Geological Quarterly, Vol. 37, No. 3, 1993, p. 431–450

Ryszard DADLEZ

Pre-Cainozoic tectonics of the southern Baltic Sea

Tectonics of the western part of the Polish Baltie sector resulted from several stages of deformations. The Caledonian folding front being in the Polish territory connected with the Teisseyre-Tornquist Zone (TTZ) separates from it at the Baltic coast, running toward WNW. The Teisseyre-Tornquist Zone runs farther in the NW direction being within this sector the rejuvenated Precambrian intracratonic deep-seated fracture. The Caledonian deformation might have been the result of the oblique collision of small crustal blocks (terranes?) of Baltic or Gondwana provenance with the East-European craton. The division of the area into faulted blocks took place at the turn of the Carboniferous and Permian probably also in transpressive conditions. After the Early Mesozoic period of tension and transtension connected with the opening of North Atlantic some of these faults were rejuvenated also in the transpressive environment. The strike-slip component decreased distinctly with the passage of time.

INTRODUCTION

The first reflection seismic investigation in the Polish sector of the Baltic Sea was carried out in the years 1964–1967 (R. Dadlez, S. Młynarski, 1967; R. Dadlez, 1974*b*). Despite the very poor work methods the results obtained at that time were reliable enough down to the Zechstein base. Not only major fault zones dividing the area into 3 blocks, i.e. the Wolin, Gryfice and Kołobrzeg ones but also some subordinate faults and major anticlinal elevations were discovered. However, no data were received from the pre-Zechstein formations. These basic characteristic features of the geological structure were confirmed by the latest investigation.

In the recent years the area was covered by dense network of reflection seismic profiles performed by W. O. Petrobaltic. In addition, deep boreholes were also drilled. The obtained results along with the geological reconnaissance of the neighbouring areas (O. V. Vejbaek, 1985; *Eugeno-S* ..., 1988; R. M. Pegrum, 1984*a*) enabled to

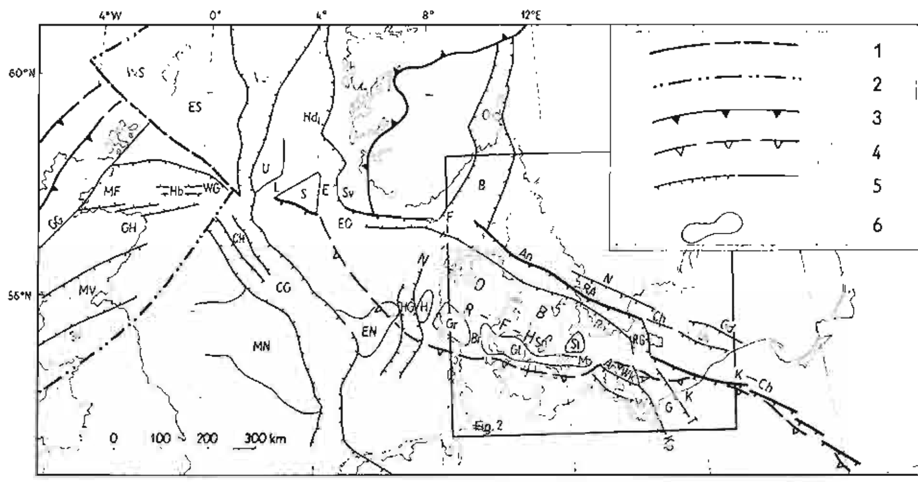

Fig. 1. Main tectonic units between North Sea and southern Baltic Sea (after: P. A. Ziegler, 1982; R. M. Pegrum, 1984*a*; J. Bergström et al., 1982 and O. Michelsen, C. Andersen, 1981; supplemented and modified)

1 — Teisseyre-Tornquist Zone; 2 — presumed cryptic suture of the Iapetus Ocean; 3 — Caledonian deformation front in Norway and Scotland; 4 — Caledonian deformation front between North Sea and Poland; 5 — major faults; 6 — boundaries of some tectonic blocks; A — Adler Fault; An — Anholt Fault; Ar — Arkona Block; B — Bamble Trough; Br — Brande Trough; CG — Central Graben; CH — Central Graben High; Ch — Christiansö Horst; E — Egersund Basin; EN — East North Sea High; EO — Outer Egersund Subbasin; ES — East Shetland Platform; E — Farsund Basin; Fj — Fjerritslev Fault; G — Gryfice Block; Gd — Gardno Fault; GG — Great Glen Fault; GH — Grampian High; Gl — Glamsbjerg Block; Gr — Grindsted Block; H — Holmsland Block; Hb — Halibut Horst; Hd — Horda Basin; HG — Horn Graben; K — Kołobrzeg Block, K-Ch — Koszalin — Chojnice Zone; Kp — Kamień Pomorski Fault; L — Ling Graben; M — Moen Block; MF — Moray Firth Basin; MN — Mid-North Sea High; MV — Midland Valley; N — Nävlinge Fault; N-D-B — Norwegian-Danish Basin; O — Oslo Graben; RA — Ringsjö — Andrarum Fault; R-F-H — Ringkøbing-Fyn High; RG — Rønne Graben; Rm — Romeleasen Fault; S — Sele High; Sn — Stigsnaes Block; St — Stevns Block; SU — Southern Uplands; Sv — Stavanger Platform; T — Trzebiatów Fault; U — Utsira High; Us — Ustka Fault; VG — Viking Graben; W — Wolin Block; Wk — Wiek Fault; WG — Witch Ground Graben; WS — West Shetland Platform

Główne jednostki tektoniczne między Morzem Północnym a południowym Bałtykiem (według: P. A. Ziegler, 1982; R. M. Pegrum, 1984*a*; J. Bergström i in., 1982; O. Michelsen, C. Andersen, 1981 z modyfikacjami)

1 — strefa Teisseyre'a-Tornquista; 2 — przypuszczalny ukryty szew oceanu Iapetus; 3 — front deformacji kaledońskich w Norwegii i Szkocji; 4 — front deformacji kaledońskich między Morzem Północnym a Polską; 5 — główne uskoki; 6 — granice niektórych bloków tektonicznych; A — uskok Adler; An — uskok Anholt; Ar — blok Arkony; B — niecka Bamble; Br — niecka Brande; CG — Rów Centralny Morza Północnego; CH — wypiętrzenie wewnętrzne Rowu Centralnego; Ch — zrąb Christiansö; E — basen Egersund; EN — wypiętrzenie wschodnie Morza Północnego; EO — basen zewnętrzny Egersund; ES — platforma wschodnioszetlandzka; F — basen Farsund; Fj — uskok Fjerritslev; G — blok Gryfic; Gd — uskok Gardna; GG — uskok Great Glen; GH — wypiętrzenie Grampian; Gl — blok Glamsbjerg; Gr — blok Grindsted; H — blok Holmsland; Hb — zrąb Halibut; Hd — basen Horda; HG — rów Horn; K — blok Kołobrzegu; K — Ch — strefa Koszalina — Chojnic; Kp — uskok Kamienia Pomorskiego; L — rów Ling; M — blok Moen; MF — basen Moray Firth; MN — wypiętrzenie środkowe Morza Północnego; MV — dolina Midland; N — uskok Nävilinge; N-D-B — basen norwesko-duński; O — rów Oslo; RA — uskok Ringsjö — Andrarum; R-F-H — wypiętrzenie Ringkøbing — Fionia; RG — rów Rønne; Rm — uskok Romeleasen; S — wypiętrzenie Sele; Sn — blok Stigsnaes; St — blok Stevns; SU — południowe wyżyny Szkocji; Sv — platforma Stavanger; T — uskok Trzebiatowa; U — zrąb Utsira; Us — uskok Ustki; VG — rów Viking; W — blok Wolina; Wk — uskok Wiek; WG — rów Witch Ground; WS — platforma zachodnioszetlandzka

revaluate the existing data and to outline the more detailed tectonic sketch of the sub-Cainozoic basement of southern Baltic Sea.

