CHAPTER 4

LATE CARBONIFEROUS TO PERMIAN EVOLUTION OF ARCTIC BASINS, THE NORWEGIAN–GREENLAND SEA RIFT AND PERMIAN BASINS OF WEST AND CENTRAL EUROPE

INTRODUCTION

Following the Early Carboniferous consolidation of the Innuitian-Lomonosov(?) fold belt and the termination of the Arctic-North Atlantic sinistral translation, the megatectonic setting of the Arctic areas underwent a fundamental change.

During the Early Carboniferous, the West Siberian Craton apparently became separated from the northern margin of Laurentia (corresponding to the northern margin of the North Alaska-Chukchi-Chukotka [East Siberian Block] and the New Siberian Islands blocks; Fig. 7), started to drift and rotate eastward, and began to converge with the eastern margin of Fennosarmatia and the Kazakhstan block (see Chapter 2, Post-Caledonian Plate Reorganization and Chapter 3, Uralian orogeny; Scotese, 1984). This was accompanied by the postorogenic collapse of the Innuitian fold belt as evident by the development of the Sverdrup Basin (Balkwill, 1978), tensional tectonics in the area of the Alaska North Slope (Hubbard et al., 1987) and rifting in the New Siberian Island (Fujita and Cook, 1986). At the same time, crustal extension governed the subsidence of the Norwegian Greenland Sea Rift through which the Arctic Seas advance southward during the Late Permian and invaded the Permian basins of Northwest and Central Europe (Plates 4–8).

SVERDRUP BASIN

The Sverdrup Basin is superimposed on the Innuitian fold belt. Its late Paleozoic to Late Cretaceous sedimentary fill attains thicknesses of up to 12 km (Fig. 13). The axis of this basin coincides closely with the trend of the Innuitian fold belt. Its southern margin is formed by the Parry Island fold belt, which represents the externides of the Innuitian orogen (Meneley et al., 1975; Balkwill, 1978; Trettin and Balkwill, 1979; Hea et al., 1980; Kerr, 1981b; Balkwill and Fox, 1982).

Shortly after the Ellesmerian consolidation of the Innuitian fold belt, the Sverdrup Basin began to subside under a tensional regime (Plate 22). Late Visean continental clastics, contained in downfaulted lows, are locally exposed (Emma Fjord formation). Crustal extension apparently accelerated during the early Namurian, leading to regional subsidence and the accumulation of conglomeratic clastics that grade basinward into marine sands (Borup formation). Carbonate deposition set in during the late Namurian, by which time tensional tectonics apparently abated. During the Westphalian and Stephanian, the Sverdrup Basin assumed the geometry of a broad downwarp. The margins of this basin were occupied by extensive reef-fringed carbonate platforms grading shorewards into cyclical mixed carbonate and clastic shelves and coastal sands. In the axial parts of the basin, deeper water conditions were established during the late Namurian. These depressions were infilled by thick halites and sulfates during the early Westphalian. These evaporites are overlain by Lower Westphalian to upper Permian deep water shales reflecting a renewed sediment starvation of basinal areas. During the Early Permian, basin subsidence apparently slowed down and shallow water conditions were gradually established also in the central parts of the Sverdrup Basin while clastic aprons prograded into it from its southern and western margins. Renewed tensional tectonics during the Late Permian, referred to as the Melvillian disturbance, were associated with major normal faulting causing subsidence of the axial parts of the basin in which deeper water conditions were reestablished. At the same time, the northwestern margin of the basin became uplifted (Balkwill and Fox, 1982). A regional regression and hiatus marks the Permian–Triassic boundary (Plates 5–8).

During the Late Carboniferous and Permian, the Sverdrup Basin was in open marine communication with the Arctic Shelf corresponding to the North Alaska, Chukchi, Chukotka and New Siberian Islands areas. In the northern Brooks Ranges and on the Alaska North Slope, for instance, the late Visean and Westphalian Lisburn carbonate platform is the equivalent of the carbonate shelves fringing the deep water troughs of the Sverdrup Basin (Dutro, 1981; Churkin and Trexler, 1981; Fujita and Cook, 1986). As in the Sverdrup Basin, the Lisburn carbonates are in part underlain by Late Devonian and Early Carboniferous clastics (Kanayut–Hunt Fork Formation and Endicott Group), which accumulated in tensional basins (Fig. 40; Bird and Molenaar, 1983; Hubbard et al., 1987).

Carboniferous and Permian sediments attain a thickness of some 5000 m in the central parts of the Sverdrup Basin. They are overlain by some 7000 m of Mesozoic sands and shales (Fig. 13; Meneley et al., 1975; Trettin and Balkwill, 1979; Balkwill and Fox, 1982). In view of this great overburden it is difficult to assess the scope of the late Visean to Namurian tensional tectonics that governed the initial phase of basin subsidence. Major grabens appear to be northeast- to east-trending and basalt flows are indicative of contemporaneous deep crustal fracturing (Trettin and Balkwill, 1979), possibly related to back-arc extension caused by the decay of the Innuitian subduction system. The Westphalian to Early Permian regional downwarp of the Sverdrup Basin, coupled with a gradual slowing down of subsidence rates, suggest that this second phase of basin evolution was governed by cooling of the thermal anomaly introduced during the earlier rifting phase (Sweeney, 1977). The resumption of tensional tectonics during the Late Permian Melvillian disturbance, which was accompanied locally by igneous activity, is probably related to contemporaneous crustal extension in the Arctic–North Atlantic rift system.

Geophysical data show that the crust of the Sverdrup Basin is drastically thinned, probably due to late Paleozoic and Mesozoic extension (Fig. 14; Sobczak et al., 1986).

SVALBARD–NORTHEAST GREENLAND OBLIQUE-SLIP ZONE

The stratigraphic record of northern Ellesmere Island, corresponding to the northeastern margin of the Sverdrup Basin, suggests that basin evolution during the Late Carboniferous and Permian was governed by wrench deformations (Plate 22). These induced the intermittent uplift of northeast–southwest-trending outer highs during the Westphalian and Artinskian. From these highs, clastics were shed in a southward direction into the adjacent subsiding troughs (U. Mayr, personal communication, 1985). This wrench system finds its continuation in the fault patterns of Western Svalbard and Northeastern Greenland (Steel and Worsley, 1934; Håkansson and Pedersen, 1982; Hakansson and Stemmerik, 1984).

