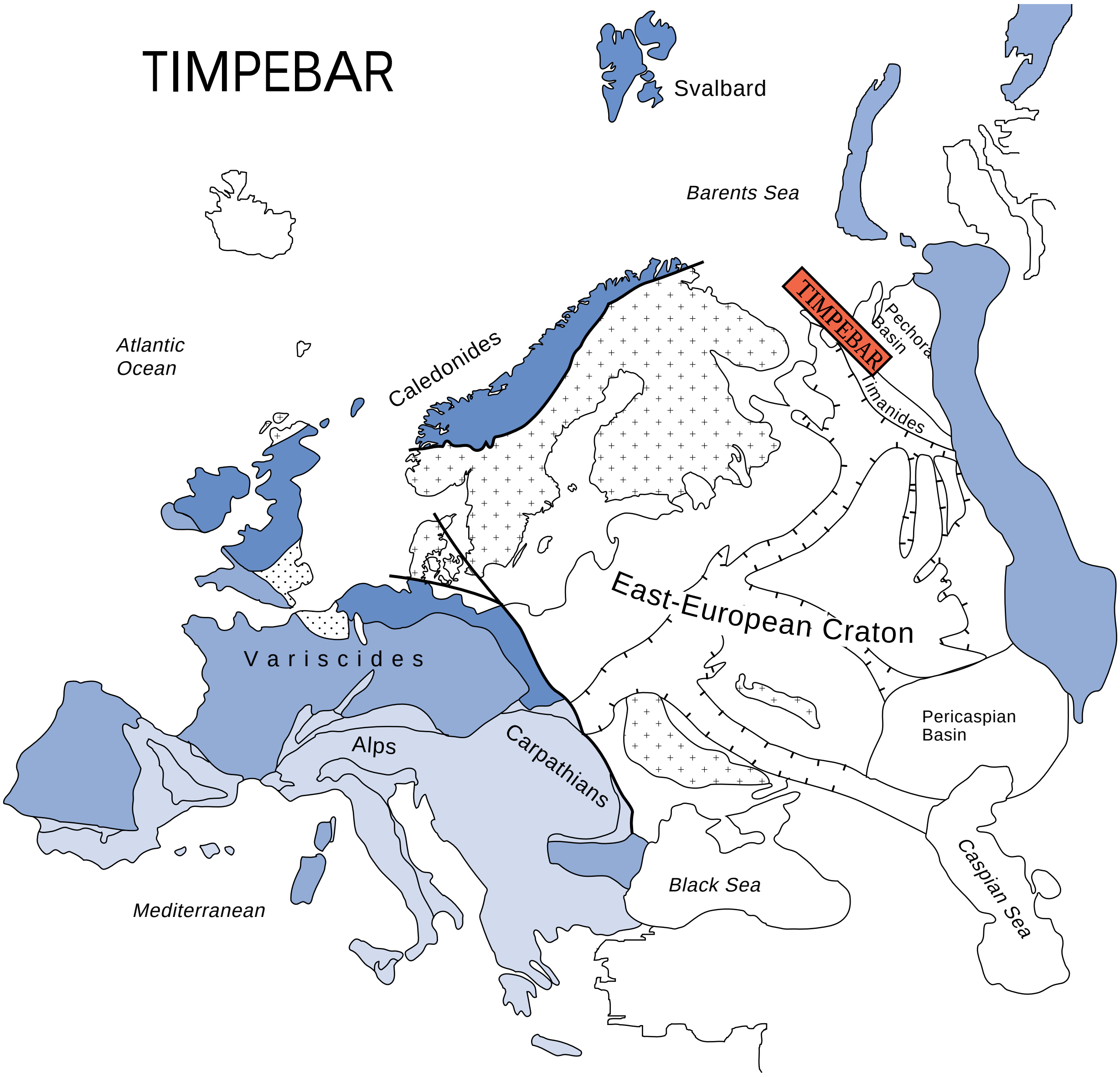
TIMPEBAR
Svalbard
Barents Sea
Atlantic
Ocean
Caledonides
TIMPEBAR
Pechora
Basin
Timanides
East-European Craton
Variscides
Pericaspian
Basin
Alps
Carpathians
Black Sea
Caspian Sea
Mediterranean

TIMPEBAR

Basement Control on Basin Evolution

by David G. Gee (Uppsala), Peter A. Ziegler (Basel) and TIMPEBAR colleagues

TIMPEBAR focuses on the evolution of Europe's northeastern Arctic shelf, comprising the Pechora, Eastern Barents Sea and North Kara Sea basins and their fringing terranes, which outcrop in the Timan Range (northeastern margin of the East-European Craton), Polar Urals, Novaya Zemlya, Taimyr and Severnaya Zemlya. Research on these areas is being integrated with on-going studies of the Western Barents Sea and the Svalbard archipelago.

The shallower Pechora Basin and the ultradeep Southeastern Barents Sea Basin host two of Europe's most important hydrocarbon provinces. These basins, together with the still little explored Northeast Barents Sea Basin, are located in the foreland of the northern parts of the Uralian Orogen. Their evolution and the age of their underlying crust differs significantly from that of the central and southern Urals foreland basins. The TIMPEBAR project will contribute to the resource assessment of this vast frontier area.

In the Pechora Basin, many drill holes penetrate its entire sedimentary fill and bottom in basement; Neoproterozoic and Baikalian-age rift-related igneous rocks and island arc volcanics have been reported. Available geophysical and well data provide a substantial base for analysing the age, composition and structure of the basement. In the Barents Sea, no wells have reached basement and its age has to be inferred from outcrops on the mainland and high Arctic islands. Deep seismic profiles crossing the Pechora and Eastern Barents Sea basins provide evidence of a crustal and upper mantle structure that differs greatly from that of the Uralide foreland to the south. A vast amount of industrial reflection-seismic profiles, in combination with results of deep wells, provide an essential data base for analysing and modelling the architecture and evolution of the Pechora and Eastern Barents Sea basins.

