2 GENERAL INFORMATION AND MAPS OF THE STUDY AREA

The study area covers the northern part of Europe (Fig. 1) including Norway, Sweden, Finland, Estonia, Latvia, Lithuania and the north-western part of the Russian Federation (the Murmansk, Leningrad and Arkhangelsk regions, the Republic of Karelia, the western part of the Pskov region and the northern parts of the Novgorod and Vologda regions). The latitudes of the study area extend from 54°N in the south (Lithuania) to 70° 40' N in the north. The longitudes are from 5° E (south-western shore of Norway) to 48° E (the eastern border of the Arkhangelsk region).

A considerable part of Northern Europe is situated north of the Arctic Circle, with the austere climate of Arctic or sub-Arctic climate zones. However, most of the region belongs to the boreal zone with coniferous forests and the transitional zone of mixed forests. The main genetic types of relief of the boreal zone are accumulative-denudation plains and weakly dissected hills and plateaus (Fig. 2). Mountainous ridges prevail in the western part of the study area in Norway and Sweden, and in the northern part of Finish Lapland and the Kola Peninsula. The Basins of the Baltic Sea and the Barents Sea are separated by a long continuous chain of areas with elevated relief along eastern Finnish Lapland and western Karelia. Low-lying accumulative plains with glaciofluvial, glacial lacustrine and alluvial deposits are common along the coastline of the Baltic and White Seas and the largest rivers and lakes (Severnaja Dvina River, Volkhov River, Lake Ladoga, and Lake Onega).

2.1 Climate

Climate conditions of the study area are mainly due to its geographical position in temperate and sub-Arctic latitudes. Because of the openness of the study area, marine aerial mass from the Atlantic Ocean and cold air from the Arctic Ocean play an important role in the formation of the climate in this area. Due to the considerable size of the territory, however, there are fundamental regional differences and climate zonality connected primarily with the significant longitudinal variation, which causes different thermal flows and temperatures in various parts of the area. In the north, in the coastal areas of the Arkhangelsk and Murmansk regions, and also in Finnish Lapland and Finmark of Norway, the average temperature of the warmest month (July) is in the range of 6-10 °C, but in the south of the study area (Leningrad region, Baltic countries, southern Sweden and Norway) it reaches 18-20 °C.

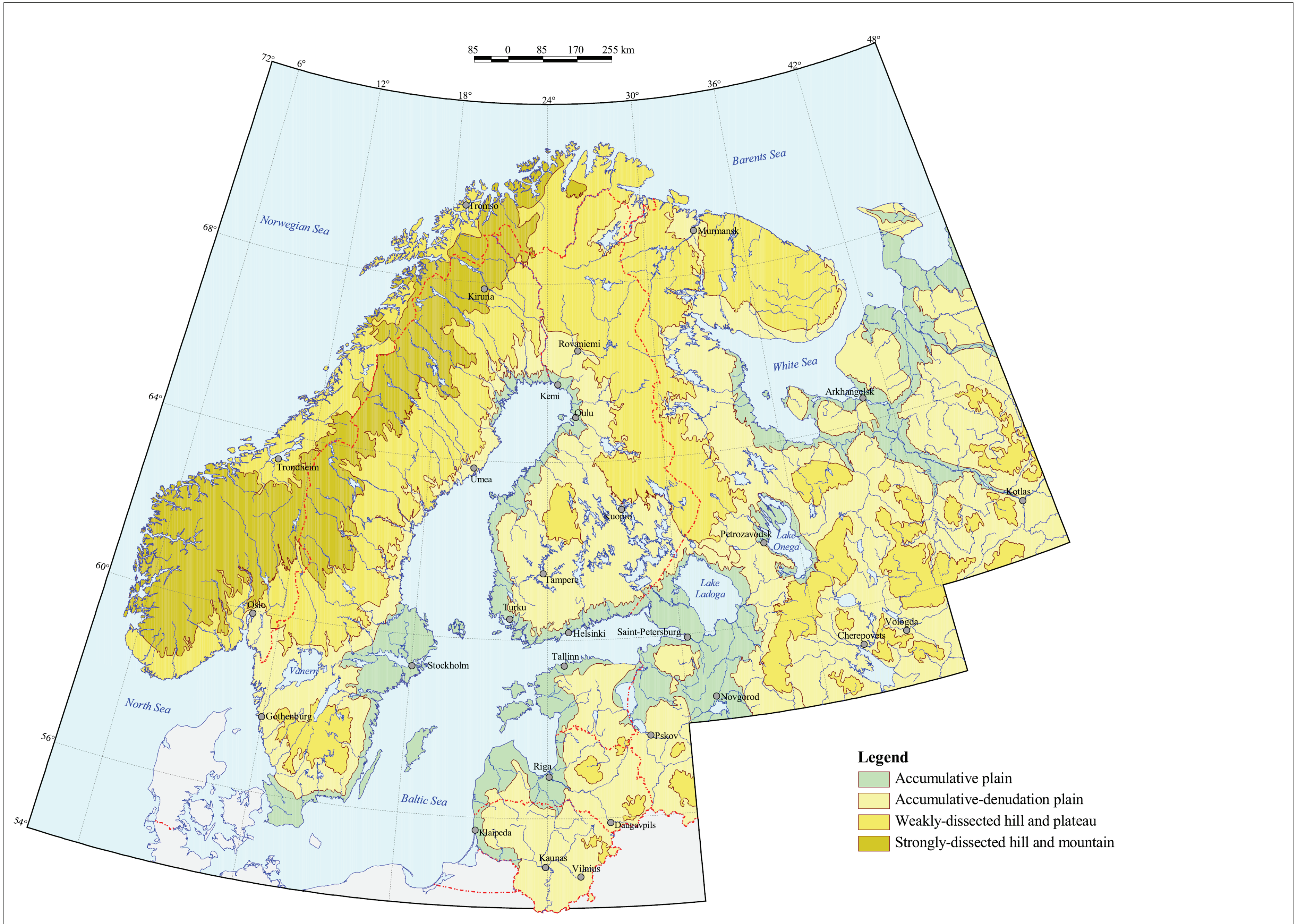
In winter time, the temperature regime is strongly influenced by the warm air mass from the Atlantic Ocean. In turn, it is also the reason for large variations in winter temperatures from west to east. The mildest winter is met in the south-western part of Norway and Sweden, Baltic countries and the Leningrad region (average temperature in January is 3 °C) while the most severe winter (down to -16 to -20 °C) is observed in the east of the Arkhangelsk region. The period of stable snow cover decreasing from north (200-250 days per year) to south (100-150) is caused by latitudinal zonality of the climate. The maximum value of this parameter (>250 days), emphasizing a particularly austere climate, is typical for high mountainous territory in Norway and Sweden.