BASEMENT — CALEDONIAN

The Baltic off-shore extending between Rügen, Scania and Bornholm on one side and the western part of the Polish coast on the other is extremely interesting and simultaneously hard to interpret because of overlapping effects of several diastrophic epochs. The most essential is the fact that the Caledonian deformation front (CDF) is separated in this area from the major tectonic Teisseyre-Tornquist Zone — lineament (TTZ). In the Polish on-shore area both these elements are closely interrelated [1]. They split up at the Baltic coast (Fig. 1). The Teisseyre-Tornquist Zone runs farther in the north-western direction through Scania, north Jutland and Skagerrak reaching the junction of Viking and Central Grabens in North Sea or maybe even the margin of the present continental shelf near Shetland Isles (R. M. Pegrum, 1984*a*). The whole zone in this segment is the inner fracture of the Precambrian platform separating the Baltic Shield from the outer platform area with the Norwegian-Danish Basin and Ringkøbing-Fyn High developed on it. The Caledonian deformation front turns from this junction in a more subparallel direction by-passing Rügen from the north and then runs toward the west bordering the Ringkøbing-Fyn High from the south (Figs. 1, 2). The fact that the Teisseyre-Tornquist Zone within its Scandinavian segment is the intraplatform fracture has been known since the Early Paleozoic strata in platform development were drilled in the Danish Basin area (T. Sorgenfrei, A. Buch, 1964). The boreholes within the Ringkøbing-Fyn High had then encountered at shallow depth the crystalline basement gneisses with isotopic ages of about 800–900 Ma. Some years later the weakly metamorphosed Caledonian rocks underlying the Devonian, Carboniferous, Permian or Mesozoic were discovered beneath the southern part of North Sea and within the southern margin of the Ringkøbing-Fyn High (R. T. C. Frost et al., 1981; P. A. Ziegler, 1982). These occurrences determined the presumable junction of the Scandinavian Caledonides with the belt of the Caledonian deformations in Rügen and Pomerania (Figs. 1, 2). The Scandinavian segment is considered to be the old Precambrian fracture (J. Watson, 1976) repeatedly reactivated. However, W. Pożarys-

[1] The notion of the Teisseyre-Tornquist Zone has recently been equivocally interpreted. According to the traditional view it is represented by the system of deep-rooted fractures separating the stable East-European craton from the more mobile areas of the middle and western Europe. Consequently it is the border of the two crustal blocks revealing during their long history the distinct differences in facies development and sediment thickness as well as in tectonic style. According to the new broadened view the TTZ is the separate elongated block of the thickened crust adjoining from the south-west to the craton. The present author supports the first view (for more details refer to R. Dadlez, 1982, 1987; J. Znosko, 1979; A. Guterch et al., 1986). But irrespective of the concept the connection of the Teisseyre-Tornquist Zone with the Caledonian deformation front in western and middle Poland is beyond all question. This front is tantamount either to the T-T Zone itself (first meaning) or to its north-eastern boundary fault (second meaning).

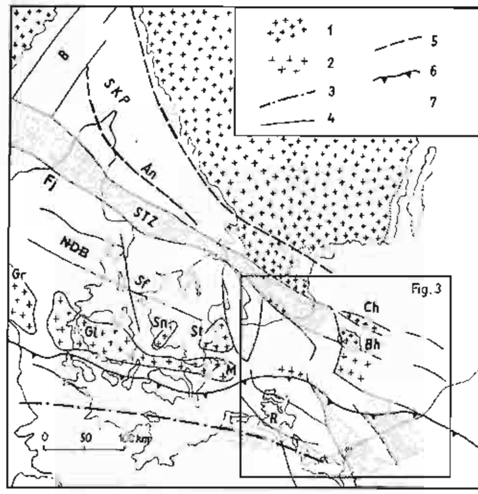

Fig. 2. Tectonic sketch of the southwestern Baltic Sea (mainly after: *Eugeno S...*, 1988 and R. M. Pegrum, 1984*b*)

1 — Precambrian rocks at the surface; 2 — Precambrian rocks at small depths; 3 — Trans-European Fault; 4 — faults; 5 — Late Carboniferous faults in the Kattegat; 6 — Caledonian deformation front; 7 — areas of the Late Cretaceous inversion; Bh — Bornholm; R — Rügen; Sf — Silkeborg — Samsø Fault; SKP - Skagerrak — Kattegat Platform; STZ — Sorgenfrei-Tornquist Zone; other abbreviations as in Fig. 1

Szkic tektoniczny południowo-zachodniego Bałtyku (głównie według: *Eugeno-S...*, 1988 i R. M. Pegrum, 1984*b*)

1 — skały prekambryjskie na powierzchni; 2 — skały prekambryjskie na niewielkich głębokościach; 3 — uskok transeuropejski; 4 — uskoki; 5 — uskoki późnokarbońskie w cieśninie Kattegat; 6 — front deformacji kaledońskich; 7 — obszary późnokredowej inwersji; Bh — Bornholm; R — Rugia; Sf — uskok Silkeborg — Samsø; SKP — platforma Skagerrak — Kattegat; STZ — strefa Sorgenfrei'a-Tornquista; inne objaśnienia jak na fig. 1

ki et al. (1982) claimed that this segment was formed only during the Variscan diastrophic epoch simultaneously with rejuvenation of the Polish segment along which a large-scale strike-slip movement took place during the Caledonian epoch.

The marginal zone of the Baltic Shield in southern Scandinavia segment have recently been investigated in the framework of the *Eugeno-S* Project. The authors of the report summarizing the results of this investigation (*Eugeno-S* ..., 1988) have underscored that crustal deformations in this area are scattered within the zone of 100–250 km wide revealing generally thinner crust whereas in the Polish territory they are concentrated within the narrower zone (50–90 km) with thicker crust (Teisseyre-Tornquist Zone in the second meaning — see footnote 1). The differences are attributed to the dominance of transtensional-tensional stresses in the Scandinavian area and the complete obliteration of their influence by prevailing transpressional--compressional stresses in the Polish area. The similarity is limited only to the increased Mesozoic subsidence and Late Mesozoic–Early Cainozoic inversion in a narrow strip of the intraplatform segment of the Teisseyre-Tornquist Zone. However,

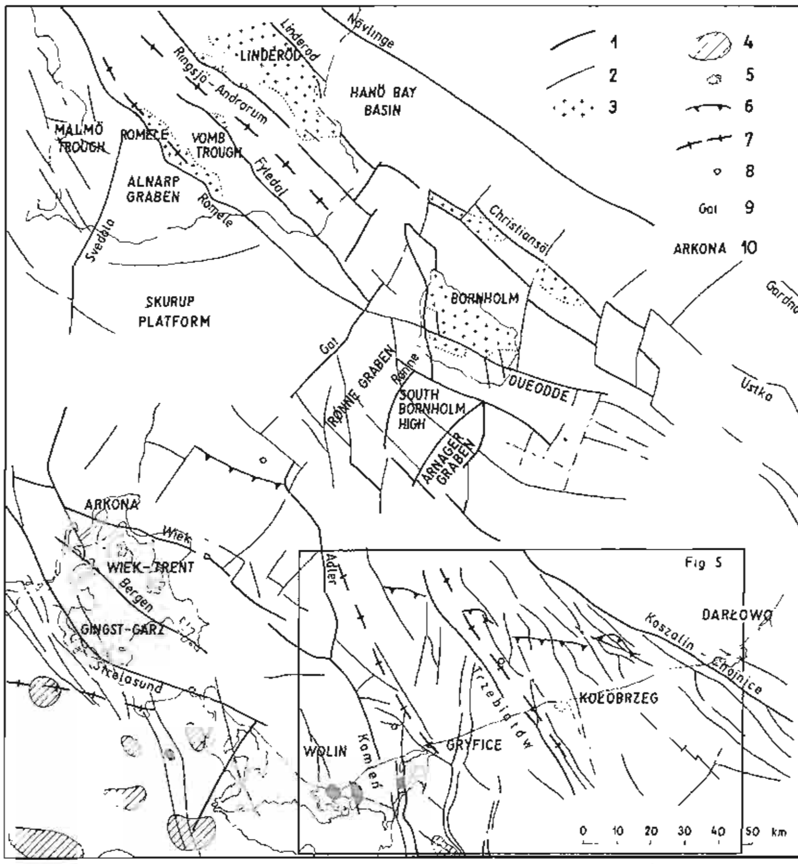

Fig. 3. Some tectonic elements of the southern Baltic Sea (Bornholm area after: O. V. Vejbaek, 1985; Scania after: J. Bergström et al., 1982)