Analysis of existing data provides the foundation for multidisciplinary investigations, including:

1) Determination of the age and composition of the Pechora basement by geochronological and geochemical analyses of drill-cores from folded Baikalian age (?) pre-Ordovician successions and their associated igneous and metamorphic rocks.
2) Complementary studies of the Polar Urals, Novaya Zemlya and Taimyr, where Baikalian-age terranes occur, locally with ophiolites and high P/T metamorphic rocks.
3) Interpretation of the crustal structure of the Pechora and Eastern Barents Sea basins from wide angle and near vertical seismic profiles, integrated with potential field data.
4) Analysis of the structure, stratigraphy, sedimentology, metamorphism and igneous activity of the Timan Range, providing control on the southwestern margin of the Pechora Basin.
5) Integrated analysis of Barentsia, underlying the northwestern parts of the Barents shelf.
6) Quantitative modelling of the evolution and thermal regime of the Pechora and Eastern Barents Sea basins; comparison with the central and southern Uralian foredeep basins.
7) Acquisition of selected new regional deep seismic profiles both on- and off-shore (CMP and wide-angle, comparable to URSEIS'95), to obtain an image of the crust and upper mantle, permitting analysis of their response to a sequence of contractional and extensional events.

Introduction

The lithosphere beneath the sea and ice of the high Arctic is probably the least known part of the Earth's crust and mantle. The TIMPEBAR project addresses the evolution of the lithosphere of the European Arctic shelf and specifically of the Eastern Barents and North Kara Sea, the most enigmatic part of Europe. A substantial data base on the Late Palaeozoic and younger history of the area is matched by a dearth of information on its earlier evolution. Nevertheless, relevant data are available from on- and off-shore areas, comprising results of deep exploration wells and extensive geophysical data bases. These provide a foundation for new research initiatives; they may justify the acquisition of new regional geophysical transects.

The Eastern Barents Sea and the North Kara Sea are fringed by Severnaya Zemlya, Taimyr, Novaya Zemlya, the Polar Urals, the Pechora Basin and the Timan Range. The latter forms the northeastern margin of the East-European Craton. The ultra-deep south-eastern Barents Sea Basin and the shallower Pechora Basin host major hydrocarbon provinces. The north-eastern Barents Sea and North Kara basins are little explored and represent major frontier provinces. This string of basins occupies the foreland of the northern parts of the Uralide orogen. Available data indicate that the evolution of these basins, as well as the age and composition of their underlying basement, differs significantly from that of the central and southern Uralian forelands.

The TIMPEBAR project has two main objectives. Firstly, it is concerned with a comprehensive analysis (combining geological, geochemical and geophysical studies) of the lithosphere in the Timan-Pechora-Barents Sea-Kara Sea area in order to define the age, configuration and evolution of the crust beneath its Palaeozoic and younger sedimentary cover and to relate it to that of the Svalbard archipelago, the western Barents Sea and northern Fennoscandia. Secondly, these data, together with information on the Palaeozoic and younger sedimentary record, provide the basis for testing models of foreland basin development.

The response of the lithosphere to basin-forming mechanisms, such as rifting and foreland deflection, depends on its pre-existing configuration. In this respect, the rheology of the crust, the thickness of the mantle lithosphere and its thermal regime play major roles. In contrast to the southern and central Uralian forelands, which are underlain by thick Archaean-Palaeoproterozoic crust, the Pechora and Eastern-Barents Sea areas appear to be underlain by dramatically thinned Neoproterozoic and early Palaeozoic crustal segments which were affected by repeated extensional and compressional events, prior to being incorporated into Uralian flexural foreland basins.

Development of the Research Plan

The TIMPEBAR project was initiated at an ITBD workshop in Amsterdam in 1992 and developed further in Opalikha (near Moscow) in 1993. Workshops in Oslo and Moscow/Ukhta in 1995 defined the details of the science plan, regulated access to the data and established East-West partnerships. Ten institutes in seven countries (the Netherlands, Norway, Russia, Spain, Sweden, Switzerland and the United Kingdom) are involved in this project.

Geological Framework

The area of interest reaches from the Timan Range, on the northeastern edge of the East-European Craton, eastwards to the mountain front of the Polar Urals and northwards through the Barents Sea (Bogdanov et al., 1996) to Svalbard, Franz Josef Land, Novaya Zemlya, Taimyr and Svernaya Zemlya (Fig. 9.1). The character of the pre-Devonian basement is enigmatic and controversial. Northern areas of the Barents Shelf (Barentsia) provide evidence of Caledonian deformation of Grenville-age crystalline complexes; they contrast markedly with those of the southern parts, where Baikalian-age tectonothermal activity dominates the margin of the East-European Craton. Palinspastic reconstruction of Caledonian terranes in the Arctic is essential for interpretation of both the earlier history and the influence of "basement" on the younger basin evolution. The main tectonic elements are summarised below.

Timanides

A Neoproterozoic basin flanks the northeastern margin of the East-European Craton (EEC) and is exposed in the Timan Range (Fig. 9.2) where it is

