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POLISH CALEDONIDES AND THEIR RELATION TO OTHER EUROPEAN CALEDONIDES*

Jerzy Znosko

Geological Institute, ul. Rakowiecka 4, 00-975 Warszawa

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Abstract: The development of opinions on the problem of the Central European Caledonides is reviewed from the work by Suess up to the present time. The results of the research started in the sixties concerning the territory of Poland and the North Sea area confirm the existence of the Central European Caledonides. The European Caledonian pattern is presented with the following chains: Irish-Scottish-Greenland chain, Cornwall-Brabant chain, and North German-Polish chain. These chains are separated from one another by the Southern Uplands fault and the paleotectonic Iapetus suture (buried and down pressed "betwixt mountains") and by Ringkøbing-Fyn and London massifs.

Key words: Caledonides, orogenic chains, betwixt mountains, median massifs, review, tectonics, Poland, North Sea, Europe.

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INTRODUCTION

Since they were first defined, the existence of Caledonides in Central Europe has been a subject of controversy. It was the publication of the first global geological synthesis, the *Face of the Earth* (Das Antlitz der Erde) by Suess (1855—1909), that started an almost century long discussion between the followers and adversaries of the existence of a Caledonian chain in Central Europe. The opinions varied, from full acceptation to full negation.

The aim of this paper is to present the general outlines of the history of evolution of opinions on the tectonic relation between the Caledonides in Europe. Subsequently, the most important geological data from Poland and the North Sea, which have been obtained during the last 20 years, relevant for the reconstruction of the Caledonian chains in Europe, will be discussed. Finally, a model of relations between the European Caledonides and that of their continual and regenerative evolution will be presented.

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* This paper is based on a lecture given in Kraków on September 26th, 1983, during scientific conference celebrating two hundred years of geological sciences at the Jagellonian University.

the data concerning regional geology, Zwerger (1948) came to the conclusion that positive magnetic anomalies in Silkeborg-Sjaelland, Little Baelt, Rügen and Usedom belonged to a large geological unit reflecting an area of Caledonian consolidation. Zwerger did not exclude the possibility that the Parachim and Husum massifs, and the main ridge of Mecklemburg, and parts of the East Elbe Massifs could have been passively incorporated into the Caledonian fold belt as massifs of pre-Caledonian consolidation. The geophysical considerations of Lauterbach (1955) supported this interpretation in general outlines. In 1950 Stille presented a new interpretation of European Caledonides distinguishing two zones: (*1*) the Circum-Laurentian (Erian) zone including the British, Brabant and Ardennes Caledonides, and (*2*) the Circum-Fennosarmatian (Norvegian) zone including the Scandinavian, West Sudetes and Holy Cross Mountains (southern part) Caledonides, and moreover the Caledonian ridge under the Carpathians ranging east as far as Dobrogea (Fig. 2). He also included the magnetic massifs of Denmark and Mecklemburg into the

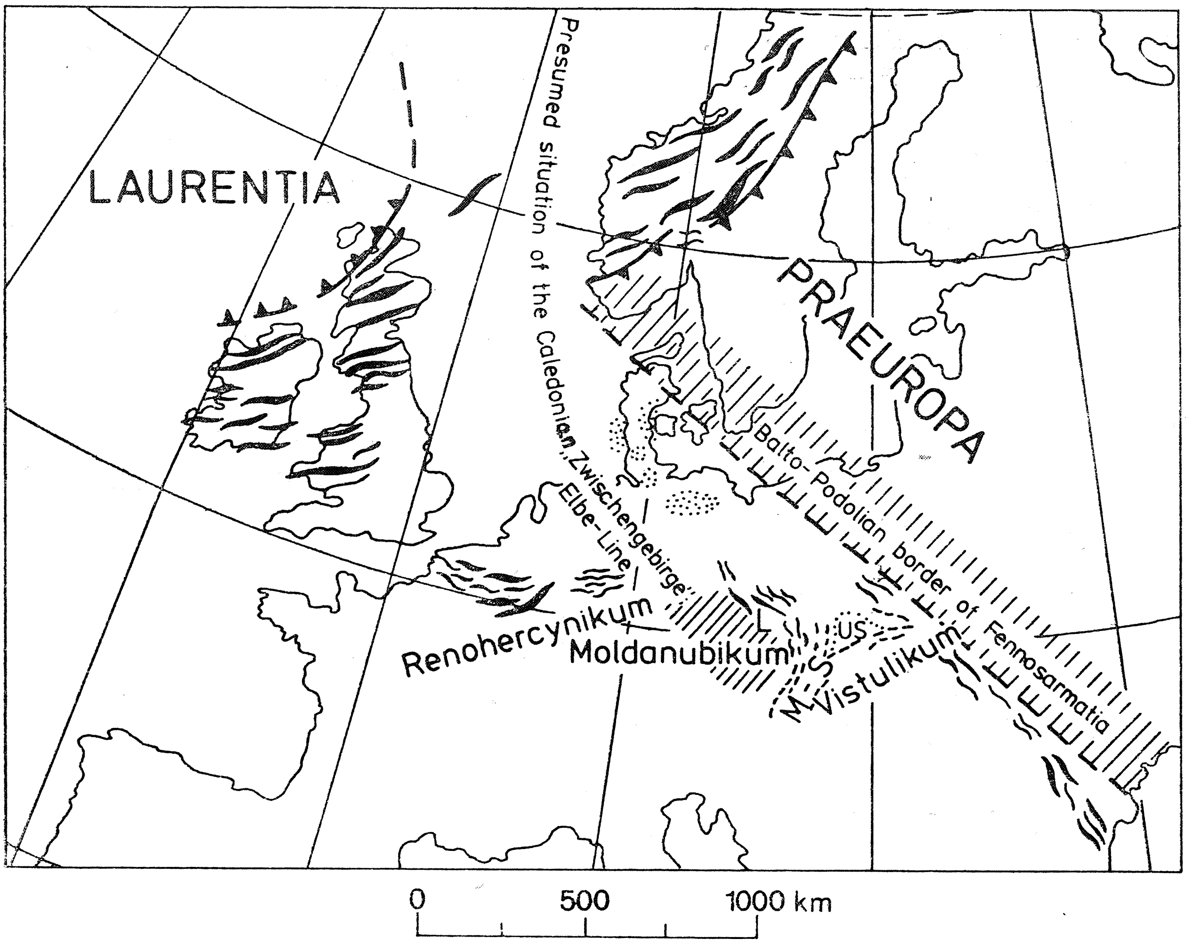

Fig. 2. Central European chains after Stille (1950). *L* — Lugicum., *M—S* ... Moravo—Silesicum, *US* — Upper Silesia. Other explanations see Fig. 3

Circum-Fennosarmatian Caledonides, considering them a geophysical reflection of intramontane Caledonian crystalline massifs. These two fold belts are separated, according to Stille, by pre-Caledonian betwixt mountains (*Innenzone* or *Zwischengebirge* of Kober, *Scheitel* of Stille) which axially separated two parallel Caledonian geosyncline branches and caused the formation of two orogenic chains of opposite vergency. Hence, a genetic separation of the British Caledonides from the Scandinavian ones was made and the western border of the Precambrian consolidation area was clearly defined.

