



EUROBRIDGE

Palaeoproterozoic Accretion of Sarmatia and Fennoscandia

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EUROBRIDGE research of the East-European Craton (EEC) is providing surprising new insights into Palaeoproterozoic processes of continental collision and crustal accretion. The EEC is composed by three major segments Fennoscandia, Sarmatia and Volgo-Uralia, each with complex Archaean and Palaeoproterozoic histories, that were assembled as part of a megacontinent in the late Palaeoproterozoic (c. 1.85-1.80 Ga). EUROBRIDGE studies are concentrated on a broad transect in the southwestern part of the craton, extending from the Palaeoproterozoic crust of the Fennoscandian Shield to the Archaean of the Ukraine, spanning the boundary between Sarmatia and Fennoscandia. Based on geophysical and geochemical studies, particularly of isotopic-age and provenance, it has been shown that this part of the craton is a remarkable assemblage of Palaeoproterozoic terranes, with arcuate belts of lower crustal rocks thrust together with upper crustal units. Archaean components, thought previously to dominate this part of the EEC, are apparently absent. The suture zone between Fennoscandia and Sarmatia separates terranes with fundamentally different Archaean and Palaeoproterozoic histories.

The EEC in the Baltic States, the Republic of Belarus and the Ukraine is largely covered by Neoproterozoic and Phanerozoic rift-related and platform successions. Knowledge of the underlying crystalline basement is primarily derived from analyses of drill cores and geophysical data. Over 6000 drillholes in the research transect provide both the unique opportunity and the challenge to decipher the Proterozoic and earlier history. New seismic experiments, complementary to the existing potential field data, are providing insight into the deeper lithosphere.

EUROBRIDGE is carrying out a wide range of interdisciplinary studies to better understand the Palaeoproterozoic and Archaean crustal evolution, in particular, the processes involved in the accretion of vast volumes of juvenile Palaeoproterozoic crust. The research centers on:

1) The deep structure of the southwestern EEC. This is being investigated by a DSS (refraction and wide angle reflection) transect extending for over 1500 km from the exposed crust of

southwestern Fennoscandia to the Ukrainian Shield. Complementary potential field data are being acquired.

- 2) Investigations of the structure and P-T conditions of the various terranes, in combination with isotope dating of crust-forming processes, with a focus on the Palaeoproterozoic terranes and the collision zone between Fennoscandia and Sarmatia.
- 3) Analysis of the Riphean and Phanerozoic structural histories, particularly of the Volhyn-Orsha depression and the Pripyat Trough, to better understand the influence of Palaeoproterozoic rheology on the younger structural evolution.
- 4) Studies of lower crustal and upper mantle xenoliths, some diamondiferous.
- 5) Comparison with other parts of the EEC and other cratons, particularly with those in North America, Greenland, South America and Siberia.

Introduction

The ancient core of Europe, the East-European Craton (EEC) is composed of three major crustal segments, Fennoscandia, Sarmatia and Volgo-Uralia (Fig. 7.2, inset). These were assembled in the late Palaeoproterozoic, subjected subsequently to episodes of rifting and then covered by Phanerozoic platform successions. Only in the north and west (the Fennoscandian Shield) and partly in the south (the Ukrainian Shield and the Voronezh Massif) are Palaeoproterozoic and older rocks exposed (Fig. 7.1). During the Soviet era, vast resources were committed to exploration of the EEC; wide-ranging geophysical investigations were integrated with deep drilling, the latter designed to pass through the Phanerozoic and Riphean cover successions and penetrate deep into the ancient crystalline bedrock. This unique data base has become generally available during the last decade. By the application of new analytical techniques, it is providing the foundation for a more comprehensive understanding of the craton; in particular, it is throwing new light on the processes of terrane collision and accretion that formed the Earth's crust during the Palaeoproterozoic.

The EUROBRIDGE project spans the southwestern part of the EEC, reaching from the Fennoscandian to the western part of the Ukrainian Shield, i.e. from the Fennoscandian segment to Sarmatia. It is designed as a broad transect and involves a wide range of geological and geophysical investigations, with over 6000 drillholes providing outstanding opportunities for studies of igneous and metamorphic petrology, isotope age and provenance, P/T paths, etc. The combination of geophysical and drillcore studies is allowing definition of independent Palaeoproterozoic terranes; their mutual interrelationships are forming the basis for modelling of an accretionary history that contrasts markedly with those further north in the Fennoscandian Shield, in Finland and Russia.

Development of the Research Plan

Research institutions from Denmark, Finland, Germany, the Netherlands, Poland, Sweden and the United Kingdom are cooperating with geological and geophysical institutes in Belarus, Lithuania, Russia and the Ukraine. The scientific plans have been developed and discussed in EUROPROBE workshops (Nykøbing, 1992; Minsk, 1994; St. Petersburg, 1994, 1995), and also during joint meetings and workshops with the relevant thematic task groups of IGCP projects 275 "Deep Geology of the Baltic/Fennoscandian Shield" and 371 COPENA ("Structure and Correlation of the Precambrian in NE Europe and the North Atlantic Realm"). In 1993, a Lithuanian initiative led to the definition a new DSS (refraction and wide angle reflection) seismic experiment along the length of the EUROBRIDGE transect. Geophysicists from the Republic of Belarus,