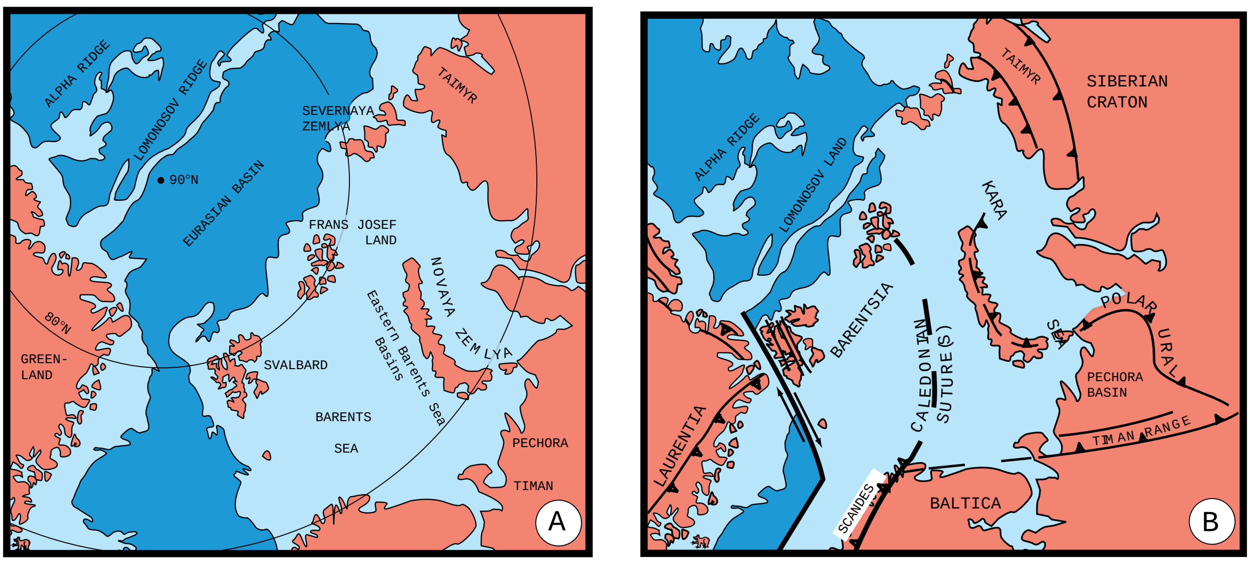

Figure 9.1: High Arctic terranes: A. Continent-Ocean relationships today; B. Early Tertiary relationships.

unconformably overlain by Devonian strata. This basin (Getzen, 1975, 1987; Dedeev and Getzen, 1987) is partially inverted along its western flank where reflection seismic (CMP) profiling provides evidence of thrusting to the southwest. To the northeast, the Proterozoic rocks are completely covered by Phanerozoic strata of the Pechora Basin; they are known only from drillcores.

In the southeastern part of the Kanin Peninsula and in an anticlinorium in the northernmost Timans, an up to 14 km thick Proterozoic succession is exposed. Metamorphism ranges from lower greenschist facies to amphibolite facies in the lower part. The successions are dissected by several generations of granite intrusions, pegmatites and dolerite dykes and are unconformably overlain by Devonian basalts and sediments.

Pechora Basin

The Devonian strata of the Timanides extend northeastwards beneath the Pechora Basin (Fig. 9.3) where they are underlain by Silurian and Ordovician successions that rest unconformably on folded and metamorphosed Vendian and older rocks. An early Ordovician rifting cycle was followed by the Late Ordovician and Silurian development of a passive margin prism. Sedimentation on this shelf was interrupted in the Middle Devonian by the onset of a new rifting cycle, giving rise to the development of the Pechora and Kolva rifts and associated transfer faults, partly involving reactivation of pre-existing crustal discontinuities. Termination of the rifting activity was followed by a post-rift thermal sag stage in the Carboniferous. During the latest Carboniferous, the Polar Ural arc-trench system collided with the Pechora passive margin. During the Permian and Triassic, the Pechora Basin evolved primarily as an orogenic foreland basin. Increasing collisional coupling between the evolving orogen and its foreland is reflected by the compressional reactivation of the Devonian rifts, causing their inversion at distances of up to 500 km to the west of the Uralian thrust front; the latter remained active till the end of the Triassic (Dedeev et al., 1994; Sobornov and Rostovshchikov, 1996). In this respect, the evolution of the Polar Urals differs from the Urals foreland to the south where such inversion structures are absent.

In the Pechora Basin, generation of hydrocarbons, mainly from Ordovician and Devonian source-rocks, reached a peak simultaneously with the Permo-Triassic foreland basin development and the inversion of the Devonian rifts (Pairazian, 1993).

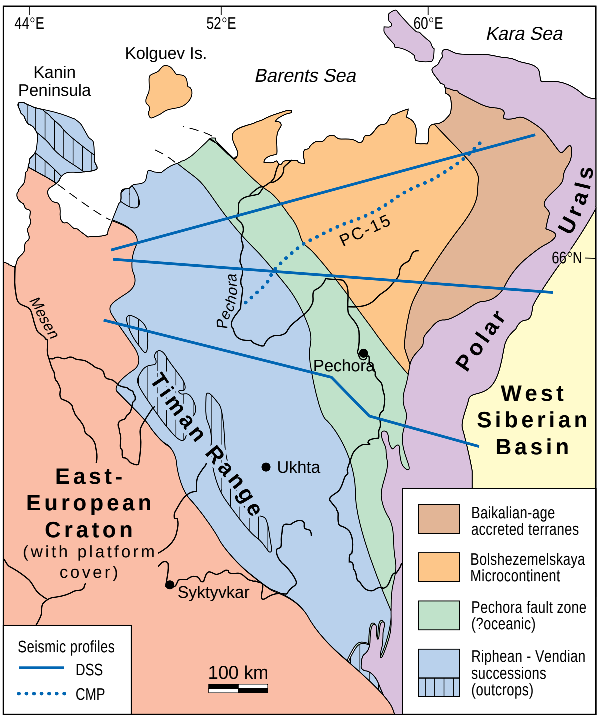

Figure 9.2: Basement provinces adjacent to the Pechora Basin.

Basement of the Pechora Basin

The basement beneath the Pechora Basin is not exposed, but is known from c. 200 drillholes that in some cases reach over a kilometre below the Palaeozoic cover. Interpretation of the character of this basement is controversial (Siedlecka, 1975). It is considered by some authors to be a rifted extension of the craton and by others as a "Timanian" (Baikalian-age) accretionary complex, perhaps an ophiolite/island arc/microcontinent assemblage, added to the EEC during Early Cambrian-Vendian (c. 550 Ma) orogeny (Nikishin et al.,1996).

The petrology of the Pechora basement drillcores has been extensively studied (Beliakova and Stepanenko, 1991). By combining drillcore and potential field data, it has been shown that the basement lying to the east of the exposed Timan Range can be divided into three major provinces (Fig. 9.2). A western (Timan-Izhmapechora) province, related to the Timan fold belt, and composed of Riphean and Vendian strata, generally deformed in sub-greenschist facies and intruded (in its eastern parts) by granites, syenites and gabbros; an eastern province (Bolshezemelskaya), extending into the Urals mountain front, with Riphean low-grade metasedimentary and volcanic rocks intruded by various granites (Mesoproterozoic and older basement may be present in this province; it is shown on figure 9.2 as both a microcontinent and Baikalian accreted terranes); separating these provinces is a wide deformation zone (the Pechora Fault Zone or rift), dominated by gabbros and diorites, with some plagiogranites and dolerites, occasional ultramafites and volcanics of possible island-arc affinities. Application of the K/Ar isotopic age-determination method on the Pechora basement intrusive rocks has yielded many latest Precambrian to Cambrian (c. 550 Ma) ages.