Gaertner (1950) studied the pre-Permian tectonic relations and took into account three variants of the positions of the Caledonian chains in Europe. He tried to find a logical place for the Brabant and Ardennes Caledonides in the tectonic mosaic of Europe. The first variant agreed with Bailey's (1928) opinion, and was adopted later by Kölbel (1959) and Shatsky & Bogdanov (1961) in their tectonic syntheses of Europe. Following them, this variant was also used for compilation of the tectonic map of Europe in its first and second editions (*Carte tectonique...*, 1962, 1974—1976; see Bogdanoff *et al.*, 1964; Peive *et al.*, 1978). The second variant generally agreed with that of Stille (1950) and assumed the existence of an hypothetical internal crystalline zone. During the elaboration of the tectonic map of Europe, Gaertner (1960) took into consideration only the first (Bailey's) and the second (Stille's) variants (Fig. 3, 4).

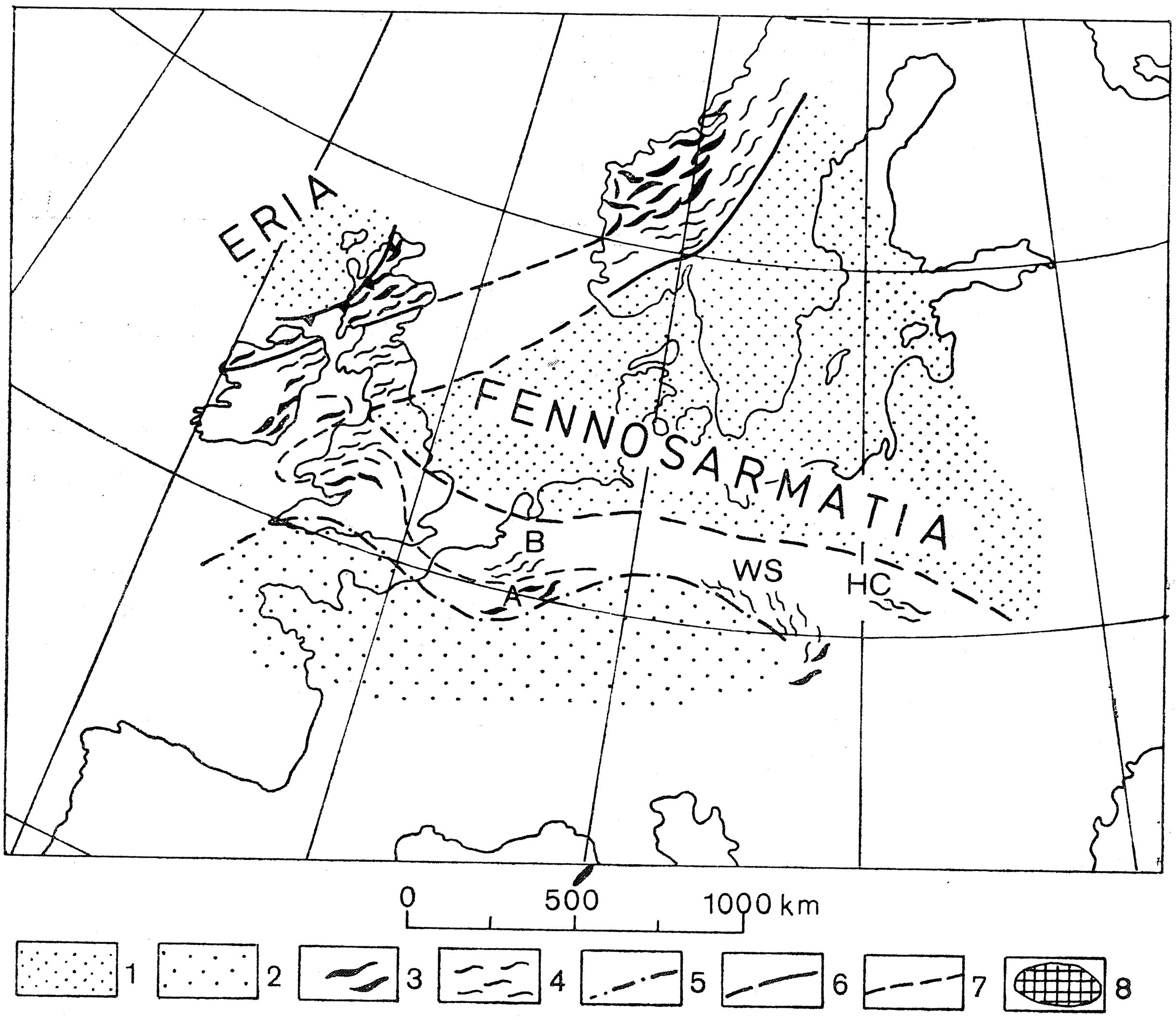

Fig. 3. Connections between Caledonian foldings after Gaertner (1960), first version. *1* — foreland, *2* — hinterland, *3* — Early Caledonian folds, *4* — Late Caledonian folds, *5* — southern limit of Caledonian foldings, *6* — external boundary of Caledonian foldings, *7* — inner boundaries of Caledonian foldings, *8* — intramontane massifs, *B* — Brabant, *A* — Ardennes, *WS* — Western Sudetes, *HC* — Holy Cross Mountains