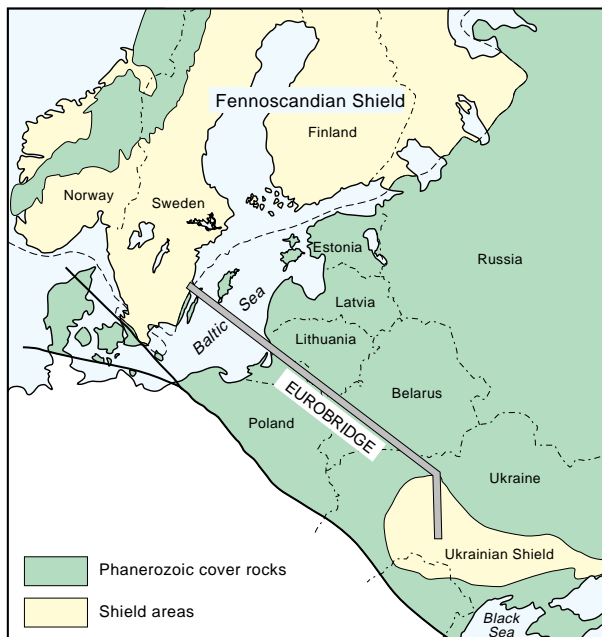


Figure 7.1: Location of the EUROBRIDGE profile.

Denmark, Finland, Germany, Lithuania, Poland, Russia, Sweden, the United Kingdom and the Ukrainian Republic are participating in the profile, which crossed the southern Baltic Sea in 1994, Lithuania in 1995 and targets Belarus in 1996 and the Ukraine in 1997.

Geological Framework

The three major segments comprising the EEC, Fennoscandia, Sarmatia and Volgo-Uralia (Bogdanova, 1993; Gorbatshev and Bogdanova, 1993; Bogdanova et al., 1996), are vast composite terranes with independent Archaean and early Palaeoproterozoic histories, that were brought together to compose part of a megacontinent in the late Palaeoproterozoic (ca. 1.85-1.80 Ga). The segments are characterized by major differences in crustal structure (as seen, for example, in the MAGSAT imagery), lithologies and age of crust-forming processes (Bogdanova et al., 1996a). The suture zones between the segments were reactivated during the Meso- to Neoproterozoic rifting; they are now covered by the Pachelma and Central Russian rift systems (including the Volhyn-Orsha depression) and younger platform cover.

In the EUROBRIDGE transect (Fig. 7.1), the depth of burial of the crystalline basement beneath platform sediments, in most areas is a few hundred metres, but is locally up to 5 km. The transect crosses the Belarusian up-lift (less than 1 km to basement), the Baltic and the Volhyn-Orsha depressions, and the Pripyat Trough with 5 km of cover rocks.

The Fennoscandian crust in the EUROBRIDGE transect is composed of arcuate belts that differ in lithology, age and internal structure (Fig. 7.2). These have been identified on the basis of the drillcore studies and correlation of aeromagnetic and gravity anomaly data (Kubiski and Ryka, 1982; Puura, 1980; Aksamentova and Naydenkov, 1990; Koistinen, 1994). Major granulite and amphibolite facies belts are juxtaposed and separated by crustal discontinuities that trend SSW-NNE across the transect corridor and then further north swing WNW in the northern Baltic States and southern Finland. E-W-trending zones of faulting complicate the Palaeoproterozoic pattern, apparently controlling the distribution of Meso-Neoproterozoic intrusions.

Until recently, this part of the EEC was considered to have been formed in the Archaean. However, recent U-Pb zircon and monazite, and Sm-Nd isotope age studies have shown the crust to be younger (2.0-1.8 Ga) and juvenile; Archaean signatures are found only in the metasediments (e.g. Huhma et al., 1991; Bogdanova et al., 1994; Claesson et al., 1994; Bibikova et al., 1995; Mansfeld, 1995). These data have fundamentally changed the understanding of the crustal evolution, providing opportunities for correlation with the classical Svecofennian complexes of the Fennoscandian Shield. The Palaeoproterozoic crustal evolution has apparently been dominated by a sequence of

accretional/collisional events (Gorbatshev and Bogdanova, 1993) that involved early crustal thickening and emplacement of granulite facies units to high structural levels, followed by rifting, crustal extension and magmatic underplating.

In contrast, adjacent Sarmatia was a stable Archaean craton with a Palaeoproterozoic platformal cover by c. 2.1 Ga (e.g. Shcherbak, 1991). This crustal segment was created by late Archaean and early Palaeoproterozoic welding together of several Archaean terranes with different ages ranging from 3.7 to 2.8 Ga. Sarmatia is the most exotic part of the EEC, resembling more the Archaean and Palaeoproterozoic terranes of the southern hemisphere (particularly those in South America) than those of Fennoscandia and Volgo-Uralia.

Palaeomagnetic studies of Sarmatia and Fennoscandia provide evidence that the assembly of these composite terranes occurred after ca. 2.0 Ga (Elming et al., 1993; Iosifidi et al., 1996).

Major tectonic units of EUROBRIDGE

EUROBRIDGE is anchored in the northwest in the exposed Fennoscandian areas of the south Baltic domain. It extends across the Baltic Sea to the West Lithuanian Granulite Domain and southeastwards via the East Lithuanian Belt, the Belarussian-Baltic Granulite Belt and the Central Belarussian Belt to Sarmatia (Fig. 7.2). Contacts between these different belts/domains are fault zones in which movement apparently continued into the latest Palaeoproterozoic (ca. 1.7-1.65 Ga, Bogdanova et al., 1996a).

