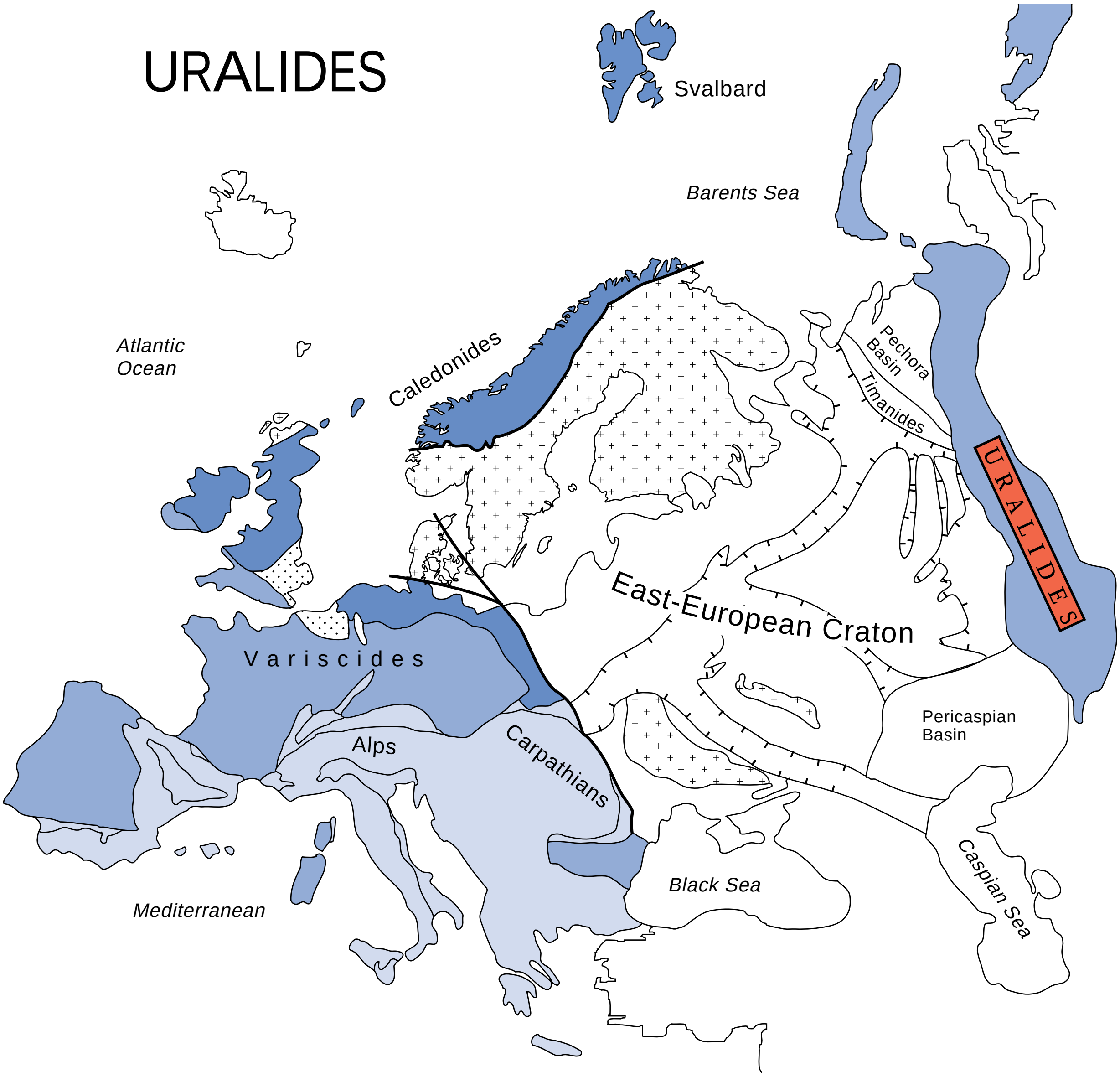
URALIDES
Svalbard
Barents Sea
Atlantic
Ocean
Caledonides
Pechora
Basin
Timanides
U R A L I D E S
East-European Craton
V a r i s c i d e s
Alps
Carpathians
Pericaspian
Basin
Black Sea
Caspian Sea
Mediterranean

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 superdeep Uralian borehole is 5.3 km; target depth is 15 km) should provide new constraints on the origin of seismic reflections from crystalline crust.