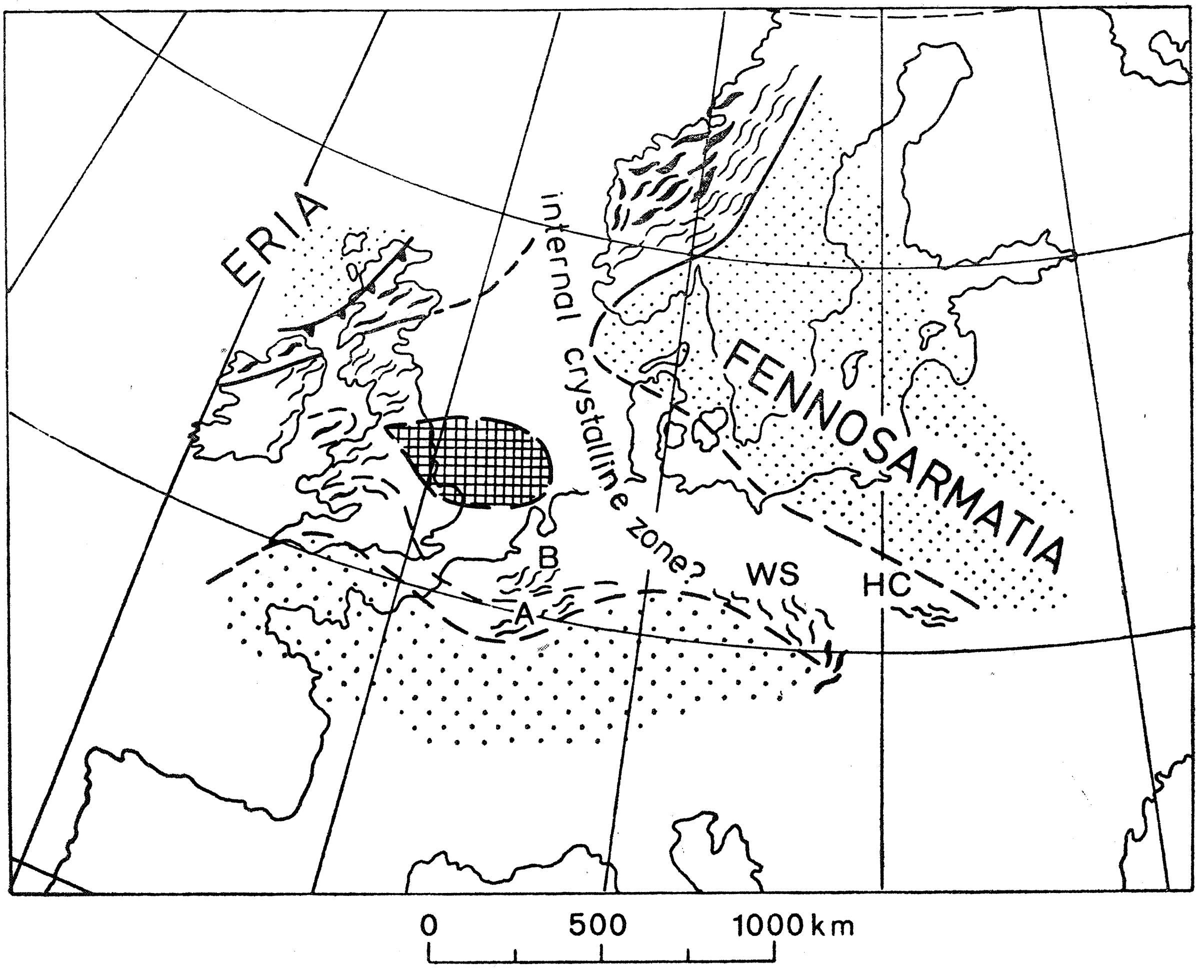

Fig. 4. Connection between Caledonian foldings after Gaertner (1960), second version; for explanations see Fig. 3

Having analysed the abundant then existing geophysical and drilling data, I reviewed (Znosko, 1962, 1964a, b) the state of knowledge of the geological structure of the deep basement in the extra-Carpathian area of Poland. In retrospect, it is worth to mention four points of this paper conclusions: (*1*) the Caledonian range adjoins the Teisseyre-Tornquist zone; (*2*) the thickness of the upper Ludlovian synorogenic sediments increases radically in the proximity of the Caledonian range, in its eastern foreland; (*3*) within the territory of Poland, the material for the upper Ludlovian synorogenic sediments could be derived only from the west or south-west; (*4*) the Caledonian orogene can indeed be buried under the platform deposits of Western Pomerania and Mecklemburg.

Two years later, this approach was enriched (Znosko, 1965a, b) with new data from deep drillings and formation analysis of the relations of Cambro-Silurian sediments in epicontinental and geosynclinal development in the territory of Poland. In the discussion, I stressed the need of tectonic comparability of rock complexes within the framework of comparative regional tectonics and I tried to oppose the views that the presence of metamorphic and magmatic rocks is a prerequisite for identifying marginal troughs (i.e. miogeosynclines or flysch geosynclines) of the Caledonian geosyncline.

In the tectonic map (*Carte tectonique*..., 1962) and its explanations (Bogdanoff *et al.*, 1964), of which I was a co-author, the whole eastern sector of the basement of the North Sea and Central-North Europe were included into the Precambrian Platform while the presence of Caledonides in Central Europe was denied. But I presented elsewhere my interpretation of those problems (Znosko, 1964c, fig. 11; 1964d, fig. 11) based upon relevant results of drillings and geophysical investigations in Poland. These results confirmed the opinions of Stille (1950) and Gaertner (1960, II variant) on possible interconnections of Caledonian fold belts in Central Europe. The Caledonian chain should extend from Dobrogea towards the north-west under the Carpathians and across Central and Western Poland towards Usedom and Rügen as far as the magnetic "massifs" of Mecklemburg, Schlezwig-Holstein, and Jutland which may represent intramontane massifs (Fig. 5).