In Western Svalbard, the Adriabukta wrench deformations at the transition from the Visean to the Namurian were followed by the rapid subsidence of a complex graben system in which alluvial fan-glomerates and sandy, in part coal-bearing, floodplain deposits accumulated. These Namurian series are up to

2000 m thick. Syndepositional oblique-slip movements resulted in local basin inversion at the transition from the Namurian to the Westphalian, while other troughs continued to subside rapidly (Plate 22). Westphalian alluvial fan-glomerates, accumulating at the foot of active fault-scarps, grade laterally into shallow marine and sabkha deposits that give way to open marine carbonates on the Barents Shelf. During the Stephanian and Early Permian, carbonate shelves containing fault-controlled evaporitic basins occupied the area of the Svalbard Archipelago. During the Late Permian, basinal areas were characterized by deeper water cyclical spiculites indicating their sediment starvation while carbonates and shallow marine sands accumulated on the offsetting platforms (Dalland et al., 1982; Plates 5–7). Although syndepositional tectonics continued through Permian time, they were less dramatic than during the Carboniferous and gave rise to local unconformities only. In Svalbard, marine sedimentation was continuous across the Permian–Triassic boundary (Nysaether, 1976; Birkenmajer, 1981; Gjelberg and Steel, 1981; Steel and Worsley, 1984).

The Wandel Sea Basin of northeastern Greenland offsets Svalbard to the southwest, according to the palinspastic reconstruction given in Plates 5–8. In this basin, sedimentation commenced in fault-controlled depressions with the accumulation of Dinantian coal-bearing continental clastics (Plate 22). This series is unconformably overlain by a transgressive cyclical sequence of late Westphalian to Stephanian coastal sands grading laterally into sabkha deposits and carbonates. These give way to Early Permian platform carbonates containing reefal buildups. The increasing tectonic instability of the area is indicated by the Artinskian influx of shallow marine sands and an intra-Ufimian unconformity. Late Permian series are represented by marine conglomerates and sands containing minor carbonates. A regional unconformity marks the Permian–Triassic boundary. These breaks in sedimentation are thought

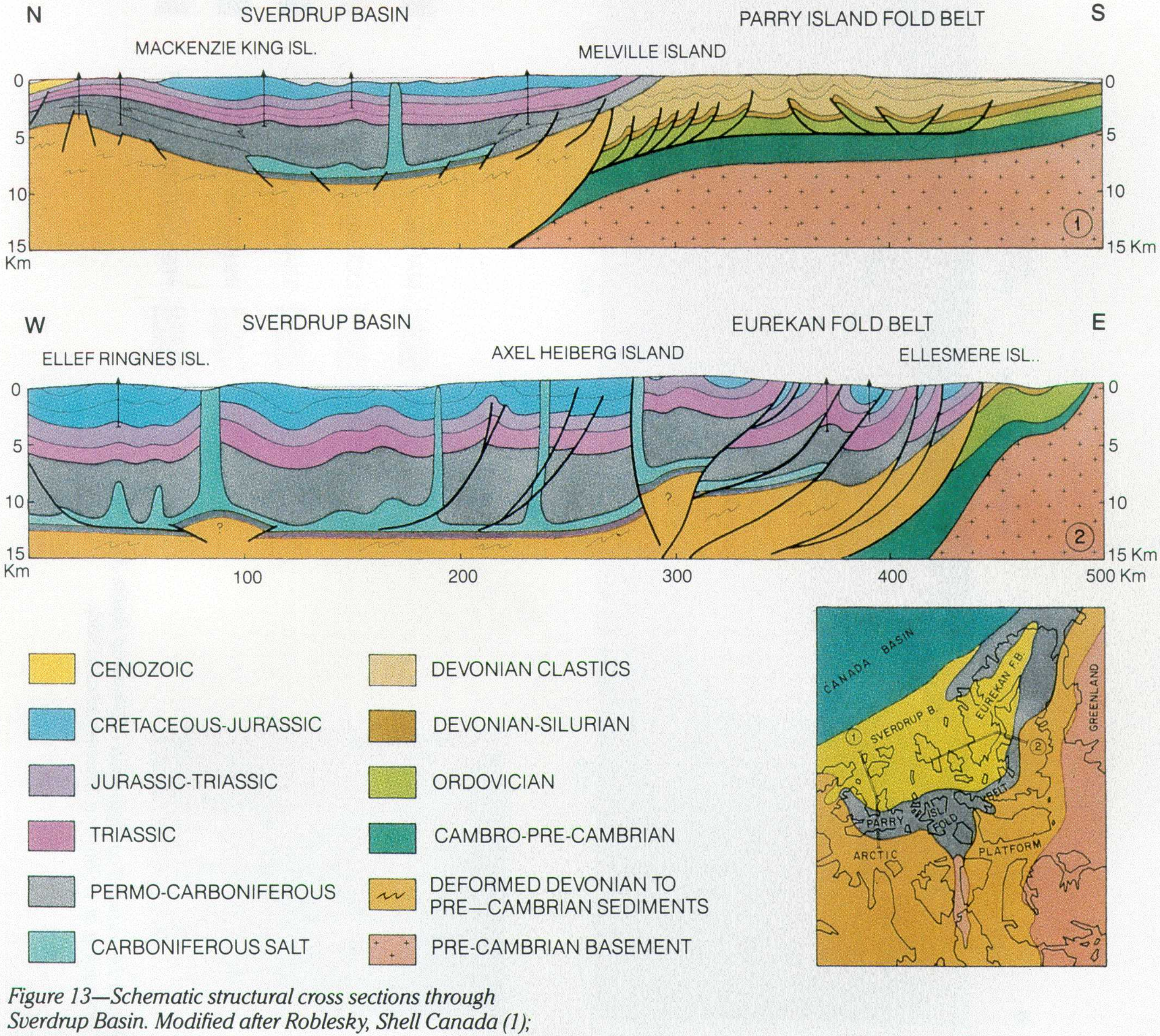

Figure 13—Schematic structural cross sections through Sverdrup Basin. Modified after Roblesky, Shell Canada (1); Fischer, Shell Canada (2).

