INTRODUCTION

Nine EUROPROBE projects are now in operation in Europe, spanning the subcontinent from Iberia to the Urals; a tenth is located in Jakutia. As the research base widens and funding improves, Europrobians feel increasingly confident that they have established a way of working that will carry them well into the 21st century – partnerships integrating the solid earth sciences, partnerships across the national borders and, increasingly, partnerships with industry. EUROPROBE is one of ESF´s most "pan-European" projects and we are proud of it.

1996 has seen some organizational changes, with Hermann Zeyen now firmly in the saddle in Uppsala and the ESSC strengthened by the return of Enric Banda and newcomers Jörg Ansorge, Vitaly Starostenko and Marjorie Wilson. A comprehensive documentation of EUROPROBE science is in press and will reach you by Christmas. It provides a full overview of our activities – accomplished, on-going and planned, up to early 1996. As EUROPROBE has moved from the planning to the operational mode, publications have multiplied and we now have three Tectonophysics and a Geological Magazine volume either in press or in the final stages of preparation; others are on line. 1995´s highlight, URSEIS, most of you will have read about in “Science“ (Oct 1996).

EUROPROBE workshops in 1996 have ranged from the Crimea to Finland and westwards via the Sudetes to Iberia. These meetings provide the essential forum for integration of the geology, geophysics and geochemistry; the programmes are dominated by presentations of research results, but with time reserved for detailed planning of new operations. The importance of the ESF workshops for keeping the science integrated cannot be overemphasized. Research results can be suitably (indeed better) presented at international conferences and symposia; but all too seldom do the latter provide the right forum for communicating across the disciplines.

Most of the dozens of EUROPROBE research partnerships involve only a few key players and modest funding (including PhD or post-Doc programmes, lab. expenses, travel money, etc). A few are major operations involving several institutes, and this is particularly the case with our geophysical projects. URSEIS 1995 was the most ambitious so far. TOR (teleseismic tomography across the TESZ) is now in operation. And a vast one (probably the largest wide angle seismic experiment ever in Europe) is planned with American colleagues for 1997 in central Poland, covering the Polish Trough, with four long-range DSS lines, recording c. 50 shots on 600-700 stations. In addition, we welcome DEKORP´s on-going commitment to the TESZ, with deep reflection seismic profiling from the southern Baltic, across the East German Basin to the Harz Mountains.

Although national budgets dominate the financing of EUROPROBE science, we have been increasingly successful both in acquiring INTAS funding for CIS colleagues (note that there is a new INTAS call for proposals in December 1996) and obtaining EU-funding (e.g. TMR Network for the URALIDES). Programmes concerned with Natural Hazards and Resources also provide opportunities for EUROPROBE. Take them!

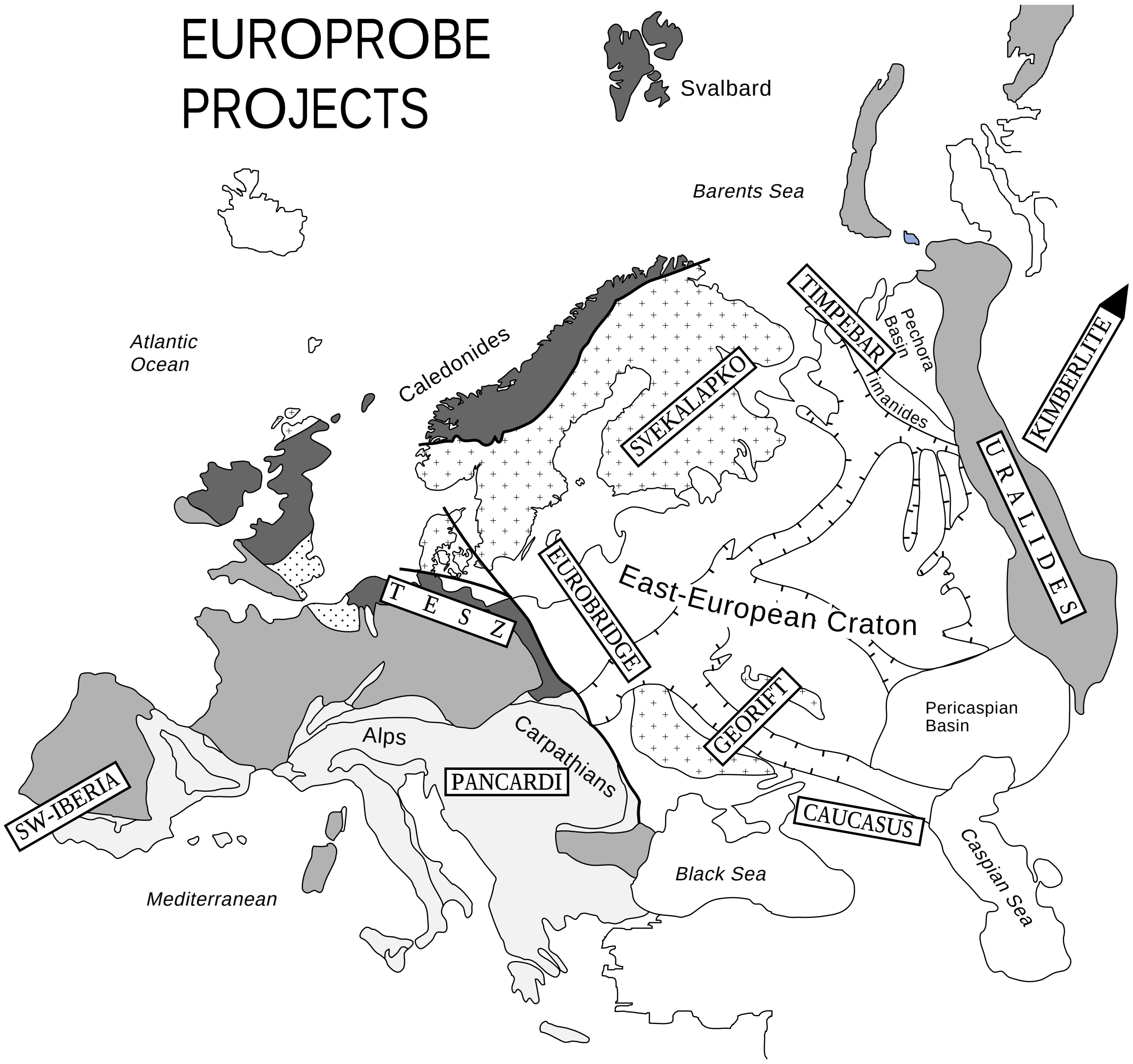
EUROPROBE meetings for 1997 (see p 24) include a range of project workshops and a few other important venues – EUG symposia in Strasbourg, EGS in Vienna and IASPAE in Thessaloniki.

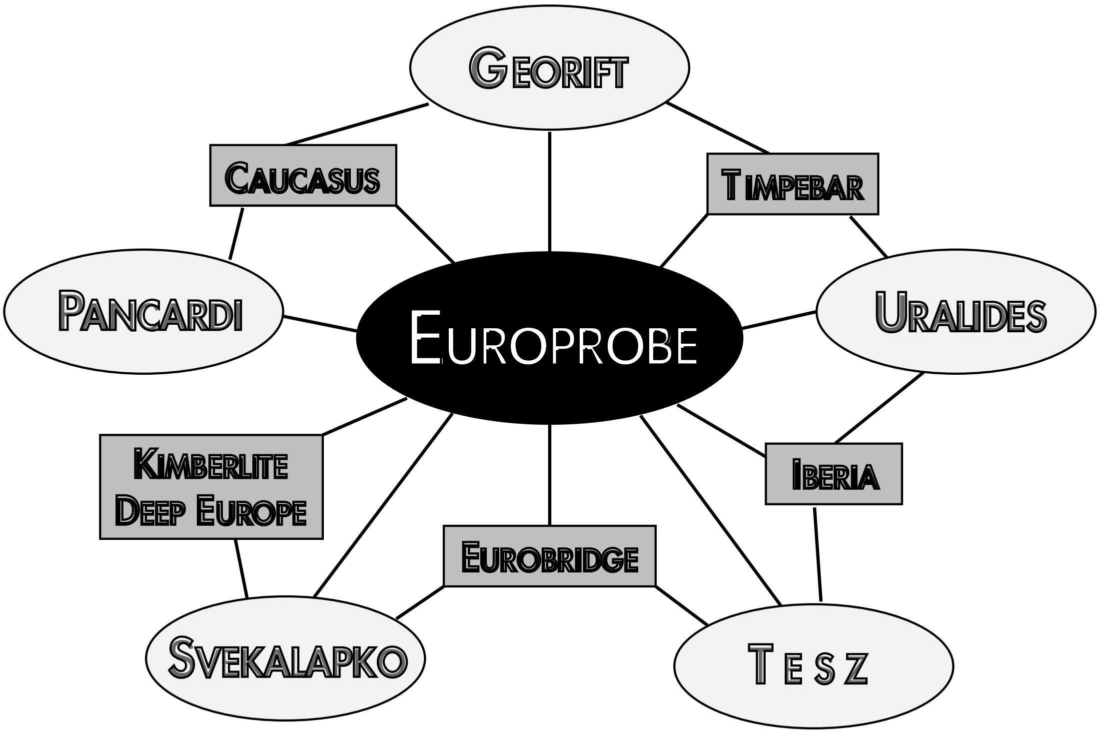
Looking further ahead, it is clear that, with EUROPROBE research activities expanding fast, many of the PhD and post-Doc projects that are starting now will carry on to end of the century. Major geophysical experiments provide data for several years´ research. As the ten projects grow and gain in strength, the need for the ESF workshop programme increases, these project meetings providing the interdisciplinary cohesion that is essential for all major lithosphere investigations. ESF´s present programme “EUROPROBE“ is scheduled to be supported through 1998. The ESSC will apply to ESF for a five year continuation of this programme in the knowledge that this application is strongly supported by the Ministries and Academies in the CIS. If you support the continuation of the EUROPROBE workshop programme into the next century, make this clear to your funding agencies.