South Baltic Domain (SB)

The EUROBRIDGE transect starts in the northwest in EGT's FENNOLORA profile where, the Svecofennian bedrock is dominated by late Palaeoproterozoic batholiths of the Transscandinavian Igneous Belt (TIB) of ca. 1.85-1.76 Ga. The TIB granulite suite of possible Andean type plutons are intruded into volcanic arc associations that are not older than 1.83 Ga (Mansfeld, 1995). The granulites are magnetite-rich; they extend far to the north, defining some of the most prominent magnetic anomalies in Scandinavia. Although magnetic anomaly data are lacking across the southern part of the Baltic Sea, the magnetic signatures appear to extend southeastwards into Lithuania and Poland, where intrusions of similar composition appear to occur.

West Lithuanian Granulite Domain (WLG)

The Western Lithuanian Granulite Domain (WLG) is an up to 200-km-wide part of the belt that extends along the eastern side of the Baltic Sea from the Kurzem Peninsula (Latvia) to Poland. The WLG metasedimentary and metaigneous granulites were metamorphosed in the lower crust at depths of 25-30 km at about 1.8 Ga (U-Pb, monazite) and then slowly exhumed to shallow structural levels by 1.4-1.3 Ga

(Ar-Ar, amphibole data). The uplift was associated with voluminous magmatic input into the crust at several stages and probably with magmatic underplating. The latter is indicated by the major troctolite-anorthosite-rapakivi Riga pluton (1.58 Ga), which occupies the northernmost part of the WLG and extends beneath the Baltic Sea to the neighboring islands (e.g. Koistinen, 1994). In the southern part of the WLG, somewhat younger (1.5 Ga) anorthosite-rapakivi intrusions in northern Poland and Lithuania (Claesson et al., 1995) occur, apparently related to an EW zone of faulting.

Geophysically, the WLG is characterized by prominent EW-trending gravity and magnetic anomalies that are truncated in the eastern contact zone to the East Lithuanian Domain.

East Lithuanian Belt (EL)

The East Lithuanian Belt (EL), extending northwards into Latvia, is dominated by amphibolite-facies metagraywackes, marbles, mantle-derived metavolcanics (c. 1.9 Ga) and mafic-to-ultramafic intrusions. These units compose separate units within widespread granulites intruded between 1.87 and 1.82 Ga. In the EL interior, metamorphism took place in the middle crust at depths of between 12 and 18 km, prior to the 1.82 Ga granulite intrusions.

The dominant NNE trends of the different units and corresponding linear magnetic anomalies are sharply discordant to the tectonic pattern of the WLG. The NNE-trending boundary between these two domains appears to be a major crustal discontinuity. Numerous small intrusions of 1.50 Ga granites intruded the metamorphic rocks of this domain along EW-trending fault zones (Sundblad et al., 1994).

Belarussian-Baltic Granulite Belt (BBG)

The Belarussian-Baltic Granulite Belt (BBG) extends for a length of 1000 km, from southeastern Poland northwards to the Estonian and Latvian shores of the Baltic Sea. Lensoid granulite units, 5 to 30 km wide and 80 to 250 km long, separated by narrow zones of shearing, blastomylonitization and retrogradation constitute the BBG. The available seismic data show that the granulite slices dip at steep to moderate angles to the west, with listric faults merging down into detachment zone at c. 20 km depth (Aksamentova et al., 1994).

The BBG features a predominance of meta-igneous granulites; metasedimentary rocks are very subordinate. A complex tectonometamorphic development is being deciphered, lasting from ca. 1.9 to 1.7 Ga. A subductional/collisional stage, indicated by clockwise P-T paths and calc-alkaline magmatism was succeeded by post-collisional (1.8 Ga) granulite facies metamorphism and emplacement of numerous ultramafic, mafic and granitic rocks. The intrusions apparently triggered the metamorphism at 20-25 km in the lower crust. Cooling and uplift of the Belarussian-Baltic