The marine air mass not only increases winter temperatures, it also causes a noticeable lowering of summer temperatures. Consequently, in the coastal area the amplitude of the annual temperature changes decreases to 16-18 °C, and the climate becomes less continental. Moving further inland, to the eastern or south-eastern part, the amplitude of annual temperatures rapidly increases to 30-32 °C because of the sharp increase in climate continentality.

Zonality is also typical for atmospheric precipitation. The smallest quantity of annual precipitation (<200 mm) is found in the sub-Arctic areas, increasing considerably (to 500- 700 mm) in the boreal zone, and reaches a dramatic maximum (>3000 mm) along the western coast of Norway. Despite the large range of precipitation , the climate of the whole study area is considered redundantly humid because of the low level of evaporation. Annually, the amount of evaporation is roughly half of the quantity of precipitation: in sub-Arctic areas it amounts to 50-100 mm, increasing up to 450-500 mm in the warmest south-western areas. The study area is therefore characterized by a constant surplus of water which causes an intensive surface flow (equal to 250-300 mm precipitation per year) in mountains and territories with a high relief. In low terrains with a small surface inclination, the humid conditions cause the extensive formation of thick peat deposits.

Overview map

Figure 1. The study area



Genetic Type of Relief

Figure 2. The genetic classification of the relief forms.

2.2. Vegetation zones and soil types

The above-mentioned climatic variations have an effect on the features of other natural conditions, such as the pronounced bio-climatic zonality of vegetation and soil types (Figs. 3 and 4). The latitudinal zonality of vegetation is an impressive feature of the study area, depending on varying annual temperatures, moisture circulation and evaporation from the north to the south. It also intensifies soil formation processes, biological activity and the diversity of flora and fauna. The northernmost territories are situated within the tundra area, but the southernmost belong to the southern taiga zone of mixed coniferous and deciduous forests. However, most of the study area is covered by the coniferous forests of the taiga zones.

The project area can be divided in two large soil-vegetation zones (sub-Arctic and boreal) with appropriate subzones (FAO 1988, Fridland 1988, Isachenko and Lavrenco 1974, Kaurichev and Gromyko 1974, Rasmussen et al. 1989, WRB 1998). The following description of vegetation zones and subzones is based on Ahti et al. (1968), Gagarina et al. (1995), Ignatenko (1979), Nauka (1980), Moscow State University (1984) and Zaboyeva (1975).

The sub-Arctic zone (including tundra and forest tundra subzones) spreads along the coastal area of the Barents Sea. Typical features of the tundra subzone are a large temperature gradient in the summer (a rapid increase in summer temperatures moving away from the coast, approximately 1 °C for each 20-30 km) and noticeable changes in the climate from east to west because of the influence of the Atlantic Ocean. The tundra subzone is divided into the northern and southern tundra, the main difference being the prevalence of permafrost. Indistinct tiers of vegetation include grass cover, lichen, and moss and low fruticulose layers. Semihydromorphic (Gleysols) and hydromorphic (Histosols) soil types are characterized by strong over-wetting and gleization throughout the soil profile. Gley soils contain little humus material and are developed on Quaternary clay and sandy clay deposits . As a rule, profiles of these soils are weakly differentiated and carry tracks of cryogenic deformations. Gleyic Podzols are typical in the areas of relief with free drainage conditions.

<u>The forest tundra subzone</u> is a transitional and rather narrow belt between sub-Arctic and boreal vegetation zones. It extends from the Varanger Peninsula in the west through the Kola Peninsula to the northern coastal areas of the Arkhangelsk region in the east. The width of this belt is small (up to 50-70 km). The appearance of trees is typical for this subzone. Mainly Arctic birch and partly Scotch pine are found both as individual stunted trees and as small sparse stands. The ground-level vegetation consists of a thick solid cover of terrestrial moss and lichen or by a suffruticous layer of Arctic birch, willow and juniper.

In comparison with the tundra, podzolization and peat swamp formation are increasing in this zone. In the case of poor drainage, acid and low base saturation Cryosols and Gleysols with weakly differentiated profiles are common. In open places with better drainage conditions, Podzoluvisols and Podzols are formed, but in the sparse stands of trees Gleyic Podzoluvisols characterized by a strongly acid reaction and low base saturation are prevalent. Ferralic Cambisols are common in dry and water-permeable soils. In some local areas these soil types form combinations with Histosols and Histic Cryosols.

The boreal zone (including subzones of the northern taiga, middle taiga and southern taiga in the coniferous forest and sub-boreal humid subzone of mixed forests) covers the largest part of the study area.

<u>The subzone of the northern taiga</u> is widely spread in the northern part of the Arkhangelsk region, in the Kola Peninsula and the Republic of Karelia, and also in the northern and central parts of Finland, Sweden and Norway. The predominant tree species are pine, spruce and birch. On account of the thin density of the tree layer, an admixture of other light-dependent tree species is common. The distribution of grass, under-shrub and moss layers normally has a mosaic texture, and thus in accordance with the composition of the ground phytom, dark coniferous forests (Siberian spruce in the east and European spruce in the west) are divided into shrub-moss, blueberry-moss and black crowberry-bilberry-moss forest types. Blueberry-moss spruce forests are spread on heavily over-wetting soils. Light coniferous and pine forests, with a solid land cover of moss and lichen and mostly fully lacking a grass-under-shrub level, are characteristic of dry sandy soil. They are especially common in the Fennoscandian Shield territory of crystalline bedrock.