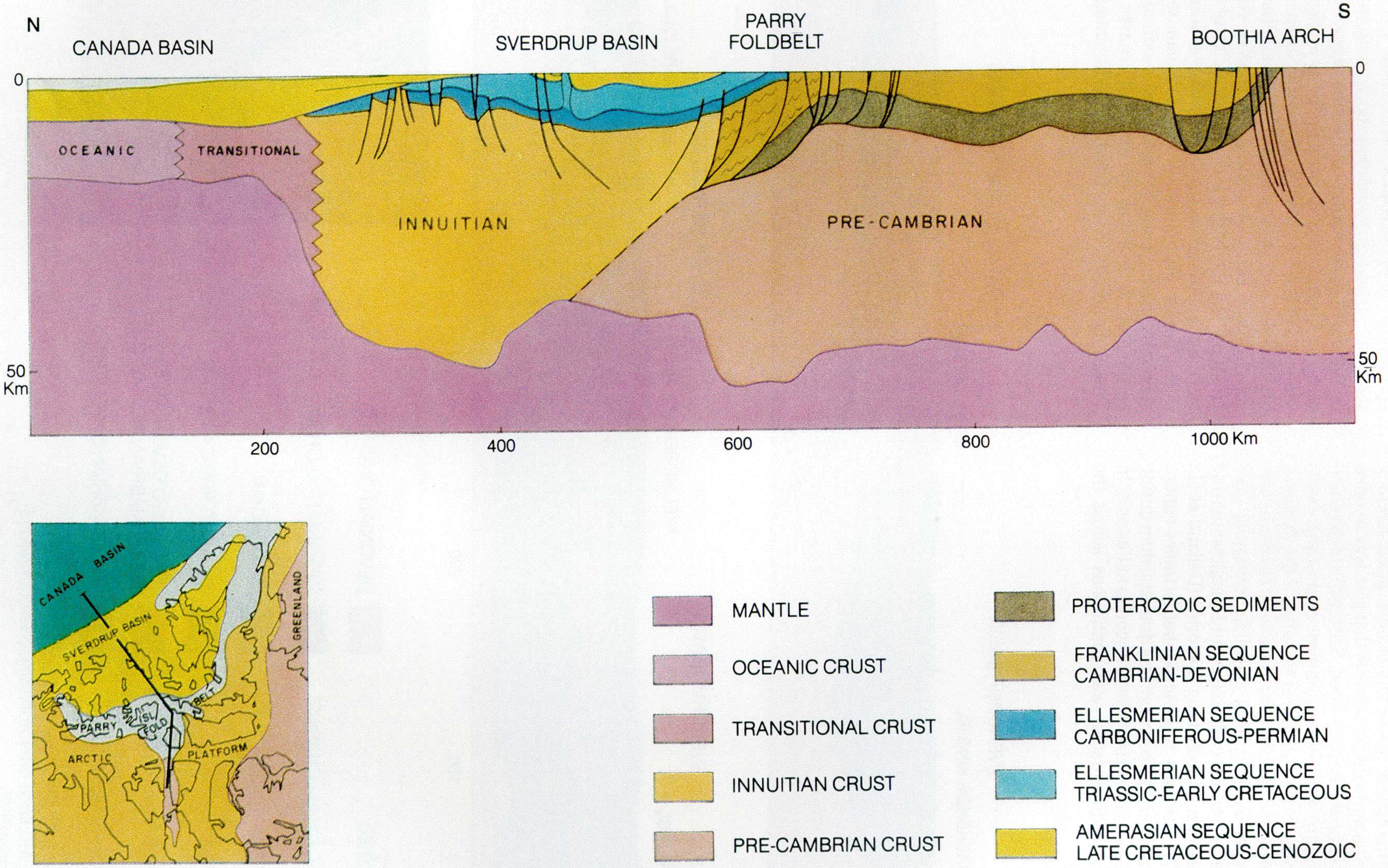

Figure 14—Crustal configuration of Sverdrup Basin. After Sobczack et al. (1986) and Sweeney et al. (1986).

to be related to dextral wrench movements along fault zones extending into Northern Ellesmere Island (Håkansson, 1979; Håkansson and Pederson, 1982; Håkansson and Stemmerik, 1984).

The stratigraphic control point located closest to the southern parts of the Wandel Sea Basin is Bear Island (Bjørnøya; Plate 22). Here, a latest Devonian to Namurian continental series accumulated in a half-graben limited to the west by an active fault. Marine transgressions reached this basin during the late Namurian. Sedimentation was interrupted at the transition from the Namurian to the Westphalian. Similar to Svalbard, Westphalian series are represented by thick conglomeratic fan deposits accumulating at the foot of an active fault scarp. These grade eastward into thinner deltaic sand and shallow marine shales that are conformably overlain by late Westphalian carbonates. In turn, these are disconformably overlain by Kazanian–Asselian (Stephanian to early Autunian) marine sands and carbonates. Wrench-induced basin inversion occurred during the Sakmarian. Artinskian clastics and carbonates transgressed over deeply truncated earlier series and the basement complex. Only minor deformations interrupted the Artinskian to Kazanian deposition of platform carbonates. A regional unconformity here also marks the Permian–Triassic boundary (Worsley and Edwards, 1976; Worsley and Gjelberg, 1980; Gjelberg and Steel, 1981, 1983).

From the above it can be concluded that the Late Carboniferous to Late Permian evolution of the Svalbard–Wandel Sea–Bear Island area was governed by extensional and oblique-slip tectonics. The latter probably compensated for contemporaneous crustal extension in the Norwegian–Greenland Sea Rift (Plates 5–8).

BARENTS SEA AREA

The Late Carboniferous and Permian paleogeographic and structural evolution of the Barents Shelf has to be deducted from reflection seismic data, limited borehole control, and projections from surrounding onshore areas. Regional compilations have been published by Faleide et al. (1984) and Rønnevik and Jacobsen (1984).