Polar Urals and Novaya Zemlya

The Uralide thrust sheets extend northwards through the Polar Urals into Novaya Zemlya. In the Polar Urals, ophiolite allochthons (Saveljeva and Nesbitt, 1996) and high pressure (eclogite-blueschist) complexes (Sobolev et al., 1986) are particularly well preserved, but Uralide hinterland terranes are largely covered by Mesozoic strata of the West Siberian Basin. The foreland and the lower thrust sheets of the Polar Urals preserve Middle to Upper Proterozoic sedimentary and volcanic rocks, variously metamorphosed in greenschist-amphibolite facies (locally higher grade), unconformably overlain by Ordovician platform cover. Uralian collisional orogeny is well documented in the Polar Urals and Novaya Zemlya as commencing in the Permo-Carboniferous and persisting till Late Triassic-Early Jurassic times (Sobornov, 1992). High P/T complexes in the Urals yield evidence of Devonian subduction and stratigraphic data suggests that closure of the Ordovician oceanic basin commenced already during the late Silurian (Saveljeva and Nesbitt, 1996).

Continuation of the Uralide Orogen into the high Arctic is seen in the W-directed thrust sheets of Novaya Zemlya, where Baikalian-age complexes, locally including granites, form a basement for Ordovician clastics of Baltica affinities; the latter pass conformably upwards into a nearly complete Palaeozoic to early Mesozoic succession, prior to orogeny.

Eastern Barents Sea Basin

The Eastern Barents Sea Basin is characterised by a 15 (perhaps up to 20) km thick Palaeozoic and Mesozoic, particularly Permian and Triassic, succession (Fig. 9.3). A broad belt of maximum sedimentary thickness parallels the strike of Novaya Zemlya (Ostisty and Fedorovsky, 1993) and is underlain by a zone of thin, high velocity crust that may represent highly extended continental or even oceanic crust. This sedimentary trough is interpreted as a Devonian rift (perhaps coinciding with a Caledonian suture zone) which links up to the south with the Devonian Timan-Pechora rift system (Zonenshain et al., 1990; Nikishin et al., 1996).

The stratigraphic record of the Eastern Barents Sea indicates that during Late Carboniferous times it was occupied by an extensive carbonate platform. This platform subsided rapidly during the Early Permian, possibly in response to thrust loading following the initial collision of the Novaya Zemlya orogen with its foreland. During the Late Permian major deltaic complexes prograded westward from Novaya Zemlya into a deep water foreland basin, thus reflecting the first phase of the Novaya Zemlya orogeny. An early Triassic flooding event was followed by the renewed progradation of deltaic complexes during the late Triassic-early Jurassic; these reflect the second phase of the Novaya Zemlya orogeny which terminated in early Jurassic times (Nikishin et al., 1996).

The Novaya Zemlya foreland basin, which is apparently devoid of classical inversion structures, contains a number of major oil and gas accumulations, mainly in Carboniferous carbonates and Triassic and Jurassic sands, which are charged with hydrocarbons generated from Devonian, Triassic and Jurassic source rocks (Ostisty and Fedorovsky, 1993).

Barentsia-Northwest Barents Sea Basement

The Eastern Barents Sea Basin is flanked to the northwest by an enigmatic Caledonian and older terrane – Barentsia (Fig. 9.1B). Only a small part of the latter is exposed on land on Svalbard; the rest is cov-

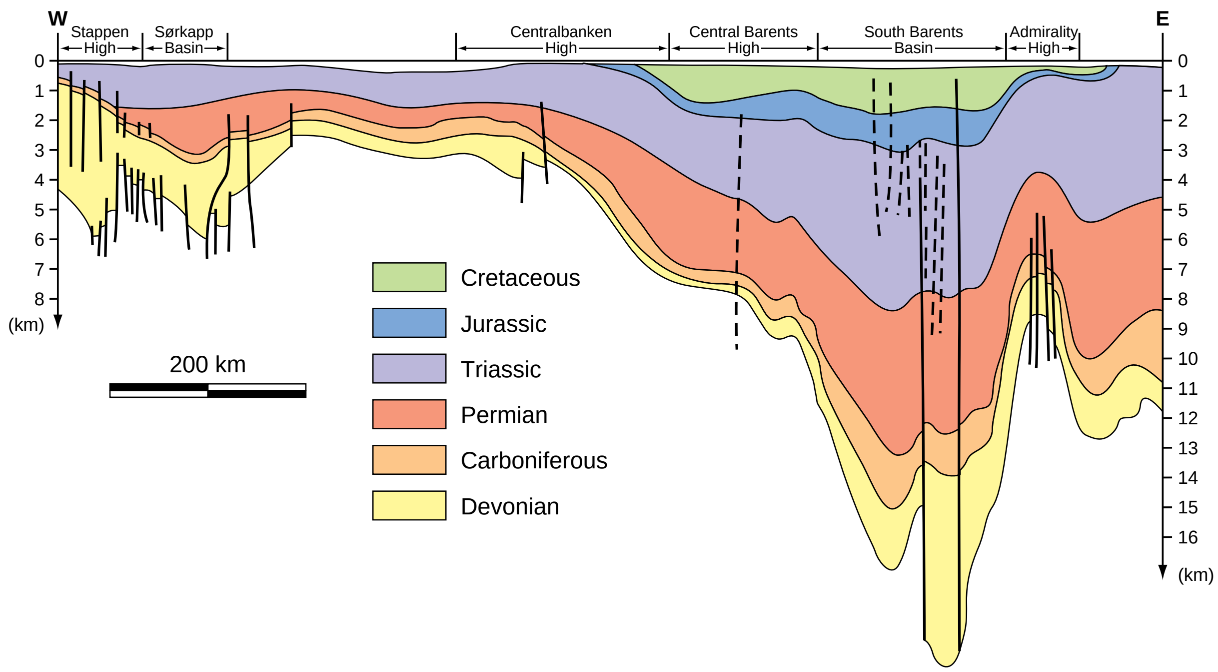

Figure 9.3: Regional east-west geologic profile, Novaya Zemlya-Stappen High. From Johansen et al. in Vorren et al., 1993.

ered by shallow seas. Our knowledge of the Caledonian and older history is based on analysis of geophysical data (particularly magnetic anomalies, but also gravity and seismic) and extrapolation off-shore. Barentsia basement is exposed on Nordaustlandet, where a Grenville age (1000 Ma) basement is overlain by Neoproterozoic and Cambro-Ordovician successions that were subject to Caledonian, W-vergent folding and greenschist facies metamorphism (Gee et al., 1995). These strata have unambiguous Laurentian stratigraphic and faunal affinities. Barentsia is bounded to the west by the West Ny Friesland Terrane, where high amphibolite facies Caledonian metamorphism accompanied thrust intercalation of Palaeoproterozoic basement and cover successions (Gee at al., 1994).