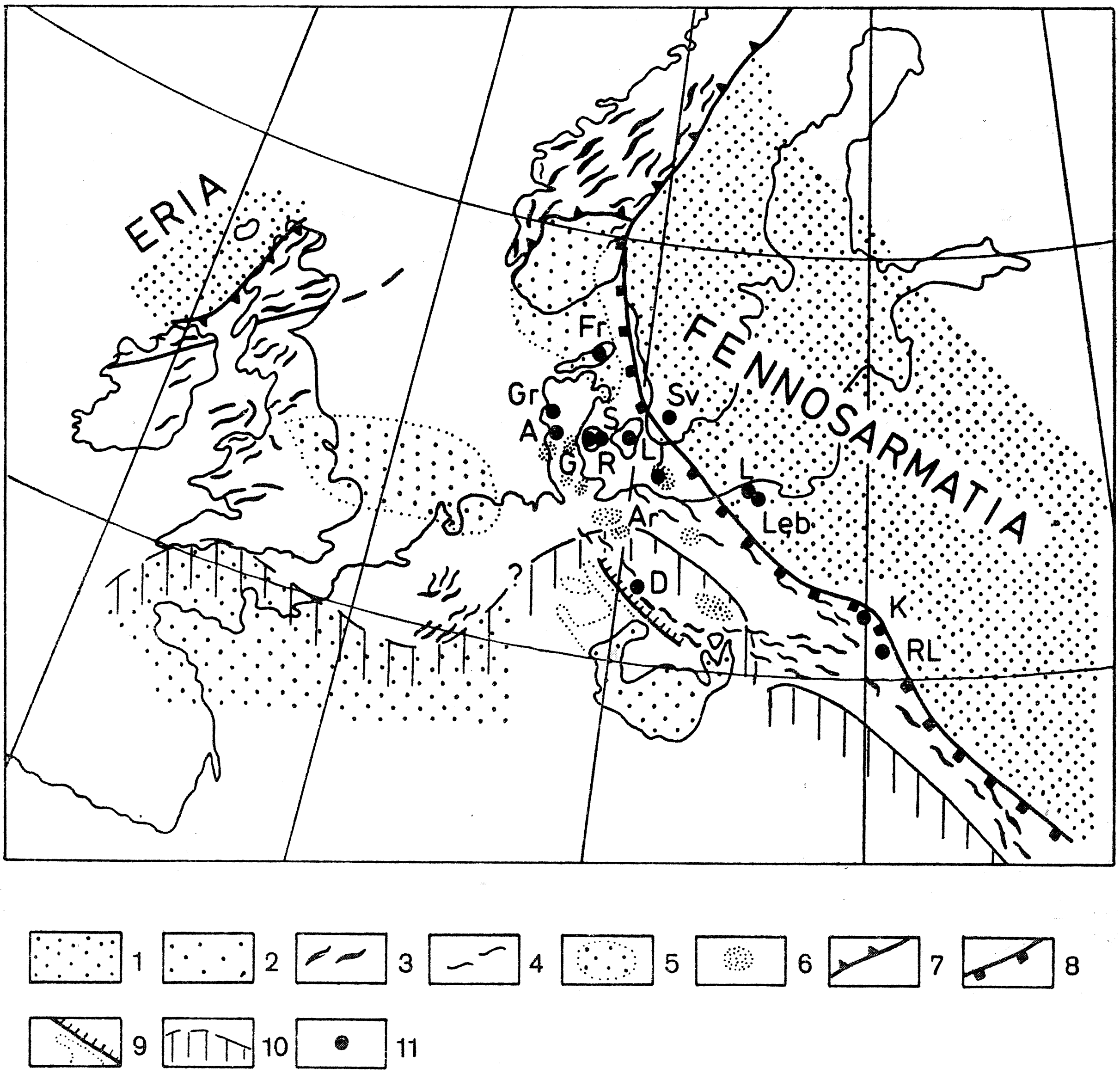

Fig. 5. Relations between Caledonian foldings in the northern part of Central Europe, after Znosko (1964c), slightly modified and complemented. *1* — foreland, *2* — hinterland, *3* — Caledonian folds, *4* — hypothetical Caledonian folds, *5* — intermontane massifs, *6* — magnetic "massifs", *7* — overthrusts, *8* — deep tectonic fracture (Precambrian Platform boundary), *9* — Elbe fault-zone and the Saxothuringicum boundaries, *10* — continuous (or regenerated) Caledonian-Variscan development, *11* — boreholes: *L* — Łeba, *Łęb* — Lębork, *K* — Kock, *RL* — Ruda Lubycka, *D* — Dobrilugk, *Ak* — Arkona, *Lj* — Ljunghusen, *Sv* — Svedala, *S* — Slagelse, *R* — Ringe, *G* — Glamsbjerg, *A* — Arnum, *Gr* — Grinsted, *Fr* — Frederikshavn

The fusion of this branch of the Caledonides with the East European Craton occurs along the tectonic zone of Teisseyre-Torquist. The long lasting post-Caledonian break in sedimentation and deep erosion caused a complete removal of the Caledonian masses thrust over their foreland. The marked erosional recession of the overthrust front of the Caledonian masses in Scandinavia was noted by Gaertner (1950, fig. 1; see also Znosko, 1965a, pp. 35, 69). Due to the removal of the thrust Caledonian masses the tectonic contact of the Caledonian fold belt with the Precambrian Platform became sharply accentuated as a tectonic suture. Along this suture, the Caledonian plutonic and metamorphic rocks occur in proximity or even in direct contact with the crystalline basement of the East European Craton (see Frost *et al.*, 1981, fig. 1; Ziegler, 1982, encl. 1).

The English-Frisian massif (Gaertner, 1960) and the Saxothuringian massif (Stille, 1950) would form, as assumed by Stille, a pre-Caledonian betwixt mountains separating the Caledonian Brabant-Ardennes chain from the Circum-Fennosarmatian one (Znosko, 1964c, fig. 11, p. 719).

Franke (1967), while working on the tectonic map of Europe, followed the version of Suess; he relied on the drilling data available at that time. However, some time later (Franke, 1977), though he did not change his earlier opinion, he admitted the possibility of the existence of Caledonian folding along the edge of the East European Craton.

Teschke (1975) considering the palaeotectonical data on the Teisseyre-Tornquist zone supposed that the edge of the old platform was represented by the outer, northeastern dislocation zone which he named the Dobrogea-North Sea lineament.

GEOLOGICAL DATA FROM POLAND AND THEIR SIGNIFICANCE FOR RECONSTRUCTION OF EUROPEAN CALEDONIDES

The sixties and seventies were the years of extensive geological-geophysical studies and drilling operations in the North Sea, and of further intensive drilling and geophysical penetration in Poland. It was established at that time that in Poland strongly folded Early Palaeozoic geosynclinal rocks adjoined the tectonic zone of Teisseyre-Tornquist between Koszalin in the north-west and Lubaczów in the south-east. Nappe structures and folds occur most probably between Koszalin and Toruń, supposedly also between Toruń and Lubaczów and are overlapped on their foreland. They form a distinct though planated rise 2—3 km high. This rise, after peneplanation, was unconformably covered with various divisions of Devonian and Carboniferous and with continuous Zechstein deposits which sometimes encroach directly on lower Palaeozoic (Fig. 6).

In this zone, the upper Ludlovian rocks are developed as clayey mudstone flysch alimented from the west and south west, the direction of turbidity currents being parallel to the margin of the East European Craton (Jaworowski, 1971, variant I).

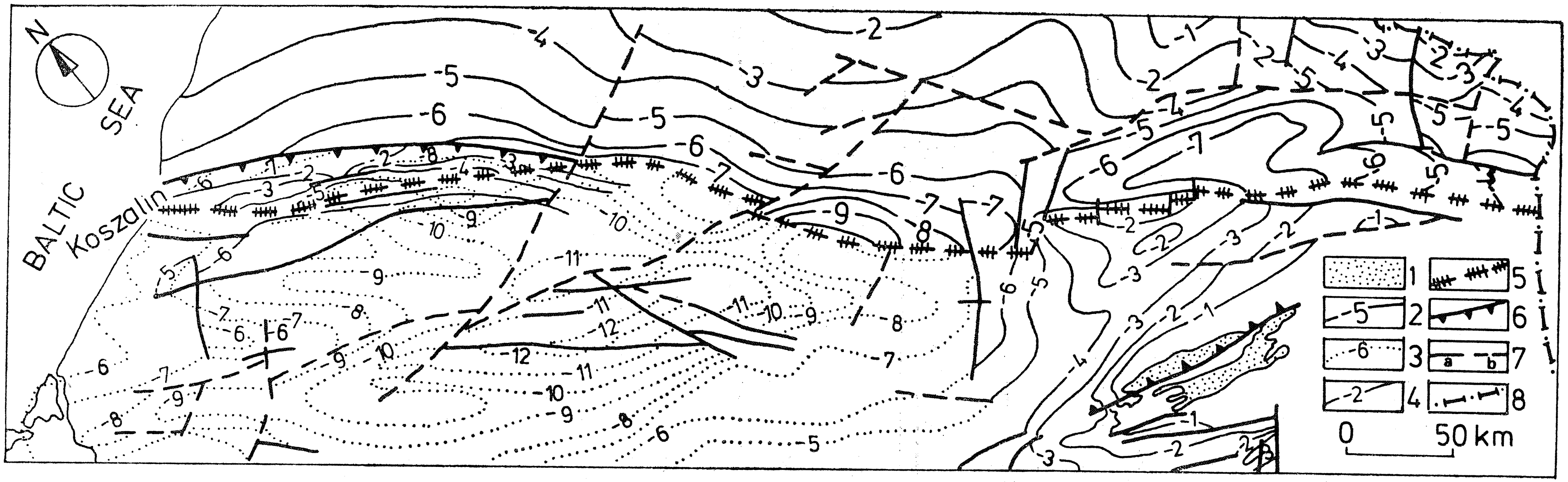

Fig. 6. Sketch-map of the top surface of Old (Pre-Vendian) and Palaeozoic Platforms in Teisseyre-Tornquist Zone. *1* — exposed Palaeozoic core of Holy Cross Mts., *2* — contour lines of top of cristalline basement of the Old Platform (in km), *3* — contour lines of seismic "basement", probably Caledonian top surface (in km), *4* — contour lines of top of Caledonian basement (in km), *5* — Teisseyre-Tornquist tectonic line, *6* — overthrusts, *7* — faults (*a* — proved, *b* — supposed), *8* — state boundary

The Holy Cross (Świętokrzyskie) Mts (Fig. 7) as a whole lie in this tectonic zone (Znosko, 1983, 1984).