Introduction

The URALIDES project comprises a coordinated, interdisciplinary investigation into the nature and history of the Uralide orogen. Comprehensive time and 3-D space analyses will improve our understanding of the orogen's structure and tectonic evolution and provide key information on the development and preservation of mountain roots. A wide range of geological, geophysical, geochronological and geochemical research is underway or planned. 1995 has witnessed one of the most comprehensive seismic investigations of an orogen ever to be attempted. The new research will allow a detailed comparison of the Uralides with other Palaeozoic orogens and yield new insights into pre-Mesozoic plate tectonic processes.

Development of the Research Plan

Research institutes in Finland, France, Germany, the Netherlands, Italy, Norway, Spain, Sweden, Switzerland, the United Kingdom and USA are collaborating with Russian colleagues in the URALIDES Project. The science plans have been defined in EUROPROBE workshops in Moscow (1989), Warsaw (1991) and Zarechnyi (1992), and on-going research has been discussed in Perlora (1993), Evora (1994) and Ekaterinburg (1995). Protocols of agreement have been signed between several research institutions from both east and west; in particular, between EUROPROBE and the Russian Academy of Sciences and the Russian State Committee for Geology. There are also agreements on specific collaborative projects, e.g. between EUROPROBE, DEKORP (Germany), ICTJA (Spain), INSTOC (USA), and SPETZGEOFIZIKA (Russia) for the acquisition, processing and interpretation of the 1995 deep seismic reflection profile across the southern Urals.

Geological Framework

The Uralide orogen is the fundamental topographic and tectonic boundary between Europe and Asia (Nalivkin, 1960; Krapotin, 1967; Ivanov and Rusin, 1986; Ivanov et al., 1975; Zonenshain et al., 1984, 1990; Khain, 1985; Puchkov, 1991; Matte et al., 1993; Matte, 1995). This linear mountain belt is more than 2500 km long and 400 to 500 km wide. It extends across Russia from near the Aral Sea northwards into the Arctic Ocean, separating the East-European Craton, the ancient Precambrian core of Europe, from the Archaean–Proterozoic Angara (Siberian) Craton and Kazakhstan microcontinents of Asia (Fig. 3.1). Overlying the East-European Craton along the western flank of the Uralides is a foreland basin of flysch and molasse sediments, a foreland thrust and fold belt comprising continental margin and continental basement units, and westerly transported oceanic crustal rocks (Brown et al., 1996). Along its eastern flank is a mosaic of accreted terranes that include obducted slabs of oceanic crust, remnants of island arcs and Precambrian microcontinents. The boundary between the continental margin sediments and the accreted terranes is the 2000-km-long Main Uralian Fault, the principal suture zone of the Urals. The Uralides, together with the Appalachian, Caledonian and Variscan orogens, record the assembly of the late Palaeozoic supercontinent Pangaea.

Principal Tectonic Zones

Russian earth scientists have traditionally divided the Uralide orogen into six major north-south striking tectonic zones (Ivanov et al., 1975). West of the Main Uralian Fault are three tectonic zones comprising basement rocks of the East-European Craton overlain mostly by foreland basin flysch and molasse deposits and continental margin sedimentary rocks that have been transported along west-vergent thrust faults. Tectonic zones east of the fault include exotic oceanic, island arc and microcontinental terranes. From west to east these six zones are (Fig. 3.2): the Pre-Uralian foredeep and the West-Uralian, Central-Uralian, Tagil-Magnitogorsk, East-Uralian and Trans-Uralian zones (Ivanov et al., 1975).

Figure 3.1: Location of the Uralides between Europe and Asia.

Pre-Uralian foredeep

Along the western margin of the Uralide orogen, the Uralian foredeep developed during late Carboniferous to Permian times. The earliest syn-orogenic sediments within this extensive foreland basin are of early and middle Carboniferous age. Deformation is characterized by thin-skinned tectonism (e.g. Sobornov, 1992) passing westward into largely undeformed foreland basin sediments. Some of Russia's largest oil and gas provinces are contained in the Uralian foredeep (Puchkov, 1993; Sobornov and Bushuev, 1990).

West-Uralian zone

Further to the east, the West-Uralian zone contains imbricated shelf and deep water sediments of Ordovician to Carboniferous age, underlain by Archaean and Proterozoic crystalline rocks and Riphean to Vendian sedimentary successions that constituted the East-European Platform during most of the Palaeozoic. Continental slope and rise sediments of the Zilair-Lemova zone (southern Urals) are included in this zone. Structurally overlying the Devonian Zilair Formation are the Kraka and Sakmara ophiolite suites.