Based on regional considerations, it is assumed that much of the eastern Barents Shelf was occupied during the Late Carboniferous and Permian by stable carbonate platforms forming the northern extension of the Moscow Platform (Plates 5–8). On the other hand, the western parts of the Barents Shelf are transected by the Tromsø–Bjørnøya and the Nordkapp grabens (Fig. 10), the subsidence history of which is not yet fully resolved owing to limited well control. These structural features form an integral part of the Norwegian–Greenland Sea Rift and of the fault systems of the Svalbard–Northeast Greenland oblique-slip zone. In this context, the occurrence of massive alkaline intrusions in the Kontozero Rift on Kola Peninsula, dated as ± 300 Ma (Churkin et al., 1981), should be noted. The western Barents Shelf was presumably occupied during the Late Carboniferous by extensive carbonate platforms (Plates 5, 6). In analogy to Svalbard, evaporitic series were probably restricted to the differentially subsiding Tromsö and Nordkapp grabens. These contain thick halites that later gave rise to major diapiric structures (Fig. 39). The age of these halites is tentatively given as Late Carboniferous Bashkirian to earliest Permian. For the Nordkapp Graben, there is reflection seismic evidence for two separate cycles of salt deposition, the earlier being of probably Bashkirian age and the younger of Early Permian age. This suggests that these grabens had subsided differentially during these times.

On the western Barents Shelf, Early Permian strata are thought to be developed in a carbonate and carbonate-evaporitic facies as observed in Western Svalbard and in the Timan–Pechora area. This is supported by limited well data and seismically evident solution features on the eastern flank of the Loppa Ridge (Fig. 15). Late Permian cherty shales and carbonates, similar to those occurring in Svalbard, have been encountered in some of the wells drilled in the southwestern Barents Sea. This suggests an increase in water depth in areas of differential subsidence. On adjacent platforms, carbonate deposition apparently continued during the Late Permian (Plates 7, 8). Seismic and well data indicate that the Loppa Ridge became sharply uplifted at the transition from the Permian to the Triassic while the Bjørnøya Basin was downfaulted (Fig. 15). The uplift of the Loppa Ridge may be interpreted as rift-induced thermal doming. There is reflection seismic evidence that the Nordkapp Graben was also affected by this rifting pulse. In the Tromsø Basin, Cretaceous series exceeding a thickness of 6 km impede seismic resolution at deeper stratigraphic levels; it is therefore uncertain whether this graben also became reactivated at the transition from the Permian to the Triassic (Fig. 39).

Intraplate compressional stresses, related to the Uralian orogeny, apparently did not impede the Permian evolution of rifts in the Western Barents Sea.

NORWEGIAN–GREENLAND SEA RIFT

Following the last transpressional deformations along the Arctic–North Atlantic megashear, corresponding in East Greenland to the intra-Visean Ymerland phase, crustal extension governed the evolution of the Norwegian–Greenland Sea area.

In Central East Greenland, Namurian to early Stephanian continental conglomerates and sandstones, attaining thicknesses of up to 1500 m, accumulated in a north–south-trending system of half-grabens some 300 km long. After a rift-induced hiatus at the transition from the Carboniferous to the Permian (Scoresby Land unconformity), differential subsidence of these half-grabens continued and 2000–3000 m of Early Permian red conglomerates, fluvial sands and occasional lacustrine black shales were deposited (Plate 22).

An important intra-Kungurian rifting pulse, accompanied by dike intrusions, resulted in a further tilting of major basement-involving rotational fault blocks and an uplift of their leading edges. This rifting phase preceded the transgression of the Late Permian seas. Late Permian strata, some 300 m thick, consist of basal transgressive conglomerates, in part reefal carbonates, evaporites, and organic-rich shales; these are overlain by turbiditic and deltaic sands and coarse conglomerates. A further rifting pulse marks the Permian–Triassic boundary (Vischer, 1943; Haller, 1971; Henriksen and Higgins, 1976; Birkelund and Perch-Nilsen, 1976; Stemmerik and Sørensen, 1980; Surlyk et al., 1984, 1986; Fig. 49).

The overwhelming evidence for Late Carboniferous and Permian rifting available from Central East Greenland cannot, however, be duplicated by the stratigraphic record available for the basins underlying the shelf of Mid-Norway. Seismic data indicate that the Trøndelag Platform, located to the west of the

Mid-Norwegian town Trondheim, is underlain by thick pre-Triassic series contained in a basin that is limited to the east by a major coast parallel fault (Figs. 37, 38; Bukovics and Ziegler, 1985). These strata are not calibrated by well data but are thought to be made up of predominantly upper Paleozoic clastics. The occurrence of Upper Permian carbonates in the West Norway Shelf Basin has, however, been confirmed by well results (Plate 26).

Further south, in the Faeroe–West Shetland Basin, poorly dated Permo-Triassic red beds, which accumulated in rapidly subsiding half-grabens, may extend into the lower Permian and partly into the Stephanian. The occurrence of Upper Permian evaporitic intervals in this red bed series has been established by boreholes. Similarly, Upper Permian carbonates and evaporites have been encountered in wells drilled in the UK part of the northernmost North Sea and also on the northern shelf of Ireland (Plate 27; Fig. 48).

The Carboniferous rifts of the Northern British Isles, which can be considered as forming part of the rift-wrench basins of the Canadian Maritime Provinces, remained active until their partial inversion during the late Westphalian in response to compressional stresses exerted on the foreland during the terminal phase of the Variscan orogeny (Plate 22, 23). These foreland stresses presumably impeded the southward propagation of the Norwegian–Greenland Sea Rift (Chapter 3). On the other hand, subsequent tensional stresses, developing during the Stephanian and Autunian at the western termination of the Bay of Biscay fracture zone and of subsidiary wrench systems crossing the Irish Sea and the British Isles, may have assisted the southward propagation of this rift system through which the Arctic Seas advanced southward during the Late Permian (see Chapter 3; Ziegler, 1982a).

The Late Carboniferous and Permian Norwegian–Greenland Sea Rift was essentially a-volcanic. The only igneous evidence reported to date are a syenite porphyry dike, dated as 297 ± 8 Ma, and a Lamprophyr dike dated as 278 ± 25 Ma occurring in the coastal area of Mid-Norway near Kristian Sund (Räheim, 1974). On the other hand, extensive Stephanian–Antunian dike systems and sills occur in Scotland (Plate 6).