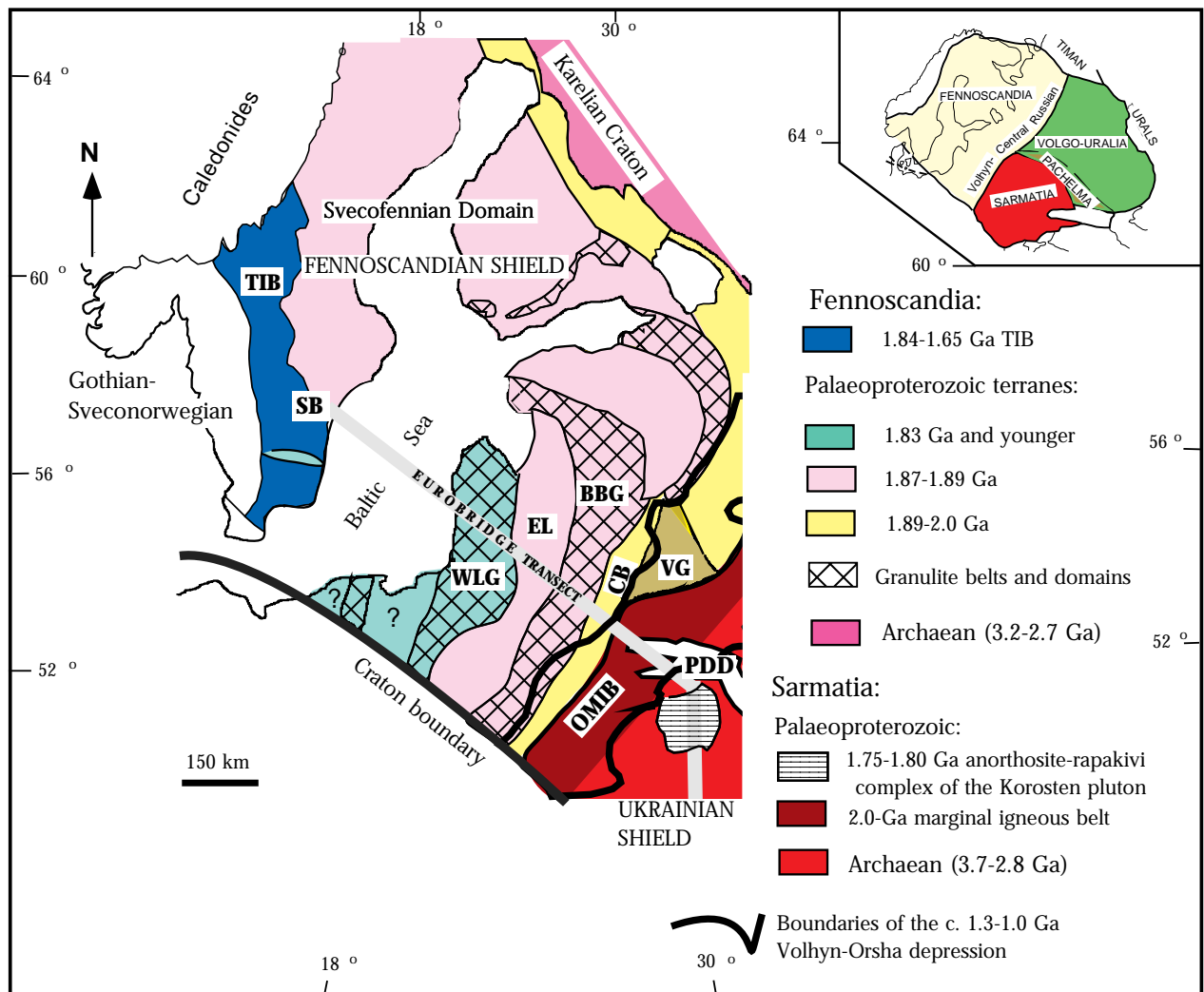


Figure 7.2a: Schematic map of the crustal structure in the EUROBRIDGE transect region (modified from Bogdanova et al., 1994, 1996). Letters are: BBG- Belarussian-Baltic Granulite Belt, CB- Central Belarussian Belt, EL- East Lithuanian-Latvian Belt, OMIB- Osnitsk-Mikashevichi Igneous Belt, PDD- Pripyat-Dniepr-Donets Palaeozoic Aulacogen, SB- South Baltic Domain, TIB- Transscandinavian Igneous Belt, VG- Vitebsk Granulite domain, WLG- West Lithuanian Granulite domain. The three-segment subdivision of the East-European Craton (inset) is according to Bogdanova et al. (1996).

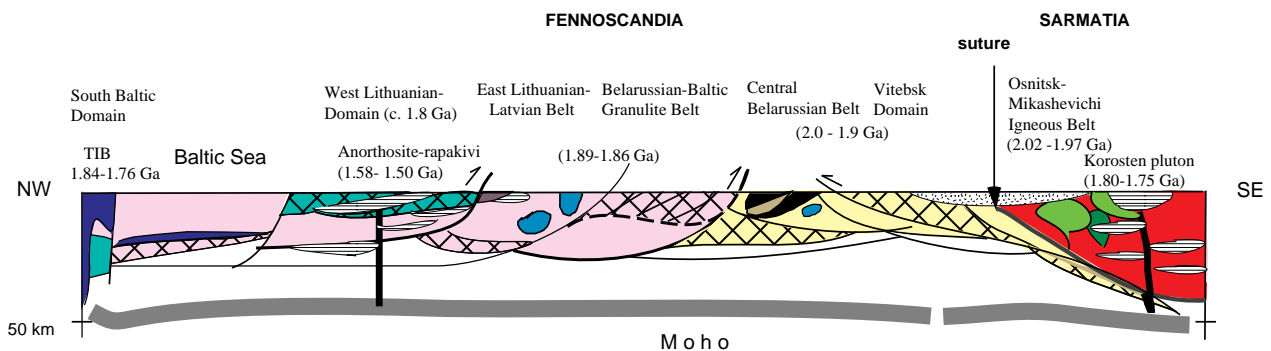


Figure 7.2b: Schematic profile of the crust along the EUROBRIDGE transect. The colours and symbols are the same as in Fig. 7.2a with some additions showing rapakivi-anorthositic intrusions in the western part of the transect (black-white stripes), intrusions of gabbro (light blue) in the East Lithuanian-Latvian Belt, the Okolovo volcanic unit in the Central Belarussian Belt (black), calc-alkaline intrusions in the Osnitsk-Mikashevichi Belt (green) and the sedimentary rocks of the Volhyn-Orsha depression (white dotted).

granulites lasted from 1.8 to 1.72 Ga and was followed by shallow-level intrusion of subalkaline granites at c. 1.6-1.5 Ga, emplaced along EW-trending fracture zones.