In the basement of the Nida trough and of the Carpathian Foredeep, the youngest Precambrian and Cambrian sub-Holmia and Holmia metasediments (Pożaryski *et al.*, 1981) were found to be strongly folded. The Ordovician and Silurian sediments are developed in the same way as in the Holy Cross Mts, probably re-

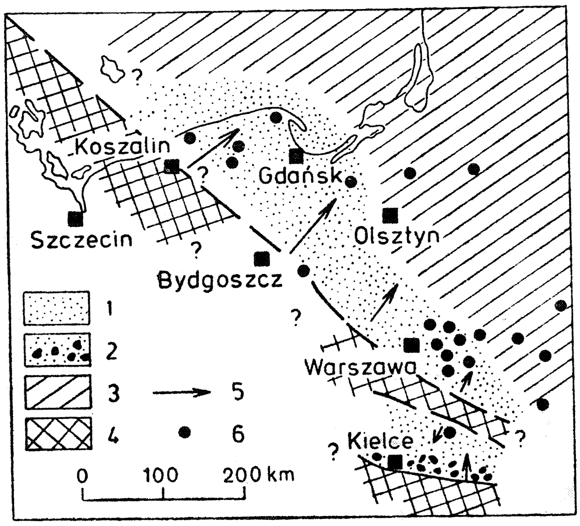

Fig. 7. Sketch-map of the Upper Silurian sedimentary basin in the Polish Lowland, variant 1; after Jaworowski (1971), somewhat supplemented. *1* — shale-siltstone complex, *2* — greywackes (locally with intercalactions of conglomerates), siltstones and shales of Holy Cross Mts., *3* — shales and marls, *4* — supposed source areas of silty material, *5* — main directions of sediment transport, *6* — important boreholes with Upper Silurian deposits

presenting nappes strongly tectonically reduced in thickness during their thrusting over the Małopolska intrageanticline. Along the north-eastern margin of Upper Silesia, various Precambrian through Silurian metasediments associated with basic and acid plutonic rocks and pre-Emsian volcanics were found. These slightly metamorphosed rocks are very strongly folded, imbricated and thrust over older Palaeozoic sedimentary rocks. Numerous examples of tectonic alternation of sedimentary and metamorphic complexes of the same age were encountered in many boreholes, suggesting a large compression of the Caledonian geosyncline. The rock representing different geosynclinal zones (more internal, more external) are now folded together.

The basement of the Upper Silesian Coal Basin, built up of gabbros, granitoid rocks, gneisses, schists, and amphibolites unconformably covered by Lower Cambrian terrigenous sediments, is considerably well recognized by drillings. This crystalline basement represents an intramontane massif with respect to the Caledonian geosynclinal system not involved in basinal and orogenic evolution of the latter*.

* According to the recent results by Z. Kowalczewski and M. Moczydłowska (oral communications, 1985) the Lower Cambrian of the Upper Silesian Massif may represent Lower, Middle and Upper Cambrian and Tremadocian. It is partly developed as strongly folded, imbricated and thrust metasediments. This massif could be thus treated as a part of Caledonian internides (metamorphides, see Znosko, 1974, p. 39, Addendum 1).

The geological cross-section from the Holy Cross Mts to Upper Silesia discussed above in rough lines gives, in the present author's opinion, evidences that in Poland we deal with an outer part of the double or multiple branch of Caledonian system. Its more distant and inner parts would be represented in the Sudetes which clearly show the stages of Caledonian evolution continuated and regenerated by Variscan geosynclinal and orogenic development.

In 1974 I forwarded an opinion (Znosko, 1974) that the folded basement of the south and central Poland, Kujawy, Wielkopolska and Western Pomerania represents part of extended Vistulikum which, according to my opinion from 1964, should continue towards the North Sea.

GEOLOGICAL DATA FROM THE NORTH SEA AND THEIR SIGNIFICANCE FOR RECONSTRUCTION OF CALEDONIAN CONNECTIONS IN EUROPE

The results of investigations carried out in the North Sea, published *int. al.* by Ziegler (1975, 1978, 1982) and Frost *et al.*, (1981) confirmed the existence of Caledonides in Central Europe. In my opinion, this closes almost a century long speculations on this subject.

Krebs (1978) returned to this problem in consequence of unexpected results of deep borings at Soest-Erwitte 1/1a, directly to the north from the Rheinische Schiefergebirge. The finding of folded anchimetamorphic early Palaeozoic rocks in the immediate vicinity of the Variscan Lippostadt High became an important information as to the extent of the Central European Caledonides. Krebs accepted Stille's (1950), Gaertner's (1960), and Ziegler's (1975, 1978) versions confirmed in the marginal zone of the East European Platform by the results of the previous Polish investigations. Moreover, Krebs (1978) included the Ringkøbing-Fyn High into the area of the East European platform and accepted the direct connection of the Scottish and Norwegian Caledonides in spite of their opposite vergency.

The most recent approach to this fascinating problem was presented by Ziegler (1982) in his well edited and excellently illustrated monography. He distinguished the following Caledonian fold belts: (*1*) metamorphic Scottish-Norwegian Caledonides, (*2*) non-metamorphic English Caledonides, (*3*) Central European Caledonides including Middle German High, and (*4*) North German-Polish Caledonides. The latter are bordered in the south by a zone of continuous Silurian through Devonian sedimentation; in this zone geosynclinal-orogenic Variscan development continued.

In the latter zone, Ziegler (1982) distinguished: (*1*) the Armorican basin, (*2*) the Saxothuringian basin, (*3*) the Barrandian basin, (*4*) the Sudetes basin, and (*5*) the basin of northern part of the Holy Cross (Świętokrzyskie) Mts. From the south the zone of the basins is bordered by the Ligerian Cordillera, the Arveno-Vosges Cordillera, and the Bohemian Massif. Moreover, Ziegler distinguished individual intramontane or intermontane massifs: the London, the Norman, and the Upper Silesian ones.

The radiometric age of the Caledonian basement rocks is determined in most borings by means of the K/Ar, Rb/Sr, U/Pb method and the recent, very precise method Ar/Ar (Frost *et al.*, 1981). The radiometric age of the plutonic and metamorphic rocks varies from 346 to 500 Ma, there are also rocks dated as 698 to 922 Ma indicating the presence of older massifs incorporated into the Caledonian basement.

In the basement of the North Sea, no rocks older than Devonian were found in the sedimentary cover (Frost *et al.*, 1981; Ziegler, 1982). The Lower Devonian sediments occur only in the north, i na restricted area, as sandy sediments of continental origin. During the Middle Devonian, in the territory of the present North Sea, a northward elongated bay was formed. It included marine, carbonate and evaporitic sediments. The Late Devonian continental sedimentation covered almost the whole territory of the present North Sea (Ziegler, 1982). The relation of these deposits to the peneplained basement is determined both by angular unconformity and discordant contours on structural maps. All these data indicate that the consolidation of the North Sea basement is of Caledonian age.

POSTULATED VARIANT OF CALEDONIAN TECTONIC RELATIONS IN EUROPE

The geological controversy concerning the existence of Caledonides in Central Europe having been settled, their mutual relationships should be considered, more so, because the existing concepts do not seem satisfactory. The following conclusions are implied by the geological data presented above:

(*1*) Taking into consideration the opposite vergence of the Irish-Scottish and Norwegian Caledonides one cannot consider them to be the same orogenic chain. The Scottish and East Greenland Caledonides of western vergency directed towards the Erian Craton form the same orogenic belt.