1 — major faults; 2 — minor faults; 3 — Precambrian rocks at the surface; 4 — salt pillows; 5 — salt diapirs; 6 — Caledonian deformation front; 7 — axes of the Late Cretaceous inversion; 8 — off-shore boreholes; 9 — names of faults; 10 — names of tectonic blocks

Niektóre elementy tektoniczne południowego Bałtyku (obszar Bornholmu według: O. V. Vejbaek, 1985; Skania według: J. Bergström i in., 1982)

1 — ważniejsze uskoki; 2 — podrzędniejsze uskoki; 3 — skały prekambryjskie na powierzchni; 4 — poduszki solne; 5 — słupy solne; 6 — front deformacji kaledońskich; 7 — osie inwersji późnokredowej; 8 — otwory wiertnicze na akwenie; 9 — nazwy uskoków; 10 — nazwy bloków tektonicznych

in the greater part of this segment the inversion is not connected with the Late Carboniferous faults (see the Anholt and Fjerritslev Faults, Fig. 2) and hence the rejuvenation was late. Taking into account these differences it was suggested (*Eugeno-S* ..., 1988) to call the whole lineament between North and Black Seas — the Tornquist Zone, its Polish segment — the Teisseyre-Tornquist Zone (TTZ) while the Scandinavian segment — the Sorgenfrei-Tornquist Zone (STZ).

The latest investigations in the Baltic Sea area enabled to study in more detail some structural elements connected with splitting of the Teisseyre-Tornquist Zone and the Caledonian deformation front. The belt of these deformations was confirmed by many boreholes in the Polish Pomerania (R. Dadlez, 1974*a*, 1978) and in the northern part of Rügen (D. Franke, 1967; W. W. Glushko et al., 1974). In all the investigated sequences strongly folded Ordovician and Silurian graptolitic shales are discordantly overlain by the Devonian or Permian deposits. Occurrences in Rügen and Pomerania are linked by the off-shore borehole profile in the Kołobrzeg Block (Fig. 3) where the steeply dipping Caradocian shales are covered by the Devonian sediments. In the north-eastern foreland of the deformed zone the very thick undeformed Early Paleozoic series of platform development occur in the Pomerania on the depressed marginal zone of the Precambrian platform. The on-shore results of the refraction measurements revealed that the top of crystalline basement lowers toward the platform margin down to depth of about 8000 m. The presence of the outer faulted step covered by the overthrusted Caledonian rock masses is not excluded here (J. Znosko, 1970; R. Dadlez, 1982). The extension of the depressed marginal zone of the Precambrian platform, confirmed also by the results of the borehole drilled in the basin halfway between Rügen and Bornholm (Fig. 3) has been found in the strongly down-faulted blocks south of Bornholm (O. V. Vejbaek, 1985) and in the Danish Basin basement (Zealand, north Jutland). The reflection seismic survey in the Polish sector revealed the presence of the deep reflector ("O") which lowers down from about 7500 m close to the Koszalin — Chojnice Fault Zone to about 11 000 m close to the southern margin of the area of its occurrence (Fig. 5). The reflector "O" may be connected with the Ordovician but it is more likely (due to the non-carbonate development of the Ordovician in the marginal platform zone which should not have yielded seismic reflection) that it represents the top of crystalline basement. Therefore the southern border of the area of occurrence of this reflector was considered to be the deep-seated border of the Precambrian craton the margin of which can be, at least locally, covered by the overthrusted Caledonian folds. Farther toward the west the overthrust of similar scale (about 50 km) has been inferred in the southern margin of the Ringkøbing-Fyn High (*Eugeno-S* ..., 1988).

In the northern foreland of the zone of Caledonian deformations the Precambrian basement is divided into numerous depressed and uplifted blocks (Figs. 1–3). Nearer the inner part of the platform the basement often emerges at the surface (horsts of Scania, Christiansö Horst — J. Bergström et al., 1982; O. V. Vejbaek, 1985; M. G. Kumpas, 1982), farther outside the basement is down-faulted and covered with thin Paleozoic and Mesozoic or only Mesozoic deposits (horst group of the Ringkøbing-Fyn High, Stevns Block, horsts south of Bornholm — O. Michelsen, C. Andersen, 1981; O. V. Vejbaek, 1985). The foundations of this block mosaic could have originated in the Caledonian epoch but they were established mainly during the Hercynian epoch.

Tectogenesis of the Caledonian deformation belt along the south-western border of the East-European craton has been interpreted in different ways. At least the most important and latest views are worth remembering in brief summary, as follows:

1. Deformations are the result of the full geosynclinal development and folding of the separate (in relation to the main Caledonian belt) branch of the North German--Polish Caledonides with a north-eastern vergence which is directly connected with the Norwegian Caledonides or through Ardennes and Brabant with the Middle England Caledonides (W. Krebs, 1978; J. Znosko, 1962, 1986 and his numerous papers published between these dates). In such a view the folded belt of our area emerged from miogeosyncline whereas the inner zones of this belt were situated farther toward the south.

2. Deformations are not of orogenic character and their extent is spatially confined. They are the result of diastrophism which took place in small separated basins formed within continental crust of the Late Precambrian age thinned in the rifting process. They are sometimes defined as aulacogens and are genetically referred to the so-called tectono-thermal events which occurred in the Early Paleozoic and brought about ascending mantle plumes located in different places of middle and western Europe (among others in the proximity of Rügen). These events were, in turn, the effect of the evolution of the main Caledonian belt extending from the Appalachians to Scandinavia and Greenland and characterized by full geosynclinal-orogenic development (H. J. Zwart, U. F. Dornsiepen, 1978; W. Pożaryski, Z. Kotański, 1978; R. Walter, 1978; K. Schmidt, F. Söllner, 1983). In this view the Precambrian basement should occur south of our deformation zone.

3. In the Late Proterozoic a great sinistral transform fault operated along the southern margin of the Laurentian-Baltic Plate (Trans-European Fault — TEE — Fig. 2) which bound the pre-Cadomian oceanic domains of middle Europe and Ural. After initiation of the mid-oceanic Cadomian subduction zone which was inclined southward the accretion of continental crust was taking place. As a result the Cadomian continent originated and toward the north the remnants of the pre-Cadomian ocean were left behind. The Fennosarmatian transform margin changed during the latest Proterozoic and Early Paleozoic into the passive one. Accumulated clastic wedges were then compressed, because of the clockwise rotation of the Cadomian continent and its northward shift forming the North German-Polish Caledonian belt overthrusted onto the Fennosarmatian margin (A. Berthelsen, 1984).

4. Along the same Laurentian-Baltic margin the great transcontinental sinistral transform fault was active from the Early Ordovician through Early Devonian. Its total displacement was of the order of 1500–2500 km having been the result of the clockwise rotation of the northern part of the Proto-Tethys and Avalonian Plate (W. Brochwicz-Lewiński et al., 1981; W. Pożaryski et al., 1982).

5. Both the deformations along the southern margin of the Ringkøbing-Fyn High, and Polish and Scandinavian segments of the TTZ resulted from the activity of the Late Caledonian sinistral transform fault of the displacement of about 500 km separating — during closing of the Iapetus Ocean — the two Caledonian branches

of reverse vergence, i.e. the Irish-Scottish and the Norwegian ones (R. M. Pegrum, 1984*a*, *b*) [2]. These two latter interpretations imply obviously the existence of the comparatively narrow deformation zone.