Central-Uralian zone

Highly metamorphosed Archaean and Proterozoic rocks and younger Riphean and Vendian successions are the major components of the Central-Uralian zone. Metamorphism of pre-Uralian age locally reaches granulite facies grade. At some locations, Ordovician, Silurian and Devonian rocks unconformably overly the Vendian and older successions. Several stages of deformation and metamorphism have been recognised in this zone, some of which produced pervasive tectonic fabrics.

Main Uralian Fault

Extending for more than 2,000 km, the Main Uralian Fault (Fig. 3.3) constitutes the principal tectonic boundary between the East-European Craton (Central-Uralian zone) and remnants of the Uralian palaeo-ocean (Tagil-Magnitogorsk zone). The character of the Main Uralian Fault varies greatly along strike. At many locations it is distinguished at the surface by bands of serpentinitic mélange, hundreds of kilometres long. It dips eastward at moderate angles and seismic reflection profiling has shown it to be associated with a wide reflective zone that extends to least 15 km depth and may continue into the lower crust

(Fig. 3.4; Juhlin et al., 1995; see also Zonenshain et al., 1990). There is a paucity of structural and kinematic data for the Main Uralian Fault and the many other deformation zones in the Uralides. It has a complex compressional and possibly extensional history (Matte et al., 1993), the timing of which is poorly constrained. In the southern Urals, the youngest rocks affected by the Main Uralian Fault are of early Carboniferous age, and in the southernmost areas it is overlapped by relatively undeformed Jurassic and early Cretaceous sediments, placing an upper limit on the age of deformation in this region.

Tagil-Magnitogorsk zone

East of the Main Uralian Fault are the spectacular ophiolites and island-arc complexes of the Tagil-Magnitogorsk zone (Fig. 3.3). This zone coincides with the long wavelength Bouguer gravity minimum and overlies the axis of the crustal root (Fig. 3.5). Ordovician ophiolites of the former Tagil island arc are characterised by a sheeted-dyke complex, tholeiitic pillow lavas, thin cherts and thick sequences of island-arc (mostly andesitic tuffs) volcanic rocks. In contrast, the former Magnitogorsk island arc rocks are mostly Devonian in age, but otherwise have similar characteristics to those of the Tagil region (Ivanov and Ivanov, 1991). According to both geological and geophysical data, these ophiolite sequences are among the most complete and best preserved in the world, representing a remnant of oceanic lithosphere more than 1000 km in length. The Tagil-Magnitogorsk zone is also, in part, characterised by anomalously low heat flow (25-30 mW/m^2; Safanda et al., 1992). A superdeep borehole, SG-4, (targeted for 15 km and presently at 5.3 km; Fig. 3.3) is being drilled in the western part of the zone.

East-Uralian zone

Microcontinental and oceanic assemblages are the principal tectonic units of the East-Uralian zone. Precambrian granitoids and gneisses are overlain by Ordovician and Carboniferous sediments and in places