Christmas is approaching fast. 1996 has been a hard year for CIS colleagues, but a good one for EUROPROBE collaboration. The Secretariat in Uppsala sends greetings to friends across Europe, wishing you all good health and a prosperous 1997.

David G. Gee
Uppsala

EUROPROBE PROJECTS





EUROPROBE PROJECTS

EUROPROBE today has a programme of ten projects. Those that started in the early 1990's are in full swing, with a wide range of new research activities; others started later and are still working with existing data and designing new experiments. The numerous PhD and post-Doc projects, which are the heart of EUROPROBE research, will continue at least to the end of the 1990's.

The project presentations have been written by the project leaders in collaboration with the participants in their various subprojects. Each presentation provides a project summary, a general background, identification of outstanding features and, finally, concise descriptions of the subproject research, on-going or planned. All subprojects are collaborative ventures between western, central and eastern European partners that have been discussed and defined at EUROPROBE workshops.

The projects fall into three categories: "Key Projects", "Other Major Projects" and "Developing Projects". "Key Projects" are major collaborative ventures where most of the subprojects are operational and some have completed major experiments or will start them in the near future. Orogenic processes provide the focus for most of the "Key Projects". They are presented below in order of "age" from on-going (PANCARDI), through Palaeozoic (URALIDES and TESZ) to Palaeoproterozoic-Archaean (SVEKALAPKO). Intracratonic and craton-margin basin evolution is the concern of the fifth key project (GEORIFT). "Other Major Projects" include three projects, EUROBRIDGE, SW-IBERIA and TIMPEBAR, in which the science plans are fully defined and research is making substantial progress. "Developing Projects" include two (CAUCASUS and KIMBERLITE), the former active, but suffering from the adverse political situation in this part of southern Europe; and the latter, with a focus in Siberia, making modest progress.

EUROPROBE'S ten projects provide the basis for integrated, comparative analysis of the contrasted signatures of the Continental Lithosphere and the processes that control its generation and modification.

Key Projects

PANCARDI	Dynamics of On-going Orogeny
URALIDES	A Key to Understanding Collisional Orogenesis
TESZ	Phanerozoic Accretion and the Evolution of Contrasting Continental Lithosphere
SVEKALAPKO	Evolution of Palaeoproterozoic and Archaean Lithosphere
GEORIFT	Geodynamics of Intracratonic Rifting

Other Major Projects

EUROBRIDGE	Palaeoproterozoic Accretion of Sarmatia and Fennoscandia
SW-IBERIA	Transpressional Orogeny in the Variscides
TIMPEBAR	Basement Control of Basin Evolution

Developing Projects

CAUCASUS	Geodynamics of Collision-Related Basins
KIMBERLITE	Structure and Evolution of Cratonic Lithospheric Roots

PANCARDI

Dynamics of On-going Orogeny

by Œstmír Tomek (Salzburg) and PANCARDI colleagues

The Pannonian Basin-Carpathian arc-Dinaride (PANCARDI) system offers an outstanding opportunity to study the interaction of asthenospheric and lithospheric processes and their mutual dependencies during volcanic arc and related fore- and back-arc basin development. The evolution of the highly arcuate Carpathians is driven by the inter-related processes of subduction, slab roll-back, plate boundary retreat into a continental embayment, asthenospheric upwelling, and lateral extrusion of the eastern Alps and Dinarides-Balkan orogens. The arc is unique in providing a snapshot of still-active, soft collision between the Carpatho-Pannonian and Eurasian plates. Another remarkable feature of the region is the interplay of contraction, strike-slip and extension which led to the formation of the Pannonian Basin, with the coeval radial displacements of nappes and the progression of volcanism during formation of the Carpathian arc. This scenario and the seismicity in the Vrancea zone, apparently related to slab detachment, provide key constraints on the relative role of lithospheric and asthenospheric driving mechanisms during orogeny.

The PANCARDI region, with its subaerial exposure and large existing data base, provides a ready opportunity for gathering new information critical to our understanding of orogen dynamics.

Within the context of a multidisciplinary investigation of the whole lithosphere, PANCARDI has a particular focus on the following main goals:

1) Reconstructing the Neogene to Quaternary evolution of the arc-basin system, with kinematic and palaeomagnetic constraints contributing to the palinspastic restoration of the orogen.
2) Relating the long-term processes of subduction, arc formation and basin development to the neotectonics and the ongoing seismicity, providing a basis for seismic hazard assessment and earthquake engineering in this densely populated area.
3) Understanding the origin of the nearly vertical Vrancea slab, as it is defined by seismicity in the mantle below the foothills of the eastern Carpathians.
4) Establishing the Miocene to Recent magmatic history of the Carpathian arc; defining the sources of the calc-alkaline and alkaline magmas that were coupled in time and space to the west-to-east progression of deformation in the foreland fold and thrust belt.
5) Understanding the chemical evolution of the mantle lithosphere beneath the Pannonian Basin and the relative importance of subduction and plume-related processes.
6) Assessing the significance of collisional thickening, extensional unroofing and lateral extrusion in the eastern Alps and Dinarides for Pannonian Basin development.

URALIDES

A Key to Understanding Collisional Orogeny

by Andrés Pérez-Estaún, Dennis Brown (Barcelona)
and URALIDES colleagues

The Uralide orogen is one of Earth's great structural discontinuities. It is the geographic and geological divide between Europe and Asia. Together with the Appalachian, Caledonian and Variscan orogens, it was one of the major zones of continental convergence that contributed to the assembly of the late Palaeozoic supercontinent Pangaea. Wedged between the East-European Craton to the west and the Angara Craton to the east, the Uralides include a 2500-km-long suture zone that juxtaposes a collage of accreted oceanic, island arc and microcontinental terranes against a west-vergent thrust stack of foreland basin and continental margin rocks.

Although the Uralide orogen has many features in common with other Palaeozoic orogens, it has a number of important distinguishing characteristics; not least, it remains more or less intact, uninfluenced by Mesozoic or Tertiary sea-floor spreading. Some of these unique characteristics offer opportunities for significant advances in our general understanding of orogenesis.

A major objective of EUROPROBE'S URALIDES Project is a multidisciplinary investigation into the structure and evolution of the Uralide orogen. In addition to resolving key problems related to the general architecture and formation of the orogen itself and to the assembly of Pangaea, several other world-class issues will be addressed, as follows:

1) Studies of anomalously thick crust along the axis of the orogen may yield clues as to how mountain roots are generated and preserved.
2) Exceptionally well-preserved ophiolites and volcanic-arc assemblages, which extend throughout the length of the mountain belt, allow processes associated with Palaeozoic ocean crust formation and subduction to be explored.
3) Mechanisms that control the exhumation of crustal material from great depth (50-80 km) will be examined through investigations of spectacular outcrops of high pressure metamorphic rocks.
4) The well-documented peneplanation of the mountain belt by the Jurassic and the relatively recent anomalous uplift history lend the Uralides to studies of post-orogenic exhumation and uplift mechanisms.
5) Comparison of seismic reflection data with very deep borehole information (current depth of the Uralian superdeep drillhole is 5.3 km; target depth is 15 km) should provide new constraints on the origin of seismic reflections from crystalline crust.

TRANS-EUROPEAN SUTURE ZONE

Phanerozoic Accretion and the Evolution of Contrasting Continental Lithospheres

by Tim Pharaoh (British Geol. Survey, Keyworth) and TESZ colleagues

The Trans-European Suture Zone (TESZ) is the most prominent geological boundary in Europe, separating mobile Phanerozoic terranes in the south and west from the Precambrian East European Craton. This complex fundamental structure crosses northwest-southeast through central Europe, from the North Sea to the Black Sea, a distance exceeding 2000 km. It is as clearly defined in the deep lithosphere as in the upper crust, Moho depths increasing across the TESZ from c. 30 km beneath Phanerozoic Europe to c. 45 km beneath the craton. Relatively high heat flow characterises Palaeozoic western Europe, in marked contrast to the thick, relatively cold, Precambrian eastern craton.

EUROPROBE studies of the crust and upper mantle along the TESZ and its margins are allowing new interpretations of the thermo-mechanical processes of Phanerozoic lithosphere accretion. The TESZ is a key enigmatic element in the evolution of the Palaeozoic orogens; together with EUROPROBE'S URALIDES project, TESZ will provide new insights into pre-Mesozoic plate tectonics and the assembly of Pangaea.

Understanding the contrasting signatures of European deep lithosphere requires detailed analysis of the Phanerozoic tectonic history across the TESZ and correlation of deep and shallow crustal structures. The Palaeozoic structures are largely obscured by Mesozoic and younger strata of the North Sea-Danish-North German-Polish Basin; a detailed analysis of this basin complex and its partial inversion is required to unravel the enigmatic early Phanerozoic history of this major suture zone. Reconstruction of the Palaeozoic history is also being much assisted by analysis of the numerous deep drillholes which penetrate the pre-Permian basement.

Highlights of EUROPROBE'S multidisciplinary TESZ project include:

1) Teleseismic and regional earthquake tomography experiments defining the complex suture in the mantle beneath the TESZ that appears to extend through the whole lithosphere into the asthenosphere.
2) Determination of variation in Moho depth and lithospheric velocity structure across this fundamental suture zone by seismic refraction – wide angle reflection experiments.
3) Correlation of deep and shallow structures of Proterozoic and Phanerozoic lithosphere by deep seismic reflection and magnetotelluric tomography experiments.
4) Deciphering the tectonothermal history of Palaeozoic terrane accretion in central Europe by multidisciplinary analysis of drillcores and outcrops.
5) Integrating the tectonothermal history of the TESZ with that of the better exposed Palaeozoic orogens of the Appalachians, Western Europe and the Uralides to better understand the assembly of Pangaea.
6) Comparison of Permian-Mesozoic subsidence and Cenozoic inversion of sedimentary basins overlying the contrasting lithospheres on each side of the suture.