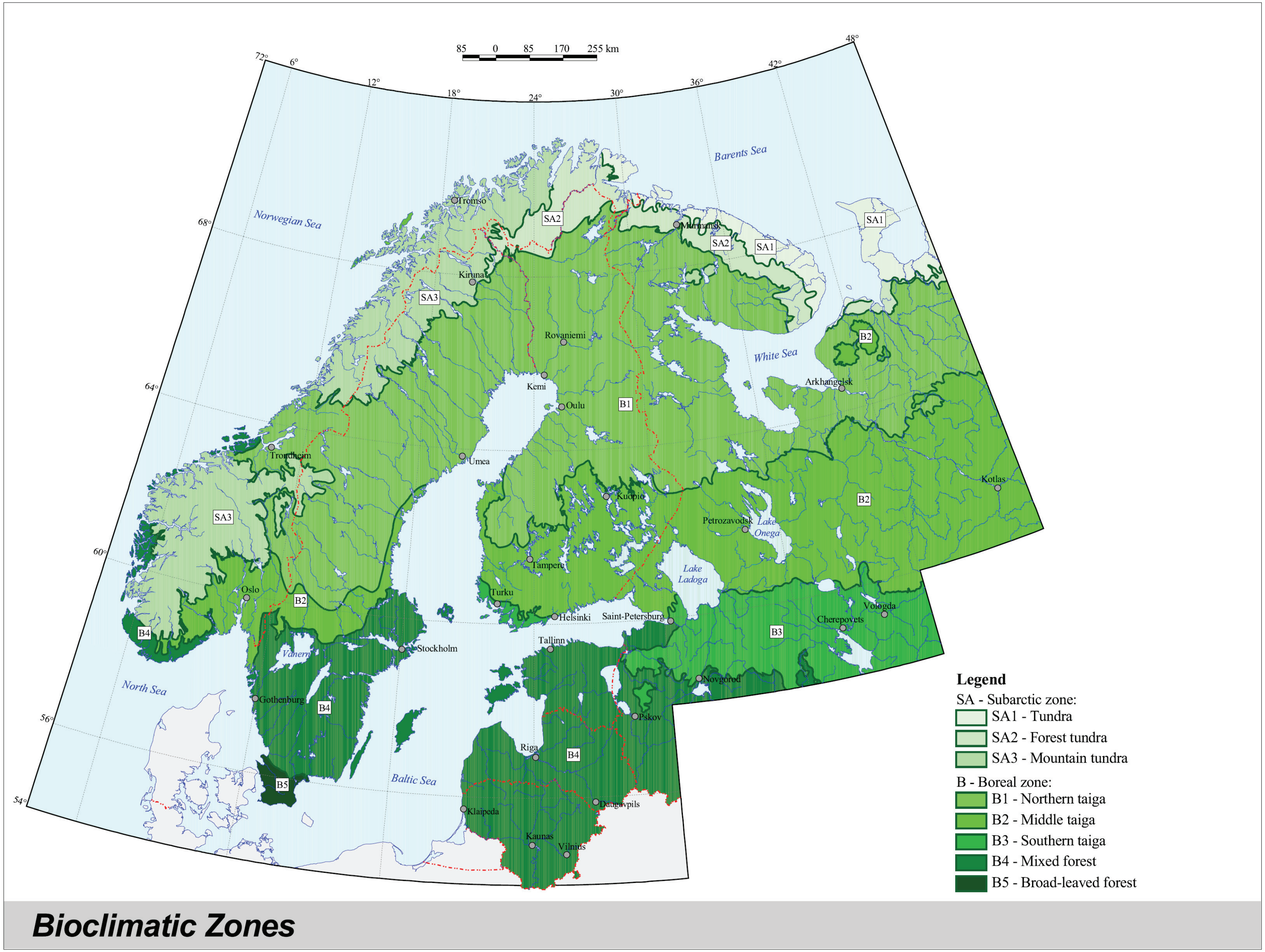


Figure 3. The bioclimatic zones of the study area.