PERMIAN BASINS OF WESTERN AND CENTRAL EUROPE

With the final consolidation of the Appalachian–Mauretanides fold belt during the Alleghenian orogenic pulse, the dextral transform system linking this fold belt with the Urals

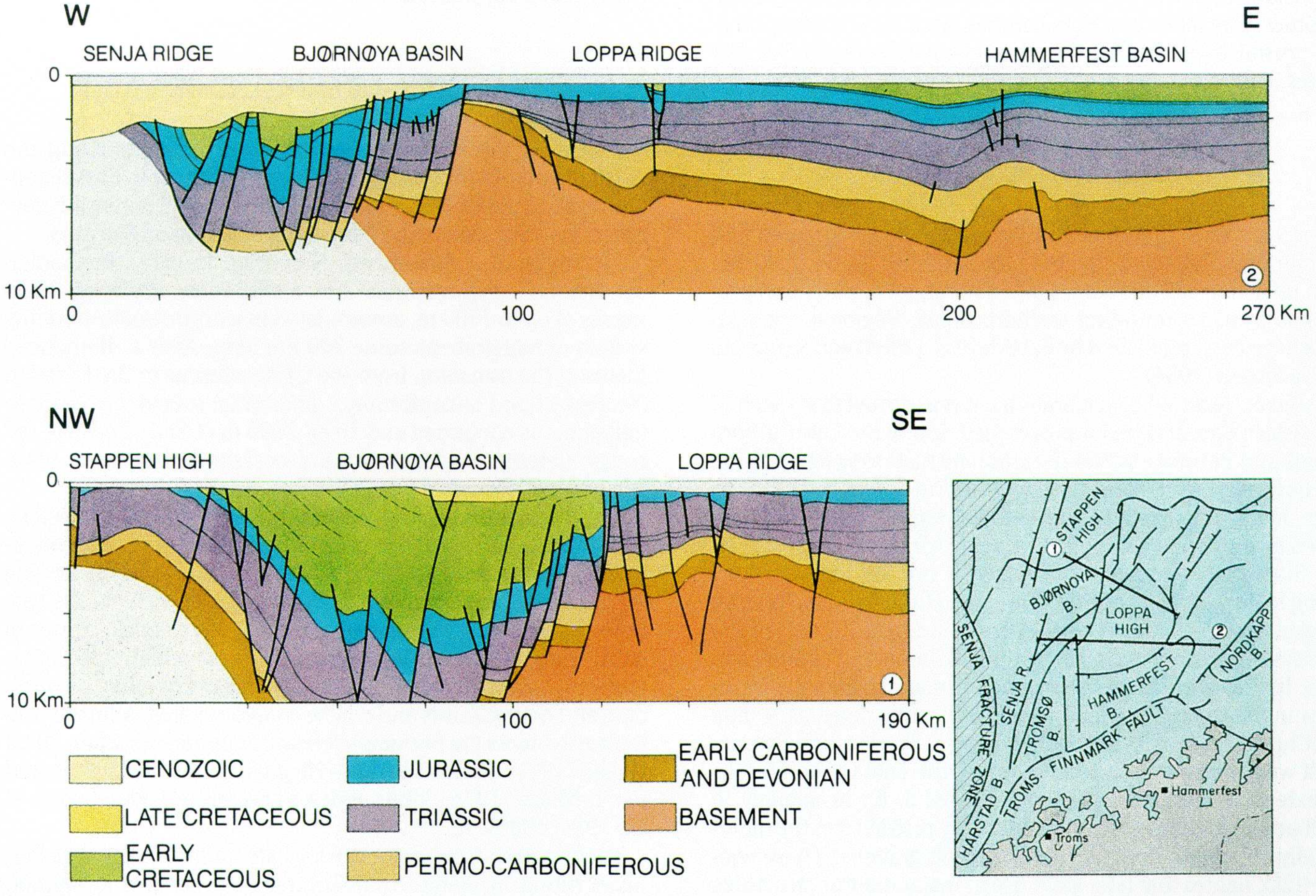

Figure 15—Schematic structural cross sections through Loppa Ridge and Bjørnøya Basin, southwestern Barents Sea. After Gorin et al., Norske Shell.

became inactive. Consequently, wrench movements and volcanic activity in Western and Central Europe abated at the transition from the Autunian to the Saxonian. Only in the Oslo Graben did magmatic activity persist into the Late Permian.

The gradual decay of the thermal anomalies, which were induced by the Stephanian–Autunian wrench and pull-apart deformations, is reflected by the progressive subsidence of the Northern and Southern Permian basins of Northwest and Central Europe. In these basins, the thick Rotliegend eolian and intracontinental playa lake deposits accumulated under arid conditions during the late Early Permian (Plate 7; Plein, 1978; Ziegler, 1982a; Glennie, 1984a, 1984b; Sørensen, 1986).

During Rotliegend times, the Northern and Southern Permian basins were separated by the Mid-North Sea–Ringkøbing-Fyn trend of highs; these highs had come into evidence during the Stephanian-Antunian (Fig. 12).

The Southern Permian Basin is essentially superimposed on the Late Carboniferous Variscan foredeep but encroaches in its eastern parts on the Variscan Externides. This basin has the form of a broad, saucer-shaped downwarp. Its depocenter, in which Rotliegend shales and halites reach a thickness of 1500 m, coincides closely with the areas of Permo-Carboniferous volcanism in northern Germany (Ziegler, 1982a; Fig. 16; Plates 6, 7). The Rotliegend sands, which are developed in a broad belt along the southern margin of the Southern Permian Basin, form the reservoir of major gas accumulations in the southern North Sea and the eastward adjacent Dutch and North German onshore areas (Ziegler, 1980; Glennie, 1986).

Subsidence of the Southern Permian Basin was accompanied by only minor faulting. An exception is the Polish depocenter that was controlled by a northwest–southeast-trending graben (Depowski, 1978). This rift zone extends from Poland into the Black Sea area (Vinogradov, 1969). Its development is contemporaneous with the subsidence of the early Tethys rifts in the Central Mediterranean and with back-arc extension in the eastern Tethys domain. The latter culminated during the latest Permian–Early Triassic in sea-floor spreading in the Black Sea area and the partial separation of the Balkan–Turkish Cimmeria Terrane from the southern margin of Fennosarmatia (Adamia et al., 1981; Khain, 1984a; Chapter 5, Permo-Triassic Tethys Rift Systems).