The BBG is characterized by a pattern of very intense gravity and magnetic linear highs trending NNE through Belarus, Poland and Lithuania and swinging EW in Estonia.

Central Belorussian Belt (CB)

The Central Belorussian Belt (CB) is dominated by the 2.0-Ga Okolovo metavolcanic complex, which extends NS for 200 km. This amphibolite facies unit is ca. 10 km thick pile of mantle-derived basalts, andesitic basalts, andesites, and dacites with thick silicous iron formations, carbonates and graphitic schists. The sequence apparently formed in an oceanic arc environment. Other rocks in the CB are amphibolites, amphibole- and biotite-bearing gneisses and migmatites. 1.9-Ga dioritic, tonalitic, trondhjemitic and granitic intrusions, partly metamorphosed and deformed, are widespread in the belt. The general amphibolite-facies metamorphism of the Okolovo rocks increases to granulite facies in the vicinity of the BBG. This may be related to thrusting of the latter onto the older CB terrane.

To the northeast of the CB, another high-grade complex, the Vitebsk granulites, appears to compose a lower part of the Okolovo metavolcanic unit. These granulites have yielded an age of 1.95 Ga, i.e. they represent the oldest lower crust northwest of the suture with Sarmatia.

Sarmatia and the Osnitsk-Mikashевичi (Volhyn-Polesky) Igneous Belt (OMI)

The contact zone between Sarmatia and Fennoscandia is located beneath the Riphean Volhyn-Orsha depression. The northwestern margin of Sarmatia is defined by a magmatic belt which is clearly imaged by strong mosaic positive magnetic and gravity anomalies. This igneous suite extends in a northeasterly direction, sharply truncating the NNE-trending crustal units of Fennoscandia, and the mainly NS-striking Palaeoproterozoic structures of Sarmatia. The suture between the two terranes dips SSE, and the Fennoscandian crustal slices may be traced in the upper and middle crust beneath the northwestern margin of Sarmatia (Bogdanova et al., 1996b; Stephenson et al., 1996).

The OMI comprises major granodioritic-granitic batholiths (2.0-1.97 Ga), with subordinate gabbros and diorites; these rocks have mantle signatures indicative of Andean-type calc-alkaline magmatism. Basalts and diabases, andesites and keratophyres (c. 2.1 Ga), metamorphosed in lower amphibolite facies, compose the country rocks into which the batholiths were intruded.

Towards the south, Sarmatia is composed of extensively reworked Archaean basement and overlying

earliest Palaeoproterozoic cover, variably metamorphosed from granulite to lower amphibolite facies. The Sarmatian complexes are intruded by numerous subalkaline and alkaline plutons of the same age as the OMIB indicating that the continental crust was much thicker in the Sarmatian hinterland than along its northwestern margin.

Anorogenic magmatism younger than c. 1.80-1.75 Ga is represented both in the OMIB and further south in Sarmatia by large gabbro-anorthosite-rapakivi intrusions, in some places with associated sediments and volcanics. The EUROBRIDGE transect crosses the Korosten pluton, one of the most prominent features of the northwestern part of the Ukrainian Shield, and the 30-km wide Ovruch graben, partly resting unconformably on the pluton. The graben is infilled by c. 1.75 to 1.70 Ga, weakly metamorphosed coarse sediments, basalts, andesites and acid volcanites. REE and gold mineralizations accompany these rocks and the sediments bear diamonds.

The sheet-like, layered Korosten pluton is c. 6 km thick and bordered by steep faults. The upper crust has a low density and is little magnetized; only the ultramafic and mafic parts of the intrusive suite have distinct magnetic and gravity positive anomalies. The reflection seismic and gravity data suggest that the crust beneath the pluton is extensively penetrated by mafic layered intrusions. Ti and P in the mafic parts and Be and REE in the granitoids are characteristic mineralizations.

General Evolutionary Model

The fundamental differences in Archaean and early Palaeoproterozoic crustal evolution characterizing Sarmatia, Fennoscandia and Volgo-Uralia imply that these crustal segments existed as independent entities prior to c. 2.0 Ga. Palaeomagnetic data suggest that they composed parts of other continental masses that were brought together to constitute a major continent towards the end of the Palaeoproterozoic (Fig. 7.3)

Between 2.1 and 2.0 Ga, an oceanic domain, separating Sarmatia from Volgo-Uralia, closed and these two continental segments thereafter shared a synchronous tectonic evolution. Meanwhile along the northern edge (present coordinates) of Sarmatia, subduction started at 2.0 Ga with establishment of an Andean-type margin and development of the Osnitsk-Mikashевичi Igneous Belt (2.0 - 1.97 Ga). Oceanic domains of this age existed to the north as represented in the Okolovo igneous suite and associated deep marine sediments. Southwards from the margin of Sarmatia, the Osnitsk-Mikashевичi Igneous Belt changes in character from primitive mantle-derived magmas to alkaline suites characteristic of craton hinterlands.