SVEKALAPKO

Evolution of Palaeoproterozoic and Archaean Lithosphere

by Sven-Erik Hjelt (Oulu), Stephen Daly (Dublin)
and SVEKALAPKO colleagues

One of the best places on Earth for studying the thermal and mechanical processes controlling the evolution of ancient lithosphere is the Fennoscandian Shield. This well-exposed, composite craton, cored by the Late Archaean granite-greenstone Karelian belt, and flanked to the northeast and southwest by Palaeoproterozoic orogens, is ideal terrain for testing plate tectonic theory and seeking to understand the contrasted signatures of Archaean and Proterozoic lithosphere. Ophiolites, magmatic arcs, fore- and back-arc basins and accretionary wedges are identified with confidence in the Proterozoic; their presence in the Archaean is conjectural. The Svecofennian Orogen, dominating much of Finland and Sweden, resulted in the accretion of vast volumes of thick juvenile crust; by contrast, in Russia north of Karelia, the Lapland-Kola Orogen is predominantly composed of Archaean crust, reworked during the Palaeoproterozoic.

A considerable geological, geochemical and geophysical data base provides the foundation for focused new EUROPROBE investigations. Deep seismic refraction profiles have defined the velocity structure of the shield; shallow CMP reflection profiles in Russia give unique insight into upper crustal structure. Deep and superdeep drillholes (including Kola) provide exceptional opportunities for calibrating further geophysical data.

EUROPROBE'S multidisciplinary investigation of the Fennoscandian Shield SVEKALAPKO: (SVEcofennian-KArelia-LAPland-KOla) focuses on the following key issues:

1) Establishing the character of the deep lithosphere (lower crust and upper mantle) and its relationship to the asthenosphere below the different parts (Lapland-Kola, Karelia and Svecofennia) of the Fennoscandian Shield. The latter provides unusually favourable bedrock conditions for major geophysical experiments aimed at defining lithosphere-asthenosphere relationships, particularly electromagnetic probing and deep tomography studies. An important target is the deep structure of the highly anomalous (c. 60 km thick) juvenile Svecofennian crust, where correlation with gravity data and topographic relief are lacking.
2) Defining the crustal evolution across the Shield to establish the timing of formation of the different major structures and their relationship to the underlying deeper lithosphere; this will provide insight into ore genesis and contribute to further exploration efforts. Particular interest concerns:
    a) The Archaean evolution of the Karelian terrane and the extent to which it has been reworked in post-Archaean time.
    b) The Proterozoic suturing, with the local preservation of ophiolites and prominent boundaries between reworked Archaean and juvenile Proterozoic rocks.
    c) The evidence for subduction-related magmatism and development of Proterozoic fore- and back-arc basins.
    d) The analysis of crustal and upper mantle xenoliths.
    e) The effects of Palaeozoic (Devonian), potentially plume-related magmatism on lithospheric structure of the Kola-White Sea areas.

The Fennoscandian Shield is a key element in the reconstruction of the Laurussian mega-continent. EUROPROBE studies will promote integration with Canadian Lithoprobe geoscience.

GEORIFT

Geodynamics of Intracratonic Rifting

by Randell Stephenson (Amsterdam) and GEORIFT colleagues

Precambrian cratons form the oldest and most stable parts of the Earth's lithosphere. Their sedimentary cover preserves a long and detailed record of intraplate deformations, ranging from rifting, hot-spot magmatism and the uplift of broad arches, to thermal subsidence of intracratonic basins, compressional reactivation with basin inversion, and crustal and lithospheric buckling. These deformations reflect changes in the intraplate stress regime and must be related to plate boundary and mantle processes. The East-European Craton (EEC), largely covered by Phanerozoic sedimentary successions, forms the core of Europe and consists of a collage of continental and arc-related terranes that were welded together during Proterozoic times. The overlying East-European Platform (EEP) sedimentary succession represents one of the globe's best natural laboratories for studying the response of craton lithosphere to changing tectonic stress regimes. In particular, Devonian and Early Carboniferous rifting of EEC lithosphere reflects a fundamentally different tectonic setting to that of the North American part of what was then one contiguous continental plate; this has important implications for understanding the driving mechanisms of intracratonic rifting.

GEORIFT addresses the mechanisms of rifting by means of regional studies of the Late Proterozoic-Palaeozoic sedimentary basins of the EEP as well as by detailed analysis of the exceptionally well documented Pripyat-Dniepr-Donets (PDD) Basin, the largest and deepest Late Palaeozoic rift in Europe. Highlights of GEORIFT include:

1) Availability of a vast geological and geophysical data base, permitting development and quantitative testing of tectonic and tectono-sedimentary models and their comparison with neotectonic analogues.
2) Analysis of the entire geodynamic record of the EEC from the Riphean to the Present concentrating on the Late Palaeozoic, a period of exceptionally intense rifting, causing the development of major sedimentary basins, some of which host important hydrocarbon provinces.
3) Integrated geological-geophysical study of the PDD basin with its exceptionally well documented structural and stratigraphic record, to better understand the interplay of tectonic, magmatic, climatic, eustatic, and other processes during the evolution of rifted intracratonic sedimentary basins.
4) Potential to resolve fundamental questions about the dynamics of rifting and basin inversion and tectonic controls on post-rift subsidence and sedimentation.
5) Comparison of the evolution of the EEC, in a plate tectonic framework, with that of the North American and other cratons in order to distinguish relative sea-level changes induced by intraplate deformations from those related to eustatic fluctuations.
6) Development of proposals for acquisition of new deep seismic near-vertical and wide-angle reflection surveys across the PDD basin and other sedimentary basins of the EEC.

EUROBRIDGE

Palaeoproterozoic Accretion of Sarmatia and Fennoscandia

by Svetlana Bogdanova (Lund) and EUROBRIDGE colleagues

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 drillcores 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.

SW-IBERIA

Transpressional Orogeny in the Variscides

by Antonio Ribeiro (Lisbon), David Sanderson (Southampton)
and SW-Iberia colleagues

The Variscan orogen in southwestern Iberia offers a unique opportunity to image and study a transpressional orogen and to examine the partitioning of deformation in 3-dimensional space and time. The region consists of a series of zones representing different tectonostratigraphic units exposed at a variety of structural levels. Varying components of shortening and left-lateral strike-slip deformation have been recognised from field studies and from geodynamic models, such as the indentor model of the Ibero-Armorican arc. Studies of the structure, stratigraphy, metamorphism, magmatism and palaeogeography will allow a reconstruction of the geometry and history of this important class of orogens produced by oblique collision of lithospheric plates.

The principal aim of this multidisciplinary project is to better understand orogeny resulting from oblique collision. This will be achieved by imaging the crust at different structural levels through collaborative work on existing data, geological and geophysical investigations of critical areas and acquisition of new seismic reflection profiles through the orogen. The seismic profiles will be fully integrated with the surface geology and provide images deep into the mantle, thus, providing a critical 'missing link' in the imaging of the Variscan orogen in Europe.

Within the Variscan of SW-IBERIA are some of Europe’s most important Volcanic Massive Sulphide ore deposits (Rio Tinto, Neves-Corvo, etc.). The tectonic setting and reconstruction of the ore bodies requires detailed stratigraphical and structural studies; this project will provide new concepts for further exploration.

The SW-IBERIA project will focus on the following main goals:

1) Imaging of the lithosphere using deep seismic reflection profiling, wide-angle studies, magnetotelluric and other geophysical experiments.
2) Testing of transpressional models through mapping of strain variation through the different structural zones. This, together with the geophysical imaging will allow testing of thick-skinned versus thin-skinned models of deformation, and constrain estimates of shortening and displacement at crustal and lithospheric scales.
3) Reconstruction of the pre-collisional (North Gondwanan) and syn-collisional palaeogeography of the crustal units using sedimentary, faunal and palaeomagnetic studies to constrain the timing and position of orogenic processes.
4) Examination of the boundaries (sutures) and associated rocks (high grade metamorphics and ophiolites), in order to constrain the processes of continental collision.
5) Examination of the origin, setting and timing of magmatism and metallogenesis to constrain emplacement mechanisms and crustal evolution.

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 ongoing 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 Uralide 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 drillholes 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 Uralide foredeep basins.
7) Acquisition of selected new regional deep seismic profiles both on- and off-shore (CMP and wide-angle, comparable to URSEIS), to obtain an image of the crust and upper mantle, permitting analysis of their response to a sequence of contractional and extensional events.

CAUCASUS

Geodynamics of Collision-Related Basins

by Riccardo Polino (Torino), Randell Stephenson (Amsterdam) and CAUCASUS colleagues

The Caucasus forms a linear collisional mountain belt, along the southern border of the East-European Platform, separating the latter from the Arabian / Turkish plates. In contrast to the mostly arcuate Alpine belts, this Cenozoic orogen allows the study of a simple relationship between collisional kinematics and the geodynamic processes leading to the formation of a foreland basin. Since this relationship is relatively well controlled, observed lateral variations in the style of the North Caucasus Foredeep Basin (NCFB) can be mainly related to pre-existing (Mesozoic) crustal inhomogeneities, which determined the development of the basins in different crustal configurations. As such, this example of simple kinematics offers a unique opportunity to understand the birth and early evolutionary stages of foredeep basins and forms the basis for comparison with different, more evolved collisional belts and their forelands.

The NCFB represents one of the best natural laboratories for studying sedimentary evolution in response to crustal and upper mantle deformation. The EUROPROBE CAUCASUS Project focuses mainly on comparative studies of the evolution of the basins developing on the northern slope of the Great Caucasus, the analysis of basin fill, the relationships between deep and superficial structures, the distribution of palaeo- and present-day stress fields and geodynamic modelling. The application of space geodetic techniques will give rates of horizontal and vertical deformation in order to provide boundary conditions for geodynamic models.