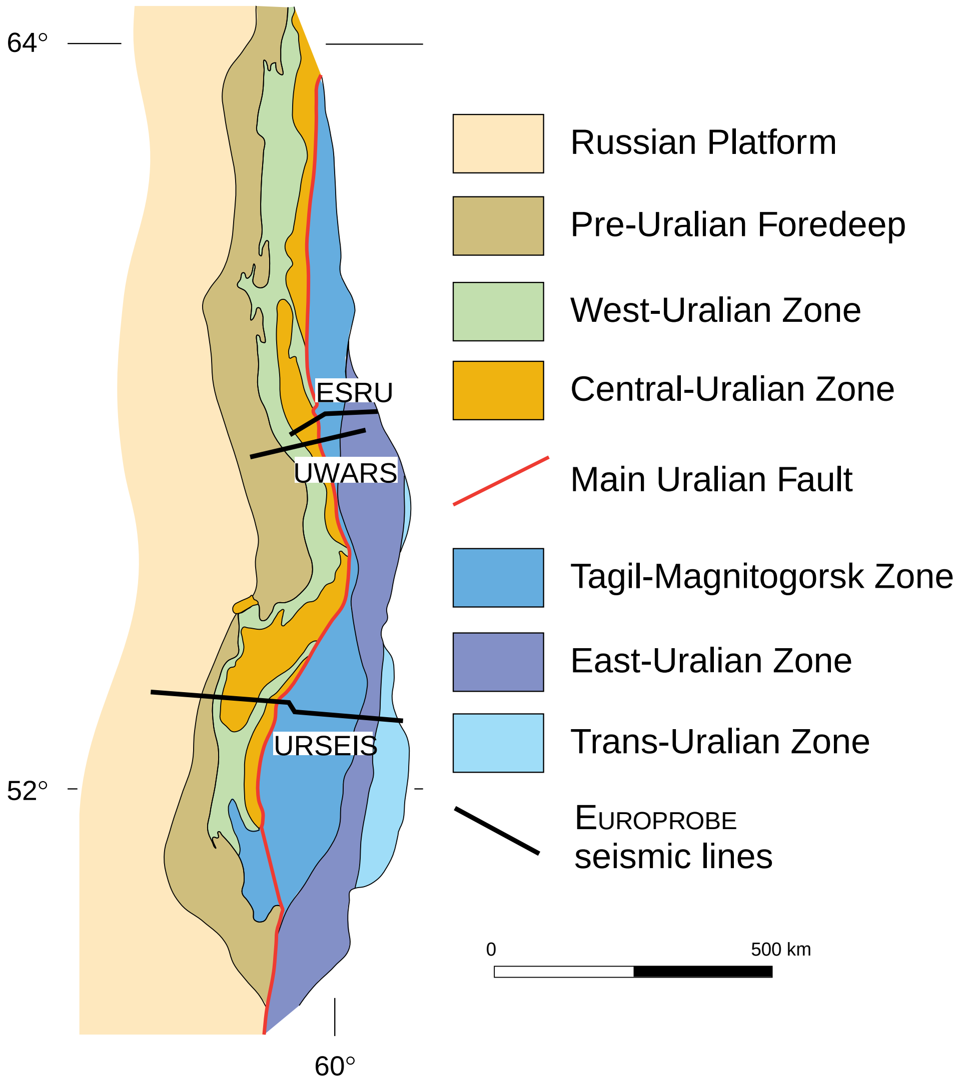

Figure 3.2: Tectonic zones of the middle and southern Uralides.

have been overthrust by Ordovician to Devonian ophiolite suites and volcanic and volcaniclastic rocks of island-arc affinity. This entire complex was intruded by granitic rocks in an Andean-type setting during the late Devonian and early Carboniferous.

Trans-Uralian zone

Mesozoic-Cenozoic sediments of the West Siberian basin cover large regions of the Trans-Uralian zone. Carboniferous sedimentary and volcanic rocks have been observed in drill cores. Major structures appear to dip westwards. A narrow zone with high-pressure metamorphic assemblages is present in the eastern part of this zone.

General Evolutionary Model

Hamilton's (1970) synthesis of the Uralide orogen was one of the first applications of plate tectonic concepts to continental geology. According to the more recent evolutionary models of Zonenshain et al. (1984, 1990), tectonic and magmatic activity associated with