Continued subduction during the 1.9 to 1.8 Ga interval led to further accretion of juvenile Svecofennian crust both to the northern margin of Sarmatia and the southwestern margin of the Archaean Karelia-Kola-

Belomorian craton. This simultaneous accretion appears to account for the arcuate form of the Svecofennian orogenic belts. Continued convergence led to the growth of this vast area of subduction accretion complexes, dominated by juvenile crust. Lower crustal granulites, at least some of which are arc-related, were thrust to high structural levels and further uplifted during extensional collapse, with accompanying late-tectonic magmatism.

The main accretion of Palaeoproterozoic Fennoscandia to Sarmatia was concluded by the 1.8-1.75 Ga widespread anorthosite-rapakivi magmatism and associated underplating. The East-European Craton was then established as part of a continental mass much larger than that existing today. Shortly thereafter interplate rifting began, particularly in the suture zones separating the main segments. Only in the western parts of the EEC did orogeny continue to influence the craton margin, until the end of Mesoproterozoic (c. 1.0 Ga).

Outstanding Features

The EUROBRIDGE transect crosses a one thousand kilometre wide belt of juvenile Palaeoproterozoic crust that took about 400 million years to form. The geodynamic setting was that of a long-lived ocean-continent interface where new continental crust was generated by accretion and "soft collision" of newly formed island arcs with a craton growing from Archaean crustal nuclei. Thus the setting of the crust formation was fundamentally different from that of many collisional orogens where two continental masses collide

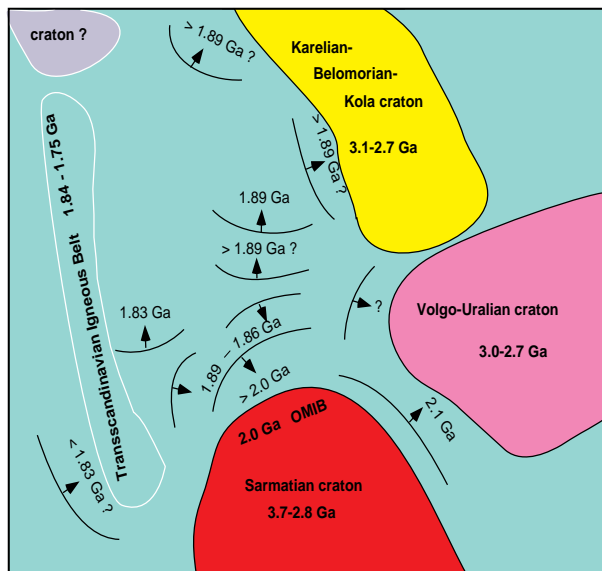


Figure 7.3: Sketch showing the axes of Svecofennian magmatic arcs and the times of Palaeoproterozoic accretion in the western part of the East-European Craton.

during a relatively short span of time.

The Palaeoproterozoic (Svecofennian) belts composing the EUROBRIDGE transect area may well have once been part of a late Palaeoproterozoic megacontinent, coherent with the Precambrian basement of northern Scotland, the Ketilidian of southern Greenland and the Penokean and other Palaeoproterozoic orogens in mid-continental North America; thus, the Svecofennides may have been part of the oldest coherent, extensive, non-collisional orogenic belt as yet identified on the Earth. This offers possibilities for comparison with similar, but younger, belts, like the late-Mesoproterozoic/Neoproterozoic orogens along the margins of post-Grenvillian Rodinia and the subsequent Palaeozoic-Mesozoic subduction/accretion complexes of the Altaiides.

Within this framework, some outstanding features are:

- 1) A geodynamic environment where episodically formed orogenic growth rims were successively accreted to cratons.
- 2) The attendant possibility to study the effects of compression, when focused along the active continental margin, on the previously formed Palaeoproterozoic crust further inland within the growing craton.
- 3) A remarkable pattern of alternating upper- middle- and lower-crustal rock belts with contrasting petrophysical properties. These are well recorded in the seismic images, and the gravity and magnetic fields.
- 4) A wide terrain where granulite and other high-grade metamorphic belts can be compared to each other. Some of these may have been created in the base of the volcanic arc during "soft collision", while others may represent uplifted segments of lower crust, exhumed in metamorphic core complexes, or are the products of stacking of already consolidated juvenile crust.
- 5) A belt of well-defined accretional-collisional tectonics along the Fennoscandian-Sarmatian suture, i.e. the site where the formation of the juvenile belt of Palaeoproterozoic crust commenced.
- 6) Huge post-orogenic massives of anorthosite-rapakivi igneous rocks in Sarmatia. These penetrate the entire continental crust and resulted in extensive modification of its lower units, and similar but smaller suites in the Fennoscandian areas of the Baltic States.
- 7) The presence of rift/aulacogen structures of Mesozoic and Neoproterozoic as well as Palaeozoic age that allow the study of the interrelationships between orogenic suture zones and the subsequent siting of anorogenic crustal failure and break-up.
- 8) The presence of rift-related, partly diamond-bearing volcanism in association with the aulacogens.

EUROBRIDGE RESEARCH

1. Deep seismic sounding (DSS) refraction and wide-angle reflection profile (*Minsk [IGS, GS], Copenhagen [U], Helsinki [U], Oulu [U], Potsdam [GFZ], Hamburg [U], Vilnius [LGI], Warsaw [PAS], Kaliningrad [SIO], Moscow [GEON], Uppsala [U], Glasgow [U], Kiev [IG]*).

