PAPROTH (1976) follows KEGEL (1950) in showing successive troughs (her TRÖGE I, II, III), meaning successive

loci of maximum stratigraphic thickness, migrating southeastward away from the eastern end (as now seen) of the Ardennes during early Devonian time. TRÖG IV (a Siegerland sink) no longer conforms to that pattern. TRÖG V, in the eastern part of the Rheinisches Schiefergebirge, shows that in mid Devonian time the locus of maximum thickness had shifted northward, north of the Siegerland, and TRÖG VI represents a further shift in that direction, which brought maximum thickness of the late Devonian sequence to a site in the northwestern part of the Rheinisches Schiefergebirge. Regional basin evolution continued later on a broader pattern, with development of the Subvariscan Foredeep still farther to the north.

PAPROTH (1976) noted that the shifts of the loci of maximum thickness trace out an anticlockwise spiral in the Rheinisches Schiefergebirge and asked what might be the meaning of such a pattern of behaviour. It is possible that two initially separate influences were at work. One is a doming, active in the Ardennes region and fading eastward of there, which induced the progressive shift of maximum thickness souteastward and away from the Ardennes during early Devonian time. The other is a new influence on relief, essentially a heating whose "epicentre" was in the evolving Saxothuringian Zone (BEHR 1978; ENGEL and FRANKE 1982) in Devonian time, whose effect in terms of thermal bulging caused the new (to the Rheinisches Schiefergebirge in mid Devonian time) northward shift of maximum thickness and whose effect in terms of thermal weakening (WEBER 1981; KUZNIR and PARK 1982) caused the northward progression of deformation recorded in slates from the eastern Rheinisches Schiefergebirge by AHRENDT, HUNZIKER and WEBER (1978).

Low-mid Devonian stratigraphic relations in the Reinisches Schiefergebirge and the area to the west of it may, on this view, involve more than a southward failure of a Caledonian Molasse (FRANKE, EDER, ENGEL and LANGENSTRASSEN 1978; BEHR, WALLISER and WEBER 1980) and more than the problem of identifying a boundary between a northwest European and a southeast European affiliation in Devonian stratigraphy (KEGEL 1950). The Devonian in the Rheinisches Schiefergebirge would here be treated instead in terms of an interplay between delivery of clastics, abundant in early Devonian time, less so later, from a direction around northwest (essentially a "Caledonian" source) and receipt of clastics in basins whose form and whose capacity to accommodate sediment were subject to modification by a regional doming (an "Ardennes effect") already evident early in Devonian time and by a second tendency to produce positive relief (a "Saxothuringian effect") which began to impose itself on the geological development of the Rheinisches Schiefergebirge in mid Devonian time. The following considerations are involved.

1. The Siegerland (GROESSENS, CONIL and STREEL 1982), where the tendency in migration of maximum thickness changes its course, is of special interest. Its succession is of a character which would, broadly, compare with the Devillien, Revinien, Salmien in the Ardennes (with the obvious exception of the fact that the Ardennes sequence represents a much longer span of time). Comments on details of structure there supplied by Borrodaille (1977) could be said to lack the geological resonance one senses in DVOŘÁK (1973), who interpreted the Siegerland Anticline as an inversion structure. The compression which his proposal requires first becomes plausible if one thinks of a weak thermal bulge, an "Ardennes effect" on the north of the Siegerland and a stronger "Saxothuringian effect" impinging on the sedimentary prism from the southeast.

2. The interfering effects would combine to produce a depression in the eastern part of the Rheinisches Schiefergebirge (TRÖG V) in mid Devonian time and would thus provide a set of circumstances in which it is understandable that Eifel accumulations of carbonate are of platform type, in contrast to build-ups in the Rheinisches Schiefergebirge which had more opportunity for upward growth.