The Caledonian terranes on Svalbard were assembled during transpressional orogeny (Harland, 1971). The western terranes are probably related to the North Greenland-Inuitian foldbelt and the eastern to the East Greenland Caledonides. The terranes extend northwards towards the shelf-edge and may be represented in the Lomonosov Ridge and in the older bedrock of the Arctic Basin.

Taimyr and Severnaya Zemlya

The Taimyr penisula, located southeast of the North Kara Sea, is divided by major S-verging thrusts into three terranes (Vernikovsky, pers. com. 1996). The northern terrane is dominated by Neoproterozoic turbidites extensively migmatized and intruded by Carboniferous syn- and post-tectonic granites (U/Pb zircon data). The migmatites have also yielded Carboniferous isotope ages. The central terrane also contains Neoproterozoic strata; island-arc volcanics and, locally, ophiolites are reported, overlain unconformably by Ordovician and younger Palaeozoic strata that were deformed and thrust southwards in the Late Palaeozoic. The Early Ordovician strata contain faunas of Baltica affinities (Cocks, pers. com. 1996). To the south, the fold and thrust belt emplaces a succession dominated by carbonates (Lower Palaeozoic) and marine clastics (Upper Palaeozoic) onto the platform successions of the Siberian craton.

The northern terrane of Taimyr strikes northeastwards into southern Severnaya Zemlya where similar Neoproterozoic strata are overlain by marine Cambrian to Devonian successions, which terminate in the Upper Devonian in a continental facies. Open folding is thought to be early Carboniferous in age (Zonenshain et al., 1990).

Despite the southerly vergence of the thrusting in the Taimyr, these terranes are thought to connect with the Polar Urals via Novaya Zemlya. Of the alternative hypotheses, two dominate; the one relating the Taimyr terranes to the eastern front of the Uralides and the other requiring substantial Early Crateceous (Katangian) shortening to control the Taimyr thrust geometry.

Geophysical data

The Timan-Pechora Basin is covered by a considerable amount of reflection seismic CMP profiles with 12- to 24-fold processing. Some profiles have been recorded using 48-fold observations (e.g. PC-15, Fig. 9.2). Only the latter crosses the whole of the Timan-Pechora area from southwest to northeast, with a recording time of 3-5 to 7-8 s (TWT); it permits study of the Lower Palaeozoic successions and the internal structure of the upper part of the Baikalian-age basement. Several models have been constructed by "Pechorageofizika" (Ukhta) and Geological Institute of the Russian Academy of Sciences, based on conventional processing adopted by the geological institutions of the former USSR. Only locally has work specifically been aimed at analysing the basement structure.

Deep seismic wide angle reflection and refraction studies (DSS), accompanied by gravity and magnetic modelling, provide the essential foundation for recognition of the deep lithospheric characteristics (Kostiuchenko, 1994) of the Timan-Pechora region. Over 2000 km of DSS profiles with three-component recording of surface displacement and interpretation of refracted (P and S), reflected (P and S) and converted waves were carried out by the GEON Centre (Moscow) over a period from 1972 till 1984 across the Timan-Pechora region. In addition, c. 1000 km of profiles, recording refracted and wide-angle reflected waves, were completed by GGP "Pechorageofizika" and ZGT (St. Petersburg). The basement topography, Moho depth and other structural elements of the consolidated crust have been identified along these deep profiles. Significant differences in velocity structure and density of rock units in the crust and upper mantle are apparent from the DSS data across the Timan-Pechora region. Typical craton margin velocities in the Timan Range give way across the Pechora Fault Zone to higher upper crustal velocity and density characteristics, implying a more mafic crust, in accord with existing drillcore data.

The characteristic geophysical signatures of the Timan-Pechora region can be followed northwards into the shallow parts of the Barents Sea. They change significantly towards the Eastern Barents Sea Basin where vast thicknesses of Mesozoic and Late Palaeozoic strata overlie a thin high velocity basement that may be oceanic (Zonenshain et al., 1990)

General Evolutionary Model

The East-European Craton formed part of a larger continental assemblage in the Riphean. It was repeatedly subject to rifting and, by the Cambrian, was established as the ancient crystalline core of the Baltica plate, a continent located in middle to high latitudes and surrounded by oceans.

The northwestern (present co-ordinates) passive margin of continent Baltica is well defined in the thrust sheets of the Scandinavian Caledonides, where prolific dolerite dike-swarms of Vendian age penetrate Neoproterozoic successions. Likewise, along the northeastern margin of the continent, Neoproterozoic rifting along the Timan axis resulted in development of a basin that may well have defined the edge of the craton (it remains to be demonstrated whether the Bolshezemenskaya Terrane includes an exotic Baikalian microcontinent or fragmented elements of the EEC margin). Whereas along the Baltoscandian margin, Neoproterozoic rifting culminated in Vendian separation of the EEC from a previous megacontinent, in the Timan-Pechora region the Vendian was a period of basin inversion that culminated, prior to the Middle Cambrian, in Baikalian orogeny. This contrast in tectonothermal history continued through the Cambrian into the Early Ordovician; syn- and post-rift platform successions were deposited across the Baikalian basement from the Pechora Basin to the Urals, simultaneously with Finnmarkian orogeny along the Baltoscandian margin. Thereafter, until the Devonian, platform deposition characterised northern Baltica.