A key part of the EUROBRIDGE project is the c.1500 km-long deep seismic sounding (DSS) refraction and wide-angle reflection profile (Fig. 7.4). It extends from the eastern coast of Sweden across the Baltic sea to Lithuania, Belarus and the Ukraine (Figs. 7.1, 7.2). The profile crosses all crustal units in the buried East-European Craton from the Fennoscandian to the Ukrainian Shields. It seeks to correlate surface and near-surface Precambrian structures with those of the deep crust and upper mantle. A particular concern are the important relationships between the belts of granulite and amphibolite-facies rocks within the Fennoscandian crustal segment; they have strongly contrasting petrophysical characteristics. The initial geological-geophysical interpretations of the seismic data indicate thickening of the crust in the northern part of this region and probable detachment of the granulite belts along rather flat discontinuities in the middle to lower crust (Fig. 7.2). The profile also crosses one of the most important structural boundaries in Europe, which separates the Sarmatian and Fennoscandian crustal segments of the Precambrian Craton from each other (Fig. 7.2). This intersegment suture ap-

pears to dip to the southeast, underneath Sarmatia following the position of the marginal late Palaeoproterozoic Osnitk-Mikashевичi Igneous Belt. The influence of the Meso- to Neoproterozoic (Riphean) and Palaeozoic platformal intraplate rifting and magmatism on geophysical images of the lithosphere in this region are being studied.

2. Magnetic, gravity and electrical conductance studies and integrated modelling (*Minsk [IGS, GS], Hannover [BGR], Vilnius [LGI], Warsaw [PAS, PGI], Uppsala [U], Kiev [IG]*).

The EUROBRIDGE study area is covered by detailed field geophysical surveys in the scale 1:200,000, and in certain areas where the mapping of the crystalline basement has been carried out, magnetic and gravity maps in the scale 1:50,000 are available. The preliminary modelling of the potential fields and available seismic data point to a very differentiated crust in terms of its density and magnetization. Sharp petrophysical distinctions of the crustal rock complexes are reflected in contrasting potential field anomalies with predominant magnetic highs in the granulite belts. Digitalization of potential field data is in progress. Magnetotelluric sounding has mainly been made in the Ukrainian Shield; it is proposed that the entire EUROBRIDGE transect should be studied. The Klaypeda magnetotelluric and heat flow anomaly is of a particular interest showing a conductive zone at c. 50

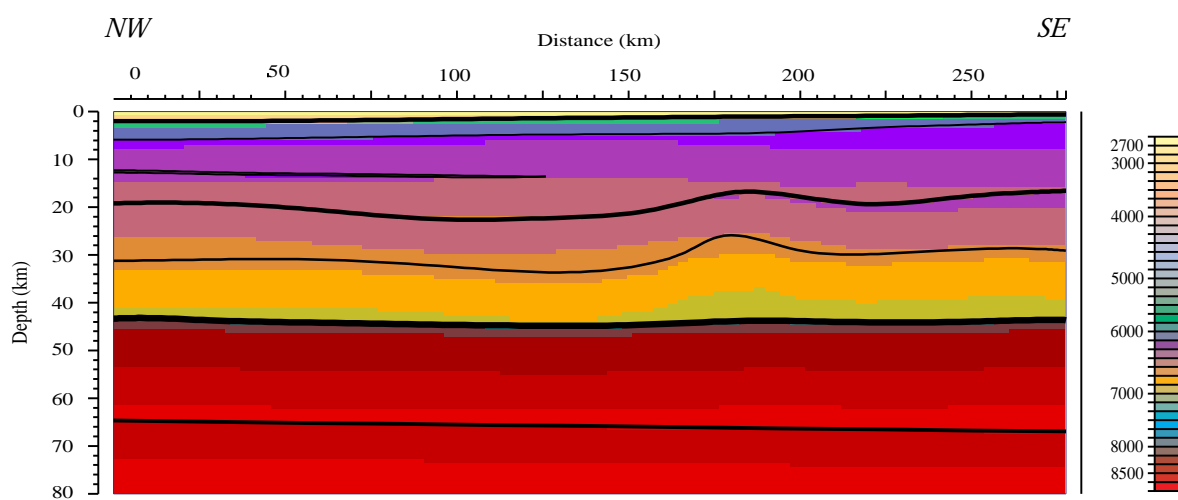


Figure 7.4: Preliminary interpretation of the lithospheric structure along the Lithuanian leg of the EUROBRIDGE transect (Giese et al., 1996).

km deep. Several conductivity anomalies in the crust outline clearly crustal discontinuities, similar to those in Finland.

3. Heat flow (*Minsk [IGS], Warsaw [PGI], Kiev [IG]*). The study area is characterized by a very inhomogeneous heat flow. The highest heat flow is exhibited along the intraplate Proterozoic and Palaeozoic rifts, and along the EEC margins. The relatively high heat flow is probably related mainly to increased radioactivity in the Belarussian and Lithuanian granulite belts. Its interpretation may thus constrain the amount of radioactive elements in the crust and support geochemical modelling of formation of the granulite belts.

4. Isotope ages and isotope chemical modelling of source materials and processes during the formation and evolution of the continental crust (*Moscow [VIGAC], Stockholm [MNH, U], Lund [U], Cambridge [MIT], Kiev [IGMO], Warsaw [PGI]*).