3. Heating proceeding from two separate sources is evident first in modifications of basin form then later, when rocks were thermally weakened to a sufficient degree, in deformation and production of cleavage. AHRENDT, HUNZIKER and WEBER (1978) have measured the northward progress of deformation (330 Ma in the Taunus to 300 Ma in the northeastern Rheinisches Schiefergebirge) proceeding in consequence of the "Saxothuringian effect". In the Ardennes, deformation may have begun earlier in consequence of the local, independent accession of heating which was first expressed as a doming in the Ardennes and the region eastward from there. KRAMM (1982) may not be justified in assuming that AHRENDT, HUNZIKER and WEBER's (1978) datings of deformation in the eastern Rheinisches Schiefergebirge apply in the Ardennes also. MICHOT, FRANSSEN and LEDENT (1973) have reported preliminary investigation of dates in Belgium and have offered a figure of 305-310 Ma. Any fuller investigation would involve recalculation of that result. It should also include some discussion of the meaning of a single date, given that deformation may have been in progress during a period of time and was apparently polyphase. Preferably, if there is to be comparison with AHRENDT, HUNZIKER and WEBER's (1978) results, the datings should be done on rocks which represent primary ash-fall rather than on run of the mill samples of slate which may include detrital argon.

An open possibility, in the present state of the evidence, is that in the Ardennes a first generation of structures emerged for local reasons of heating, and that a later generation was produced when the region was eventually overtaken by a stronger flux of heating, the "Saxothuringian effect", with special features developing as stress was brought to bear on the already to some extent

determined form of an Ardennes dome and on the special qualities developed in the lithostratigraphic succession (especially the availability of anhydrite : PIRLET 1972; BOUCKAERT, DELMER and GRAULICH, 1977) there.

WESTWARD TO BELGIUM AND BEYOND.

One should ask whether any additional evidence in the geology of the Rheinisches Schiefergebirge would be consistent with the interpretation sketched above. Evidence which may have a bearing on the argument comes from the Soest-Erwitte borehole. Dark slates with graptolite remains (TEICHMÜLLER 1978) can, in KREBS' (1978, 1982) view, be incorporated in a proposal of Caledonian tectonism. The steady northward younging of AHRENDT, HUNZIKER and WEBER's (1978) K/Ar dates falters in this neighbourhood and an anomalous older (340 Ma) result appears. KRAMM (1982) suggests that the 340 Ma figure may represent a mixture of Caledonian and Variscan ages; but it is now doubtful whether the term "Caledonian" is in any sense applicable in this area. The anomalous result may better deserve to be regarded as representing interference of a remote eastward Ardennes effect and the Saxothuringian effect which the main run of results describes.

FRANKE, EDER, ENGEL and LANGENSTRASSEN (1978) remark that features of the geology which can be traced from the Harz into the eastern part of the Rheinisches Schiefergebirge tend to lose their identities in the neighbourhood of the Siegerland Anticline, where a similarity to geology west of the Rhine and into the Ardennes is already detectible. One accepts these points without necessarily subscribing to their further comment that the new influence emerging is a pronounced stability from the upper Emsian onward.

KAISER, PAPROTH and STADTLER's (1978, fig. 4) map of the western part of the Ebbe Anticline (and including the site of the Schwartzbachtal borehole) shows a palaeogeography which would be in accord with proposals offered here.

Farther to the west, across the Rhine, the Eifeler Nord-Sud Zone is a prominent element in the regional structure. It, like the Krefelder Gewölbe farther north, has had an influence on tectonic development from Palaeozoic through into Mesozoic time. When the Eifeler Nord-Sud Zone was first instituted is not understood. It is suspected that it was already active when the synclines that contain the Middle Devonian limestones in the Eifel came into being (SCHENK 1937). But it is not clear whether that pattern of folds is better explained by invocation of a north-south basement structure than by a suggestion of accommodation to the form of a growing (Ardennes) dome. Possibly both influences were at work.

BEHR, WALLISER and WEBER (1980), like FRANKE, EDER, ENGEL and LANGENSTRASSEN (1978), make the prosaic assumption that the Ardennes is to be treated as part of the Rhenohercynian Zone. Such an interpretation would mask the significance of a special heating ("Ardennes effect") within the Rhenohercynian Zone, which may be suggested to be first evident on a southwestward traverse at Soest-Erwitte, is progressively more clearly expressed southwestward from there, comes to a culmination in the Ardennes region itself and may be regarded as fading westward from there in MICHOT's (1978) proposal of a "bombement" (but not a Caledonian bombement) which is no longer effective at Liévin. Questions arise : what becomes of the Rhenohercynian Zone within Belgium, and why does it not resume its normal character in the west when the doming has faded ? And does that problem become clearer if we appeal to the idea of a Variscan geosyncline ?

COMPARISON WITH SOUTHWEST IRELAND.