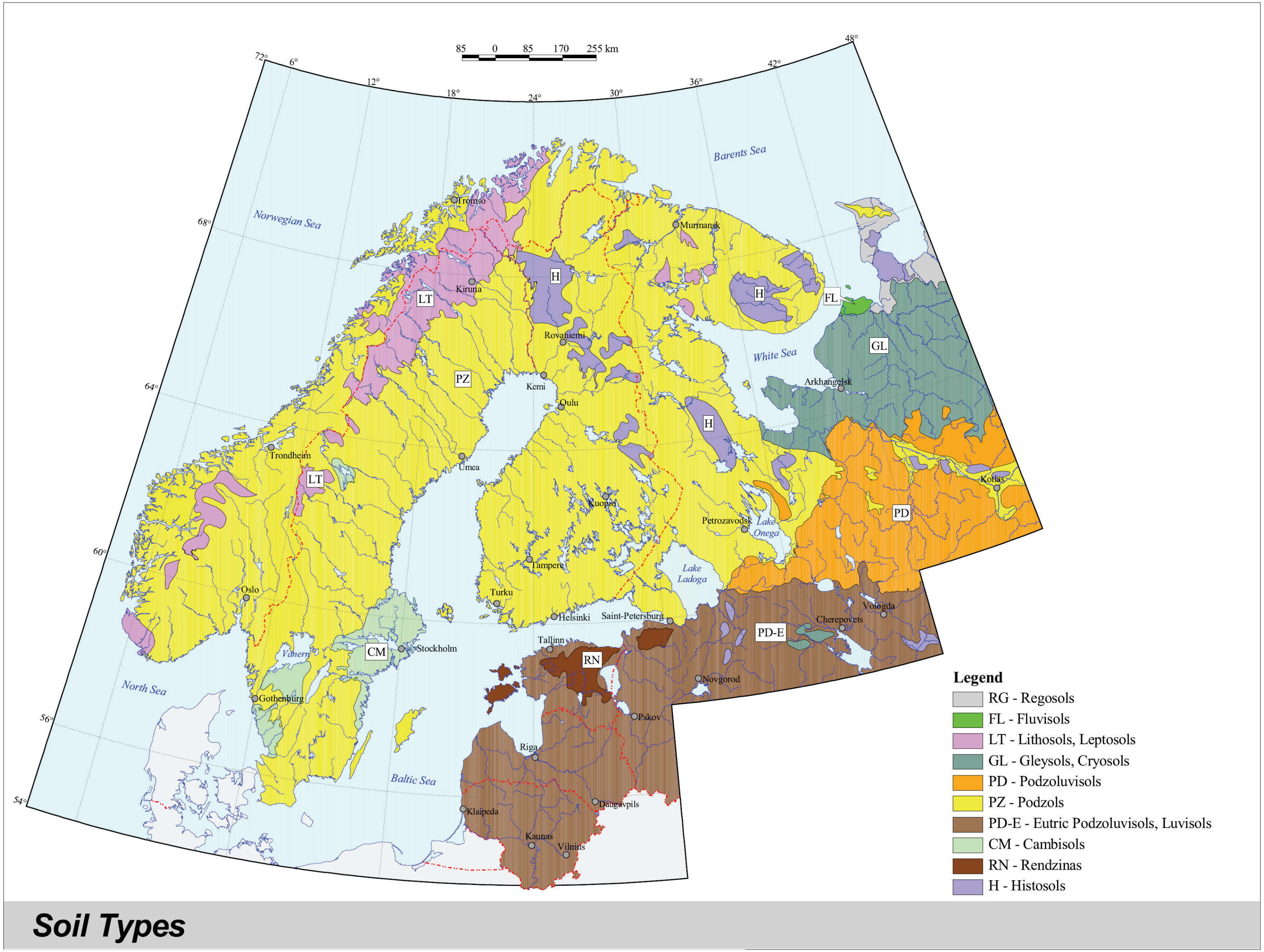


Figure 4. The distribution of different soil types in the study area.

Typical Podsols with a thin organic horizon predominate in the western and central parts of the study area. In the east, Podzoluvisols, Gleyic Podzoluvisols and Carbic Podzols formed on sandy-clayey till deposits are common. Podsolic residual carbonate soils are found in areas of carbonate bedrock occurrences.

In the northern taiga, the abundance of semihydromorphic and hydromorphic azonal soils (Histosols) is rather high because of the typical relief forms. On the Kola Peninsula and in the Republic of Karelia, the share of these soils is about of 40%, and the majority (30%) belong to Histosols (Isachenko and Lavrenco 1974). In the north of the Russian Plate, the share of these soil types increases up to 50-60%, forming large patches of bogs with dwarf pine trees.

The subzone of the middle taiga occupies the area between latitudes 600N and 640N and is characterized by a notably lower abundance of peat bogs compared to the northern taiga. Dense spruce and pine (pine cedar in the east) forests dominate. Shrub level is absent or weekly developed, but grass-sub shrub vegetation with terrestrial moss is homogenous and spread everywhere. Moss cover is continuous or forms large clumps. Bilberry-moss spruce forests are most typical, especially in the areas of rich humus soils. Cowberry-moss spruce forests grow on dry sand and sandy till deposits.

Opposite to the northern taiga, zonal soil types (Podzols and Podzoluvisols) prevail over semi-hydromorphic (Histic Podzols) and hydromorphic (Histosols) azonal soils. The total sum of the last ones is less then 30% (Isachenko and Lavrenco 1974). Eutric Podzoluvisols are spread in the areas with rare outcrops of carbonate bedrock. A weakly developed humus horizon is common for this soil compared with typical Luvisols of southern taiga. Large patches of flood-plain soils are traced along the Severnaja Dvina River.

The subzone of southern taiga occupies a comparatively small area (the Leningrad, Novgorod and Vologda regions in north-western Russia, and the northern coast of the Gulf of Finland in Finland). The predominant landscape type of this area is glacial-accumulative relief, which together with the warm climate produces favourable conditions for vegetation growth and smaller bogging. European spruce and pine forests with dense ground cover prevail in this area. Within coniferous forests there is a regular admixture of deciduous trees. In the under-shrub level, different kinds of grasses dominate, and the moss cover is disconnected. There is an abundance of ferns in the ground cover.

The main zonal soil type is Luvisol formed on loamy glacial and sandy glaciofluvial deposits in both coniferous and deciduous forests. Rendzinas belong to the residual carbonate soil types and are thus formed on carbonate rocks.

The sub-boreal humid subzone of mixed and broad-leaved forests is mostly spread across the southern parts of Norway, Sweden, and in the Baltic countries. The tree level of this area consists of deciduous species together with spruce, pine and birch, forming lime-spruce, oak-lime-spruce or ash-oak-spruce forests. According to the composition of the grass level, these forests are classified as glague-slender sedge, glague-arhangel or stipule types. Birch-black alder forests with spruce and a nettle-glague-meadowsweet ground level is formed during conditions of flowing humidification. The main zonal soil type is Luvisol, which is comparable with soils of the subzone of the south taiga.

Mountain tundra. Large mountainous masses cause a vertical zonality distribution of vegetation and soil types over a broad area in the western part of the study area. Vertical changes in vegetation zones are clearly seen in the areas with a mountain relief (from 400-500 m to 1000 m a.s.l.). The extended Scandinavian mountain system in Norway and Sweden (the Scandinavian Caledonides), Finnish Lapland and certain mountain ridges in the Kola Peninsula belong to this type of relief. In all these areas, replacement of northern taiga forests by dwarf birch forests followed by mountain tundra of the sub-Arctic zone takes place with increasing altitude. Mountain peaks with a sloping or plateau form are covered by layers of broken rock, or consist of outcrops of bedrock where only lichens grow, and higher plants are absent. From the valley to the top of mountains there is a successive change of Podzoluvisols and Luvisols to typical Regosols and Leptosols.