6. The North German-Polish Caledonian belt originated under transpressional conditions as a result of the oblique collision between the East-European (Fennosarmatian) craton and microcontinents (allochtonous terranes?). The latters either separated from the Gondwana and collided with Fennosarmatia after moving across the Prototethys Ocean (Tornquist Sea — L. R. M. Cocks, R. A. Fortey, 1982) or were first separated from the Fennosarmatia and again joined with it (P. A. Ziegler, 1982, 1984). This concept has been proved by some paleomagnetic data (R. van der Voo, 1983; H. Perroud et al., 1984).

Considering this, the tectogenetic concepts are differentiated and often contradictory though based on the same facts. The point is that the data from the Mid-European Caledonian deformation zone are very scarce being derived from geophysical measurements and scattered boreholes. This fact implies by itself the ambiguous interpretations which will probably remain hypothetical for a long time. Therefore their acceptance or rejection may fall rather under a category of faith than of scientific evidence. Just in these terms the author supports the last-aforementioned concept [3].

Keeping in mind the fact of the very existence of the Caledonian deformation zone it should also be noted that this belt, due to its monotonous clayey lithological composition, could have formed within the Rügen-Pomerania segment neither morphologically marked mountain range nor foredeep. It could have been syndeformationally eroded being no source for "molasse" deposits.

DEVONIAN-CARBONIFEROUS

The folded Ordovician and Silurian are — probably diachronously — overlain by continental clastic sediments of the Devonian (Emsian through Givetian). The Devonian profiles of Rügen (K. Schmidt, D. Franke, 1977) and the Western Pomerania (R. Dadlez, 1978) are very similar. In the Early Givetian several marine transgressions

[2] R. M. Pegrum assumes that the displacement along the Teisseyre-Tornquist Zone (Fig. 1) is measured by the shift of the south-western segment of the Iapetus suture (extension of the Solvay line in northern England) in relation to its north-eastern segment (in the basement of the continental rise in the proximity of Shetland Isles). However, this present displacement is a sum of all the displacements which took place in the geologic past. If we assume that the effects of the Mesozoie transtension and the Mesozoic/Cainozoie transpression compensated mutually and consider the proposed by this author Late Variscan dextral displacement of 300–350 km, then the total Late Caledonian displacement will turn out to have been 750–800 km instead of 450–500 km. In other words, the Lower Paleozoic strata of the Western Pomerania would have deposited opposite their equivalents in the vicinity of Oslo, and the Holy Cross Mts. strata — opposite the mouth of the Baltic Syneclise. After sinistral strike-slip movements at the end of the Late Paleozoic the Devonian of the Western Pomerania would have in turn deposited opposite the Warsaw area whereas the Holy Cross Mts. — opposite Podole.

[3] During the preparation of the Polish version of this paper for publication (R. Dadlez, 1990) another two works were published (D. Franke et al., 1989; W. Pożaryski, 1990) favouring the terrane hypothesis. However, the arguments given there are as disputable as before and do not change my opinion.

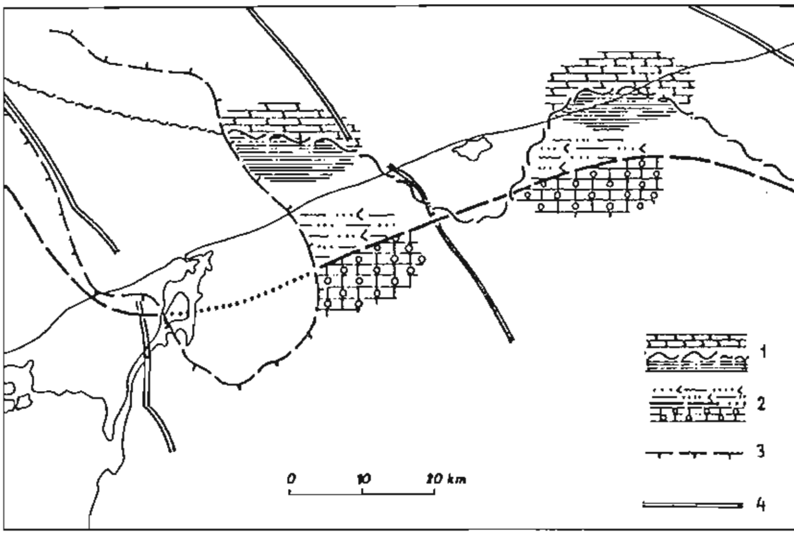

Fig. 4. Major palaeogeographic and palaeotectonic features of the Devonian and Early Carboniferous
1 — presumed external boundary of the Frasnian carbonate platform; 2 — presumed internal boundary between the Visean carbonate platform and lagoon; 3 — presumed boundary of the pre-Westphalian erosion (after: A. M. Żelichowski); 4 — major fault zones

Ważniejsze elementy paleogeograficzne i paleotektoniczne dewonu i wczesnego karbonu
1 — przypuszczalna zewnętrzna granica frańskiej platformy węglanowej; 2 — przypuszczalna granica wewnętrzna między wizeńską platformą węglanową a laguną; 3 — przypuszczalna granica przedwestfalskiej erozji (według: A. M. Żelichowski); 4 — główne strefy uskokowe

took place leaving behind clastic-marly-carbonate deposits. The main transgressive impulse occurred also diachronously at the turn of the Givetian and Frasnian. A broad carbonate platform (Fig. 4) was formed in the north and east (including the off-shore area which was evidenced by boreholes drilled in the Kołobrzeg Block and near the coast of Rügen — Fig. 3). Toward the south this platform was bounded by clayey-marly-limestone basinal facies (Człuchów complex). In the Famennian the basin at first grew larger and the basinal facies covered the older carbonate platform. In the latest Devonian the regressive tendency prevailed. At the turn of the Devonian and Carboniferous a weak diastrophism (vertical movements along faults) probably associated by the increase of magmatic activity might have taken place. The subsequent erosion partly removed the Człuchów complex deposits.

In the Early Carboniferous more differences in sedimentation type between Rügen (N. Hoffman et al., 1975) and the Western Pomerania (R. Dadlez, 1978: A. M. Żelichowski, 1983) appeared. In Rügen the sequence is more complete, thicker and represents clayey-marly-limestone basinal facies. In the Pomerania the lithologic composition is much more variable being represented in its lower part by clayey shales overlain in turn by sandstones predominantly of arkosic and lithic wacke type. Above these deposits an extensive carbonate platform consisting of detrital-oolitic limestones developed in the Late Visean. Behind this platform farther northwards (including also the Polish off-shore area) probably the lagoonal deposits periodically formed under conditions of increased salinity (Fig. 4).

The diastrophic movements were presumably more intensive toward the close of the Early Carboniferous than at the turn of the Devonian and Carboniferous both on regional and local scales. Vertical displacements caused the regional absence of the Namurian and Westphalian and the variable truncation of the Lower Carboniferous sediments. In extreme cases the erosion reaching the Upper Devonian (which is directly overlain by the not earliest Westphalian) is assumed (Fig. 4). However, this interpretation is unequivocal.

In the Late Carboniferous the similarity of the Rügen (G. Hirschmann et al., 1975) and Pomerania (A. M. Żelichowski, 1983) sequences was revealed so markedly that it was possible to carry out the reliable lithostratigraphic correlation. Grey limnic sediments of coal-bearing association pass upwards into clastic sediments of red-bed association.

At the turn of the Carboniferous and Permian the main structural rebuilding of the Devonian–Carboniferous complex took place. The area was strongly faulted forming the complex mosaic of different-sized blocks and perhaps also broad anticlines. At that time the pattern of the principal division of the basin area into three blocks, i.e. Kołobrzeg, Gryfice and Wolin, and numerous secondary faults and blocks was probably established. The difference of structural style between the Kołobrzeg Block and two remaining ones is observed.

