THE PRECAMBRIAN IN EUROPE

by

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In Europe, the Precambrian includes rocks as old as 3000 Ma, and most of the global orogenic cycles. This article provides observations on the regional geology, the major features of the Precambrian and the Baltic Shield, and the geological evolution of the Precambrian in Europe, particularly as it relates to uniformitarian theory.

Introduction

An essential feature of the tectonic structure of all continents is that the oldest exposed crust consists of Precambrian platforms. These old stable areas or cratons are surrounded by younger Phanerozoic fold belts.

In Europe, the main area of Precambrian rocks consists of the broad East European or Fennosarmatian Platform, the larger part of which (known as the Russian Plate) is covered by younger unmetamorphosed sediments. Precambrian crystalline rocks in this platform are exposed in the Baltic or Fennoscandian and Ukrainian Shields. The platform is rimmed by younger Phanerozoic fold belts, including Caledonidic, Variscidic and Alpidic orogenic zones (Fig. 1).

In addition to the East European Platform, stable smaller blocks occur around the Barents Sea, in northwestern Britain and in the adjacent regions. The Precambrian of the Barents Platform underlies northeastern Spitzbergen. Metamorphic complexes of the Eria Platform, exposed in northwestern Scotland and the Outer Hebrides, form the western foreland of the Caledonidic belt. Greenland too consists for the most part of Precambrian complexes, which may be correlated with those of the Canadian Shield.

Precambrian rocks are also found within the younger Phanerozoic fold belts. For example, late Precambrian (Eocambrian) rocks are a common component of the Caledonides. Many small massifs or nuclei of Precambrian rocks of different ages occur in the Caledonidic and Variscidic zones, whereas in the Alpidic zone they appear to be rare.

Figure 1. Major structural units of Europe: 1 - Precambrian metamorphic rocks of shields; 2 - inferred Precambrian shields covered by younger strata; 3 - Caledonian fold belt; 4 - Variscan fold belt; 5 - Massifs in the Variscan zone; 6 - Alpine fold belt. Precambrian units: I - Baltic Shield; II - Ukrainian Shield; III - East European Platform; IV - Barents Platform; V - Eria Platform; VI - Armorican Massif; VII - Massif Central; VIII - Vosges; IX - Black Forest; X - Bohemian Massif.

Precambrian Platforms

East European Platform

The broad East European Platform, the basement of which consists of Precambrian metamorphic complexes, extends across Denmark, part of Norway and Sweden, Finland, the north of Germany, northern and eastern Poland, and most of the Soviet Union's European part (Fig. 1). Different proposals regarding the position of the platform's southwestern border have been made (Fig. 2), some suggesting that the platform extends as far as central England, where small inliers of Precambrian metamorphic rocks have been identified.

The platform is exposed in the Baltic and Ukrainian Shields, but the largest part of it - the Russian Plate - is overlain by a thick cover of unmetamorphosed sedimentary rocks.

Figure 2. Suggested position of the southwestern border of the East European Platform: I - Törnquist line (1910); II - H. Stille (1924); III - The tectonic map of Europe (1960); IV - E. Bailey (1928).

The Baltic Shield

The Baltic or Fennoscandian Shield, the broadest shield area on the European continent, is an uplifted part of the East European Platform whose boundaries and main structural features dip gently under the platform's sedimentary cover. Broad areas of early Precambrian (Archean) basement gneisses are exposed in the east - the oldest part of the Shield (Fig. 3). The Belomeric gneiss belt and the granulite arch of Lapland represent high-grade metamorphic parts of this basement complex, which became intensively reworked and recrystallized during the younger Svecofennian orogeny. The ages of the basement gneisses are usually 2600-2800 Ma, although older ages (ranging from 3000 to 3500 Ma) have been recorded, especially in the Kola Peninsula.

An old basement complex of unknown age, thoroughly reworked by Dalslandian movements about 1000 Ma ago, occurs in the southwestern part of the Shield. Some authors have correlated it with the basement in the eastern part of the Baltic Shield. In northern Finland (about 2400 Ma ago) basement gneisses were penetrated by mafic igneous intrusions which formed layered sheet- or lopolith-like bodies.