The main goals of the CAUCASUS Project include:

1) Deciphering the tectonic history of the northern Caucasus by multidisciplinary analysis of the geological record of Cenozoic sedimentary basins and their underlying (and partly overthrust) crust.
2) Reconstruction of the palaeostress and strain regimes (kinematics and dynamics).
3) Linking the present-day stress regime to observed (geodetic) and palaeotectonic vertical and horizontal movements through geodynamic modelling.
4) Exploiting existing geological and geophysical data sets for quantitative modelling of tectonic and tectono-sedimentary processes.
5) Construction of palaeogeographic maps for the period of development of the foredeep.
6) Redefinition of the crustal structure and basement controls on sedimentary basin development and deformation from existing geophysical data and definition of targets for new deep seismic near-vertical and wide-angle reflection surveys across the western foredeep (Indola-Kuban).
7) Comparative studies of the evolution of the NCFB and other foredeeps of the peri-Mediterranean region.

KIMBERLITE

Structure and Evolution of Cratonic Lithospheric Roots

by Stephan Sobolev (Moscow, Strasbourg), Karl Fuchs (Karlsruhe) and KIMBERLITE colleagues

The Precambrian cratons are characterized by deep lithospheric roots; the latter are apparent as geoid highs and as positive velocity anomalies in global seismic tomographic images down to a depth of 200-300 km. These roots are explained by a variety of hypotheses, ranging from cooling of an old lithosphere to chemical differentiation. EUROPROBE'S KIMBERLITE project aims at clarifying the origin and evolution of the deep cratonic lithosphere, combining geochemical and petrological investigation of xenoliths from kimberlites and basalts with geophysical studies for definition and characterization of deep structures.

Kimberlites and lamproites seem to be always related to thick Archaean and Palaeoproterozoic cratonic lithosphere. Their ages are mainly Phanerozoic, but range back to the Mesoproterozoic, eruptions occurring often in relatively small areas over a long time span. The magmatic rocks as well as the xenoliths shed light on the mineralogical composition, fluid content and thermal evolution of the lithosphere and asthenosphere at depths down to at least 250 km. Geophysical, especially different seismic methods, are able to define structures in the deep lithosphere, such as shear zones or chemical layering, which may give clues to the origin of the lithospheric roots and kimberlite magmatism.

The Yakutian province in Siberia and the Arkhangelsk province in northern Europe are major kimberlite areas. The former offers an outstanding data base of xenoliths and exceptionally detailed crustal and uppermost mantle seismic data. The KIMBERLITE project therefore focuses on studies in this area, exploiting existing and contributing new data. Highlights of KIMBERLITE studies include:

1) Reinvestigation of the detailed seismic images of the crust and upper mantle, showing azimuth-independent very high velocities (8.8-9.0 km/s).
2) Exploitation of very long-range seismic profiles sourced by peaceful nuclear explosions (PNE), giving high resolution information about upper mantle structures, including the transition zone down to c. 670 km depth, and characterization of small scale heterogeneities in the scattered wave fields.
3) Search for anisotropy (both structural and mineralogical) in the upper mantle, as an indicator of processes in the lithosphere, asthenosphere and deeper levels, by observation of birefringence of seismic S-waves in broad band recordings.
4) Study of a large number of diamondiferous kimberlite and lamproite pipes, which are commercially exploited, ranging in age from 450 to 150 Ma, with numerous crustal and mantle xenoliths, derived from depths of down to 250 km.

CONTRASTING SIGNATURES OF THE LITHOSPHERE

Structure, composition and evolution of the continental lithosphere-asthenosphere system

by Jörg Ansorge (Zürich), Hermann Zeyen (Uppsala)
and Deep Europe colleagues

Understanding the evolution of the continental lithosphere through geologic time is one of the prime goals of the Earth Sciences. The joint efforts of geoscientists during the recent decades have revealed the complexity of the processes that have caused the present structure and state of the lithosphere-asthenosphere system. Precise knowledge of structure and understanding of tectonic processes, however, are to a large degree still limited to the crust. Plate tectonic and global geodynamic models underline the relevance of upper mantle structure and dynamics for the evolution of the overlying structure.

The study of the evolution of the continental lithosphere-asthenosphere system involves such intriguing questions as:

1) How do mountain ranges form and lose their roots?
2) Can a “normal cooling” history of crust, lithospheric mantle and possibly tectosphere be defined and if so, what are its characteristics?
3) What are the sources of thermo-mechanical events such as the rise of mantle plumes or the initiation of rifting, subduction and back-arc spreading, and what are their effects on continental lithosphere in different evolutionary stages?
4) Are the geodynamic processes acting today similar to those that have acted during the Archaean and Early Proterozoic?
5) How does the continental lithosphere grow and change its characteristics through time?

INTAS

INTERNATIONAL ASSOCIATION FOR THE PROMOTION OF COOPERATION WITH SCIENTISTS FROM THE INDEPENDENT STATES OF THE FORMER SOVIET UNION

The new call for proposals will be announced in mid December '96 (closing date early April '97). EUROPROBE lithosphere partnerships are tailor-made for the INTAS programme. So far, the GEORIFT, URALIDES, CAUCASUS and SVEKALAPKO projects have been successful. Good luck in the new round!

TIMING AND TECTONIC SETTING OF NEOGENE MAGMATISM IN THE PANNONIAN BASIN AND CARPATHIAN ARC

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Introduction

Neogene magmatism in the PANCARDI region can be broadly classified into two types (Szabó et al, 1992): (a) an earlier phase of volcanism of calc-alkaline affinity, identical in its petrography and geochemistry to subduction-related magmatic rocks from all over the world; (b) a generally later phase of alkaline volcanism, which is extremely similar to the late Tertiary/Quaternary intraplate activity found elsewhere in Europe (Wilson and Downes, 1990). In this report, we will discuss the timing of this magmatism and attempt to relate it to different stages in the tectonic evolution of the PANCARDI region. For a more detailed review of all aspects of PANCARDI magmatism, a Special Issue of the journal of the Italian Volcanological Association "Acta Vulcanologica" (volume 7) has recently been published on this topic.

Areal distribution of PANCARDI magmatism

Fig. 1 shows the areal distribution of the volcanics as compiled by Pecskay et al. (1995). A large volume of the earliest volcanics is buried in the Pannonian and Transylvanian Basins, although some outcrops also occur around the edges of the basins. Much of this material is highly siliceous acidic pyroclastic tuffs and ignimbrites, which may have travelled far from their source areas, and in general the precise source areas of these deposits is unknown.

The main outcropping calc-alkaline volcanoes are dominantly intermediate (andesitic) in composition and form a generally arcuate chain in the Western Carpathians, trending W-E from central Slovakia and northern Hungary into eastern Slovakia (localities 11-21 on Fig. 1). In the Ukrainian Carpathians, the trend of the chain becomes NW-SE and in the Eastern Carpathians of Romania, NNW-SSE (localities 26-30). An exception to this geographic trend is the calc-alkaline volcanism of the Apuseni Mts. situated between the Transylvanian and Pannonian Basins.

The alkaline magmatism is equally widespread, occurring sporadically across the whole of the region from the Graz Basin to the Persanyi Mts. of the Transylvanian Basin. The main regions of alkaline activity are on the northern margin of Lake Balaton (locality 2) and in the region of southern Slovakia/northern Hungary near Nograd-Novohrad (locality 13). However, alkaline volcanics are absent in eastern Slovakia, Ukraine and most of the Eastern Carpathians of Romania. Alkaline magmatism consists mostly of small basaltic cinder-cones and lava flows. Many of these primitive basalts carry mantle-derived xenoliths (Downes et al., 1992; Vaselli et al., 1995) which give us an insight into the composition of the lithospheric mantle beneath the region.

Timing and tectonic setting of magmatism

Detailed and accurate geochronology is crucial to enable us to understand the relationship between magmatism and tectonic events. A first-order observation is that the alkaline magmatism post-dates the calc-alkaline eruptions throughout the area. Only at the very southern part of the Eastern Carpathians are the two types of magmatism contemporaneous. This clearly indicates a strong relationship between magmatism and tectonic activity, i.e. calc-alkaline magmatism is related to collisional events, whereas the alkaline type relates to extensional events.

Previous work had indicated that the age of the calc-alkaline volcanism became progressively younger from west to east around the Inner Carpathian arc. Recently, Pecskay et al. (1995) compiled and reviewed all of the available geochronological data, based largely on K-Ar age determinations (Fig. 2). Their remarkable conclusion was that much of the age-trend was not valid and, instead, acid magmatism began in several regions 19 Ma ago, followed by the formation of andesitic stratovolcanoes along the Western Carapthian arc at ca. 16 Ma. The majority of these calc-alkaline volcanoes were extinct by 10 Ma, an age which coincides with a major E-W compressional event in the region, which Decker and Peresson (1995) suggest was related to the entry of continental crust into the subduction zone (i.e. cessation of subduction of oceanic crust). Only in the Eastern Carpathians (from the Gutii volcanic area to the south Harghita volcanoes) do we see a significant age-progression along the chain