The outlines and geometry of the Northern Permian Basin(s), located in the Central North Sea, is less well known owing to its deep burial under younger sediments and the intensity of Mesozoic rift tectonics (Fig. 18). Limited well control indicates that Rotliegend clastics in this basin attain thicknesses ranging between 200 and 600 m; there is no evidence for the development of an axial, evaporitic playa lake. The Rotliegend clastics of the Northern Permian basin overlay a variable thickness of Devonian and/or Lower Carboniferous sediments and, particularly in its eastern parts, transgressed directly over the Caledonian basement complex and lower Paleozoic sediments

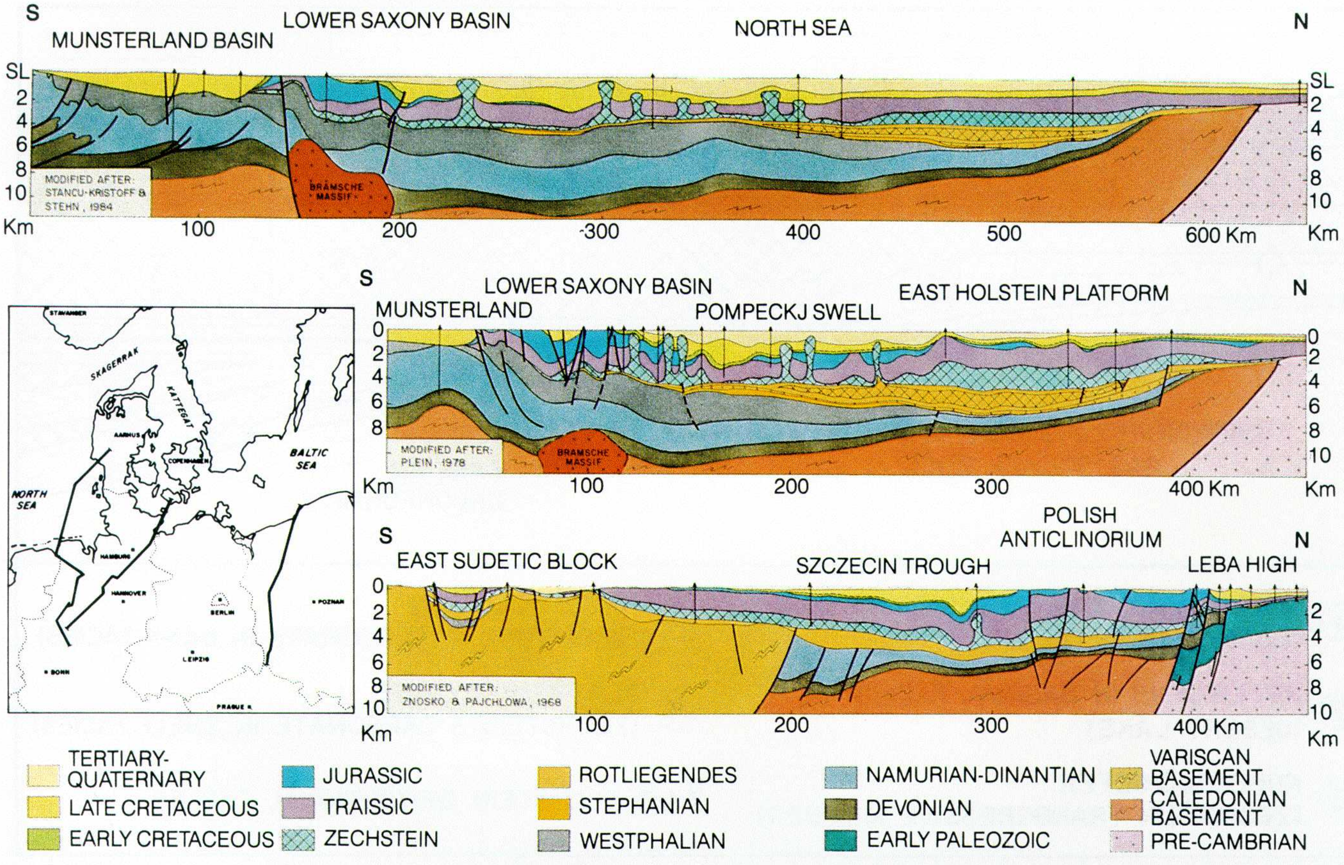

Figure 16—Regional structural cross sections through North German and Polish Lowlands showing relation of southern Permian Basin to Variscan fold belt and foredeep. Modified after Stancu-Kristoff and Stehn (1984) (top); Plein (1978) (center); and Znosko and Pajchlowa (1968) (bottom).

preserved in the Caledonian foreland (Fig. 12; Hospers et al., 1986a).

Progressive subsidence of the Norwegian-Greenland Sea Rift, combined with a glacioeustatic rise in sea level related to the deglaciation of Gondwana, resulted in the Late Permian rapid southward transgression of the Arctic Seas (Plate 8). At the transition from the Kungurian to the Ufinian, the barriers separating the Norwegian-Greenland Sea Rift from the Northern and Southern Permian basins of Europe broke down (were overstepped?) and the Arctic Seas invaded the latter, forming the huge Zechstein inland sea, which had a length of some 1700 km and a width of about 600 km. This transgression was apparently catastrophic as indicated by the basin-wide correlative, transgressive Kupferschiefer which corresponds to a sharp time-marker. The depositional water depth of this highly organic shale was clearly below wave-base and could have been in the 200–300 m range in the central parts of these basins. This suggests that the Rotliegend basins had subsided below the global sea level already before the transgression of the Zechstein Sea.

The Zechstein seas entered these intra-continental depressions probably via the incipient Viking Graben of the northern North Sea and via the Faeroe-Rockall Trough, the Irish Sea (Manx-Furness Basin, "Bakevillia Sea"), and across the area of the Pennine High (the Solway-Vale of Eden depression; Fig. 35; Pattinson et al., 1973; Ziegler, 1982a; Glennie, 1984a). Syndepositional faulting is evident in areas bordering the Faeroe-Rockall Trough, in the Irish Sea, the Moray Firth area, and also in Poland, but otherwise plays only a minor role. On the basis of the available seismic and well data, it is unlikely that the Central North Sea Graben had already started to subside differentially during the Late Permian. In the northern parts of the Viking Graben, presumably thin Zechstein series, if at all present, are confined to its axial parts where they cannot be reached by the drill. Zechstein salts contained in the southern parts of the Viking Graben (Curtin and Ballestad, 1986) and in the Central Graben represent on the basis of seismostratigraphic evidence downfaulted prerift sediments and were not deposited in a differentially subsiding rift. The Horn Graben, on the other hand, forming the southernmost part of the Early Permian Oslo Rift, continued to subside differentially during the Late Permian (Fig. 18).