The main part of the Baltic Shield belongs to the Svecofennian fold belt which exhibits many features similar to younger orogenic belts. The early Precambrian basement

Figure 3. Main structural units of the Baltic Shield: 1 - Paleozoic and younger sedimentary rocks; 2 - Paleozoic igneous rocks; 3 - Caledonides. 4 - Precambrian unmetamorphosed sedimentary rocks; Jotnian formations. 5 - Dalmandian fold belt; gently folded Dalmandian formations; 6 - Dalmandian granites; 7, 8, 9 - Precambrian igneous rocks, representing the period of cratonization following the Svecokarelian orogeny; 7 - diabbases; 8 - Gothian granites and rapakivi granites; 9 - volcanic rocks; 10, 11 - Svecokarelian fold zones; 10 - schists and gneisses; 11 - plutonic rocks; 12, 13 - Basement complexes; 12 - Presvecokarelian basement; 13 - basement of unknown age.

was deeply eroded and peneplained about 2300 Ma ago, forming the so-called Jatulian continent; on it and along its border, sedimentation of the transgressive Jatulian group (basal beds, quartzites, dolomites and sapropelic pelites) took place some 2300-2000 Ma ago. This sedimentation was accompanied by lively mafic volcanism which occurred in phases 2200-2000 Ma ago.

Geosynclinal basins then developed west of the Jatulian continent and thick geosynclinal deposits accumulated, the associated volcanism (1920-1880 Ma) being only slightly older than the orogenic plutonism of the Svecokarelian. These deposits were metamorphosed into crystalline schists during the Svecokarelian orogeny about 1900-1800 Ma ago, accompanied by the emplacement of enormous masses of granitoids.

The Svecokarelian orogeny was followed by a long period of erosion and cratonization. Vertical block movements took place and large volumes of diabbase, granite and associated volcanic rocks were intruded in many pulses into the stable platform about 1700-1550 Ma ago; these intrusions included the rapakivi granites, the Gothian granites in Sweden and their volcanic equivalents.

The Jotnian red beds, arkoses, and siltstones, were deposited about 1400-1300 Ma ago upon the deeply eroded Precambrian surface to form the oldest nonmetamorphic sedimentary cover of the Baltic Shield. Diabbase dikes and sills occur abundantly in many Jotnian deposits, and they represent hypabyssal eruption channels for basaltic magma intrusions into the stable platform.

The so-called Dalslandian, or Sveco-Norwegian tectonic movements took place about 1000 Ma ago in the southwestern corner of the Baltic Shield. Dalslandian formations, deposited upon an old basement of unknown age, are of the platform type; no geosynclinal strata are present. The formations underwent gentle folding accompanied by intrusions of granites and pegmatites. These tectonic movements caused a regional rejuvenation of the ancient basement in the southwestern corner of the Baltic Shield.

The youngest Precambrian of Scandinavia consists of so-called Eocambrian sediments, deposited on the Shield along what is now the eastern margin of the Caledonides.

The Ukrainian Shield

Five megacycles subdivide the Precambrian of the Ukraine:

		Ma
Precambrian	I	3500 - 2600
"-"	II	2600 - 1900
"-"	III	1900 - 1600
"-"	IV	1600 - 1100
"-"	V	< 1100

The Ukrainian Shield is composed mainly of megacycles I to IV, with Riphean platform sediments (Precambrian V) overlying the western boundary of the Shield and demonstrating that the folding and metamorphism of the Shield originated in pre-Riphean times. The geological evolution of the Precambrian in the Ukrainian Shield is similar to that of the Baltic Shield.

Basement of the Russian Plate

The basement under the thick sedimentary cover of the East European Platform has been studied thoroughly by Soviet and Polish geologists. The basement surface occurs at depths which vary from a few hundred meters to 1-2 km above the uplifts (anticlines) and up to 3-4 km in the depressions (synclines). The structure of the basement is characterized by faults with great vertical displacements measuring up to many kilometers, narrow graben-like depressions (aulacogens) as deep as 10 km, and well defined horsts.

The basement consists of metamorphic and plutonic rock complexes of pre-Riphean age related to those in the Baltic and Ukrainian Shields, while the cover comprises Late Precambrian (Riphean), Paleozoic, Mesozoic and Cenozoic formations.

Barents Platform

An old platform whose extent is still unknown occurs in the area of the Barents Shelf. It seems to have formed one foreland of the Caledonides on the platform's western side. The southern corner of this fragmentary platform is rimmed by the Assyntian fold belt of Kanin-Timan and by the Variscan Novaya Zemlya zone; the northern boundary is unknown. Basement rocks are exposed only in northeastern Spitzbergen.