2.3 Geology

2.3.1 Pre-Quaternary deposits

The study area is a part of the East European Platform, including three large mega blocks (Fig. 5):

1) the Caledonian folded belt, phanerozoic deposits that cover a considerable part of the western Fennoscandian Shield,

2) the Fennoscandian Shield proper, representing a large-scale bulge of the Precambrian basement and
3) the Russian plate, a Palaeozoic cover that overlaps the crystalline basement of the Fennoscandian Shield from east and southeast. In the far northeast the border of the Russian Plate lies along the Timan folded belt, diverting it from the Barents Sea-Pechora mega plate.

The main geological features of the territory are illustrated on the generalized geological map Fig. 5), which was presented for the Map of Major Mineral Deposits. The original data were published as digital cartographical materials by Koistinen et al. (2001), Sigmond (2002), and Salminen et al. (2004)

The Fennoscandian Shield

Precambrian crystalline and volcanic-sedimentary rocks from the Early Achaean to the Riphean form the main geological complexes of the Fennoscandian Shield. Certain massifs of ultramafic alkaline rocks, dykes and small areas of volcanic-sedimentary formations in the Kola Peninsula, in the south of Finland and Norway, and also in the western part of Sweden belong to the Palaeozoic formations.

Within the Fennoscandian Shield, three large structural tectonic regions occur: (i) Kola-Lapland-Karelian, (ii) Svecofennian and (iii) Sveco-Norwegian regions. Each of them has an independent geological history, internal constitution and visible distinctions of metallogenic features.

The Kola-Lapland-Karelian region is divided into Kola (II-1), Belomorian (II-2) and Lapland-Karelian (II-3) structural blocks. It occupies the eastern and north-eastern parts of the Shield, including the territories of the Murmansk region and Republic of Karelia in Russia, Lapland in Finland and partly northern Sweden and Norway.

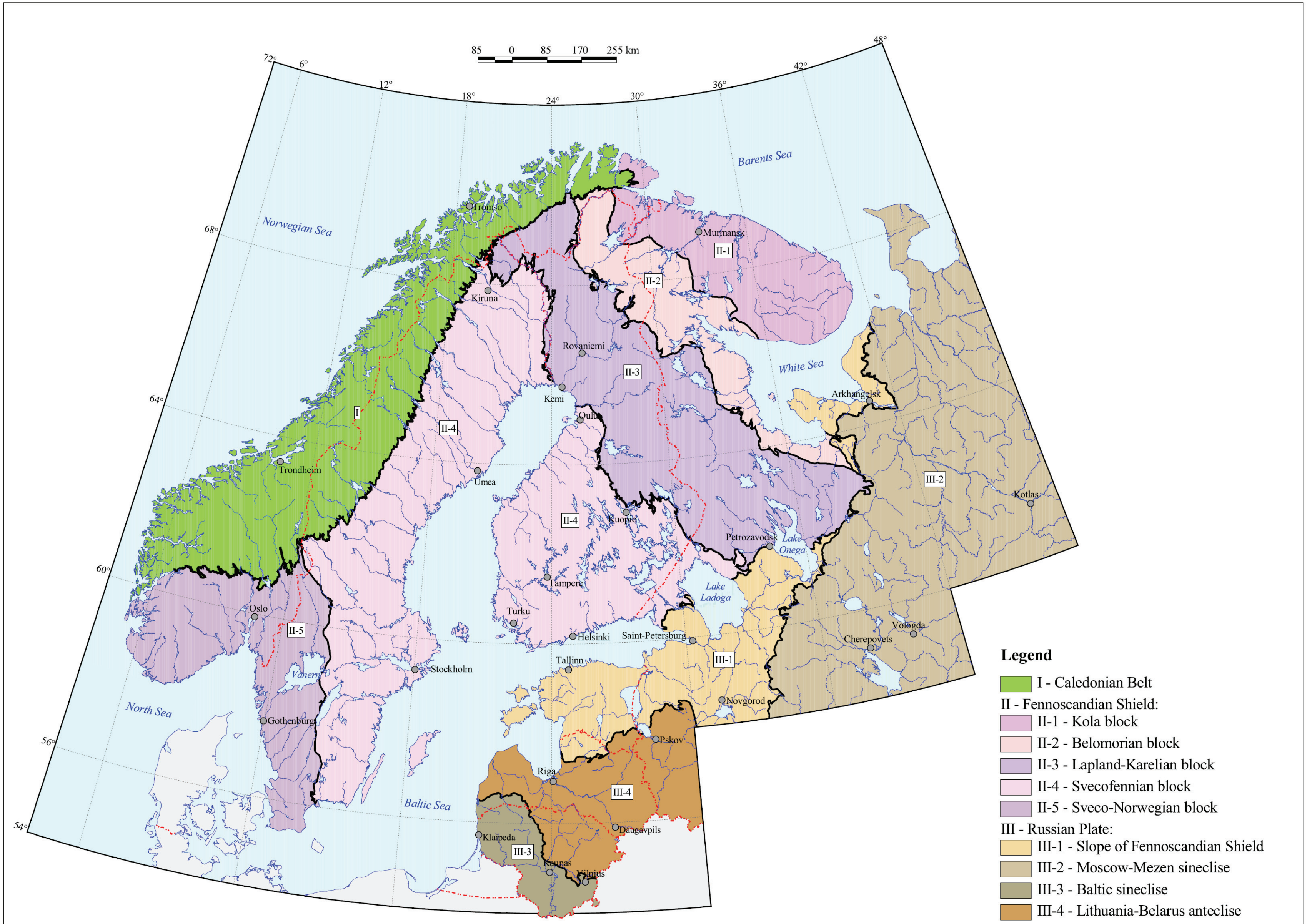
On the current erosion level, Archaean gneisses and ultra-metamorphic granites (Saamian complex) comprise the majority of this tectonic region and form a system of interconnected structures of north-western orientation (first of all in the Lapland-Karelian block). In the lower part of the Saamian section there are spatially uniform biotite gneisses and granite gneisses, changing up the cross section into amphibole gneisses with interlayers of amphibolites, biotite and granite-biotite gneisses. A very strong migmatization and granitization are typical for the rocks of the Saamian complex. Early Archaean intrusive and ultra-metamorphic formations are presented by an enderbyte-diorite-tonalite complex, comparable with the oldest complex of so-called “grey granites”. Pyroxene-bearing schists, amphibolites, and aluminous and mica schist of granulite belts form lengthy deflections in the Kola Peninsula, in Finland and northern Norway. They are associated with the rocks of the Saamian complex, overlapping them or having tectonic contacts.