The depositional cycles recognized in the Zechstein series of the Northern and Southern Permian basins (Fig. 17) are fully correlative and thus illustrated that these basins were in full communication with each other across the Mid-North Sea High (Jenyon et al., 1984). Since Zechstein salts are missing, or only thinly developed, in the central parts of the Danish sector of the North Sea Central Graben, it must also be assumed that this segment of this major Mesozoic rift had not yet started to subside differentially during the Late Permian.

Faunal evidence indicates that during the Ufimian a temporary link was established between the Arctic-dominated Zechstein Seas and the Tethys via the Polish-Dobrugea Rift (Peryt

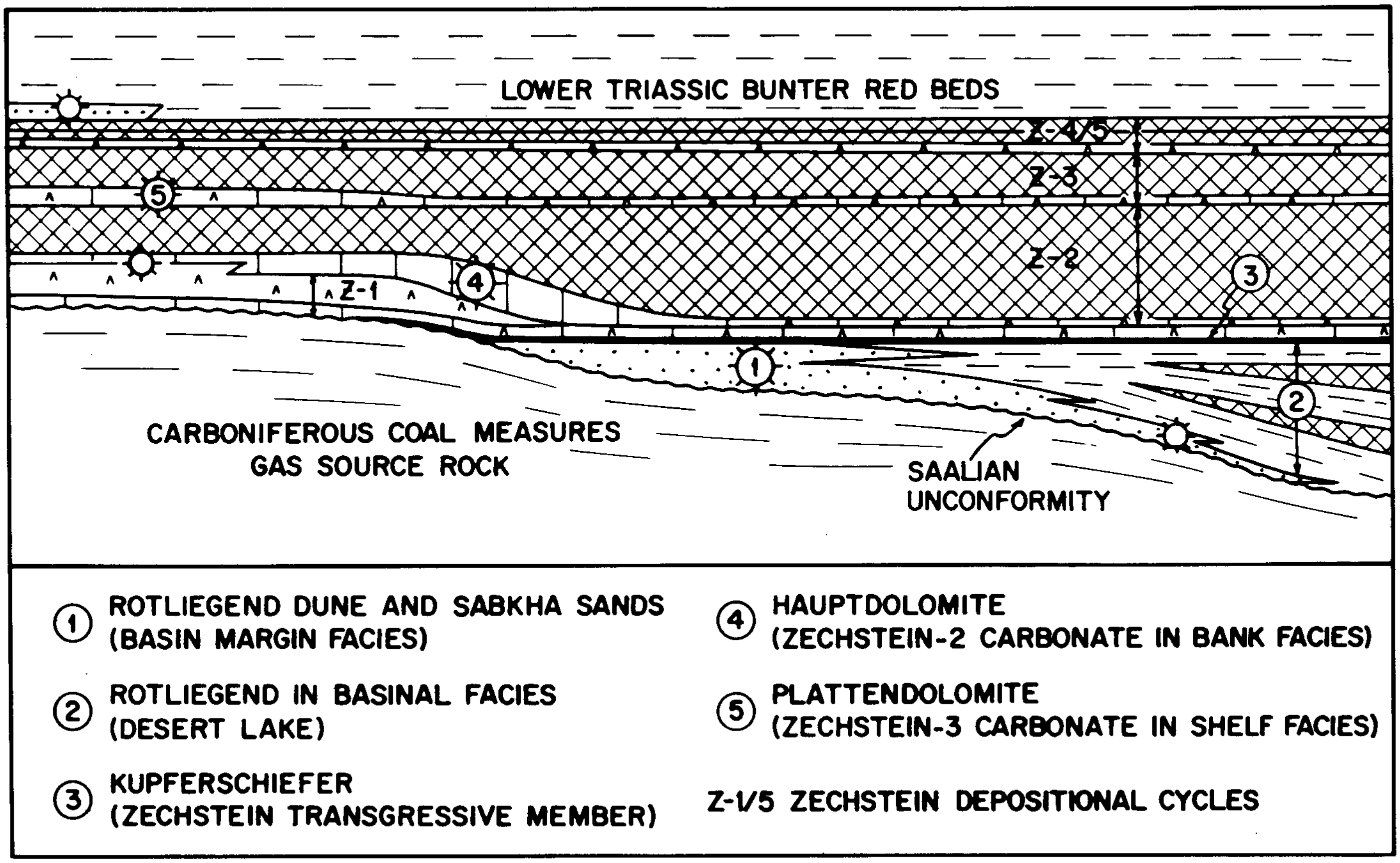

Figure 17—Permian depositional cycles of the Northern and Southern Permian basins. Star symbol indicates principal gas reservoirs.