Eria Platform

This old platform with unknown boundaries is exposed in northwestern Scotland and the adjacent regions. Here the crust is composed of Precambrian (Lewisian) metamorphic complexes, overlain discordantly by Late Precambrian (Torridonian) and Cambrian sediments.

The fragmentary Eria Platform forms the northwestern foreland of the British Caledonides. The basement consists of Lewisian gneisses, schists and igneous rocks which represent at least two metamorphic complexes of different ages. An older Scourian complex was metamorphosed about 2400-2600 Ma ago, while a younger Laxfordian complex was folded and metamorphosed ~1600 Ma ago, causing rejuvenation of the older rocks. The Late Precambrian, unmetamorphosed Torridonian sediments were deposited about 1000-650 Ma ago, and consist mainly of molasse-type terrestrial arkose sandstones which form a cover up to 6 km in thickness over the Lewisian complex.

Lewisian/Torridonian unconformity exposed to the south of Loch Torridon, Northwest Scotland. The undulating erosional surface can be clearly identified. (Photo courtesy National Museum of Wales).

Greenland Platform

The Precambrian of Greenland can be regarded as the most eastern extension of the Canadian Shield, and is briefly mentioned here because the 26th International Geological Congress plans to include some excursions to this largest island in the world. Areas of folded Precambrian underlie the greater part of Greenland, covered mostly by glaciers. Precambrian rocks, however, are well exposed in the ice-free coastal areas of West, South and Southeast Greenland. The Greenlandic Shield is bordered by areas of folded Paleozoic strata to the north and east of the island.

The Precambrian includes folded strata of Archean and Proterozoic ages as well as anorthosite, gabbro and rapakivi granite intrusions (~1600-1700 Ma) belonging to the so-called Sanerutian complex. The Gardar group of southern Greenland (<1400 Ma) is composed of sandstones and red quartzites with basaltic lavas, and overlies the Ketelidian and Sanerutian complexes.

Precambrian in Phanerozoic Folded Areas

Late Precambrian (Eocambrian) deposits are part of strata deformed by Caledonidic movements in Spitzbergen, Scandinavia and Great Britain. For example, a major part of the Hecla Hoek geosynclinal succession in Spitzbergen, the psammites of the Sparagmitian in Scandinavia and the Moinian in Scotland, are all of Late Precambrian age. The upper part of the Late Precambrian strata contains glacial-boulder beds and tillites which are important key units for stratigraphical correlation.

Precambrian metamorphic and plutonic rocks of different ages occur as many windows, especially in the Caledonidic belt of Scandinavia. The rocks in autochthonous windows are correlated with those of the Baltic Shield. By contrast, the Precambrian rocks involved in the Caledonidic metamorphism have been so thoroughly reworked and rejuvenated that correlation with Precambrian strata is commonly difficult.

In a zone trending from southern Great Britain and western France as far east as Czechoslovakia, many massifs in areas of folded Variscan or Hercynian strata are Precambrian. They include the well-known Armorican Massif, Central Massif, Vosges, Black Forest and the Bohemian Massif (Fig. 1). Relicts of Precambrian occur also in the Variscan zone of Portugal and Spain.

Most Precambrian rocks of the Variscan zone are considered to be Late Precambrian. Tillites characteristic of the upper part of the Eocambrian reported in these strata support this age assignment. The rocks are polymetamorphic with evidence of Assyntian, Caledonian and Variscan folding and metamorphism. They too have been so intensively reworked by the effects of Variscan folding, plutonism and polymetamorphism, that in many instances it is difficult to determine

their original age even with radiometric methods.

Remnants of older Precambrian appear in the Variscan zone in addition to the late Precambrian rocks. For example, three periods of Precambrian metamorphism (2800-2700 Ma, 2000-1900 Ma and 1100-900 Ma respectively) have been reported from the Pentevrian complex of the Armorican Massif of France. Furthermore, the highly metamorphic Moldanubian nucleus of the Bohemian Massif is now known to include Precambrian rocks older than the low-grade metamorphic Late Precambrian ones of Assyntian, which border the nucleus.