(*2*) The Norwegian Caledonides, and especially their outer non-metamorphic nappes, that in some places escaped complete erosion (sparagmite fields), have their natural prolongation in unmetamorphosed Caledonian sediments of northern and central England. From the Scottish Southern Uplands their vergency is directed towards the south or south-east towards the London Massif. According to Gaertner (1950), the final and most intense folding shifted southwards with time.

(*3*) Consequently, the zone lying between the southern Scottish fault and the palaeotectonic Iapetus suture could be considered as buried and compressed betwixt mountains. It should continue to the north-east and further on to the north, separating the Scottish-Greenland from the English-Norwegian Caledonian belts. Plutonic and deep metamorphic rocks drilled along the axis of the North Sea as far as the north-eastern Shetlands, seem to permit such point of view. The betwixt mountains during the Early and Middle Cambrian separated the Pacific province from the Acadian-Baltic province, and were inversed during the Ordovician. The land massif of the Irish Sea (also partly inversed) became accreted to it at the end of the Caledonian epoch as a result of successive consumption of the oceanic crust of the Iapetus. Thus, the role of the betwixt mountains was finally taken over by the Iapetus suture (Philips *et al.*, 1976).

(*4*) The south-western corner of Fenno-Scandia formed by the Ringkøbing-Fyn High seems to continue in the basement of the North Sea, possibly to the London Massif. The results of borings in the North Sea do not contradict this hypothesis, since plutonic and high metamorphic rocks occur between these two massifs. These rocks would constitute other cristalline betwixt mountains, separating the sedimentary Anglo-Scandinavian Caledonides from the Cornwall-Brabant-North German-Polish Caledonides.

(*5*) The Silurian-Devonian zone of continuous geosynclinal sedimentation, stretching from Central Armorican Basin through Saxothuringian, Sudetes, and Łysa Góra (northern part of the Holy Cross Mts) basins extended as far as Dobrogea (Romania).

(*6*) From the south it was accompanied by the zone of cordilleras and intermontane massifs represented by the: Ligerian, Arverno-Vosgian, Bohemian, Upper Silesian, and Pannonian massifs. This zone together with the adjoining zone of Silurian-Devonian continuous deposition (*5*) was included into the Variscan development which embraced elements of both ensialic and oceanic crust.

(*7*) The Variscan betwixt mountains disturbed and obscured the original Caledonian vergence (Fig. 8).

(*8*) The front of the Caledonian overthrust respective to the Fenno-Scandia--Baltica Craton is erosional. The outer zone of the non-metamorphic Scandinavian Caledonides is marked by tectonic caps of sparagmite fields: Valdres, Gudbrandsdal, Gausdal, and Hardangervidda. In Poland, the front is probably marked by nappes of claystone-mudstone Ludlovian flysch found along the tectonic zone of Teisseyre-Tornquist where they form a structural unit strongly contrasted with the East European Craton.

(*9*) The borings performed in the closest vicinity of the Ringkøbing-Fyn massif: Flensburg, Loegumkloster and Westerland found biotite schists and phyllites of epi- and mesozonal metamorphic grade. The borings PER IX and Q1 found microgranite dated at 435 Ma and gneisses dated at 415 Ma, respectively (Ziegler, 1982; Frost *et al.*, 1981). It is interesting that these Caledonian plutonic and metamorphic rocks contact directly the Ringkøbing-Fyn "Massif" — doubtlessly Precambrian but, so far, of unclear tectonic position.

(*10*) Taking into account that: (*a*) the borings Nøvling 1 and Rønde 1 in northern Jutland penetrated only Ludlovian rocks representing the top of the presumably thick Cambro-Silurian complex (Christensen, 1971; Rasmussen *et al.*, 1971); (*b*) the borings Hønning 1 and Aabenraa 1 in Southern Jutland pierced Ludlovian rocks with quartz veins (?) dipping at an angle 37° (Krebs, 1978); (*c*) in the boring Slagelse in western Sjaelland a 400 m long section of only Llandoverian rocks (Poulsen, 1974) dipping at angles 6—7°, 16—40° and 10—20° (Sorgenfrei & Buch, 1964) occurred; and (*d*) in all these borings the Silurian rocks are overlain by strata not older than the Upper Permian, it may be supposed that, similarly as in Poland, we deal here with deposits of the marginal trough (miogeosyncline) of the Caledonian geosyncline. These deposits, similarly as the Scandinavian sparagmites and the clayey-muddy flysch in Poland, were possibly thrust far over their foreland. The