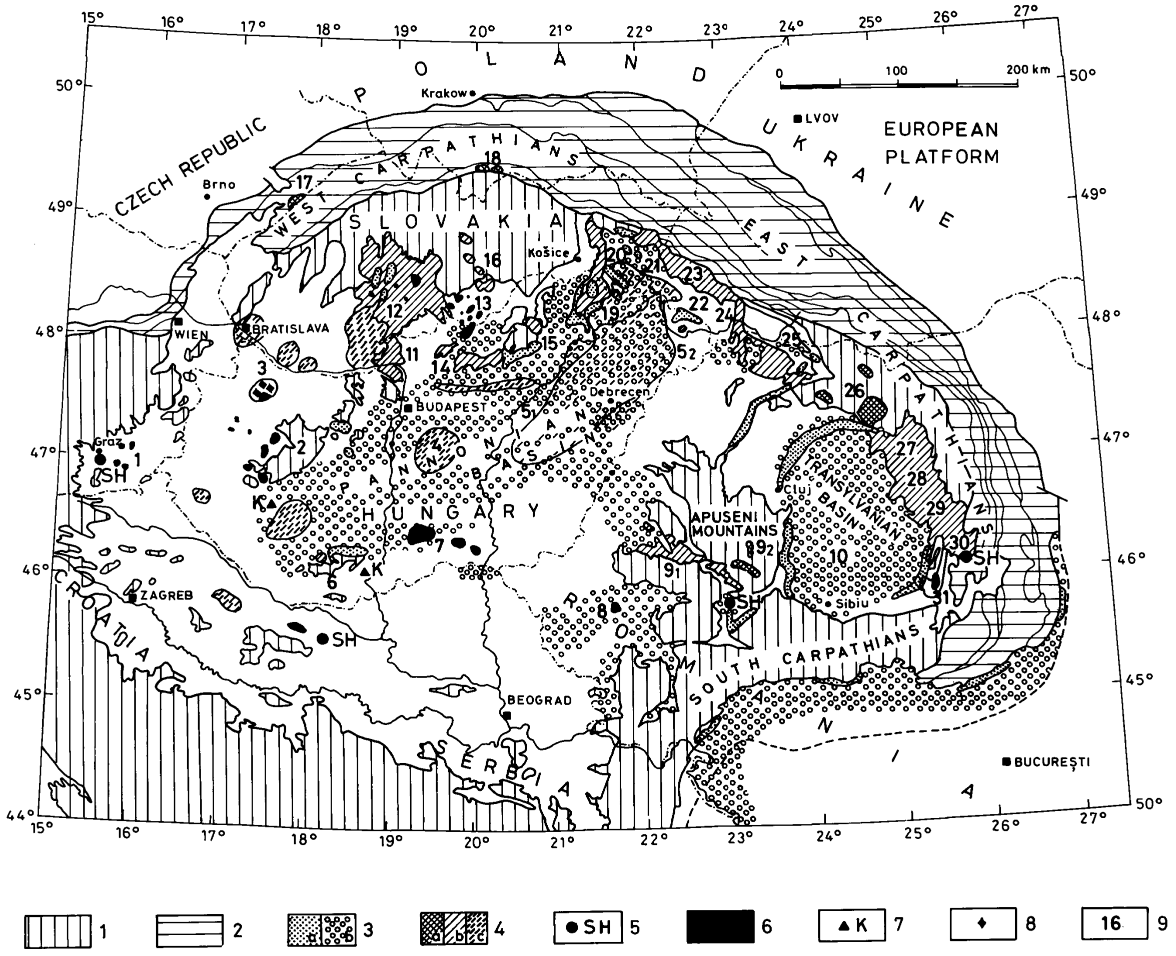

Figure 1. Location and distribution of the Neogene-Quaternary igneous rocks in the Carpatho-Pannonian region showing the volcanic areas. 1 = Inner Carpathian units; 2 = External Carpathian units; 3 = Acidic calc-alkaline volcanism: (a) outcropping, (b) buried; 4 = Intermediate calc-alkaline magmatism: (a) intrusive outcropping, (b) stratovolcanic outcropping, (c) buried; 5 = Shoshonitic magmatism; 6 = Alkali-basaltic volcanism; 7 = Ultrapotassic volcanism; 8 = Potassic trachytic magmatism; 9 = Number of areas and regions corresponding to number in Fig. 2.

from 10 Ma in the north to 0.2 Ma at the southern end of the chain. The age-progression along the Calimani-Gurghiu-Harghita segment of the East Carpathian chain is very striking.

The tectonic significance of this result is that, if subduction is responsible for the calc-alkaline magmatism, then the subducted slab first reached the required depth for magma generation of 100-120 km (the "magma generation window") simultaneously beneath the whole of the Western Carpathians between 19 and 16 Ma ago, and ceased to generate calc-alkaline magma after only 6-9 Ma had passed. In contrast, the slab which subducted beneath the Eastern Carpathians must have reached the magma generation window at a progressively later and later time. Another striking feature revealed by Fig. 2 is that the oldest extension-related alkaline magmas (black shading on Fig. 2) are about 9-11 Ma old and were erupted just as the calc-alkaline magmatism was waning. From this we can conclude that we have a "switch" from a tectonic regime dominated by collision to one dominated by extension at this time. After this, alkali basalts occurred sporadically both in time and place, until the eruption of the youngest flow (Nova Banya in central Slovakia) which overlies a post-glacial river terrace. These magmas may be related to a widespread upwelling of the asthenospheric mantle beneath Europe (Hoernle et al., 1995). If this is the case, then they could not be erupted from the upwelling asthenosphere until after the subducting slab had become detached and had sunk into the asthenosphere. Such "slab window" alkali basalts have been observed in other regions of the world when a subducting slab has been detached.

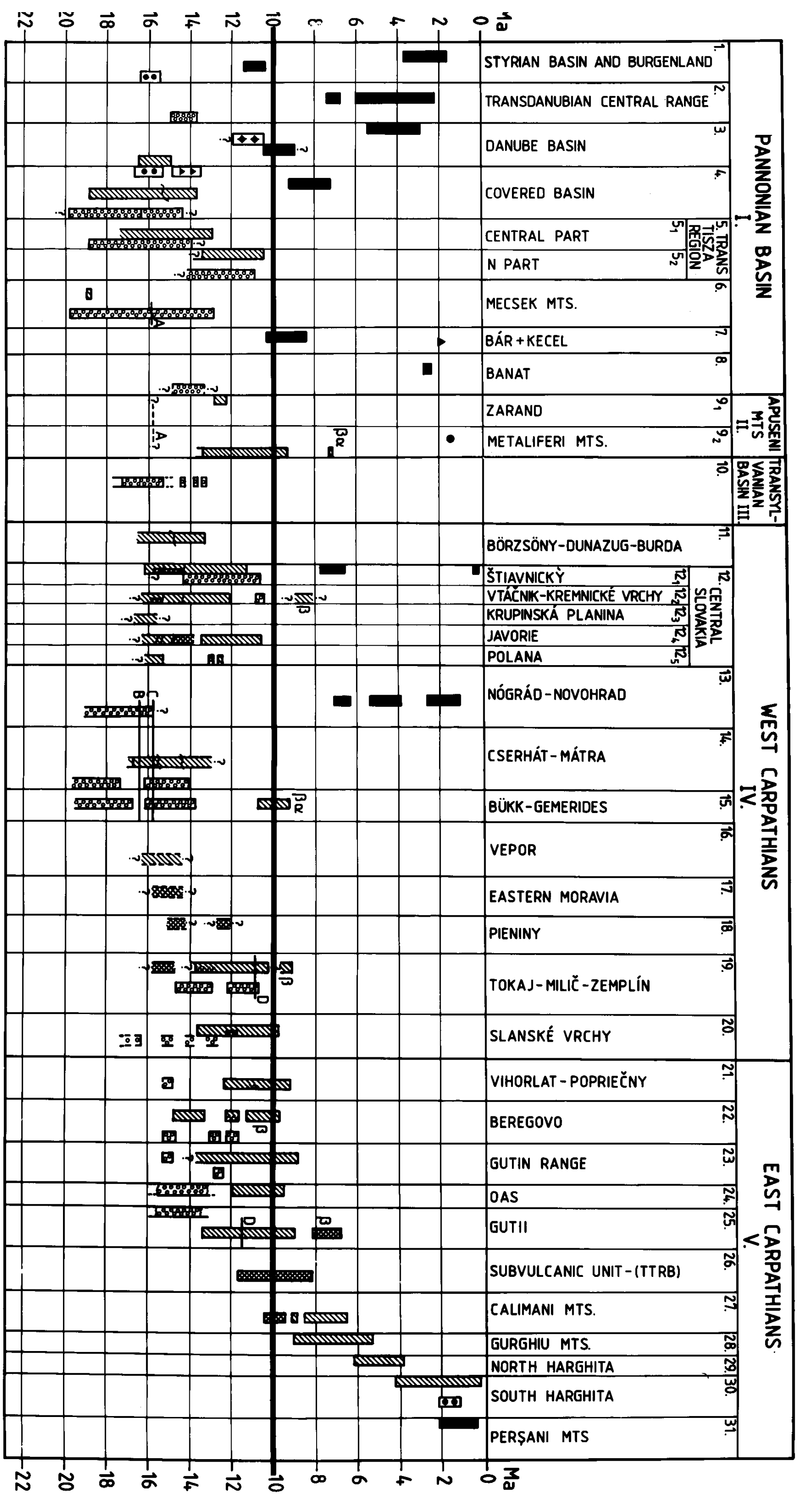

Figure 2. Distribution of volcanic activity in space and time in the Carpatho-Pannonian region. Symbols for different rock-types are the same as in Fig. 1. The thick line at 10Ma represents the Late Miocene compressional event (Decker and Peresson, 1995). b = calc-alkaline basalts; ba = calc-alkaline basaltic andesites; A-D = palaeomagnetic marker horizons which signify short intervals of drastic changes in orientation (rotation) with respect to north in those areas where such horizons are indicated. A represents a clockwise rotation; B-D represent anticlockwise rotations.