The Kołobrzeg Block is in this respect the extension of the Koszalin — Chojnice Zone in which, based upon numerous boreholes and in the absence of the reliable seismic data, the presence of narrow blocks elongated NW–SE and of homothetic or antithetic patterns has been assumed. This structure was confirmed by the seismic survey within the off-shore part of the Kołobrzeg Block. The pattern of the sub-Zechstein seismic horizons C/D?, D_2 and D_1 referred to the Devonian and Carboniferous also reveals the presence of several narrow antithetic blocks bounded by faults with the north-eastern hanging walls and with throws generally of a few hundred meters, occasionally exceeding 1000 m (Figs. 5 and 6). Within the elevated parts of these blocks the Devonian and Lower Carboniferous deposits subcrop the Permian whereas within the lowered ones the Upper Carboniferous sediments occur. The same style was evidenced farther toward the north-west along the Sorgenfrei-Tornquist Zone (*Eugeno-S* ..., 1988; J. Liboriussen et al., 1987). Although antithetic blocks in the latter area are composed of the Lower Paleozoic deposits their origin is assumed to be syn-Variscan.

The Gryfice and Wolin Blocks seem to reveal less complicated structure though the interpretation of the seismic results is unequivocal to some extent. Within the continental parts of these blocks the reliable sub-Zechstein seismic reflections do not exist. A vast sub-Zechstein elevation composed of the Lower Carboniferous deposits was evidenced by boreholes in the south. The Upper Carboniferous sediments appear toward the north occurring probably along the whole Baltic coast within both these blocks. Several seismic horizons were detected within the off-shore area but the gaps in recording make difficult the spatial correlation. Most probable seems to be the

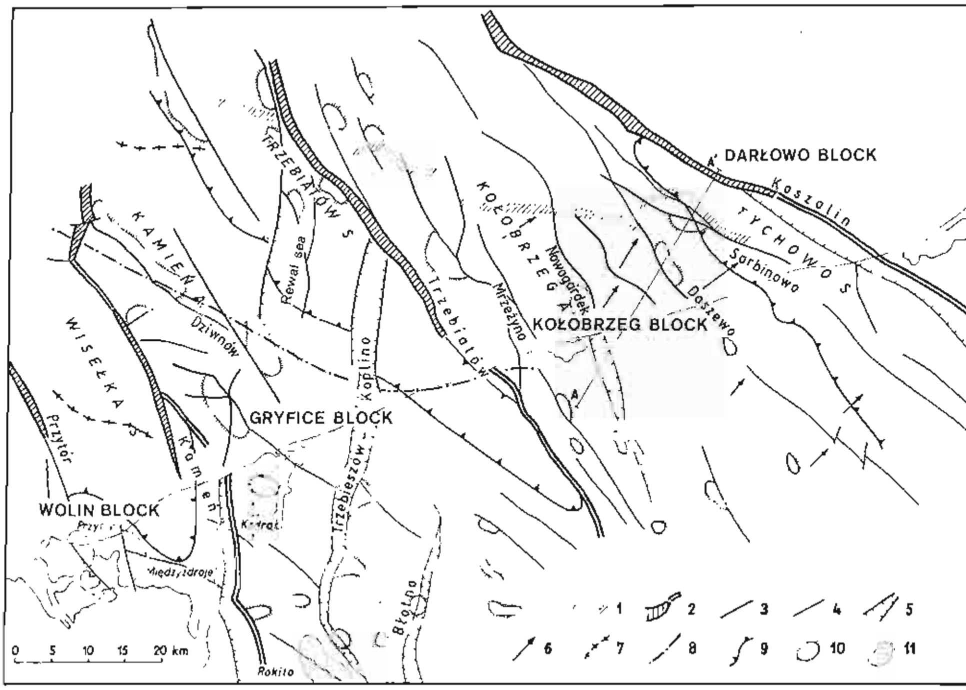

Fig. 5. Tectonic sketch of the southern Baltic Sea, Polish sector

A — anticline; S — syncline; 1 — southern limit of the occurrence of O reflector (= ? Caledonian deformation front); 2 — major fault zones; 3 — major sub-Permian faults; 4 — minor faults; 5 — Mesozoic synsedimentary grabens; 6 — tilting of the Devonian–Carboniferous blocks; 7 — axes of the Upper Carboniferous synclines; 8 — concealed zone of the sub-Permian disturbances; 9 — extent of the Upper Cretaceous; 10 — non-salt anticlines in the Zechstein reflectors; 11 — salt anticlines

Szkic tektoniczny polskiego sektora południowego Bałtyku

1 — południowa granica występowania poziomu refleksyjnego O (=? front deformacji kaledońskich); 2 — główne strefy uskokowe; 3 — główne uskoki podpermskie; 4 — podrzędne uskoki; 5 — mezozoiczne rowy synsedymentacyjne; 6 — nachylenie bloków dewońsko-karbońskich; 7 — osie synklin górnokarbońskich; 8 — ukryta strefa zaburzeń podpermskich; 9 — zasięg górnej kredy; 10 — antykliny niesolne w poziomach cechsztyńskich; 11 — antykliny solne

interpretation in the western part: within the Wolin Block and in the south-western part of the Gryfice Block where the C_1 horizon refers to the base of Upper Carboniferous. The Upper Carboniferous–Lower Permian complex in the Wolin Block reaches (along the coast line) approximately 2000 m in thickness decreasing to about 1000 m near the north-western border of the Polish off-shore area.

In the remaining northern and eastern parts of the Gryfice Block the interpretation is slightly ambiguous. Two seismic sub-Permian horizons of regional extent not verified by boreholes occur here. A symbol of one of these horizons (C_1) suggests the same age as compared to the horizon within the Wolin Block. The second horizon (C_2) is located 600–800 m higher. Various possibilities should be taken here into account. First that the C_1 horizon is really of the same age and then C_2 horizon runs

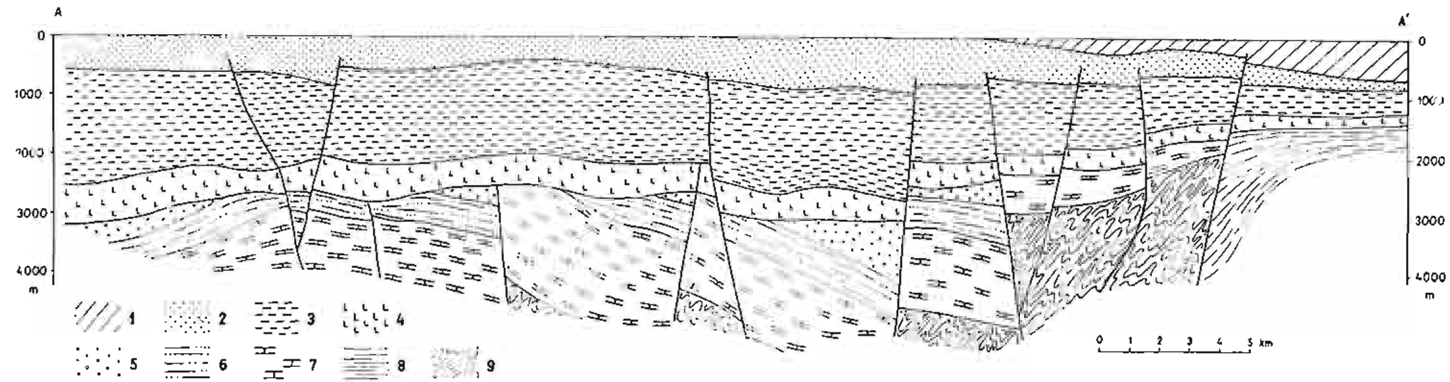

Fig. 6. Cross-section through the Kołobrzeg Block (after: N. Kosjak, unpublished, slightly modified — for location see Fig. 5)
1 — Cretaceous; 2 — Jurassic; 3 — Triassic; 4 — Zechstein; 5 — Upper Carboniferous; 6 — Lower Carboniferous; 7 — Devonian; 8 — undeformed Lower Paleozoic; 9 — folded Lower Paleozoic

Przekrój przez blok Kołobrzegu (według: N. Kosjak, niepublikowany, nieco zmieniony; lokalizacja na fig. 5)
1 — kreda; 2 — jura; 3 — trias; 4 — cechsztyn; 5 — górny karbon; 6 — dolny karbon; 7 — dewon; 8 — niezdeformowany starszy paleozoik; 9 — sfałdowany starszy paleozoik

within the Upper Carboniferous. Second that the C_2 horizon represents the base of Upper Carboniferous in this part of the basin. And third, that both these horizons are connected with older geological boundaries, i.e. C_2 with the base of Carboniferous whereas C_1 — with the middle parts of the Devonian. Depending on the accepted variant the assumed extent of the Upper Carboniferous and Rotliegendes deposits and their thickness must change. In the first case it can reach 1700–2000 m close to the Trzebiatów Fault Zone while in the second the Upper Carboniferous may not be present at all in the northern part of the Gryfice Block.