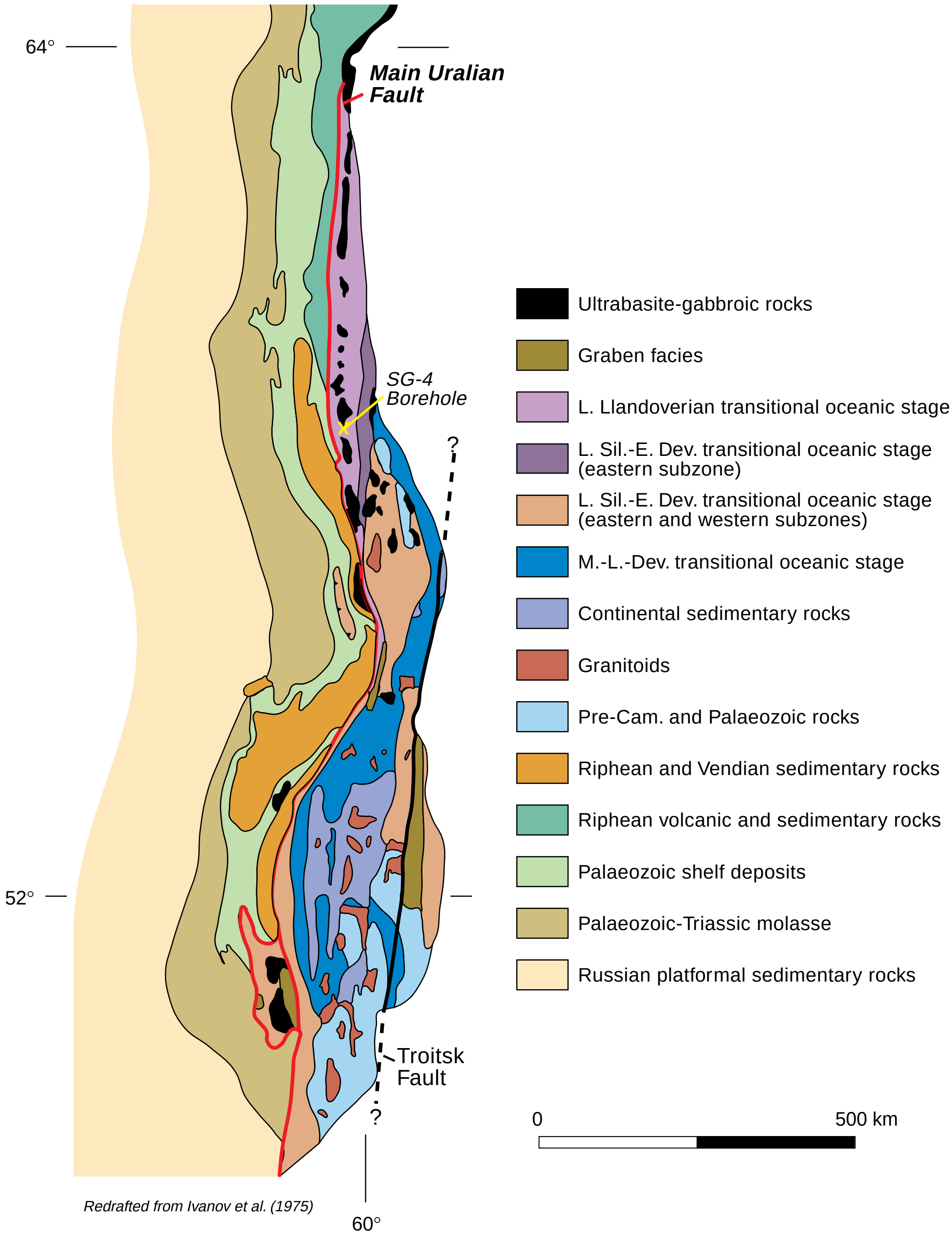

Figure 3.3: Geological map of the Uralide orogen. The Main Uralian fault, shown in red, separates the orogen into units developed on the East-European Craton to the west from accreted oceanic, island arc and microcontinental terranes to the east (after Ivanov et al., 1975).

the Uralides began in late Cambrian to early Ordovician times. During this period continental rifting, continental breakup and seafloor spreading along the eastern edge of the East-European Craton led to a passive continental margin facing a broad ocean. Further rifting and calving of microcontinental fragments, together with island arc and associated back-arc basin formation, occurred during the middle Palaeozoic. The island arcs were mostly active during Ordovician to Devonian times. Subsequently, various microcontinental and island arc terranes amalgamated within the Uralian palaeo-ocean and in the late Palaeozoic were accreted to the East-European cratonic margin (Sengör et al., 1993; Nikishin et al., 1996). Based on the west-vergent nature of many thrust faults (including the Main Uralian Fault), and the geometries and locations of the island arc remnants, post-collisional intrusions and the foreland basin, it is generally assumed that terminal subduction was east-directed. Closure of the ocean basin and continent-continent collision involving the Precambrian cratons took place in late Carboniferous to Permian times. Convergence between the cratons likely continued into the early Triassic, although Permian and Triassic extension governed the development of the West Siberian basin, one of the most important Russian hydrocarbon provinces.

Outstanding Features

From the above description it appears that the Uralides followed a similar evolutionary path to those of the Appalachians, Caledonides and the Variscides. Common to these and many other orogens, both younger and older, are foreland basins, foreland thrust and fold belts, and hinterlands characterized by exotic or suspect terranes and crustal-scale ramps (Cook and Varsek, 1994). However, the Uralide orogen has a number of distinct features. Research by Russian scientists indicates that the orogen is distinguished by:

1) preservation of a crustal root that locally extends to 60 km depth (Fig. 3.5);
2) relatively minor syn- or post-collisional collapse in the exposed part of the orogen;
3) very low terrestrial heat flow, a globally unique feature;
4) extremely well-preserved ophiolites and volcanic-arc assemblages;