Current debates and unanswered questions

The general features outlined above are largely accepted by the volcanological and petrological community working in the region. However, some disagreements still exist. For example, Ukrainian and Romanian colleagues have pointed out that tectonic events such as nappe emplacement and thrust faulting had ceased in the Eastern Carpathians long before the onset of magmatism. Thus, they argue, the calc-alkaline magmatism of the Eastern Carpathians cannot easily be related to subduction. Our response is that it will take a finite time for a subducted slab of oceanic crust to reach the temperature and depth of the magma-generation window; this could account for the gap between the cessation of tectonism and the onset of magmatism. The time interval between the beginning of subduction and the arrival of the subducting slab in the magma generation window will be a function of the angle of subduction and the rate of subduction. In fact, if subduction is very shallow, as occurs in some parts of the Andes, magma generation may not occur at all. In the Eastern Carpathians we see a remarkably narrow volcanic zone and fast progressive movement of volcanism, indicating that the period of time which the slab spent in the magma generation window was short. This in turn suggests that the piece of oceanic crust which was subducted was of small dimensions. Slab detachment in the Eastern Carpathians may have followed the arrival of unsubductible continental crust of the Tornquist zone or East-European Platform at the trench around 10 Ma ago (Decker and Peresson, 1995).

Another unsolved problem is the origin of the widespread acidic magmatism which is the earliest magmatic feature of the region. Although most workers suggest that the source volcanoes were situated to the N and NE of these basins, in the Western Carpathian arc, the precise relationship between the stratovolcanoes and the pyroclastic deposits is unknown, particuarly as the pyroclastics appear to pre-date most of the stratovolcanoes. It has also been suggested by Slovak colleagues that many of the widespread intermediate and acidic volcanics of the Western Carpathians are not directly related to subduction, but may be more closely linked with some other major tectonic process such as lithosphere delamination, in which hot asthenosphere is brought into direct contact with the base of the crust, heating it and causing melting. Such hypotheses can be tested using isotopic and other geochemical methods on the earliest products of the acidic magmatism.

Conclusions

In the past few years, before and since EUROPROBE became interested in the PANCARDI region, researchers from all of the PANCARDI countries have been engaged in joint collaboration both among themselves and with colleagues from the UK, Italy and the USA. Numerous projects on individual volcanic regions have been undertaken and many publications have resulted. Now, however, we are at a point where we have a large amount of geochronological, geochemical and volcanological data which must be synthesised into a tectonomagmatic framework. We should be asking ourselves "what is the tectonic significance of our results?" and "how do our results fit into the larger-scale picture of tectonomagmatic processes in the PANCARDI region?" Only in this way will we be able to move forward to achieve a greater understanding of the relationship between magmatism and tectonics in this region.

Acknowledgements

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References

Decker, K. and Peresson, H., 1995. Late Miocene E-W compression in the Alpine-Carpathian-Pannonian region linked to late subduction in the Eastern Carpathians. Terra Abstracts, 7, 271.

Downes, H., Embey-Isztin, A. and Thirlwall, M.F., 1992. Petrology and geochemistry of spinel peridotite xenoliths from the western Pannonian Basin (Hungary): evidence for an association between enrichment and texture in the upper mantle. Contrib. Mineral. Petrol., 109, 340-354.

Hoernle, K., Zhang, Y.-S. and Graham, D., 1995. Seismic and geochemical evidence for large-scale mantle upwelling beneath the eastern Atlantic and western and central Europe. Nature, 374, 34-39.

Pecskay, Z. et al., 1995. Space and time distribution of Neogene-Quaternary volcanism in the Carpatho-Pannonian Region. Acta Vulcanologica, Special Issue 7, 15-28.

Szabó, Cs., Harangi, Sz. and Csontos, L., 1992. Review of Neogene and Quaternary volcanism of the Carpathian-Pannonian Region. Tectonophysics, 208, 243-256.

Vaselli et al., 1995. Ultramafic xenoliths from Plio-Pleistocene alkali basalts from the Eastern Transylvanian Basin: depleted mantle enriched by vein metasomatism. J. Petrol., 38, 23-54.

Wilson, M. and Downes, H., 1990. Tertiary-Quaternary Extension-Related Alkaline Magmatism in Western and Central Europe. J. Petrol., 32, 811-849.

Generation and evolution of subduction-related batholiths from the Central Urals: constraints on the P-T history of the Uralian Orogen

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Introduction

The Uralian orogen has abundant Hercynian granitic rocks, organized in medium-sized batholiths with a section either roughly circular or, more commonly, N-S elongated. Urals granitoids show strong W-E polarity, from subduction-related batholiths in the accreted terrains in the West, to continental-type batholiths in the East (Fershtater et al., 1994; Fershtater et al., 1997). Subduction-related batholiths are formed by a wide variety of granitoid facies which have extraordinarily complex field relationships due to repeated episodes of melting and intrusion. The existence of multiple intrusion pulses clearly separated in time, together with the close spatial relationship with the Main Uralian and Serov-Mauk faults (sutures) as well as with other large-scale shear zones (Fig. 1) make these batholiths potentially useful markers for unravelling the tectono-magmatic evolution of the Urals. A presentation (Bea et al., 1997) at the Europrobe Uralides-Variscides meeting in Granada (April 1996) described the petrogenesis of Verkhisetsk, the largest and one of the most complex subduction-related batholiths in the Central Urals, as a tool to obtain insight into the tectono-magmatic evolution of the Urals collisional orogen. The most important conclusions are summarized here.

The Verkhisetsk batholith

The Verkhisetsk batholith, c. 100 km long and c. 25 km wide, is elongated N-S (Fig. 2), and located between the Serov-Mauk (in the west) and Ekaterinburg (in the east) shear zones; it intrudes middle Palaeozoic metavolcanic rocks. In general, the Verkhisetsk batholith comprises an outer envelope - composed of older, coarse-grained, strongly deformed tonalites, trondhjemites and granodiorites with Rb-Sr ages of 315-320 Ma - intruded by an inner core composed of younger (Rb-Sr ages of 285-275 Ma), fine-grained, undeformed granodiorites, adamellites and granites. The younger intrusions frequently contain rounded and partially assimilated enclaves of older rocks and usually have sharp intrusive contacts with the latter, although gradational contacts and migmatite-like relationships are also common.

Older intrusions crystallized at c. 6 kb and have a chemical composition similar to that of high-Al TTG/ adakite, with positive ε^{t}_{chur}(Nd) and initial ^{87}Sr/^{86}Sr

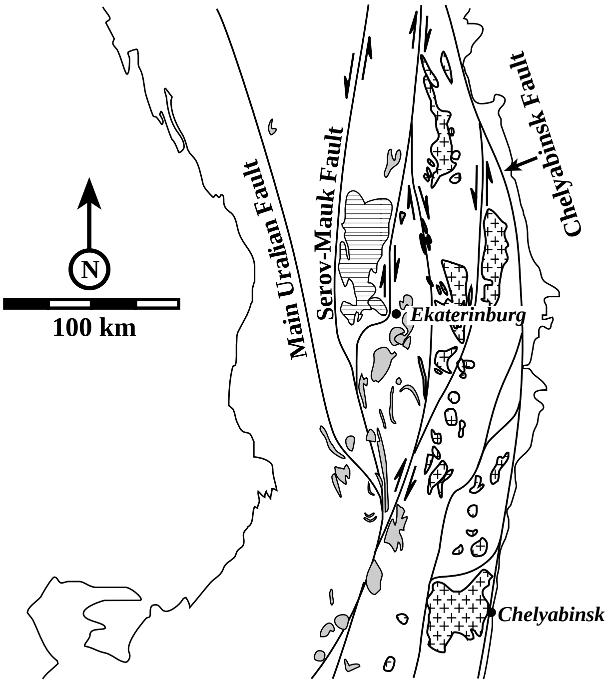

Figure 1.- Granite batholiths and large-scale shear zones in the Central Urals. Crosses: continental-type batholiths. Dotted: subduction-related batholiths. Horizontal lines: the Verkhisetsk batholith.

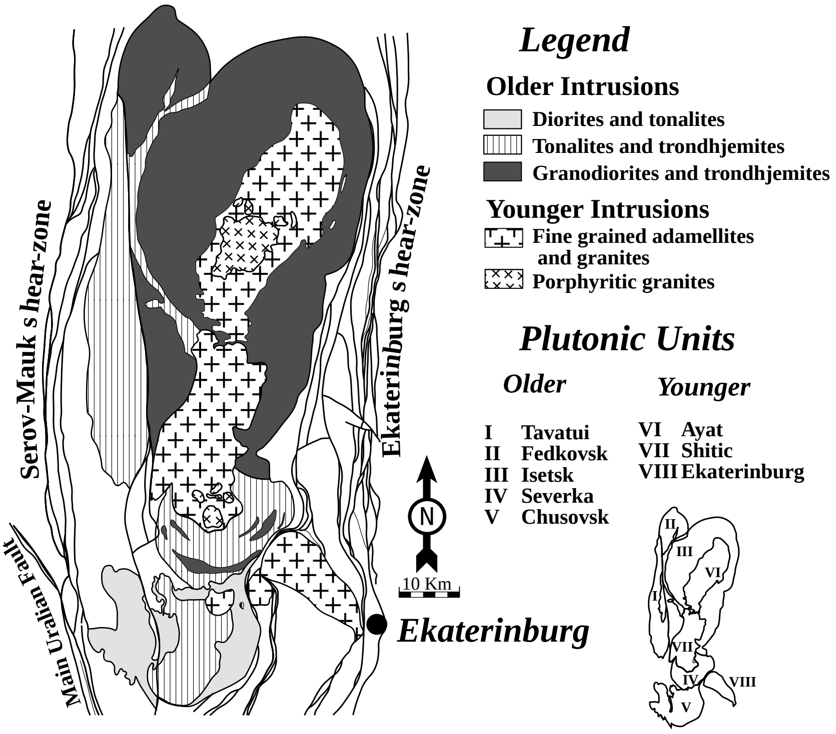

Figure 2.- Geological sketch of the Verkhisetsk batholith.

ratios c. 0.7043; these characteristics suggest that they crystallized from magmas produced by partial melting of metabasalts at a depth of c. 50 km. They show a marked west to east magmatic polarity, with an increase of Mg number, Cr and Ni contents (Fig. 3) and LREE/HREE fractionation (Fig. 4). This asymmetric zoning, as well as the close spatial relationship to the Serov-Mauk suture, clearly favours the idea that they were derived from a subducted slab of oceanic lithosphere.