The Lopian complex is mainly composed of rocks of the granite-greenstone belts. They form linear or flexuous local structures of crystalline rocks (dominantly metamorphosed volcanites or volcanogenic-sedimentary deposits), extended along tectonic sutural zones and bordering intrusions of plagioclase-microcline granites. The most important of these formations are Keivy, Pulonjga-Sergozero, Uraguba-Kolmozero and Uzhno-Pechengskaja in the Kola Peninsula, Kostamuksha-Gimolskaja, Hautovaara, Pebozero and Sumosero-Kenozero in the Republic of Karelia, and Kuhmo and some others in eastern Finland and northern Norway.

Plutonic complexes such as gabbro-diabase, peridotite-gabbro-norites, diorite-charnockite and migmatite-granite are connected with the Archaean tectono-magmatic stage. The Lower Proterozoic Karelian complex is manifested by sedimentary and volcanogenic-sedimentary formations, which are widely spread in the Kola and the Lapland-Kola blocks. The largest greenstone belts of this age are Pechenga and Imandra-Varzuga in the Kola Peninsula, and Lachta, Vetrjany Belt and Onega in the Republic of Karelia. Analogous with this belt are Kittilä and Puolanka in Finland, and Karasjok in Norway. Intrusive activity, connected with the Early Proterozoic tectono-magmatic cycle, includes different complexes of mafic-ultramafic rocks (peridotite-pyroxenite-norite layered massifs), and intrusions of gabbro-peridotites, gabbro-verlites and alkaline gabbros. Granite complexes (alkaline granites and syenites, granite-monzonites and migmatite-granites) dominate the late stages of this cycle.

The Upper Proterozoic period is characterized by sedimentary and volcanic formations of Riphean and Vendian complexes. Thick Riphean deposits are spread through the northern and southern parts of the Kola Peninsula. Thinner sections of these deposits are known in the Belomorian blocks and in the Ladoga flexure.

The Phanerozoic period in the Kola-Lapland-Karelian region is connected with an intensive development of specific intrusive complexes: alkaline ultramafic rocks with carbonatites and agpaite nepheline syenites.



Structural Tectonic Blocks

Figure 5. The structural tectonic blocks of the bedrock.

A large variety of ore formations is typical for the Kola-Lapland-Karelian region. Along with Archaean ore formations characterized by simple mineral composition, there is a wide spectrum of Proterozoic and Palaeozoic formations with a multiple assortment of ore components. Polygenetic and polychronic features connected with repeated processes of magmatic activization are characteristic of these deposits.

A large tectonic zone in the north-western direction is situated along the south-western border of the Lapland-Kola block and separates it from the Svecofennian block. The particular significance of this zone is emphasized by its metallogenic specialization. Within this zone is one of the most productive belts of polymetallic sulphide ores in the Fennoscandian Shield. This zone also controls the position of the Kotalahti-Laukunkangas nickel ore district. In the territory of Finland, it is known as the Ladoga-Bothnian Bay zone and it continues in a north-western direction in Sweden as the Skellefte ore district.

The Svecofennian region (structural tectonic block II-4) consists of the central part of the Fennoscandian Shield and is situated within central and south-eastern Sweden, southern Finland and the south-western part of the Republic of Karelia. It is nowadays generally accepted that this region corresponds to volcanogenic-sedimentary formations of ancient island-arc belts. These formations are well studied in southern Finland, for example the Aijala-Orijärvi ore zone, Tampere schist belt and Vihanti-Pyhäsalmi-Kiuruvesi zone of polymetallic deposits. The volcanic centres of these structures consist of calciferous-alkaline volcanites of acid to intermediate composition and are surrounded by sedimentary rocks with interlayers of volcanites. Submarine hydrothermal processes and alkaline metasomatism are usual in volcanogenic-sedimentary rocks. The supracrustal thickness of these rocks is subject to low to medium grade metamorphism and they are intruded by numerous sticks and batholites of granites in association with gabbros and diorites. The thickness of the Svecofennian formation is up to 10,000 m. The lower and upper parts of this section are predominantly represented by sedimentary rocks, but the middle parts are composed of volcanogenic rocks with a prevalence of acid and intermediate derivatives.

Early Proterozoic plutonic rocks are widely represented by syn- and late-orogenic granite complexes of the Svecofennian stage (charnockite-granites, migmatite-granites and granites), which form large batholites and migmatite-plutons. Basic rocks of the gabbro-verlite complex are more uncommon and irregularly distributed throughout the whole Svecofennian block. Gabbro-syenite-granite ("Småland granites" in the south-western part of Sweden) and gabbro-anorthosite-rapakivi granite intrusive complexes in the southern part of the region intruded during the final stage of this magmatic cycle.

The formation of Riphean sedimentary and volcanogenic-sedimentary complexes in the local synclinal structures and Vendian deposits along the western border with the Caledonides is connected to the Late Proterozoic period of the geological development of this region. In the stabilization stage of this period, intrusives of an anothosite-syenite-rapakivi granite complex were formed in the western part of the Svecofennian region.