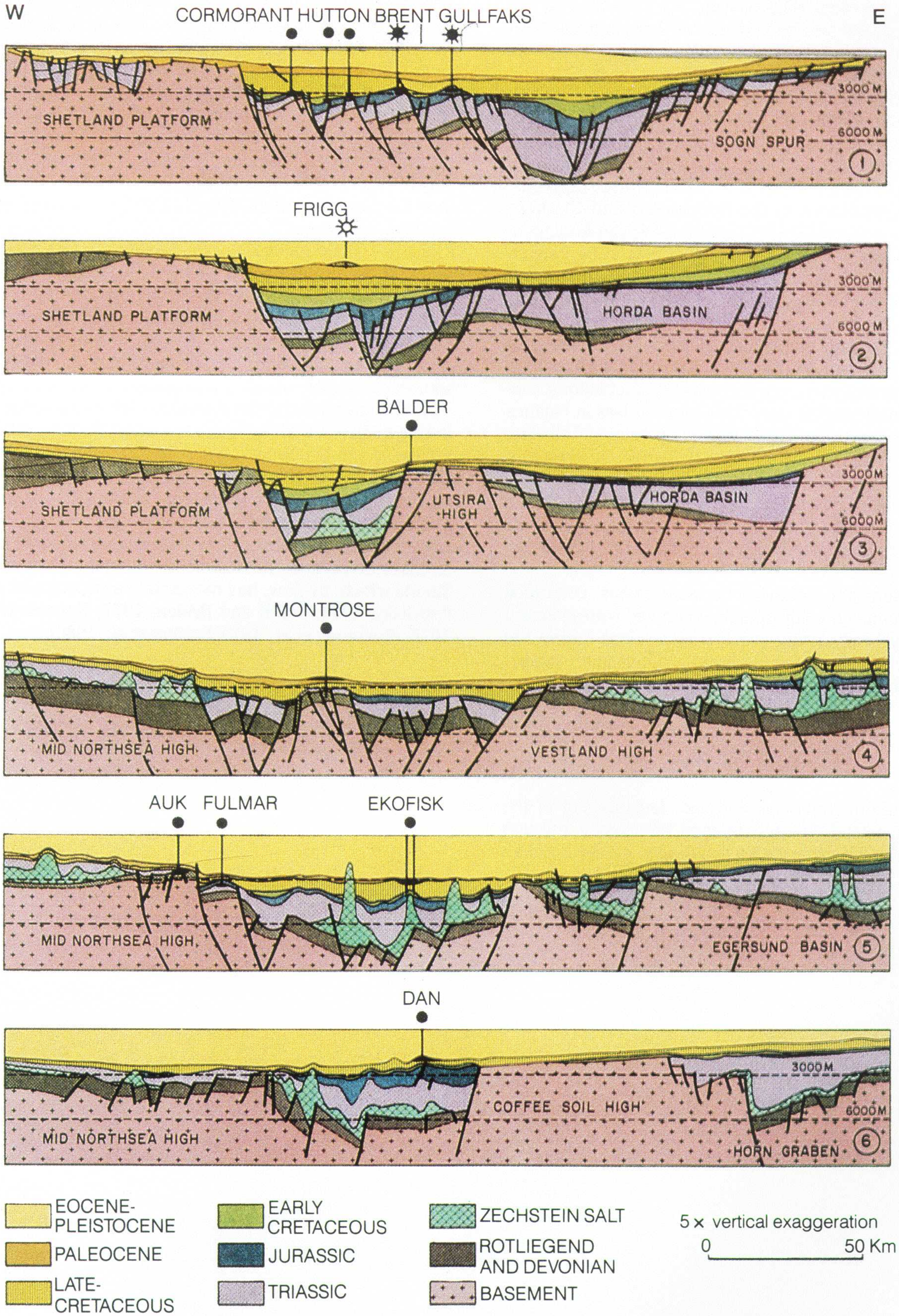

Figure 18—Structural cross sections of the Central and Northern North Sea. For locations see Figure 19. After Louwerens, SIPM.

and Peryt, 1977). Following the initial transgression of the Zechstein Seas, repeated glacioeustatic sea level fluctuations resulted in the cyclical restriction of the Northern and Southern Permian basins. This impeded a further faunal exchange between the Arctic and Tethys Seas.

During the deposition of the Zechstein I and II cycles (Fig. 17), water depths increased to some 400–500 m in basinal areas while carbonate and sulfate banks developed along the basin margins. The Dolomites capping these banks and their prograding slopes (Hauptdolomite) contain important gas-condensate accumulations in the Netherlands and Northern Germany (Sannemann et al., 1978; Smith, 1981; Van Adrichem-Boogaert and Burgers, 1983; Taylor, 1984; Clark, 1986; Ziegler, 1980).

Accumulation of the Hauptdolomite was interrupted by a sharp restriction of basinal areas, presumably in response to a sea level drop, causing their infilling by the thick Stassfurth Salts (Z-2 salt). During the subsequent depositional cycles III to V, which were controlled by repeated sea level fluctuations, subsidence and sedimentation rates were more or less in balance and the basinal areas were characterized by relatively shallow water depths (Pakulska and Kuna, 1981). During the latest Permian, the Arctic seas withdrew from Northwest Europe.

The five glacioeustatically induced depositional cycles of the Zechstein Basin correlate with the same number of cycles evident in the spiculite series of Western Svalbard (see Steel and Worsley, 1984).

In the Northern and Southern Permian basins, continued thermal relaxation of the lithosphere, combined with sediment loading and cyclically rising sea levels, resulted during the accumulation of the Zechstein series in a significant overstepping of the basin margins (Ziegler, 1982a).

CONCLUSIONS

The Late Carboniferous and Permian development of the Norwegian–Greenland Sea Rift opened an avenue through which the Arctic Seas transgressed during the Late Permian into Northwest and Central Europe where they temporarily linked up with the Tethys Seas advancing northwestward through the Polish–Dobrugean Rift. Crustal extension in the Norwegian–Greenland Sea Rift was compensated by transform faults marking the northern margin of the Sverdrup and Wandel Sea basins. The southward propagation of the Norwegian–Greenland Sea Rift was apparently impeded by compressional foreland stresses during the Westphalian phases of the Variscan orogeny. After the relaxation of these stresses, this rift system began to propagate itself southward during the Late Permian into the Faeroe–Rockall Trough and possibly also into the northern North Sea.

In the Tethys domain, back-arc extension in the Black Sea area and rifting in the South Alpine, Dinarid, and Balkan areas heralded the early Mesozoic plate reorganization that culminated in the Mid-Jurassic crustal separation between Laurasia and Africa (Chapter 5).

During the Late Carboniferous and Permian, long-term and short-term eustatic sea level changes played an important role. These can be related to the glaciation of Gondwana that peaked during the latest Carboniferous to earliest Permian and waned rapidly at the beginning of the Late Permian (Hambrey and Harland, 1981; Caputo and Crowell, 1985). Yet, the highly cyclical nature of the Late Permian series is suggestive of continued glacioeustatic sea-level fluctuations. It is, however, uncertain whether during this time span remanent ice sheets still existed, for instance, in Antarctica or whether new ice caps developed in Siberia which, by now, had moved into a circumpolar position (Ustritsky, 1973; Smith and Briden, 1977; Kanasevich et al., 1978; Firstbrook et al., 1979; Scotese et al., 1980).