The pronounced lateral zoning of the Verkhisetsk batholith gives further information about melting conditions. The low LREE/HREE fractionation of western magmas suggest that they did not leave garnet as a residual phase, whereas eastern magmas did; therefore, the garnet-in univariant marked the boundary between their respective generation loci within the subducted slab. Recent experimental work on dehydration melting of metabasalt (Rapp and Watson, 1995; Wyllie and Wolf, 1993) (Fig. 5) indicates that at 1000 ºC the garnet-in univariant is placed at 13 kb approx., and that just below this univariant and inside the amphibole stability field, the melt fraction at 1000-1050 ºC is as high as 25-30%, sufficient to permit melt segregation (Rushmer, 1995; Wolf and Wyllie, 1995). We therefore suggest that the melting conditions for the "Western" intrusions were near 1000-1050 ºC and 12-13 kb, at slightly lower pressure than the garnet-in univariant (Fig. 5). Given the close spatial relationships and similar age, the "Eastern" magmas were obviously generated on the same geotherm, but at slightly higher pressure than the garnet-in univariant, near 1050-1100 ºC and 13-14 kb (Fig. 5). The differences in Cr, Ni, and Mg contents suggest that the intensity of the magma-mantle interaction increased eastwards (see Drummond et al., 1996), thus indicating that the temperature of the asthenospheric wedge above the melting slab also increased, which is consistent with the hypothesis that the depth of magma generation increases towards the east.

The younger intrusions of the Verkhisetsk batholit were equilibrated at c. 4 kb. The existence of migmatite-like structures as well as the abundance of enclaves of older rocks with different stages of assimilation indicate that these intrusions were produced by anatexis of older rocks. Major-, trace-element, and isotope geochemistry also support this interpretation. The composition of the less silicic younger intrusions is indistinguishable from that of older suite with similar silica content, probably due to insignificant melt-restite segregation. The composition of the more silicic younger intrusions, however, becomes increasingly potassic and peraluminous as silica increases. This effect could be due either to low-pressure magmatic differentiation of anatectic melts, involving amphibole fractionation, or by the segregation of low melt-fraction magmas with Q-Or-Ab compositions near the "ternary minimum", these being enriched in alumina by the effect of reequilibration of restitic amphibole at lower pressure. The great abundance of dykes and the homogeneous undeformed fabric of the younger intrusions indicate that they were generated during an extensional episode.

Regional implications

1.- Elevated thermal regime in the subducted slab

The thermal regime, inferred above for the generation of the older magmatic suite, implies a temperature of c. 1000 ºC at c. 50 km depth, corresponding to a "warm" geotherm of c. 20 ºC/km. Several authors have shown that the temperature/depth trajectory in a subduction zone depends mainly on the age of the incoming lithosphere, the amount of previously subducted lithosphere, the vigour of convection in the mantle wedge induced by the subduction slab, the convergence rate and, to a lesser extent, the existence of high rates of shear stress (Peacock, 1990; Cloos, 1993; Peacock et al., 1994). According to these authors, such a "warm" thermal regime may be caused

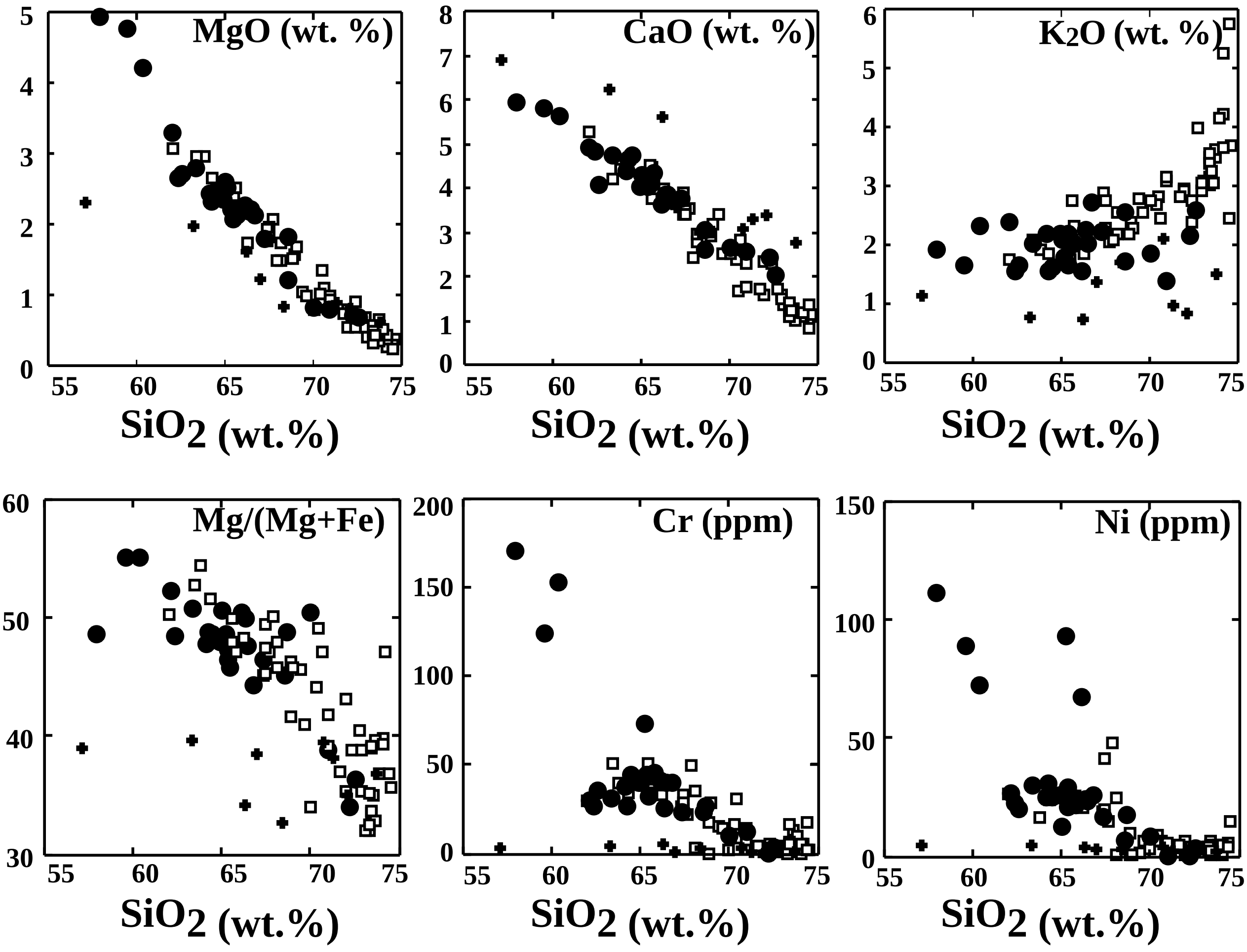

Figure 3.- Variation diagrams for Verkhisetsk samples. Crosses: Western (Tavatui)-type older rocks. Dots: eastern-type older rocks. Squares: younger rocks. Note the clear separation between western-type and eastern-type older rocks, as well as the remarkably low Mg number and Cr and Ni contents of western-type rocks. The K_2O-SiO_2 diagram reflects the transition of younger rocks from Na-rich to K-rich varieties with increasing silica content.

by two mechanisms that are not mutually exclusive: the subduction of young lithosphere, or highly oblique convergence involving slow subduction and high shear stresses. The geometry of large-scale shear zones in the central Urals (Fig. 1) suggests that oblique convergence existed but, according to available numerical modelling of shear heating (Peacock et al., 1994), it is unlikely to have produced temperatures of c. 1000 ºC at 12 kb by itself. We therefore suggest that the inferred thermal regime for the Verkhisetsk massif also required the subduction of a young lithosphere, which might have been generated by back-arc spreading during the early Carboniferous stages of the Urals collision (Fershtater and Bea, 1996).

2.- The significance of the melting event at 275-290 Ma

Granites with an age of 275-290 Ma are extraordinary abundant throughout the Urals. In the hinterland, most major batholiths appear to be of this age. ^{207}Pb/^{206}Pb single zircon grain dating of the Dzyabyk massif, for example, gives an age of 292 Ma (unpub-

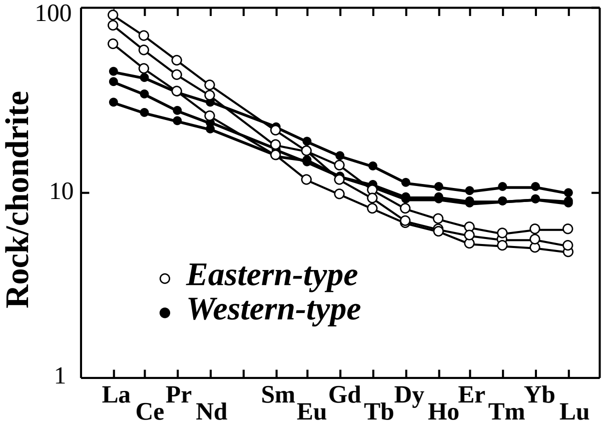

Figure 4.- REE chondrite-normalized patterns for Verkhisetsk rocks. Note the increasing LREE/HREE fraction from western-type to eastern-type older rocks.

lished). Reported Rb-Sr ages for Mochagui, Murcinka, etc. are in this range (see compilation in Fershtater et al., 1994). In the western part of the massif, where subduction-related batholiths predominate, the melting event at 275-290 Ma is represented by the partial melting of older batholiths and the appearance of younger rocks as described above for Verkhisetsk.