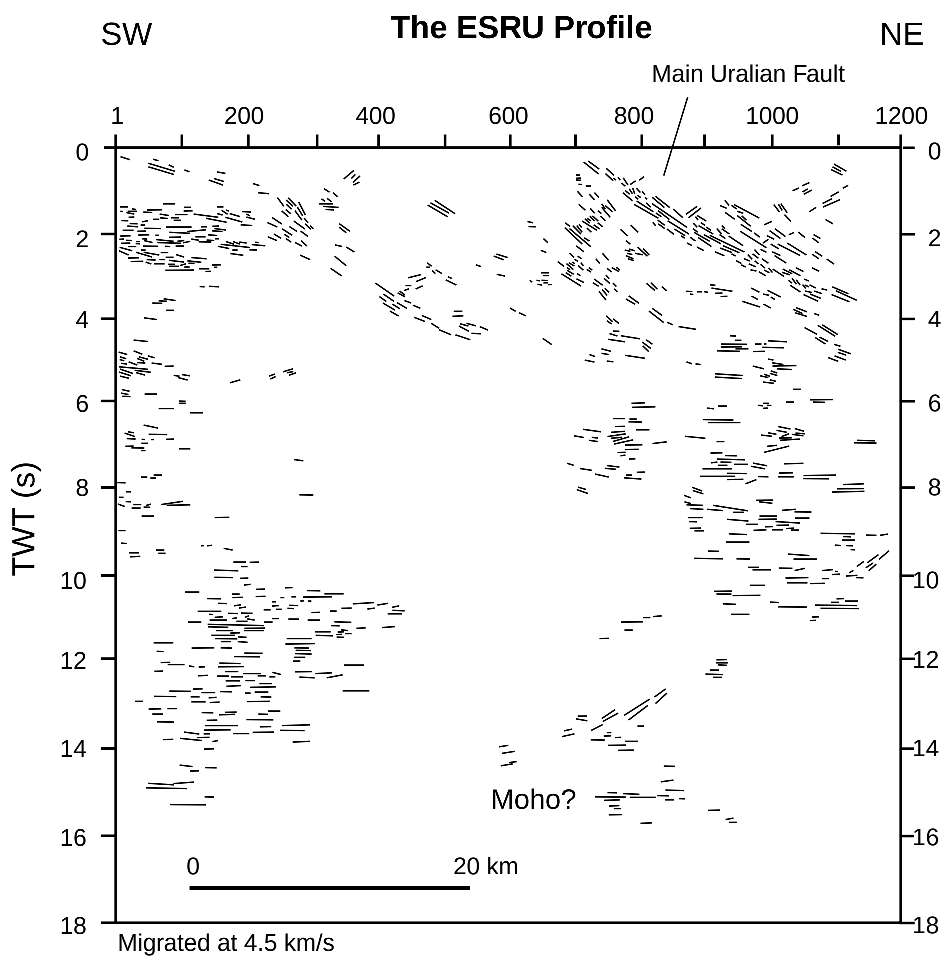

Figure 3.4: Europrobe's Esru CMP reflection profile (Fig. 3.2) pilot project in the middle Urals (Bader, 1994, unpublished MS thesis, Cornell University). The steeply east-dipping band of reflections is associated with the Main Uralian Fault.

5) remarkable outcrops of high-P / low-T (blueschist and eclogite facies) metamorphic rocks in the footwall to the main suture zone;
6) some of the largest hydrocarbon reserves in the world associated with foreland and hinterland basins (including the Timan-Pechora and West Siberian basins);
7) a wide range of genetic and epigenetic ore deposits, making the Uralides one of the most mineralised orogens;
8) widespread peneplanation by the Jurassic, and a history of uplift that began in the Tertiary and probably continues to the present day.

Spectacular Crustal Root

One exceptional aspect of the Uralides is its crustal root, which is defined by velocity models determined from wide-angle seismic data (Fig. 3.5; Egorkin and Mikhaltev, 1990; see also Thouvenot, 1995 and Juhlin et al., 1995). Crustal thickness varies from 35 to 40 km beneath the East-European Platform and West Siberian Basin and increases to more than 50 km beneath the Uralides, locally reaching 60 km (Fig. 3.5). The crustal root appears to be deepest slightly to the east of the Main Uralian Fault. This feature is particularly intriguing when the present topographic relief, gravity field and history of topographic variations are considered. Maximum elevations of only 2 km are reached in both the northern and southern Urals, and even lower values are typical in the middle Urals. A relatively subdued Bouguer minimum of about 40 mGal is recorded along the axis of the mountain belt. Assuming isostatic equilibrium and typical average crustal (2.7 g/cm^3) and mantle (3.3 g/cm^3) densities would lead to the conclusion that the crustal root grossly over-compensates the topographic load (Kruse and McNutt, 1988; Juhlin et al., 1995). The age of the crustal root is an additional outstanding problem that needs to be addressed. Was the crustal root formed during Palaeozoic compressional orogeny or was it generated by processes associated with the more recent uplift?