The structural pattern of the C_1 and C_2 horizons indicates the existence within the Wolin and Gryfice Blocks of two synclines with axes striking nearly W–E (Fig. 5). In addition, faults of similar strike are more frequent within these blocks than within the Kołobrzeg Block. The trends of the main faults vary in the former area mainly from N30°W to N40°W whereas in the latter they range from N50°W to N70°W. These directions, being generally parallel to the Caledonian deformation front, reflect probably regeneration of the older foundations.

The origin of the described fault-block system of the Devonian–Carboniferous complex is synchronous with the Variscan foldings farther to the south in middle Europe. This is the faulted cratonic foreland of the folded belt. On a wide supraregional background toward the close of the Variscan epoch the existence of the main fault system striking W–E to NW–SE and of dextral strike-slip component, conjugated with a subordinate system of faults striking N–S to NE–SW and of sinistral strike-slip component has been assumed. This system was formed as a result of the general stress pattern between the Appalachians and Ural (F. Arthaud, P. Matte, 1977). R. M. Pegrum (1984*b*) assumes the Variscan dextral strike-slip motion of about 300–350 km along the Teisseyre-Tornquist Zone. Nonetheless his reasoning favouring this displacement is not convincing as for the Polish territory. There is no reason to link the Ringkøbing-Fyn High and the Variscan foredeep on one hand to the Mazury-Byelorussian Elevation and the Podlasie Depression on the other because the geological composition and the origin of these units are quite different. If Pegrum's arguments concerning the north-western segment of the TTZ were right and the displacement really existed, then the aforementioned coincidences within the Polish territory would be accidental.

In the described pattern of stresses the origin of the Late Variscan grabens such as Oslo-Bamble, Rønne and Arnager Grabens of the nearly N–S general directions has also been considered. They would be the pull-apart structures, the secondary elements in relation to dextral displacements (J. Liboriussen et al., 1987).

The mosaic of the Devonian–Carboniferous blocks, which forming was accompanied and then followed by the strong volcanic activity, underwent intensive erosion toward the close of the Carboniferous and in the Early Permian. As a result of this the Devonian and Carboniferous deposits of different age are subcropping the Permian and the present northern boundary of both these systems is erosional at a whole length. The question of the extreme primary northern extent of these sediments, remains a matter of dispute. It seems to have been much larger than it has been assumed by the reconstructions of the connection between the Mid-European and Moscow Basins through the Baltic Syneclise. It is evidenced by the preserved post-erosional remnants of the Namurian in the Oslo Graben (J. Bergström et al., 1985) and by the results of the fission track investigation of the Precambrian minerals near the lake of Vänern in southern Sweden which indicate the primary presence of sedimentary cover of 3–4 km thick which was later completely eroded (H. P. Zeck et al., 1988). This view is also strongly supported by the results of the vitrinite reflectance analyses from the Silurian of the marginal platform zone which indicate considerable heating of these sediments caused by their deeper sinking as compared to the present. The Devonian and Carboniferous deposits, particularly their upper sections, may have then originally covered the whole southern part of the Scandinavian Shield.

PERMIAN–MESOZOIC

The products of the erosion of sub-Permian deposits were transported southward. In the on-shore areas of the Western Pomerania there was the basin in which red clastic sediments of the Lower Permian were accumulated. The bays of this basin could enter the area of the Polish off-shore area. The extent of the basin became larger after the transgression of the Zechstein sea which left behind the clastic-carbonate-evaporitic series, the farther toward the north and north-west the more in near-shore development. In the latter direction the influence has been marked of the eastern pericline of the Ringkøbing-Fyn High which extended as far as northern Rügen and the areas adjoining to the east.

The same trend of thickness reduction and of northward passage into marginal facies continued during the Mesozoic. Influences of weaker marine transgressions of the Middle Triassic and Early Jurassic from the south were gradually diminishing in the off-shore area. Stronger eustatic transgressions which took place in the Late Jurassic and Late Cretaceous invaded the whole area but the influxes of clastic material from the Scandinavian Shield always emphasized the marginal character of sedimentation.

The Permo–Mesozoic phase of development was mostly devoid of any signs of local diastrophism. All breaks of sedimentation were the result of regional processes and no structural disconformities are connected with them. Only in the southern margins of the area south of the Baltic coast the processes of salt tectonics began probably already in the Late Triassic (Fig. 5). They lead to formation of the salt diapirs piercing the Mesozoic sediments within the tectonically predisposed fault-related zones (Przytór, Międzyzdroje — Wapnica, Kodrąb). The area of regional salt flowage and wide--spread occurrence of the salt anticlines is situated farther southward.

Besides, in the Triassic and Early Jurassic there formed narrow synsedimentary grabens infilled with thicker sediments than in their neighbourhood. At least part of these grabens might have been connected with the older faults of nearly meridional trends. These are the grabens along the fault zones of Kamień Pomorski, Rewal-sea, Trzebieszów — Koplino (Gryfice Block) and Nowogardek (Kołobrzeg Block) and also in the fault zone of Koszalin (Fig. 5). They are primarily V-shaped in cross-section, asymmetric with their eastern sides marked more distinctly, sometimes rooted in a single fault of the sub-Permian basement. The system of similar grabens is known farther west in northern Mecklenburg (G. Beutler, F. Schüler, 1978). Its origin indicates the sublatitudinal tensional stresses. They could have been the result partly of dextral rotation and partly of left-lateral transtension (J. Liboriussen et al., 1987). They are similar to transtensional flower structures and genetically must have been connected with the first phases of the North Atlantic opening.

The fundamental structural rebuilding occurred in the latest Cretaceous and lowermost Tertiary. These tectonic processes finally shaped the present structural pattern of the region. It has been studied in detail because of the existence in the Zechstein and Mesozoic of several seismic reflection horizons of good quality which can be correlated in the whole area or at least in its considerable parts.

The discussed processes reactivated, first of all, the older major fault zones, i.e. Koszalin, Trzebiatów and Kamień Pomorski Zones (Fig. 5). Their mean trends are N60°W, N40°N and N20°W respectively. They converge north-westwards coming together in the proximity of the southern border of the Rønne Graben. These zones divide the area into the three aforementioned blocks: Kołobrzeg, Gryfice and Wolin.

During the rejuvenation period the eastern or north-eastern sides of these fault zones were uplifted. The fault throws in the Trzebiatów Zone reach 1000 m whereas in the Kamień Pomorski Zone — 900 m. The structural differences measured at the Zechstein bottom between elevations and depressions on both sides of zones amount up to 1600 and 1100 m respectively. These values are comparable with the fault throws within the Devonian–Carboniferous complex. The inversion uplift of the western parts of the Kołobrzeg and Gryfice Blocks formed again the antithetic pattern against the Teisseyre-Tornquist Zone but on a larger scale: the Devonian–Carboniferous blocks were strongly elongated and of smaller sizes while the Kołobrzeg and Gryfice Blocks are more isometric and amount within the off-shore area about 1500 sq. km each. The inversion was expressed — in other words — by forming anticlines of half-horst character, i.e. the Kołobrzeg and Kamień Pomorski Anticlines outlined by the Jurassic subcrops below the Cainozoic. They both form the north-western branches of the Mid-Polish Swell (which cuts diagonally the whole area of the country) entering deeply into the off-shore area. These anticlines are bounded from the east by synclines infilled by the Cretaceous sediments, i.e. the Trzebiatów and Tychowo Synclines.