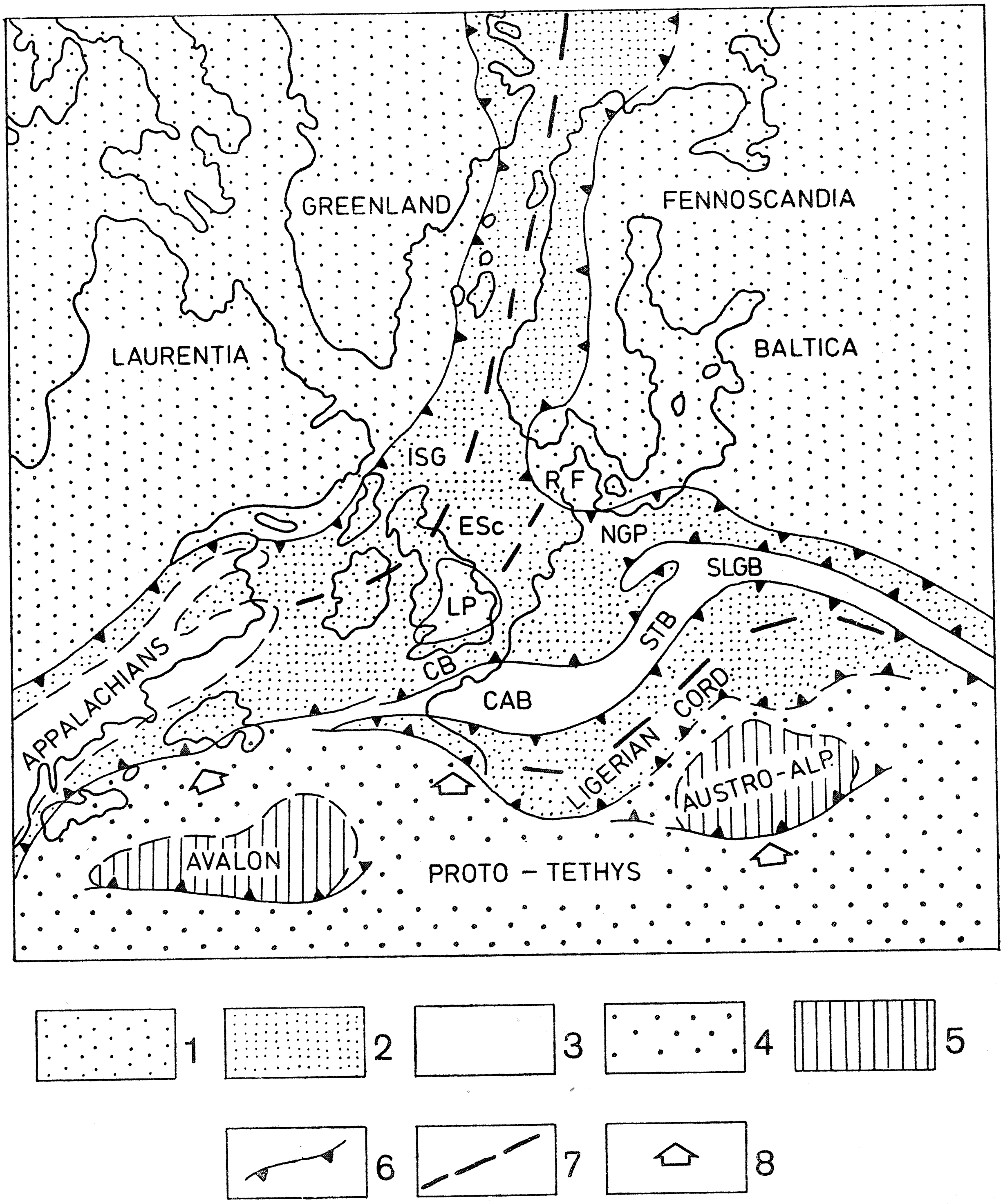

Fig. 8. Tentative Late Caledonian tectonic framework of Arctic-North Atlantic realm, after Ziegler (1982), slightly modified and supplemented. *1* — continental cratons, *2* — active fold belts, *3* — basins with continuous marine sedimentation across Silurian-Devonian boundary, *4* — oceanic domains, *5* — microcontinents, *6* — deformation fronts of active fold belts, *7* — hypothetical betwixt mountains (median massifs, Iapetus suture), *8* — direction of oceanic crust subduction, movement of microcontinents and their accretion to Central European Caledonides, *ISG* — Irish-Scottish-Greenland Caledonides, *CB* — Cornwall-Brabant Caledonides, *NGP* — North German-Polish Caledonides, *LP* — London massif, *RF* — Ringkøbing-Fyn massif, *CAB* — Central Armorican Basin, *STB* — Saxothuringian Basin, *SLGB* — Sudetic-Łysa Góra Basin

original front of the Caledonian overthrust would then run from the vicinity of Oslo across Sjaelland, Scania and Koszalin. (see Fig. 5).

(*11*) On adopting such an assumption (*10*), the very strong compression and coming to close contact of rocks of genetically different zones would be accounted for by collision, which closed the Proto-Atlantic (Iapetus) and partly the Proto--Tethys. This collision caused downpressing of some zones (betwixt mountains and median massifs) as well as piling up and overthrusting of others (elevated massifs, external nappes). Erosion and the thick cover of the post-Caledonian sedimentation obscured this picture.

(*12*) This reconstruction of the mutual relations between the divergent Caledonian chains leaves out the question of some Caledonian or post-Caledonian lateral displacements. Due to these, some genetically matching Caledonian chains could be found far apart. But some palaeozoogeographical data, such as those concerning the Cambrian trilobites (Orłowski, 1975; Bergström, 1985), deny the idea of Brochwicz-Lewiński *et al.* (1981) that the Upper Silesian Massif has been displaced 2—2.5 thousand km away.

CONCLUDING REMARKS

What still remains to be considered is the nature of the Caledonian evolution of Europe with respect to the preceding epochs. It would also be of interest to establish the extent of the tectonic continuation in the Variscan evolution which definitely closed the long lasting and complex, continuative and regenerative Grenvillian--Variscan development against the background of the new global tectonics. Zwart & Dornsiepen's (1978) palaeotectonic reconstruction suggests that the Grenvillian--Sveconorwegian, Cadomian, Caledonian and Variscan developments proceeded according to the triple junction model. From this junction, in post-Grenvillian tectonic epochs, the oceanic floor spreading took place causing the cratons of Laurentia, Europe and Africa to drift away.

The Grenvillian-Sveconorwegian stage resulted in the formation of the tripple junction. The Cadomian stage was marked as continuating in the Appalachians and Mauretanides and in Western and Central Europe leaving out the Greenland--Scandinavian part. The latter was regenerated in the Caledonian Epoch.

The Caledonian continental collision and the resultant consolidation definitely closed the Iapetus Ocean in its Greenland-Scandinavian branch and separated the British, Brabant, and North German-Polish Caledonides from the territory of the Silurian-Devonian consolidation.

The Variscan consolidation completely closed the Proto-Atlantic, closed partly the Proto-Tethys and formed Pangea, leaving over to the Alpine continuation only the Algerian Atlas, the Betides, the Pireneans, the Alps, the Apennines, as well as the whole Carpathian-Dynaric sector and the Hellenides.

The consolidation of the Alpine epoch left only relics of the oceanic crust of the Tethys, which seem to occur also in the territories of earlier tectonic consolidations.

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Streszczenie

POLSKIE KALEDONIDY I ICH ZWIĄZKI Z KALEDONIDAMI EUROPY

Jerzy Znosko

Od czasu opublikowania syntezy geologicznej E. Suessa pt. *Oblicze Ziemi* rozpoczął się prawie 100-letni spór między zwolennikami a przeciwnikami egzystencji kaledonidów w Europie Środkowej. Kontrowersyjność poglądów uruchomili Suess (1885—1909) oraz Haug (1907). Pierwszy negował egzystencję kaledonidów w Europie Środkowej, drugi opowiadał się za ich obecnością.

Od tych dwu odmiennych ujęć tektonicznych rozpoczęła się ich alternacja w zależności od wymowy coraz to nowszych faktów geologicznych. Przedtem jednak Stille (1920) ustalił ogólnie przyjętą zasadę konsolidacji tektonicznej.

Alternację poglądów rozpoczął Kober (1921), który w znacznej mierze podzielił stanowisko Suessa. Ten punkt widzenia został również przyjęty przez Bailey'a (1928), Bailey'a i Holtedahla (1938), Kölbela (1959), Szatskiego i Bogdanowa (1961), Frankego (1967, 1977). Uznano go też za obowiązujący przy międzynarodowej konstrukcji I i II wydania mapy tektonicznej Europy (1962, 1974—76).

Pierwszym, który poparł pogląd Hauga i wyraził myśl o zrastaniu się kaledonidów skandynawskich i środkowoeuropejskich łączących się następnie z brytyjskimi, był Limanowski (1922) (Fig. 1A). Najogólniej rzecz biorąc, takie ujęcie wyrażone jest również w konstrukcjach kaledonidów europejskich Stillego (1924), Bubnoffa (1926), Sobolewa (1926), Schwinnera (1934), Kossmata (1936) (Fig. 1B), Beurlena (1939), a spośród geofizyków w konstrukcjach Zwergera (1948) oraz Lauterbacha (1955), wreszcie ponownie u Stillego (1950; Fig. 2), który wskazał na przeciwną wergencję kaledonidów cirkumlaurentyjskich i cirkumfennosarmackich. Gaertner (1950) rozważył trzy warianty związków kaledońskich, które potem zredukował do dwóch, pokrywających się konstrukcjami, wymienionych już dużych grup tektoników (Fig. 3, 4; Gaertner, 1960).