Although the existence of a crustal root beneath the Uralides is anomalous when compared with other well-studied Palaeozoic orogenic belts, similar features are observed beneath both younger (e.g. Alpine and Himalayan) and older (e.g. Penokean and Trans-Hudson) orogens. Deep seismic reflection profiling is essential for an improved understanding of the Uralide crustal root and its relationship to on-going uplift. By comparing data from the Uralides with the other Palaeozoic orogens, it may be possible to determine which parameters govern the creation and which parameters govern the preservation of crustal roots.

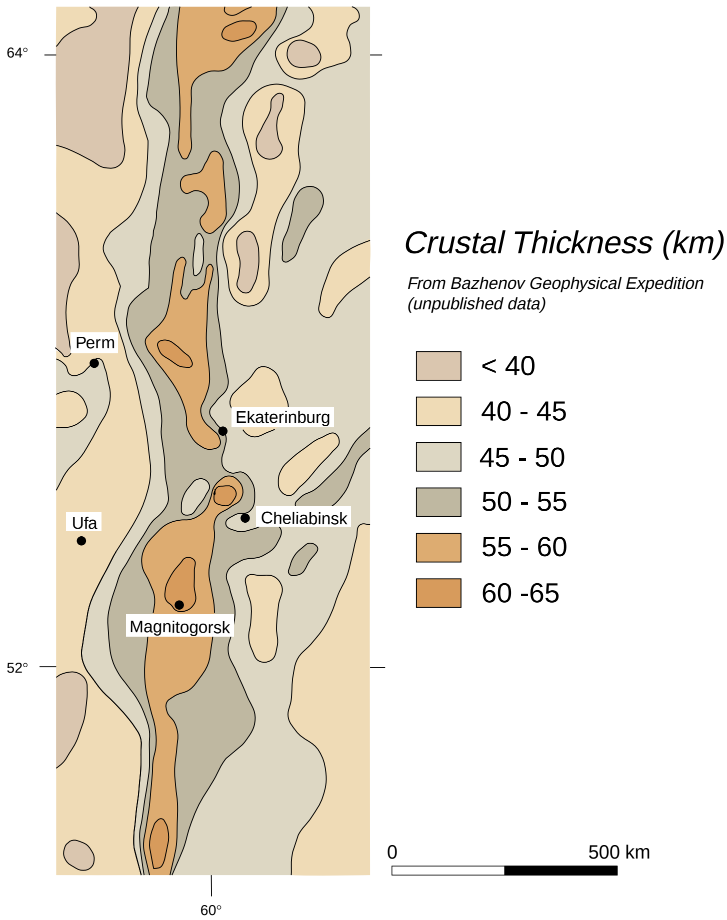

Figure 3.5: Crustal thickness of the Uralides.

URALIDES RESEARCH

1. URSEIS: Trans-Uralide deep seismic reflection profile *(Western Consortium: DEKORP, Corvallis [INSTOC], Barcelona [ICTJA]; Eastern Consortium: Moscow [SG], Scheelit [BGE], Ufa [BG]).*

A key element of the Urals Project is a c. 500 km long deep seismic reflection profile extending from the Uralian foredeep across the axis of the orogen to the hinterland beneath the West Siberian Basin (Fig. 3.2). Results of previous reflection profiling experiments in the Urals (Zonenshain et al., 1990; Sokolov, 1992; Juhlin et al., 1993, 1995) show the Uralian crust to be generally reflective. The URSEIS experiment has been designed to relate the surface geology to structures in the lower crust and upper mantle. In particular, potential connections between Palaeozoic tectonic features and the development and preservation of crustal roots are being investigated. Two alternative survey routes were proposed and delineated, one in the middle Urals at the latitude of the SG–4 superdeep borehole (Fig. 3.3) and another in the southern Urals. The southern profile, was selected for URSEIS and the experiment, carried out in 1995, has included vibroseis and explosion reflection surveying as well as the acquisition of refraction / wide-angle reflection data.

2. ESRU - Reflection seismic imaging and structural interpretation in the middle Urals *(Uppsala [U], Corvallis [INSTOC], Zürich [ETH], Potsdam [GFZ], Scheelit [BGE], Ekaterinburg [UGC]).*

Several shallow reflection seismic lines have already been recorded in the vicinity of the SG-4 superdeep borehole. Some of these data have been reprocessed. The results of a 60 km long deep seismic reflection profile, acquired in 1993 (Juhlin et al., 1995), were analysed at a URALIDES workshop (Fig. 3.4). This pilot profile has been extended to the east across the site of the superdeep borehole and will continue 150 km eastwards in 1996 (Fig. 3.2). Complementary geological studies along this seismic line focus on structure and tectonic evolution of the middle Urals.