The proposal is that an elongate, dome-like structure was developing during Devonian and possibly into Carboniferous time, and expressed itself on a long axis (Ebbe Anticline to Liévin) which measures over 300 kilometres. Close to its culmination, in the Ardennes, there are the Venn intrusions (the depth from which they were derived has not been estimated) which have been metamorphosed to some degree and which carry a cleavage. One thinks to suggest a comparison with southwest Ireland, where an elongate dome-structure has been the site of Carboniferous heating, where intrusions in small volume derived from considerable depth have been emplaced, and where one finds that the intrusions are housed in a doming produced by inversion. The doming was already in progress when Variscan folding took place, and continued its development later to produce distortion of some of the Variscan folds (MATTHEWS, NAYLOR and SEVASTOPULO 1983; MATTHEWS in press). The following questions of possible resemblance to the Ardennes suggest themselves :

1. In both cases there is an earlier and a later "Variscan" tectonic effect. The inversion in County Cork has been interpreted as the consequence of a mantle delamination (BIRD 1979) triggered by the collision which closed the Iapetus Ocean - i.e. much of what is regarded as "Variscan" tectonism in southwest Ireland is to be attributed to a "Caledonian" cause.

2. The Ardennes and County Cork differ in certain respects. In County Cork development of a large half-graben, the Munster Basin, preceded the doming. Nothing of comparable character is preserved in the Ardennes. If such a depression had at one time developed there, before heating supervened, it would have been of Silurian age. A slightly improbable alternative view of the Ardennes is that a precursory depression is represented in the thick early Palaeozoic sequence. The improbability is in the lenght of time involved (cf. calculations in BIRD 1979). If the early Palaeozoic depression and the later Palaeozoic doming are nevertheless

to be suspected to be in some way related, the relationship may be that of a double inversion (cf. KENT's 1980 reference to a late Carboniferous inversion on the same site as a late Cretaceous effect of much the same kind in northeast England).

3. The timing of events is different in County Cork and the Ardennes. In County Cork the inversion, identified as the beginnings of doming (i. e. in the literal sense of words an eversion) took place, according to stratigraphic evidence, in Viséan time. In the Ardennes, stratigraphic evidence suggests that doming was already in effect during early Devonian time. If delamination theory applies in both cases, it does not necessarily follow that there should be an exact match in timing. Heat lost from the mantle in two separate instances should not necessarily induce effects such as doming simultaneously in the geology at high level in both regions. Variation in crustal thickness is one obvious reason why the two heatings should not keep pace with one another. Equally, one should not expect that rocks in both regions arrived simultaneously at critical thresholds of thermal weakening. A separate consideration in the matter of timing is that the time of inception of delamination cannot be exactly identified because the collision is not dated with any great accuracy.

4. Brief mention should be made of an apparent similarity which may or may not be accidental. The Glandore High (NAYLOR, JONES and MATTHEWS 1974; NAYLOR, SEVASTOPULO, SLEEMAN and REILLY 1981, esp. fig. 5) is an approximately north-south structure sited close to the transverse axis of the doming in County Cork. The offshore evidence southward of Ireland shows that its activity continued in Mesozoic time. The resemblance to the Eifeler Nord-Sud Zone may or may not be a matter of coincidence.

5. Brief mention may be made of an obvious difference. There is a conspicuous copper anomaly associated with the geology of southwest Ireland. One presumes that a copper anomaly in the Ardennes would not have escaped the attention of Belgian geologists, given their awareness of copper in Africa.

6. One possible similarity deserves fuller examination. What has been regarded as the Variscan Front in southwest Ireland is reverse faulting on the northern flank of the growing dome. The faulting fades eastward as the doming fades. There may be a resemblance to Belgium, where the Faille du Midi is well-developed along the front of the Ardennes doming, but fades eastward (MATTHEWS 1974) into the Rheinisches Schiefergebirge as the doming fades. Whatever the involvement of the culmination of a first structure, it is evident that the major thrusting in Belgium is to a large extent an expression of a second generation of deformation, with strong northwestward drive. If it is permissible to think of this second generation of structure as the "Saxothuringian effect", one is required to explain why this should have produced a much more powerful development of thrusting in Belgium (possibly comparable in scale with "Saxothuringian" thrusting in the southeast Rheinisches Schiefergebirge : WEBER 1981) than it did in the adjacent, northwestern part of the Rheinisches Schiefergebirge. The critical influence here seems to have been the availability of evaporites in the Upper Devonian and Lower Carboniferous (DELMER, GRAULICH and LEGRAND, 1978) and the availability and primary distribution of these in turn may have been influenced by the Ardennes doming. One would wish to know whether there is any evidence of major thrusting south of the original limit of distribution of anhydrite. This might set contraints on proposals of the amount of movement on the Dinant Nappe (BLESS, BOUCKAERT and PAPROTH, 1980 : see further comment below on that same need) - and one would wish to ask, when the structural succession north of the Ardennes is better understood in depth than it is now, whether early Devonian stratigraphy there shows a pattern of progressive migration of maximum thickness away from the Ardennes, a mirror image of the pattern to the southwest. This would greatly reinforce the idea of an Ardennes doming already in progress in early Devonian time.