The Sveco-Norwegian geostructural region (structural tectonic block II-5), situated in southern Norway and south-western Sweden, is characterized by the extension of Early Proterozoic and Late Proterozoic volcanogenic-sedimentary and intrusive formations. In the east, a large tectonic zone called the "Sveco-Norwegian front" separates this block from the Svecofennian one. This zone forms a system of lengthy sub-meridianal faults. It is characterized by intensive schistosity of Svecofennian and Vepsian supracrustal and granitic rocks, and includes bodies of basic rocks (gyparites). Within the Sveco-Norwegian block, gneiss-granite and gabbro-syenite-granite complexes are the most common, and the latter typically occur as large batholite-like bodies. The Late Proterozoic formations are presented by Riphean and Vendian sediments, small intrusive bodies of granites, migmatite-granites, and gabbro-dolerites and an anorthosite-syenite-rapakivi granite complex called "Arendal". In the central part of the Sveco-Norwegian block is a large structure (Oslo rift) of alkaline nepheline-syenitic complex (granites, nepheline syenites, monzonites, gabbros, basalts, sandstones and conglomerates).

Svecofennian and Sveco-Norwegian regions are characterized by a smaller variety of ore formations than the Kola-Lapland-Karelian region. The role of the siderofile elements is lesser and the number of siderofile-chalcofile and lithofile formations increases. The importance of certain polymetallic ore types, in particular, is significantly greater.

The Caledonian fold belt

The Caledonian fold belt, covering almost the whole territory of Norway and the north-western part of Sweden, is part of the very large Ireland-Scotland-Scandinavian orogenic belt, displaced by hundreds of kilometres from the west and moved over the Precambrian basement of the Fennoscandian Shield.

In the territory of Sweden the Lower Allochton of Caledonian cover, metamorphosed from the green schist to the amphibolite facies, is mainly represented by Vendian intrusive and sedimentary formations. The Upper Allochton Caledonian cover, mostly spread in Norway, is composed of metamorphosed volcanogenic-sedimentary rocks of Cambrian-Silurian age. In many places, Precambrian rocks of the Fennoscandian Shield form anticlinal or dome-shaped protrusions in tectonic windows along the whole Caledonian folded belt. In many cases the Precambrian rocks are exposed to the deformations and metamorphism of the Caledonian orogenic stage.

The Russian Plate

The Russian Plate is the northern part of the East European ancient platform and it is joined to the Fennoscandian Shield at the east and south-east. The basement of the Russian Plate is formed by highly metamorphosed (in amphibolite facies) deposits of the Pre-Riphean age. Geological data on its lithological composition is very limited. Based on geophysical information, it is thought that the Archaean and Low Proterozoic formations of the Kola, Belomorian and Lapland-Karelian blocks of the Fennoscandian Shield have a continuation under the Russian Plate. On a regional scale, the following spatial features of the relief of the submerged Precambrian basement have been recognized: (i) the blocks of the Fennoscandian Shield in the west are sinking monoclinally down to 1.5-2 km in a south-easterly direction, (ii), a zone of large risings (up to 2.0-2.5 km) in the north, and (iii) the central axial depression with the basement depths of 2.5- 4.5 km. In addition, there are numerous local horst and rift-valley type structures, forming peculiar interrelated apophasis, mainly in a north-westerly direction.

Four large structural blocks of the Russian Plate are situated in the study area:

(i) the Slope of the Fennoscandian Shield (II-1),
(ii) the Moscovskaja-Mezenskaja syneclise (III-2),
(iii) the Baltic syneclise (III-3), and
(iv) the Lithuanian-Belarussian anticlise (III-4).

In the north, the Moscovskaja-Mezenskaja syneclise continues under the White Sea, while in the east it is bordered by the Timan mountain ridge.

The Slope of the Fennoscandian Shield is traced along the eastern and south-eastern border of the Shield. This block has the longest geological history of sedimentary cover formation (more than 1 Ga). It includes the Baikalian structural complex and the Caledonian structural stage. The Baikalian structural complex is divided into Low Baikalian (terrigenous and volcanogenic deposits of Riphean age) and Upper Baikalian (sands, siltstones, mudstones and sandy clays of Vendian age) structural stages. The Caledonian structural stage consists of limestones, terrigenous cabonate and sand-clay deposits of the Cambrian, Ordovician, Silurian and Middle Devonian periods. The maximum thickness of this mega-block is 3-3.5 km, and it exceeds the total thickness of all overlying deposits of the Moscovskaja-Mezenskaja syneclise. The main tendency of the tectonic events is the common subsidence of the territory with different sinking velocities in its separate parts.

The sedimentary deposits of the Moscovskaya-Mezenskaya syneclise, Lithuanian-Belarusian anticlise and Baltic syneclise correspond to the Herzinian (Upper Devonian and Carboniferous dolomites and lime stones and Low-Middle Permian terrigenous-anhydride-carbonate deposits) and Alpine, mainly shallow marine (Upper Permian siltstones, marls, some limestones, dolomites and sands, and Mesozoic and Quaternary sand-clay deposits) structural lithologic stages.

Deposits of the Herzinian structural stage are widely spread in the west of the Plate along the border with the Fennoscandian Shield. Its thickness is about 500- 600 m in the northern part of the Moscovskaja-Mezenskaja syneclise and increases up to 1 km and more to the south-east. Deposits of the Alpine structural stage are spread through the east of the study area (Moscovskaja-Mezenskaja syneclise) and south-western Lithuania (Baltic syneclise).

The main tectonic tendencies of these two stages are sinking in the central part of the Moscovskaja-Mezenskaja syneclise, permanent differentiated rising of blocks (Lithuanian-Belarusian anticlise) and a prevalence of positive tectonic movements, transforming the majority of this territory into continental land at the end of this stage. In the east, along the border with the Timan ridge, the Plate formations become thinner over a short distance. As a rule, this border zone of the Plate is complicated by explosive tectonics.

The Timanian fold belt

The Late Proterozoic Timanian fold belt is a part of the Baikalian fold system, forming the basement of the Timan-Pechora Plate. Tectonically the Timan ridge is the south-western border of the Timan-Pechora plate.

In the study area, geological formations of the Timanian fold belt are situated in the Kanin Peninsula and they form an external part of the

Riphean geosyncline. This structure is composed of carbonate, terrigenous-carbonate, clay-siltstone and flysch-carbonate-schist formations. It is traced as a narrow (10-15 km) zone in the south-east along the whole Timan ridge.