The described maximum throws of both fault zones observed off-shore near the coast, decrease gradually toward the south — they finally disappear on-shore at the distance of several tens of kilometers from the coast. Northward the throw of the Trzebiatów Zone remains the same as far as the border of Polish off-shore area. The Kamień Pomorski Zone extends northward into the Adler Fault Zone of the opposite, eastern throw direction. The pattern of the Kamień Pomorski — Adler Zone is then of pivotal character whereas the Wiek Fault Zone merging from the west is a hinge of them (Fig. 3).

Not too wide (approximately 10 km) zones of the Kołobrzeg and Gryfice Blocks within the off-shore area, adjoining directly to the main fault zones, are distinctly uplifted higher than their adhering more eastern areas of the blocks. These zones form a sort of weakly outlined horsts bounded from the east by secondary faults, namely Mrzeżyno and Dziwnów (Fig. 5), the throws of which are much smaller than those of the main fault zones, amounting to hundreds of meters at most.

Local groups of small uplifts recorded in the seismic horizons of the Zechstein and Triassic are connected in the Polish off-shore area with those highly elevated zones of both blocks and their accompanying faults. These uplifts are of small amplitudes and sizes, the latter being up to tens of square kilometers in closed contours. In most cases, they are bounded from one side by a fault and also complicated by the presence of subordinate faults.

The inversion movements at the turn of the Mesozoic and Cainozoic were an expression of analogous processes occurring at that time in all the middle and western Europe in the foreland of the Alpides and genetically connected with the folding of this chain (P. A. Ziegler, 1982, 1987). They are depicted either by the inversion of whole basins and sedimentary furrows on a large regional scale, or by the inversion of minor fault-related structures. The example of the former is the inversion of the Mid-Polish Swell, Sorgenfrei-Tornquist Zone (*Eugeno-S...*, 1988) and Grimmen Swell in northern Germany. Numerous examples of the latter type of inversion are cited for the whole area of middle Europe (R. Baldschuhn et al., 1985; R. Dadlez, 1974*c*; R. M. Pegrum, 1984*a*). The stress pattern resembling that of the end of the Variscan epoch implies the presence of the right-lateral transpressional component. Strike-slip displacements, analyzed in many places (E. Norling, J. Bergström, 1987; O. V. Vejbaek, 1985; O. V. Vejbaek, C. Andersen, 1987; E. Herbich, 1984) are rather small, of the order of a few kilometers.

It is interesting that in the structure of the Zechstein–Mesozoic complex, apart from the Kołobrzeg Block where older faults were simply rejuvenated and their connection with the Devonian–Carboniferous structure seems to be obvious, also in the Gryfice Block the influences of the sub-Zechstein basement structure may be traced (Fig. 5). They appear: 1 — in the aforementioned hinge between fault zones of Kamień Pomorski and Adler; 2 — in the northward termination of the Dziwnów Fault as well as southward one of the Rewal-sea Fault Zone; 3 — in strike disturbances of the fault zones Trzebieszów — Koplino and Trzebiatów. All these features are arranged along the line with the trend of about N75°W located in the prolongation of the Wiek Fault Zone.

Acknowledgements. The author wants to express sincere thanks to the management and staff of W. O. Petrobaltic for rendering all the relevant geophysical and geological data and for many discussions.

Translated by Zdzisław M. Migaszewski

Zakład Geologii i Ropo-gazonośności Niżu
Państwowego Instytutu Geologicznego
Warszawa, ul. Rakowiecka 4
Received: 5.04.1993

REFERENCES

ARTHAUD F., MATTE P. (1977) — Late Paleozoic strike-slip faulting in southern Europe and northern Africa: result of right-lateral shear zone between the Appalachians and the Urals. Geol. Soc. Amer. Bull., **88**, p. 1305–1320, no. 9.

BALDSCHUHN R., FRISCH U., KOCKEL F. (1985) — Inversionsstrukturen in NW-Deutschland und ihre Genese. Z. Dtsch. Geol. Ges., **136**, p. 129–139, no. 1.

BERGSTRÖM J., HOLLAND B., LARSON K., NORLING E., SIVHED U. (1982) — Guide to excursions in Scania. Sver. Geol. Unders., Ser Ca, no. 54.

BERGSTRÖM J., BLESS M. J. M., PAPROTH E. (1985) — The marine Knabberud Limestone in the Oslo Graben: possible implications for the model of Silesian palaeogeography. Z. Dtsch. Geol. Ges., **136**, p. 184–194, no. 1.

BERTHELSEN A. (1984) — The early (800–300 Ma) crustal evolution of the off-shield regions of Europe. Proc. First Workshop EGT, northern segment. Europ. Sc. Found., p. 125–142.

BEUTLER G., SCHÜLER F. (1978) — Über altkimmerische Bewegungen im Norden der DDR und ihre regionale Bedeutung (Fortschrittsbericht). Z. Geol. Wiss., **6**, p. 403–420, no. 4.

BROCHWICZ-LEWIŃSKI W., POŻARYSKI W., TOMCZYK H. (1981) — Mouvements coulissants de grande ampleur au Paléozoique inférieur le long de la marge sud-ouest de la plate-forme Est-Europeénne, C. R. Acad. Sc., **293**, Sér. II, p. 855–858.

COCKS L. R. M., FORTEY R. A. (1982) — Faunal evidence for oceanic separations in the Paleozoic of Britain. Jour. Geol. Soc. London, **139**, p. 465–478, no. 4.

DADLEZ R. (1974*a*) — Tectonic position of Western Pomerania (North-western Poland) prior to the Upper Permian. Biul. Inst. Geol., **274**, p. 49–87.

DADLEZ R. (1974*b*) — Some geological problems of the Southern Baltic Basin. Acta Geol. Pol., **24**, p. 261–276, nr 1.

DADLEZ R. (1974*c*) — Types of local tectonic structures in the Zechstein–Mesozoic complex in north--western Poland. Biul. Inst. Geol., **274**, p. 149–177.

DADLEZ R. (1978) — Sub-Permian rock complexes in the Koszalin — Chojnice Zone (in Polish with English summary). Kwart. Geol., **22**, p. 269–301, no. 2.

DADLEZ R. (1982) — Permian–Mesozoic tectonics versus basement tract along the Teisseyre-Tornquist Zone in the territory of Poland (in Polish with English summary). Kwart. Geol., **26**, p. 273–284, no. 2.

DADLEZ R. (1987) — Evolution of the Phanerozoic basins along the Teisseyre-Tornquist zone. Z. Angew. Geol., **33**, p. 229–233, no. 9.

DADLEZ R. (1990) — Tectonics of the Southern Baltie (in Polish with English summary). Kwart. Geol., **34**, p.1–20, No. 1.

DADLEZ R., MŁYNARSKI S. (1967) — Deep geological structure of the Baltic Sea substratum east of the Odra River (in Polish with English summary). Kwart. Geol., **11**, p. 488–501, no. 3.

EUGENO-S WORKING GROUP (1988) — Crustal structure and teetonic evolution of the transition between the Baltic Shield and the North German Caledonides (the EUGENO-S Project). Tectonophysics, **150**, p. 253–348, no. 3.

FRANKE D. (1967) — Der erste Aufschluss im tieferen Paläozokum Norddeutschlands und seine Bedeutung für die tektonische Gliederung Mitteleuropas. Jb. Geol., **1**, p. 119–165.

FRANKE D., HOFFMANN N., KAMPAS J. (1989) — Alter und struktuller Bau des Grundgebirges im Nordteil der DDR. Z. Ang. Geol.; **35**, p. ,No. 10/11.

FROST R. T. C., FITCH F. J., MILLER J. A. (1981) — The age and nature of the crystalline basement of the North Sea Basin. Petrol. Geol., Cont. Shelf NW Europe. Inst. Petrol. London, p. 43–57.