These are arguments based on a fairly free-ranging treatment of stratigraphic evidence and on interpretations of the tectonic consequences (regarded as Variscan) of heating. It remains to be seen whether the suggestion of two tectonic effects ("Ardennes" and "Saxothuringian") may eventually be brought into coherence with classical German work on structural geology in regions close to the Ardennes (e. g. CLOOS 1950; HOEPPENER 1957 especially; ENGELS 1959) or with WEBER's (1978, 1981) increasingly more widely effective analyses of the different generations of structure in the Rheinisches Schiefergebirge.

THE INFLUENCE OF PRE-VARISCAN TECTONISM.

The discussion has touched on the question of the continuance of the Rhenohercynian Zone in the southwest where the "bombement" fades. The likelihood is that development of "Variscan" tectonism ends at a major pre-Variscan structure running northwestward from Paris toward southern England (GÉRARD and WEBER, 1971; WEBER 1973, 1980). This structure continued in activity and has shown some movement in sub-Recent time (FOURNIGUET, VOGT and WEBER 1981). It can be treated as part of a pattern of pre-Variscan structure in Central and Western Europe discussed by MATTHEWS (1984, in press). These pre-Variscan structures are essentially riftings which can be argued to have had their inception in late Precambrian-early Palaeozoic time. The severely deformed state of such a rift in Central Europe is what is identified as the Saxothuringian Zone there (BEHR 1978; BEHR, ENGEL

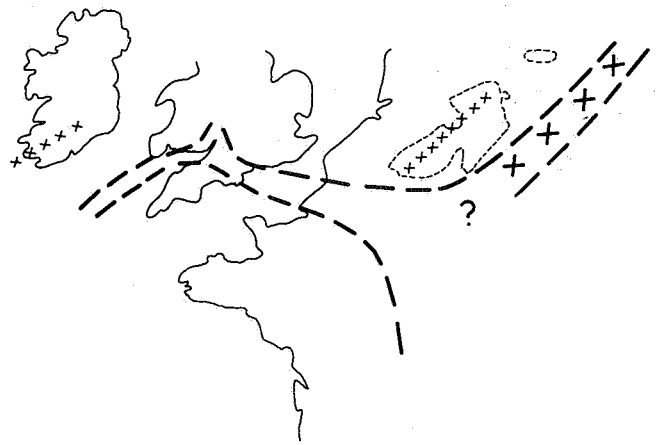

Fig. 1 - Heavy dashed lines : a pattern of pre-Variscan structure in Central and Western Europe. Large crosses : major Variscan heating ("Saxothuringian effect"). Small crosses : two other sites of heating ("Ardennes effect" and the in some respects comparable case in southwest Ireland).

and FRANKE 1982). The belts of rifting are quasicontinuous, but imposed Variscan heating and deformation is not everywhere as advanced as in Central Europe. The pattern of rifting runs northwestward through France to southern England and continues down the Bristol Channel to the Celtic Sea (MATTHEWS, in press). The geology of Brittany is not involved : nothing there deserves to be interpreted as a continuation of the Saxothuringian Zone. The Rhenohercynian Zone, as known in the Harz and the Rheinisches Schiefergebirge, ends in Belgium and northern France. It is not continuously developed toward southwest England, where there was a quite separate occasion of Variscan tectonism.

A point of particular relevance to present arguments is that the two sites of presumed delamination, Ardennes and County Cork, appear to occupy comparable positions in relation to the earlier established pattern of rifting. Each is set on the northwest side of a run of the rifting which trends southwest. The implication is that the existence of rift-structures, so disposed, may have tripped the delamination process at a time when the Iapetus Ocean had closed and the inertia of the southeast plate was obliging the lithosphere to deform.