Ordovician faunas indicate that Baltica's Early Palaeozoic platform facies extended far to the northeast from the EEC, across the Pechora Basin to Novaya Zemlya and Taimyr. Late Cambrian-Early Ordovician rifting along the eastern margin of Baltica, resulted in the detachment of continental terranes and the opening of the Uralian ocean (Zonenshain et al., 1990; Nikishin et al., 1996). During the Silurian, Scandian collisional orogeny, Laurentia and Baltica were welded together along a suture which extends from the Scandinavian Caledonides northwards towards the Franz Josef Archipelago.

During Late Devonian-earliest Carboniferous times, Arctica was sutured to the northern margin of Laurussia along the Inuitian fold belt which extends from the Canadian Arctic archipelago into the North Greenland fold belt (Ziegler, 1989).

The major Devonian rifting event, which affected the eastern Barents Sea and the Timan-Pechora area, may be related to changes in subduction geometries along the Uralian arc-trench system which had come into evidence during the Silurian (Nikishin et al., 1996). This rifting event played a very important role in the development of the Late Palaeozoic sedimetary basins which were incorporated into the Uralian orogen during latest Carboniferous and Permo-Triassic times.

The foreland basins of the Uralian Orogen differ considerably in their width and depth as well as by the presence and absence of foreland compressional structures. This reflects lateral changes in the rheological characteristics of the foreland crust; these are related to the composition and age of crustal consolidation (Archaean and Early Proterozoic in the south), and subsequent modification during Baikalian-age orogeny and Palaeozoic rifting events.

Outstanding Features

The difference in the character of the basement beneath the Uralian foreland basins (Fig. 9.4), extending from 50° N into the High Arctic, provides outstanding opportunities to investigate the influence of basement composition and structure on basin evolution. The apparent absence of Archaean and Palaeoproterozoic crystalline complexes beneath the Pechora and Eastern Barents Sea areas, the dominance of Baikalian-age accreted terranes and the superimposed mid-late Devonian rifting and associated igneous activity, established a basement rheology that differed fundamentally from that further south and responded to Uralian compression accordingly.

The TIMPEBAR project integrates a wide range of geological, geophysical and geochemical studies that will provide a foundation for quantitative modelling of the basin evolution, initially of the Pechora area and subsequently in the Eastern Barents Sea. Outstanding opportunities for basin modelling are provided by the following features:

1) Many thousands of kilometres of industrial reflection seismics (CMP) profiling, together with deep drillhole data, provide the basis for analyses of the basin fill.
2) In the Pechora Basin, a large number of drillholes, penetrating deeply into the pre-Ordovician basement, provide control on the composition and structure of the Baikalian-deformed Riphean and Vendian rocks. Comparison with the tectonothermal evolution of adjacent areas of the Timan Range and Uralian foreland allochthons, will provide the basis for new analyses of the Neoproterozoic rifting history, Baikalian-age orogeny and subsequent early Palaeozoic passive margin evolution.
3) A few deeper reflection seismic (CMP) profiles provide information on the upper part of the basement. Together with the wide angle seismic (DSS) data they will allow extrapolation of upper crustal structure to depth.
4) The Eastern Barents Sea Basin, like the Pechora Basin, appears to have developed on top of a zone of Mid-Palaeozoic rifting. However, in the case of the former, proximity to the Caledonian suture(s) suggest a possible relationship to late Caledonian orogenic collapse. Further work on Svalbard's Caledonian terranes, including offshore Barentsia, and comparison with Novaya Zemlya will provide new constraints for this hypothesis.
5) Comparison of the evolution of the Pechora and Eastern Barents Sea basins with that of the foreland basin in the Southern Urals (within the framework of EUROPROBE'S URALIDES project) provides exceptional opportunities for assessing the influence of basement rheology on basin development.

TIMPEBAR RESEARCH

1. Timanide Tectonic Evolution – Proterozoic structure, sedimentation and magmatic activity *(Trondheim [NGU], Syktyvkar [RAS], Moscow [GIN], Stockholm [MNH]).*
The Baikalian-age tectonothermal evolution of the Timanides is being studied (new analysis of existing data and collections). Field and laboratory investigations of the central Timans (Chetlaski Kamen), northernmost Timans and Kanin Peninsula are planned with a focus on 1) sedimentary facies associations, reflecting the Neoproterozoic tectonics of the basin, 2) stages of Baikalian-age deformation and field relationships between deformation episodes and emplacement of magmatic bodies, and 3) isotopic ages of intrusive and metamorphic rocks.

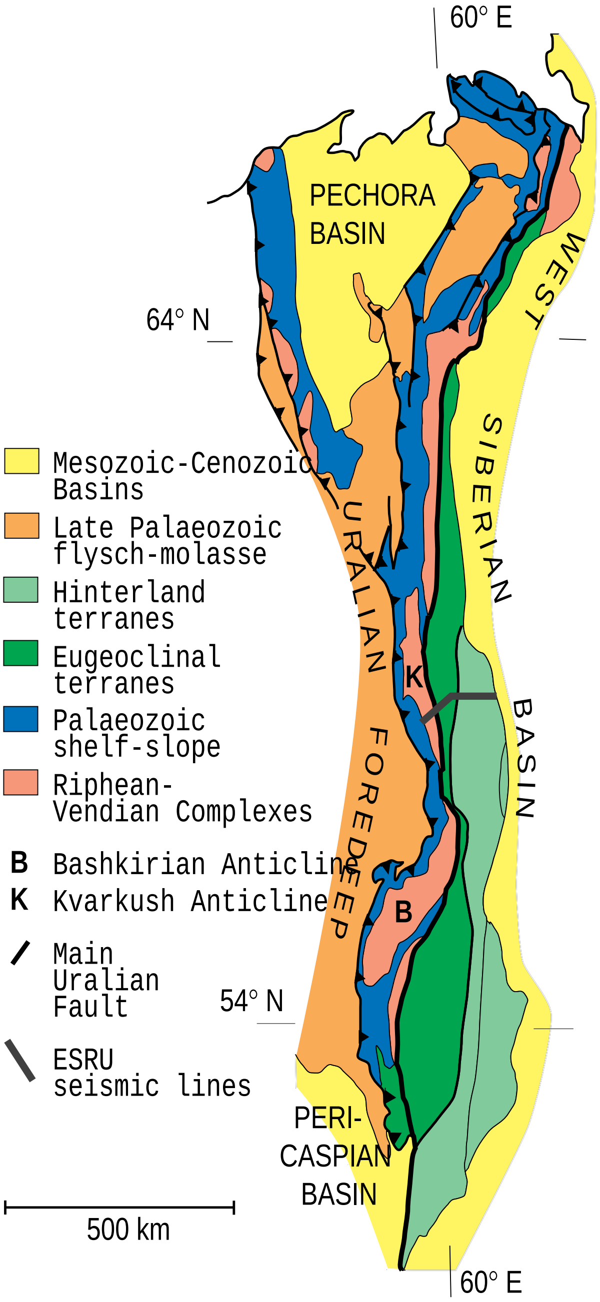

Figure 9.4: Main tectonic units of the Uralides.