Some relicts of Precambrian rocks have also been reported from different parts of the Alpidic zone. These have commonly been subjected to Assyntian or Variscan metamorphism and reworked during Alpidic folding. Again, the Precambrian age of many of these polymetamorphic rocks is difficult to determine with certainty.

Acid and gneissic Precambrian plutonic rock forming part of a Caledonian thrust sheet NW of Rdal, Norway. (Photo courtesy W.H. Poole)

Evolution of the Precambrian

At the end of the nineteenth century, great progress was made in studies of the early history of the Earth when the actualistic or uniformitarian theories proved applicable to the study of metamorphic Precambrian complexes. For example, Precambrian crystalline schists display many sedimentary and volcanic features, which indicates that their deposition took place under conditions similar to those prevailing at present.

Geological events during a period of about 3000 Ma are recorded in the Precambrian and Phanerozoic of Europe. Intensive geological studies of Precambrian tracts in different continents, complemented by age determinations, show that the tectono-plutonic orogenic events in that era took place periodically and simultaneously in wide areas of different continents. These new data have been used for the compilation of international geological, tectonic, and metamorphic maps of the continents.

Most worldwide orogenic cycles are also represented in Europe. For example:

	Ma
Katarchean (Saamian)	> 3300
Presvecokarelidic	~ 2800 - 2600
Svecokarelidic	~ 1900 - 1800
Dalslandian (Grenville)	~ 1000
Assyntian (Baikalian)	~ 550
Caledonian	450 - 400
Variscan (Hercynian)	340 - 240
Alpine	< 85

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These orogenic cycles with their approximate ages suggest that the orogenic pulses have been more frequent in the Phanerozoic than in Precambrian times.

Precambrian platforms played an important role during the evolution of the younger orogenic zones by controlling the position of the thick, broad zones of late Precambrian geosynclinal deposits around the cratons, which were later subjected to folding and/or metamorphism during the Assyntian, Caledonian and Variscan orogenies. The occurrence of a coherent Assyntian fold belt in Western Europe is still disputed, though many relicts of Assyntian deformation have been found.

The oldest Archean fold belts contain greater relative volumes of volcanic and plutonic rocks than the younger belts, possibly because the ancient crust was rather thin and not differentiated into the platforms and geosynclines which later acted as major structural elements controlling crustal evolution from Proterozoic time onwards.

Some Archean and Early Proterozoic rocks (for example - quartz-banded iron ores, lazurite deposits) suggest that their sedimentation took place in the absence or deficiency of oxygen in a primitive atmosphere. Red beds, typical representatives of sediments deposited in an oxidizing environment, are widespread among the Proterozoic rocks deposited after the Svecokarelidic orogeny (the Jotnian sediments, 1300-1400 Ma old, serve as an example).

Archean carbonaceous black schists suggest the existence of primitive organisms during earliest geological times. The first organisms were probably algae capable of living in many kinds of extreme environments, including anaerobic ones. Organic remains are very rare in the Early Precambrian rocks, but stromatolites do occur in the Proterozoic and are abundant in the Late Precambrian. Documentary evidence of metazoa also exists.

Precambrian complexes contain some rock types that are characteristic of certain phases of crustal evolution. For example, quartz-banded iron formations are characteristic of the Archean greenstone belts, while rapakivi granites, with associated anorthosites and volcanic rocks, seem to be peculiar to the crustal evolution of the Middle Precambrian (1700-1500 Ma ago).

Most of the Precambrian is metamorphic and displays varying grades of metamorphism. Amphibolite facies are common and widespread. Granulite facies rocks occur in some places in Archean terrain, and greenschist facies are common in the Late Precambrian. Metamorphic zoning of Precambrian areas does not seem to be as distinct as in younger orogenic belts, and mineral associations representing relatively high pressure/low temperature are rare.

Deeply eroded roots of Precambrian orogenic zones have provided a key for investigations of the composition of the Earth's crust and of the many transformation processes that have taken place in the depths of the Earth. Geological studies of the Precambrian areas in Europe have yielded abundant material for petrogenetic studies, which have proved fruitful in developing the petrology of metamorphic and plutonic rocks. The concepts of mineral facies classification, metamorphic differentiation and remelting (anatexis) of rocks developed through investigations of the Precambrian. Furthermore, the study of the Precambrian, so rich in granites and migmatites, brought the global problem of the origin of granites and the processes involved in cratonization into the forum of lively scientific discussion.