Identification of age provinces for distinguishing crustal terranes is an essential method for understanding the history of crust formation and for modelling the differentiation of crustal materials from the Earth's mantle and the recycling of earlier crustal components into the mantle. In view of the complex crustal structure in the study area, with distinct Archaean and Palaeoproterozoic terranes, much reconnaissance and detailed isotope work is in progress. The previous studies have provided the basis for the accretional/collisional model for the development of the Palaeoproterozoic belts in the Fennoscandian part; it is being used for integrated geological-geophysical interpretations. The isotope signatures of magmatism in the continental margin of Sarmatia can help to assess geometry and structure of Fennoscandia-Sarmatia junction with time.

5. Metamorphism and crustal dynamics by pressure-temperature (PT) estimations and construction of PT-time paths for different crustal units (*Minsk [IGS, GS], Vilnius [LGI], Warsaw [PGI], Moscow [VIGAC], Lund [U], Stockholm [MNH], Kiev [IGMO]*).

The remarkable alternation of the granulite and amphibolite-facies belts of different ages, both in the Fennoscandian and in the Sarmatian segments of the study area, allow identification of geodynamic regimes of crust formation and exhumation, and their interpretation in terms of plate-tectonic processes; they enable comparison of the regimes and processes in space and time. These studies are particularly important for the crystalline basement which is studied only in drillcores, with limited structural control and few direct observations of rock relationships. Pressure-temperature-time (PTt) paths give invaluable information about crustal development, even using small samples. Age determinations for metamorphic minerals, with different closure temperature, accompany the detailed petrological studies.

6. Igneous petrology as an indicator of Precambrian geodynamic environments (*Minsk [IGS, GS], Vilnius [LGI], Warsaw [PGI], Kaliningrad [SIO], Lund [U], Stockholm [U], Kiev [IGMO], Lvov [USGI]*).

Petrogenetic studies of unmetamorphosed and metamorphosed igneous rocks in the EUROBRIDGE region include analysis of major, minor and rare-earth elements and isotope geochemistry. These help to identify the different geodynamic environments for the magmatism and the possible plate-tectonic processes operational during crustal evolution. Many of the original characteristics of igneous rocks in EUROBRIDGE'S high-grade terrains are highly deformed and "healed" by metamorphism; detailed geochemical studies are required for their interpretation.

7. Study of xenoliths as a window to the deep crust and mantle (*Minsk [IGS, GS], London [U]*).

Xenoliths in Palaeozoic volcanic rocks brought up from lower crust and mantle depths are being investigated to assess composition, origin, age, pressure-temperature parameters in the lithosphere and to model geothermal gradients. Some of the xenoliths entrained in Palaeozoic volcanics from the Pripyat Trough are derived from the lower crust and can be compared with lower crustal xenoliths from elsewhere in the EEC, e.g. from Palaeozoic volcanics of the Kola Peninsula. The investigations of the Belarussian xenoliths can help to trace some of the Palaeoproterozoic lower crustal units beneath the Archaean crust of Sarmatia. Studies of lower crustal xenoliths in the Korosten pluton are of importance to determine the origin of the lower crust of the Palaeoproterozoic continent of Sarmatia.

8. Metallogeny and crustal evolution (*Minsk [IGS, GS], Vilnius [LGI], Warsaw [PGI, U], Stockholm [U], Kiev [IGMO], Lvov [USGI]*).

The study area features a range of ore deposits and minor mineralization both in igneous and in supracrustal rocks of various ages and tectonic positions. This provides the opportunity to study metallogenic processes in the Precambrian, to apply plate-tectonic approaches to the prospecting of economically important deposits, and in general to assess the economic potential of the region.

9. Palaeomagnetism of Precambrian (*St. Petersburg [VNIGRI], Lund [U], Luleå [U], Warsaw [PAS]*).

The task of this subproject is to assess the relative positions of the crustal segments of the East-European Craton through time. The on-going palaeomagnetic investigations of Palaeoproterozoic rocks indicating different positions of the Fennoscandian and Ukrainian Shields (Elming et al., 1993) are being expanded to include studies of the Voronezh Massif, the Osnitsk-Mikashevichi Igneous Belt in Belarus and other crustal units of Sarmatia. Studies of Vendian basalts and dykes will help test hypotheses that re-

quire significant rotation of Baltica in the early Palaeozoic, hypotheses that throw doubt on many trans-Atlantic Palaeoproterozoic correlations.

10. Basement-cover relationships and intraplate rifting (Minsk [IGS], Vilnius [LIG], Kiev [IG], Amsterdam [VU], Utrecht [U], Lund [U]).

The deposition of thick Meso- to Neoproterozoic and Palaeozoic sediments in the Volhyn-Orsha and other aulacogens and related structures in the study area was clearly controlled by rifting along Palaeoproterozoic fault zones. By contrast, the Pripjat-Dniepr-Donets Trough truncates previous structures. In this project, the different amounts and mechanisms of deformation and reorganisation of Precambrian lithosphere will be studied. It is expected that these studies will shed light on some of the observed anomalous properties of the lithosphere and their relevance to the distribution of hydrocarbons and other mineralisations both in the basement in its platformal cover. The hydrocarbon resources of the platformal sediments in Lithuania, Belarus, Russia (Kaliningrad area) and the northern Ukraine are of great industrial interest.

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