2. Pechora Basin Basement *(Stockholm [MNH], Ukhta [TPSRC], Moscow [GEON, GIN], Uppsala [U]).*
Geochemical (including isotope age and provenance) studies of metamorphic rocks from basement drillcores are providing new evidence on the character the Baikalian-age tectonothermal history. Single zircon, Pb / Pb, U / Pb and ion microprobe work, complemented by Sm / Nd and Rb / Sr studies, will define the character of the Baikalian outboard terranes, now underlying the Pechora Basin to the northeast of the Pechora Fault Zone (Fig. 9.2). Potential field data are helping to define the regional extent of the different basement complexes.

3. Polar Urals and Novaya Zemlya *(Uppsala [U], Barcelona [ICTJA], Moscow [GIN], Stockholm [MNH], Ekaterinburg [MA]).*
Within the thrust front of the Polar Urals, in inliers below the Ordovician unconformity, metamorphosed Proterozoic complexes, containing eclogites and possible fragmented ophiolites, will be investigated. The work focuses on structural analysis and isotope age studies. Access to Novaya Zemlya may be possible and new field studies are planned to reinvestigate relationships between Baikalian-age intrusions and deformation; isotope age studies are in progress. Early-mid Palaeozoic coarse clastic facies will be analysed for identification of westerly source terranes.

4. Barentsia - Northwest Barents Sea Basement *(Uppsala [U], Stockholm [MNH], Oslo [NPI], Lomonosov [PMGE]).*
Assembly of Svalbard's Caledonian terranes during transpressive orogeny is being investigated. Research concentrates on studies of structure, isotopic age and provenance of Svalbard's Caledonian and older basement, particularly in the eastern on-shore areas of Nordaustlandet (c. 80° N). Some of the Barentsia magnetic anomalies can be directly related to plutons of Caledonian age; their geochemistry and provenance is being investigated. Rock samples collected off-shore by Norwegian and Russian marine surveys will be incorporated in this project to interpret the magnetic signatures of eastern Barentsia.

5. Taimyr Connections *(Moscow [GIN], Novosibirsk [RAS], Noril'sk [MG], Ekaterinburg [MA], St. Petersburg [], Cambridge [CASP], Uppsala [U], Stockholm [MNH]).*
The location of Caledonian sutures in the Barents Sea rest on evidence not only from Svalbard and Novaya Zemlya, but also from Franz Josef land (drillcores), Taimyr and Severnaya Zemlya. Analysis of the Late Palaeozoic and younger tectonothermal history of these areas is essential for deciphering their earlier evolution. It is also central to an understanding of the relationship between the W-vergent late Palaeozoic to early Mesozoic Polar-Urals - Novaya-Zemlya orogen and the S-vergent Taimyr orogen. The research includes analysis of geophysical data and geochemical (including isotope age and provenance) studies of deep drillcores from the northern parts of the West Siberian Basin. New field work in the Polar Urals, Taimyr and Severnaya Zemlya is planned for 1997-99.

6. Pechora Basement Structure interpreted from reprocessed CMP data *(Uppsala [U], Lausanne [U], Moscow [GEON], Ukhta [PG]).*
This project concerns structural analysis of the upper parts of the pre-Ordovician basement and their relationship to the unconformably overlying Palaeozoic strata. Reprocessing of the existing CMP profile PC-15 (Fig. 9.2) is necessary to obtain a reliable seismic image for further geological interpretation. Other short CMP lines crossing the Pechora Fault Zone will be reprocessed to define the geometry of this important deformation zone and its relationship to adjacent terranes. These are essential first steps for the planning of new deep reflection seismic profiling in the Timan-Pechora region. Local reprocessing of the CMP data has already shown that significant structural information can be obtained from lower (in basement) parts of the CMP records. Reprocessing of the data in Uppsala, Moscow and Ukhta, will build on previous experience from the URALIDES project (reprocessing gave the first indications of the highly reflective nature of the lower crust in the middle Urals).

7. Deep Crustal and Upper Mantle Structure based on the analysis of DSS and potential field data *(Moscow [GEON], Lausanne [U], Uppsala [U]).*
The new research focuses on reprocessing of existing DSS data (Fig. 9.2) with the use of new methods and computer technology. Digitization of two of the profiles will be necessary and possible in Moscow. Programmes designed to investigate the 2D structure along the profiles will be employed. Magnetic and gravity data constrain the regional development of the Pechora Rift Zone and some other major igneous bodies in the basement. This subproject, in combination with subproject #5 above, is essential for the planning of a new deep reflection (CMP) and wide angle reflection/refraction profile across the Pechora Basin.

8. Basin Modelling *(Amsterdam [VU], Ukhta [PG, TPSRC], Syktyvkar [RAS], Moscow [SU], Cambridge [CASP]).*
Research will focus along east-west transects, close to existing DSS profiles, and consists of 1) selected basin analysis studies, (chrono-lithostratigraphic and palaeo-environmental synopses and reinterpretation of seismic reflection profiles etc.) to determine the timing and nature of tectonic activity; these are prerequisites for quantitative modelling. The extensive set of exploration-driven shallow (to c. 5 s TWT) reflection seismic (CMP) and drillhole data provides a comprehensive database for this work; 2) 1-D and 2-D sediment backstripping subsidence analyses and palinspastic reconstruction of the Pechora and Eastern Barents Sea basins backwards through the compressional and extensional deformation phases; 3) quantitative tectonic modelling of the evolution of the Pechora and Eastern Barents Sea basins, utilising the interpreted geological-geophysical transects, backstripped subsidence curves and palinspastic reconstructions, to test hypotheses about their geodynamic evolution.