GLUSHKO W. W., DIKSHTAIN G. H., SHMIDT K. (1974) — Kaledonidy ostrowa Rjugen. Dokł. AN SSSR, **214**, p. 885–887, no. 4.

GUTERCH A., GRAD M., MATERZOK R., PERCHUĆ E. (1986) — Deep structure of the Earth's crust in the contact zone of the Palaeozoic and Precambrian platforms in Poland (Teisseyre-Tornquist zone). Tectonophysics, **128**, p. 251–279, no. 3/4.

HERBICH E. (1984) — Tectonic analysis of seismically controlled faults in the vicinities of Lipno and Sierpc (in Polish with English summary). Prz. Geol., **32**, p. 142–149, no. 3.

HIRSCHMANN G., HOTH K., KLEBER F. (1975) — Die lithostratigraphische Gliederung des Oberkarbons in Bereich der Inseln Rügen und Hiddensee. Z. Geol. Wiss., **3**, p. 985–996, no. 7.

HOFFMAN N., LINDERT W., WEYER D., ILLERS K. H. (1975) — Zum Unterkarbon-Vorkommen auf den Inseln Rügen und Hiddensee. Z. Geol. Wiss., **3**, p. 851–873, no. 7.

KREBS W. (1978) — Die Kaledoniden im Nördlichen Mitteleuropa. Z. Dtsch. Geol. Ges., **129**, p. 403–422, no. 2.

KUMPAS M. G. (1982) — Seismic interpretation of the Christiansö Horst, southern Baltic. Stockh. Contr. Geol., **38**, p. 47–55, no. 4.

LIBORIUSSEN J., ASHTON P., TYGESEN T. (1987) — The tectonic evolution of the Fennoscandian Border Zone in Denmark. Tectonophysics, **137**, p. 21–29, no. 1–4.

MICHELSEN O., ANDERSEN C. (1981) — Überblick über die regionale Geologie und Tektonik Danemarks. Z. Angew. Geol., **27**, p. 171–176, no. 4.

NORLING E., BERGSTRÖM J. (1987) — Mesozoic and Cenozoic tectonic evolution of Scania, southern Sweden. Tectonophysics, **137**, p. 7–19, no. 1.

PEGRUM R. M. (1984*a*) — The extension of the Tornquist Zone in the Norwegian North Sea. Norsk Geol. Tidskr., **64**, p. 39–68, no. 1.

PEGRUM R. M. (1984*b*) — Strutural development of the southwestern margin of the Russian-Fennoscandian Platform. Petrol. Geol. North Europ. Margin. Norw. Petrol. Soc. Graham and Trotman, p. 359–369.

PERROUD H., VOO R. VAN DER, BONHOMMET N. (1984) — Paleozoic evolution of the Armorica plate on the basis of paleomagnetic data. Geology, **12**, p. 579–582, no. 10.

POŻARYSKI W. (1990) — The Middle Europe Caledonides — wrenching orogen composed of terranes. Prz. Geol., **28**, p. 1–9, No. 1.

POŻARYSKI W., KOTAŃSKI Z. (1978) — Baikalian, Caledonian and Variscan events in the fore-field of the East-European Platform. Z. Dtsch. Geol. Ges., **129**, p. 391–402, no. 2.

POŻARYSKI W., BROCHWICZ-LEWIŃSKI W., TOMCZYK H. (1982) — Sur le caractère hétérochronique de la Ligne Teisseyre-Tornquist, entre l'Europe centrale et orientale. C. R. Acad. Sc., **295**, Sér. II, p. 691–696, no. 6.

SCHMIDT K., FRANKE D. (1977) — Zur lithologisch-faziellen Entwicklung des Präperms im Nordteil der DDR. Z. Angew. Geol., **23**, p. 543–548, no. 11.

SCHMIDT K., SÖLLNER F. (1983) — Towards a geodynamic concept of the "Caledonian Event" — in Central and SW-Europe. Verh. Geol. B–A, **3**, p. 251–268.

SORGENFREI T., BUCH A. (1964) — Deep tests in Denmark 1935–1959. Danm. Geol. Undres. III Raekke, no. 36.

VEJBAEK O. V. (1985) — Seismic stratigraphy and tectonics of sedimentary basins around Bornholm, southern Baltic. Danm. Geol. Unders, Ser. A, no. 8.

VEJBAEK O. V., ANDERSEN C. (1987) — Cretaceous–Early Tertiary inversion tectonism in the Danish Central Trough. Tectonophysics, **137**, p. 221–238, no. 1–4.

VOO R. VAN DER (1983) — Paleomagnetic constraints on the assembly of the Old Red Continent. Tectonophysics, **91**, p. 271–283, no. 3/4.

WALTER R. (1978) — Die geotektonische Entwicklung im nordwestlichen Mitteleuropa während des Altpaläozoikums. N. Jb. Geol. Paläont. Mh., **10**, p. 621–639.

WATSON J. (1976) — Eo-Europa: the evolution of a craton. In: Europe from crust to core, p. 59–78. Wiley and Sons. London.

ZECK H. P., ANDRIESSEN P. A. M., HANSEN K., JENSEN P. K., RASMUSSEN B. L. (1988) — Paleozoic paleo-cover of the southern part of the Fennoscandian Shield — fission track constraints. Tectonophysics, **149**, p. 61–66, no. 1/2.

ZIEGLER P. A. (1982) — Geological atlas of Western and Central Europe. Shell Int. Petr. Maatsch., 5. Elsevier.

ZIEGLER P. A. (1984) — Caledonian and Hercynian crustal consolidation of Western and Central Europe — a working hypothesis. Geol. Mijnb., **63**, p. 93–108, no. 1.

ZIEGLER P. A. (1987) — Late Cretaceous and Cenozoic intra-plate compressional deformations in the Alpine foreland — a geodynamic model. Tectonophysics, **137**, p. 389–420, no. 1–4.

ZNOSKO J. (1962) — Der geologische Bau des tiefern Untergrundes des ausserkarpatischen Polen. Z. Dtsch. Geol. Ges., **114**, p. 550–569, no. 3.

ZNOSKO J. (1970) — Pozycja tektoniczna obszaru Polski na tle Europy (in Polish only). In: Geologia i surowce mineralne Polski. Biul. Inst. Geol., **251**, p. 45–70.

ZNOSKO J. (1979) — Teisseyre-Tornquist tectonic zone: some interpretative implications of recent geological and geophysical investigations. Acta Geol. Pol., **29**, p. 365–382, no. 4.

ZNOSKO J. (1986) — Polish Caledonides and their relation to other European Caledonides. Ann. Soc. Geol. Pol., **56**, p. 33–52, no. 1–2.

ZWART H. J., DORNSIEPEN U. F. (1978) — The tectonic framework of Central and Western Europe. Geol. Mijnb., **57**, p. 627–654, no. 4.

ŻELICHOWSKI A. M. (1983) — The Carboniferous in Western Pomerania. Prz. Geol., 31, p. 356–364, no. 6.

Ryszard DADLEZ

TEKTONIKA POŁUDNIOWEGO BAŁTYKU

Streszczenie

Tektonika zachodniej części polskiego sektora Bałtyku jest wynikiem kilkufazowych deformacji. Front fałdowań kaledońskich, na lądzie polskim związany ze strefą Teisseyre'a-Tornquista, na skraju akwenu oddziela się od niej, biegnąc ku WNW. Strefa T-T zmierza ku NW, będąc na tym odcinku odmłodzonym prekambryjskim rozłamem wewnątrzplatformowym. Deformacje kaledońskie mogły być rezultatem skośnej kolizji małych bloków skorupowych (terranów?) pochodzenia bałtyckiego lub gondwańskiego z kratonem wschodnioeuropejskim. Podział obszaru na zuskokowane bloki dokonał się na przełomie karbonu i permu, zapewne również w warunkach transpresyjnych. Po wczesnomezozoicznym okresie tensji i transtensji, związanej z otwieraniem północnego Atlantyku, niektóre uskoki zostały odmłodzone także w środowisku transpresyjnym. Udział składowej przesuwczej z biegiem czasu wyraźnie malał.