In a more local tectonic context, one would direct particular attention to the Givonne Massif (BEUGNIES 1976). Should the large underlying basic body to which the positive gravity anomaly is due be conceived to relate to delamination, or to earlier tectonism? If there is a relationship between the insertion of such a body and potassium metasomatism in the Upper Palaeozoic rocks above (BEUGNIES 1976), does this age-relationship settle the question of the body's tectonic affiliation ? And does the same evidence suggest that no major structural detachment underlies the Givonne Massif ? In this again, one finds cause to resist BLESS, BOUCKAERT and PAPROTH's (1980) impression of the possible scale of Variscan nappe structure in Belgium. The pattern of regional structure shown in Fig. 1 differs in some respects from a proposal at a comparable scale made by LEFORT, WEBER and BEUGNIES (1977). Fig. 1 is less insistently belt-like. It suggests more of a correspondence between "Variscan" and pre-Variscan structure. It opens up a possibility of understanding why the Ardennes Massif trends southwestward, in contrast to the Brabant Massif, whose trend, through a long range of geological time, has been northwestward toward southeast England.

CONCLUSIONS.

These are proposals which pay no respect to the idea that Palaeozoic geology in Belgium came early to a state of stability or "consolidation" (see a recent example of that view in ZIEGLER 1982). The idea of consolidation seems perverse when one considers, for example, the evidence of the Saint-Ghislain borehole (DEJONGHE, DELMER and GROESSENS, 1976; DELMER, GRAULICH and LEGRAND, 1978; GROESSENS, CONIL and HENNEBERT, 1979) which shows availability of anhydrite in thickness of the order of a thousand metres and more and which implies production of a considerable degree of structural relief in order to accommodate such a a pile. Or one might cite the matter of the long-term activity of the Eifeler Nord-Sud Zone or the question of the antiquity of the Rhine Graben structure as examples of continuing tectonic activity in the general region of Belgium. The Bray structure running northwestward through France is still active and the anhydrite which did much to lubricate late Palaeozoic structural transpositions in Belgium is still available.

It is difficult to account for Caledonian tectonism in Belgium and northern France in terms of a plate tectonic model. It is difficult to summon up any plate tectonic model specific to the Variscides which would promote a better understanding of Variscan tectonism in Belgium. A curious (as it may appear at first sight) outcome of the argument here is that "Variscan" tectonism in the Ardennes (as in southwest Ireland) may be more readily explicable if one treats it as being largely a consequence of a "Caledonian" scheme of events. The lesson is, perhaps, that we should not strive too hard to separate Caledonian from Variscan (MATTHEWS 1978). We should not regard the unconformity at the base of the Gedinnian around the Ardennes as the most important single consideration in any attempt to understand Palaeozoic tectonism in the region. Nor should we insist that local accessions of heating drove tectonic processes everywhere at the same rate. Certainly, there seems to be little justification nowadays for the opinion that all in Europe came to some common climax which deserves the name "Asturian" (cf. MATTHEWS 1983c).

Structures established earlier, within what was the plate on the southeast side of the Iapetus Ocean in early

Palaeozoic time, have exerted an influence on later Palaeozoic tectonism. Nothing in the layout of the earlier Palaeozoic structure in the neighbourhood of Belgium suggests a relationship with Brittany (even although the Armorican Massif, like the Ardennes and adjacent massifs, carries the imprint of more than one generation of tectonism). The influence of earlier geology suggests that VOLL (1978) may be mistaken in regarding the crust in this region as being largely a Variscan production. And one notes, in TEICHMÜLLER and TEICHMÜLLER (1979, fig. 2), a suggestion that in the southern part of the Ardennes, a deep reflector may be the top of the Precambrian rather than any continuation of a Variscan structural surface.

ACKNOWLEDGEMENTS.

I have in the past issued all too brief comments on geology in Belgium (e.g. "Belgium is structurally complex but tectonically relatively simple" : MATTHEWS 1977) and I have regretted the lack of an opportunity to offer a fuller statement of my views. I am grateful that such an opportunity has come now, and am particularly glad that it comes on the pleasant occasion of our doing homage to MM. DELMER and LEGRAND. I thank Dr. Eric GROESSENS, a good colleague, for extending to me the Society's invitation to take part in the Symposium. Monica SIEWERTZ (Uppsala) produced the typescript. She, too, deserves my thanks.

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