2.3.2 Quaternary deposits

In the study area, the main Quaternary deposits (Fig. 6) consist of glacial, glacial lacustrine, glaciofluvial and marine deposits. Locally, there are areas of colluvial-dealluvial and eluvial-dealluvial deposits on watersheds, along seashores and in mountain ridges. Fluvial deposits are typical in the valleys of large rivers.

The Glacial formations include deposits of basal till, which occupies large areas in slightly rolling hilly plains. The till is mainly made up of boulders, pebbles, gravel, crushed stone and clay sand, and loosely sorted materials of earlier stages of glaciation. In places, terminal moraines form hilly-ridge relief deposits. These deposits are composed of boulders with different roundness, gravel-pebble material and layered sands of different grain size.

Widespread occurrences of glacial-lacustrine, glaciofluvial and, in some cases, glacial-marine (with marine fauna and flora) deposits are common in the areas with an accumulative hilly-ridge relief. These deposits usually consist of sandy-loam and clay material of laminar types with well rounded boulders, gravel and pebbles or rhythmic layered clays.

The Pleistocene marine deposits mainly consist of sands of different grain size, siltstones, sandy clays and layered clays with marine flora and fauna. The Pleistocene formations also include alluvial marine deposits of coastal sea floor plains and sub-mountain or denudation troughs (complexes of interlayered alluvial, deltaic, estuarial and marine deposits).

The fluvial formations include alluvial (along big river valleys) and lake-alluvial (within accumulative lake-alluvial plains and valleys) deposits. They consist of gravel-pebble material, sands of different grain size, sandy clays and rhythmic layered clays with buried soil horizons of the hydromorphic type.

The colluvial, colluvial-dealluvial and eluvial-dealluvial deposits on the watersheds of hills and mountain ridges consist, as a rule, of angular gravel-pebble and rubble material from surface outcrops, different grain size sands and, in some cases, thin layers of sandy clay and clay.

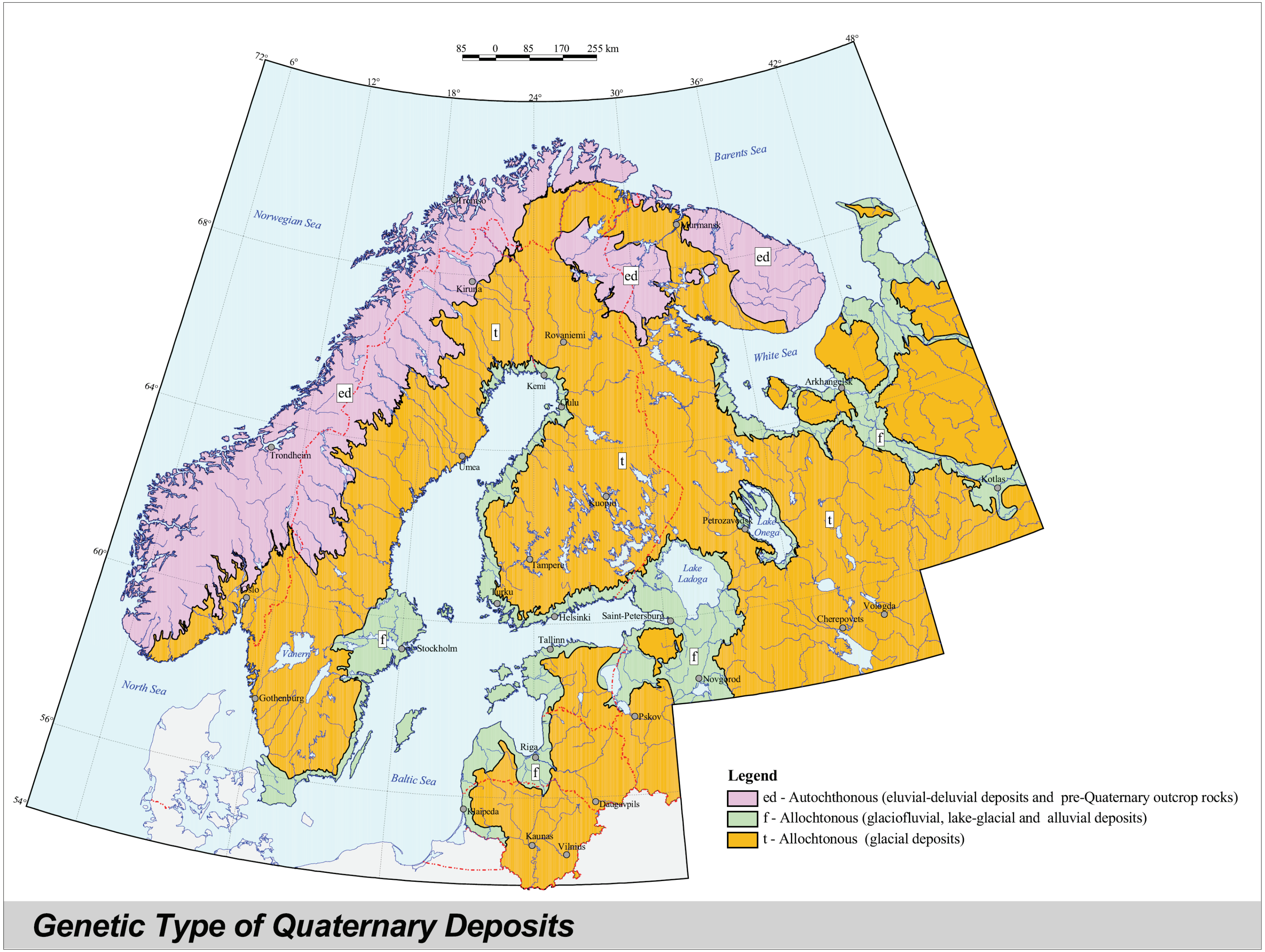


Figure 6. The genetic types of the Quaternary deposits.