References

Beliakova, L.T. and Stepanenko, V.J., 1991. Magnetism i geodinamika Baikalid fundamenta pechorskoj sineklizy. Izvestia AN SSSR, Sena geologichesk., 106-117.

Bogdanov,N.A., Khain, V.E., Sobolev, S.F., Senin, B.V., Shipilov, S.F., Bogatsky, V.I. and Kostyuchenko, S.L., 1996. Tectonic map of the Barents Sea and North European Russia, 1:2,500,000. Institute of the Lithosphere, RAS, Moscow.

Dedeev, V.A. and Getzen, V.G. (eds.), 1987. Riphean and Vendian of the European Northern areas of SSSR, Komi Branch AN SSSR, 124 pp (in Russian).

Dedeev, V.A. et al., 1994. Evolutionary model of Timan-Pechora oil and gas bearing basin as the base of fuel and energy complex development. Contribution from the conference "Timan-Pechora province: the strategy of devlopment of new oil and gas fields", Usinsk.

Gee, D.G. and Sturt, B.A. (Eds.), 1985. The Caledonide Orogen - Scandinavia and related areas. John Wiley&Sons, Chichester, 1252 pp.

Gee, D.G., Björklund, L. and Stølen, L.-K., 1994. Early Proterozoic basement in Ny Friesland – implications for the Caledonian tectonics of Svalbard. Tectonophysics, 231, 171-182.

Gee, D.G., Johansson, Å., Ohta, Y., Tebenkov, A.M., Krasilshchikov, A.A., Balashov., Yu.A., Larionov, A.N., Gannibal, L.F. and Ryungenen, G.I., 1995. Grenvillian basement and a major unconformity within the Caledonides of Nordaustlandet, Svalbard. Precambrian Research, 70, 215-234.

Getzen, V.G., 1975. Structure of the basement of the Northern Timan and Kanin Peninsula. 'Nauka', Leningrad, 144 pp (in Russian).

Getzen, V.G., 1987. Tectonics of the Timan. 'Nauka', Leningrad, 172 pp (in Russian).

Harland, W.B., 1971. Tectonic Transpression in Caledonian Spitsbergen. Geol. Mag., 108 (1), 27-42.

Ivensen, Yu.P., 1964. Magmatism of the Timans and Kanin Peninsula. Moskva. 123 pp (in Russian).

Kostiuchenko S.L., 1994. A continental plate tectonic model of the Timan-Pechora Province based on integrated deep geophysical study. In: Tectonics and magmatism of East-European Platform. Proceedings of the International Europrobe Workshop. Intraplate Tectonics and Basin Dynamics. (Opalikha 12.05.93-15.05.93), Moscow (in Russian).

Nikishin, A.M., Ziegler, P.A., Stephenson, R.A., Cloetingh, S.A.P.L., Furne, A.V., Fokin, P.A., Ershov, A.V., Bolotov, S.N., Korotaev, M.V., Alekseev, A.S., Gorbachev, V.I., Shipilov, E.V., Lankreijer, A., Bembinova, E.Yu. and Shalimov, I.V., 1996. Late Precambrian to Triassic history of the East-European Craton: dynamics of sedimentary basin evolution. Tectonophysics (in press).

Ostisty, B.K. and Fedorovsky, Y.S., 1993. Main results of oil and gas prospecting in the Barents and Kara Seas inspire optimism. In: Vorren, T.O., Bergsager, E., Dahl-Stammnes, Ø.A., Holter, Johansen, E.B., Lie, E. and Lund, T.B. (Eds.). Arctic Geology and Petroleum Potential. Norwegian Petr. Soc., (Elsevier), Sec. Publ. 2: 243-252.

Pairazian, V.V., 1993. Petroleum geochemistry of the Timan-Pechora basin. First Break, 11: 279-286.

Savelieva, G.N. and Nesbitt, R.W., 1996. A synthesis of the stratigraphic and tectonic setting of Uralian Ophiolites. J. Geol. Soc., London, 153: 525-537.

Siedlecka, A., 1975. Late Precambrian stratigraphy and structure of the north-eastern margin of the Fennoscandian Shield (East Finnmark - Timan Region). Norges Geol. Unders. 316, 313-348.

Sobolev, N.V., Dobretsov, N.L., Bakirov, A.B. and Shatsky, V.S., 1986. Eclogites from various types of metamorphic compexes in the USSR and the problems of their origin. Geol. Soc. Am., Memoir 164, 349-363.

Sobornov, K.O., 1992. Blind duplex structure of the North Urals thrust belt front. J. Geodyn., 15, 1-11.

Sobornov, K.O. and Rostovshchikov, V., 1996. Structure and hydrocarbon prospects of the North Urals thrust belt. Petroleum Geoscience, 2: 177-184.

Vernikovsky, V.A., 1995. Riphean and Paleozoic metamorphic complexes of the Taimyr foldbelt: conditions of formation. Petrology, 3, 55-72.

Vorren, T.O., Bergsager, E., Dahl-Stammnes, Ø.A., Holter, E., Johansen, B., Lie E. and Lund, T.B., 1993. Arctic Geology and Petroleum Potential. Norwegian Petr. Soc., (Elsevier, Amsterdam), Sec. Publ. 2.

Ziegler, P.A., 1989. Evolution of Laurussia, a study in Later Palaeozoic plate tectonics. Kluver Acad. Press., Dortrecht, 102 p.

Zonenshain, .P., Kuzmin, M.I. and Natapov L.M., 1990. Late Paleozoic and Mesozoic-Cenozoic sedimentary basins. In: Page, B.M. (ed.), Geology of the USSR; a plate-tectonic synthesis. Geodynamics-Series, 21, American Geophysical Union, Washington D.C., 119-203.

Svalbard's Northwestern Terrane – looking west across the Raudfjorden Old Red Sandstone Graben to the migmatites of Vasaholvøya.