W 1962 r. opowiedziałem się za modelem Stillego (1950), wskazując na wyraźne w Polsce oznaki sedymentacji synorogenicznej w ludlowie górnym (Znosko, 1962). W 1965 r. poparłem ten pogląd analizą formacyjną skał kambro-syluru na obszarze Polski (Znosko, 1965a, b), a w 1964 r. przedstawiłem model związków kaledońskich w Europie (Fig. 5; Znosko, 1964a), potwierdzający w ogólnych zarysach hipotezę Stillego (1950) i Gaertnera (1960, II wariant), z uwypukleniem międzygórza, które by rozdzielało łańcuchy walijsko-brabancko-ardeński i cirkumfennosarmacki. Odnotować wreszcie trzeba próbę interpretacyjną Teschkego (1975), który strefę Teisseyre'a-Tornquista uznał za granicę południowo-zachodnią platformy wschodnioeuropejskiej, a samą strefę za jednostkę tektonicznie samodzielną należącą do platformy Zachodniej Europy.

Lata sześćdziesiąte i siedemdziesiąte to okres intensywnych wierceń na Morzu Północnym i dalsza penetracja wiertnicza i geofizyczna w Polsce. W tym czasie ustalono w Polsce, że: *1*) utwory kambro-syluru w strefie Teisseyre'a-Tornquista są rozwinięte w facjach geosynklinalnych, są intensywnie sfałdowane, najprawdopodobniej są spłaszczowinowane, złuskowane i nasunięte na przedpole. Tworzą one w stosunku do podłoża krystalicznego starej platformy wyraźne wypiętrzenie o amplitudzie do 2—3 km (Fig. 6); *2*) górny ludlow tej strefy rozwinięty jest jako flisz (Fig. 7); *3*) Góry Świętokrzyskie znajdują się w tej strefie (Fig. 7); *4*) w podłożu zapadliska przedkarpackiego i niecki Nidy stwierdzono prekambr oraz w 4 miejscach kambr subholmiowy i holmiowy rozwinięte jako skały anchimetamorficzne lub metaskały bardzo intensywnie sfałdowane, ordowik i sylur o wykształceniu jak w Górach Świętokrzyskich i prawdopodobnie spłaszczowinowany, a na skutek tego wewnętrznie powyciskany i nieregularnie zredukowany w trakcie nasunięcia na geantyklinę małopolską; *5*) w NE obrzeżeniu Górnego Śląska ujawniono różne metaskały prekambru-syluru z plutonitami kwaśnymi i zasadowymi oraz wulkanitami preemskimi, przefałdowane i złuskowane wspólnie ze skałami osadowymi kambru (?) oraz ordowiku-syluru, co dowodzi dużej kompresji geosynkliny kaledońskiej; *6*) podłoże Górnego Śląska budują skały plutoniczne kwaśne i zasadowe, gnejsy i łupki krystaliczne nakryte epikontynentalnym kambrem dolnym. Masyw Górnego Śląska był w systemie kaledońskim masywem śródgórskim, choć ostatnie badania Z. Kowalczewskiego i M. Moczydłowskiej (informacja ustna) wskazują na obecność również kambru środkowego, górnego i tremadoku oraz umożliwiają inną interpretację tektoniczną, według której masyw Górnego Śląska można by traktować jako część kaledońskich internidów (metamorfidów).

Omówiony przekrój geologiczny dowodzi, że w środkowopołudniowej Polsce istniała zewnętrzna część systemu kaledońskiego. Jego dalsze części istniały m. in. w Sudetach, ale zostały objęte kontynuacją waryscyjską. Uogólniając można stwierdzić, że w Polsce Centralnej, na Kujawach, Wielkopolsce i na Pomorzu Zachodnim istnieje w podłożu pogrzebane kaledońskie Vistulikum, które powinno się kontynuować w stronę Morza Północnego (Znosko, 1974).

Wyniki badań na Morzu Północnym najlepiej oddaje monografia Zieglera (1982), który wyróżnia następujące pasma kaledońskie: *1*) metamorficzne, szkocko-norweskie, *2*) niemetamorficzne — angielskie, *3*) środkowoeuropejskie wraz z wysoczyzną środkowoniemiecką, *4*) północnoniemiecko-polskie. Przylega do nich od południa strefa kontynuacji sylursko-dewońskiej obejmująca: basen armorykański, saxothuryngijski, Barrandienu, Sudetów i Łysogór. Od południa strefa ta jest ograniczona kordylierą Liguryjską i Arverno-Wogezyjską oraz Masywem Czeskim. Ponadto

Ziegler wyróżnia jeszcze odosobnione masywy: londyński, normandzki i Górnego Śląska.

Mając już rozstrzygnięty geologiczny spór 100-lecia, trzeba rozpatrzyć wzajemne związki kaledonidów Europy. (*1*) Przeciwna wergencja kaledonidów szkockich i skandynawskich nie zezwala uznać ich za jeden i ten sam łańcuch górski. Kaledonidy irlandzko-szkockie i grenlandzkie o wergencji ku Erii są logicznym pasmem górskim. (*2*) Kaledonidy Skandynawii, szczególnie ich zewnętrzne, niemetamorficzne, płaszczowinowe partie (sparagmit Valdres i inne) mają naturalne przedłużenie w osadowych kaledonidach północnej i środkowej Anglii, które od wysoczyzny południowej Szkocji mają wergencję ku S. (*3*) Strefę zawartą między południowoszkocką dyslokacją a paleotektonicznym szwem Iapetusu można by uznać za pogrzebane i zaciśnięte w głębi międzygórze (*Innenzone, Scheitel*), które rozdziela pasmo szkocko-grenlandzkie od angielsko-norweskiego. Skały krystaliczne nawiercone na E i NE od Szetlandów umożliwiają taki punkt widzenia. (*4*) Naroże Fennoskandii (Ringkøbing-Fionia) ma, jak się wydaje, swoje przedłużenie w masywie londyńskim. Wyniki wierceń na Morzu Północnym również umożliwiają i ten pogląd. Elementy te tworzyłyby następny dział tektoniczny rozdzielający kaledonidy angielsko-skandynawskie od kornwalijsko-brabancko-północnoniemiecko-polskich. (*5*) Strefa kontynuacji sylursko-dewońskiej ciągnęła się bez wątpienia do Dobrudży. Przylegała do niej od południa strefa rozwoju geosynklinalnego (Fig. 8). (*6*) Granica frontu nasunięcia kaledońskiego na starej platformie jest erozyjna. Zewnętrzną, niemetamorficzną strefę kaledonidów Skandynawii tworzą pola sparagmitowe a w Polsce flisz górnego ludlowu. (*7*) Wiercenia wykonane bezpośrednio przy masywie Ringkøbing-Fionia wykazały kaledońskie skały plutoniczne i mezozonalnego metamorfizmu. (*8*) W związku z tym wydaje się, że skały sylurskie w wierceniach Nøvling 1, Rønde 1, Slagelse, Hønning 1, Aabenraa 1, można interpretować jako utwory miogeosynklinalne nasunięte na przedpole. Wtedy pierwotna granica nasunięcia kaledońskiego mogłaby przebiegać od okolic Oslo przez Zelandię na Skanię i Koszalin (*vide* Fig. 5). (*9*) Wytłumaczalna byłaby wtedy bardzo intensywna kompresja skał różnych stref tektonicznych przy ostatecznej kolizji tektonicznej. Mogła ona doprowadzić do wgniecenia niektórych stref oraz wypiętrzenia i nasunięcia innych. (*10*) Erozja i sedymentacja pokaledońska zaciemniły ten plan tektoniczny i uczyniły go pod pokrywą skał osadowych nieczytelnym geologicznie i geofizycznie.