The interpretation of this melting event is not clear. On the one hand, the small pressure variation recorded by Verkhisetsk rocks (from 6 kb to 4 kb) precludes decompressional melting. On the other hand, the low amount of heat-producing elements in the Urals crust (Fershtater et al., 1997, and unpublished data) also precludes melting related to the accumulation of radiogenic heat in an overthickened crust. It seems therefore that the melting event at 275-290 Ma required an input of energy from below. One key point for understanding in what way the heat for melting was supplied to the lower crust could come from the fact that the depth of the Moho beneath the Urals is currently placed at c. 50 km (Thouvenot et al., 1995). Since we cannot expect the Urals island-arc crust to be significantly thicker than recent island-arcs (20-30 km, Tanimoto, 1995), it is logical to suppose that the Urals crust grew from the Moho downwards, with the most feasible mechanism being repeated underplating by mafic magmas. Once heat was available, the fertile nature of the eastern crust - with a significant quartzofeldspathic component - produced abundant continental-type granite batholiths. In the west, the low fertility of the western crust - mostly formed by metabasalts - restricted the generation of younger granites to the reactivation of former batholiths.

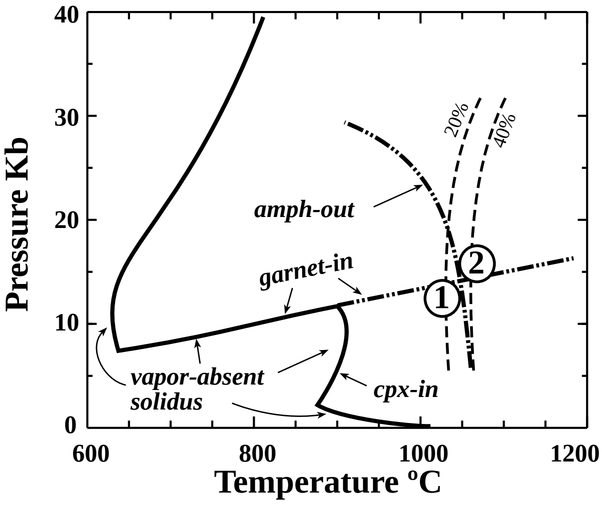

Fig. 5.- Inferred loci for the generation of western-type and eastern-type older rocks within the P-T field. Phase relationships were taken from Wyllie and Wolf (1993) and Rapp and Watson (1995).

References

Bea, F., Fershtater, G.B., Montero, P.G., Smirnov, V.N. and Zin'kova. E., 1997 Generation and evolution of subduction-related batholiths from the Central Urals: Constraints on the P-T history of the Uralian Orogen. Tectonophysics, in press.

Cloos, M., 1993. Lithospheric buoyancy and collisional orogenesis: Subduction of oceanic plateaus, continental margins, island arcs, spreading ridges, and seamounts. Geol. Soc. Am. Bull., 105, 715-737.

Drummond, M.S., Defant, M.J. and Kepezhinskas, P.K., (1996). The Petrogenesis of Slab-Derived Trondjemite-Tonalite-Dacite/Adakite Magmas. Transactions of the Royal Society Edinburg. Earth Sciences, 87, in press.

Fershtater, G. B. and Bea, F., 1996. Geochemical typology of Urals ophiolites (in Russian). Geokhimiya, 3, 195-219.

Fershtater, G.B., Borodina, N.S., Rapoport, M.S., Osipova, T.A., Smirnov, B.H. and Levin, M.Y., 1994. Orogenic Granitoid magmatism of the Urals (in Russian). Russian Academy of Sciences. Urals Branch, Miass., 247 pp.

Fershtater, G.B., Bea, F., Borodina, N.S., Montero, P.G., Smirnov, V.N., Pushkariov, E.V., Rappaport, M.S. and Zinger, T.F., 1997. Magmatism as a key to deep Urals. Tectonophysics, in press.

Peacock, S.M.., 1990. Fluid Processes in Subduction Zones. Science, 248, 329-337.

Peacock, S.M., Rushmer, T. and Thompson, A.B., 1994. Partial melting of subducted oceanic crust. Earth Planet. Sci. Lett., 121, 227-244.

Rapp, R.P. and Watson, E.B., 1995. Dehydration melting of metabasalt at 8-32 kbar: Implications for continental growth and crust-mantle recycling. J. Petrol., 36, 891-931.

Rushmer, T., 1995. An experimental deformation study of partialy molten amphibolite: Application to low-melt fraction segregation. J. Geophys. Res., 100, 15,681-15,695.

Tanimoto, T., 1995. Crustal Structure of the Earth. In: T.J. Ahrens, Ed. Global Earth Physics. A Handbook of Physical Constants, p. 214-224. A. G. U., Washington.

Thouvenot, F., Kashubin, S.N., Poupinet, G., Makovskiy, V.V., Kashubina, T.V., Matte, P. and Jenatton, L., 1995. The root of the Urals: Evidence from wide-angle reflection seismics. Tectonophysics, 250, 1-13.

Wolf, M.B. and Wyllie, P.J., 1995. Liquid segregation parameters from amphibolite dehydratation melting experiments. J. Geophys. Res., 100, 15,611-15,621.

Wyllie, P.J. and Wolf, M.B., 1993. Amphibolite dehydration-melting: sorting out the solidus. In H.M. Prichard, T. Alabaster, N.B.W. Harris, and C.R. Neary, Eds. Magmatic Processes and Plate Tectonics, Geol. Soc. Spec. Publ., 76, 405-416.

EUROPROBE SUMMARY REPORT TO ESF 1996

EUROPROBE is a Lithosphere Dynamics programme, concerned with the origin and evolution of the Continents. It was conceived and has grown within the International Lithosphere Programme and, since 1992, has been supported by the European Science Foundation. This major venture of European geoscientists is focused on, but not confined to Europe. It is dedicated to carrying out a new generation of major projects that will improve our understanding of the tectonic evolution of the Earth´s crust and mantle, and the dynamic processes that controlled this evolution through time.

The character of the crust is very different in eastern and western Europe, with a stable ancient platform dominating the east and younger mobile belts in the west. Geophysical probing has shown that these differences extend through the lower crust and deep into the mantle. These contrasted signatures of the lithosphere have set the scene for many new ventures in the solid earth sciences.

Ambitious projects to investigate the whole lithosphere require close collaboration of geologists, geophysicists and geochemists and multinational cooperation. The interplay of modelling and theory in partnership with field studies is central to EUROPROBE. The application of state-of-the-art technology is vital. To meet this challenge, EUROPROBE receives support from the European Science Foundation for a workshop programme to define, develop and implement a wide range of major interdisciplinary projects; these reach in space across Europe from the Ural Mountains to the Iberian Peninsula and in time from the Archaean to the Present.

EUROPROBE is driven by a combination of two priorities - scientific excellence and East-Central-West European collaboration. This recipe has been anchored in partnerships, first and foremost between individual scientists, but also between geoscience institutions. The EUROPROBE programme has been promoted by a growing spirit of cooperation in Europe; without this, it would have been impossible to overcome the barriers of language and tradition that have hindered communication in past decades. For geoscientists, direct access to the tectonic phenomena is essential; the political changes of the last decade in Europe have greatly expanded the range of possible targets.

Although EUROPROBE research focuses on fundamental geodynamic processes and appeals to our fascination for planet Earth and its origin and place in the universe, the programme has considerable practical application. The tools we develop and use are the same as those required for seismic hazard mitigation, natural resource exploration, toxic waste disposal and many other practical things essential for management of a sustainable environment. Several of the EUROPROBE projects have direct relevance to societal needs, ranging from earthquake prediction in the Vrancea Zone in Romania to mineral exploration in the Urals and Kola Peninsula and hydrocarbons in the Donets and Pechora Basins.

EUROPROBE´s ESF programme has now been running for nearly five years. Thirty-six workshops in eighteen countries have generated a wide range of collaborative research. During 1996, EUROPROBE has held six workshops for communicating the results of the interdisciplinary research:-

URALIDES and IBERIA	Granada, Spain	March 23rd-29th
TESZ	Ksiaz, Poland	April 10-17th
EUROBRIDGE	Oskarshamn, Sweden	June 8-15th
PANCARDI	Lindabrunn, Austria	September 23rd-29th
GEORIFT/CAUCASUS	Gurzuv (Yalta), Ukraine	November 1st-5th
SVEKALAPKO	Lammi, Finland	November 28-30th

1995 witnessed the first of EUROPROBE´s major coordinated ventures, the URALIDES project´s seismic transect through the southern Urals (URSEIS), with Russian, German, American and Spanish partners. Several of EUROPROBE´s projects have support from INTAS (the International Association for the Promotion of Cooperation with Scientists of the former Soviet Union) and other EU related programmes. Many PhD and Post-Doc projects are involving the younger generation, laying the foundation for East-West collaboration in the years to come.

A presentation of EUROPROBE research is in press, providing a comprehensive overview of on-going activities. It has been prepared at the Europrobe Secretariat in Uppsala, based on presentations by leaders of the projects and other associated scientists. EUROPROBE science now involves many hundreds of geoscientists from twenty-six European countries; the programme is promoting research that will last well into the next century.

D. G. Gee
Chairman, Europrobe Scientific Steering Committee

EUROPROBE workshops and meetings in 1997

TIMPEBAR	St. Petersburg	February 12-16th
EUG	Strasbourg	March 23rd-27th
DEEP EUROPE (KIMBERLITE)	Moscow	April 17th-20th
(with NATO workshop on Upper Mantle Heterogeneities)		April 13th-16th
EUROBRIDGE	Vilnius	June
IASPEI	Thessaloniki	August 18-29th
URALIDES	Moscow	Autumn
TESZ	Potsdam	end October
GEORIFT	Zürich	Autumn
PANCARDI	Krakow	October 19-24th
SVEKALAPKO	Finland	end November