3. UWARS: Uralides wide-angle seismic reflection and related teleseismic studies *(Grenoble [U], Scheelit [BGE]).*

The Uralides wide-angle seismic reflection and related teleseismic experiments were designed to map deep seismic reflections beneath the middle Urals and check the existence of the crustal root (Fig. 3.5). This ongoing program began in 1992. Wide-angle reflections generated by explosions detonated at seven shotpoints were recorded at distances critical for the Moho. A passive teleseismic experiment was conducted along a 600 km long profile (Fig. 3.2). Inversions of the teleseismic data are providing a velocity model of the lithosphere-asthenosphere system beneath the Uralides. Initial results of this sub-project are in accord with the existence of a shallow (c. 5 km) root beneath part of the middle Urals (Thouvenot et al., 1995).

4. Potential field studies and integrated modelling *(Scheelit [BGE], Berlin [FU], Ekaterinburg [RAS, UGK], Keyworth [BGS]).*

Regional gravity and magnetic data are available for the Uralide orogen, and large areas are even covered by detailed surveys at a line spacing of about 500 m. In the early stages of this sub-project the appropriate digital data will be compiled and a suite of modern potential field maps and images of the Uralides will be generated. These will be used to better delineate the principal tectonic elements and study the heterogeneity and segmentation of the crust. They will provide an important structural framework for other subprojects. Target-oriented potential field imaging will be performed in selected areas, for example along the deep seismic reflection profiles. Integrated potential field and seismic modelling will be undertaken along the seismic lines.

5. Dynamic stratigraphy and sequence analysis of the early Paleozoic basins *(Berlin [TU], Ekaterinburg [RAS]).*

Within the continental margin and rift basins on either side of the former Uralide palaeo-ocean various cycles of marine onlap and offlap are recognised. Their timing can be constrained by biostratigraphic and palaeofacies indicators. An attempt will be made to reconstruct the early Palaeozoic history of the Uralides using basin dynamic and depositional history analyses in conjunction with the GEORIFT project.

6. Dynamic biogeography during the middle and late Paleozoic convergence of the Uralides *(Montpellier [U], Ekaterinburg [RAS]).*

Certain aspects of plate convergence between the East-European and Angara Cratons and intervening microcontinents may be defined by increasing diversity of shallow biotic communities since early Devonian times. By calculating similarity factors of facies-dependent and biostratigraphically-controlled biota from formerly separated blocks, an analysis will be made of the evolution of plate convergence during the late Palaeozoic.

7. Integrated structural and basin analysis of the southwestern Uralides *(Aachen [RWTH], Ufa [RAS]).*
The objectives of this project are a detailed structural, petrographical and geochemical analysis of the exposed lithologies in the western part of the Urals, regionally concentrated on the Bashkirian Mega-anticlinorium and the Uralian foredeep. Study of the diagenetic and temperature histories of the rocks will also be included.

8. Structural analyses of the suture footwall in the southern Urals *(Barcelona [ICTJA], Oviedo [U], Aachen [RWTH], Ufa [RAS]).*
Balanced cross-sections of the Uralian foredeep and West Uralian zone along the URSEIS seismic reflection line will be attempted. Integration of information extracted from detailed structural and foreland basin investigations and from interpretations of seismic reflection data should yield initial estimates of crustal shortening. The sequence of deformations and the location of the different detachment levels will have to be determined. This information, when combined with the new deep seismic reflection data, will provide a synthesis of the Uralian crustal structure, west of the Main Uralian Fault (i.e., the suture footwall).

9. Exhumation and uplift of the Urals *(Zürich [ETH], Barcelona [ICTJA], Ufa [RAS]).*
Knowledge of the exhumation and uplift history of the Urals mountain belt will provide important constraints for interpretations of its Neogene tectonic history and active seismicity. Key issues to be addressed are the processes by which the current topographic relief was generated and the relationship between this topography and the crustal root. Rock samples will be collected from selected locations along the seismic traverses for fission-track analysis.

10. Hinterland deformation in the Uralides and accretion of microcontinents *(Potsdam [GFZ], Ekaterinburg [RAS], Freiberg [BA]).*
Within the hinterland of the Uralide orogen, east of the accreted oceanic and island arc rocks of the Tagil-Magnitogorsk zone, Precambrian crystalline complexes occur in major antiforms beneath thrust sheets composed of Palaeozoic oceanic and arc-related assemblages. These Precambrian crystalline complexes have been interpreted to be parts of microcontinents that were accreted to the East-European Craton during the late Palaeozoic. Investigation of the status and role of these microcontinents requires a detailed analysis of the Palaeozoic deformation that has affected the Precambrian complexes and their cover rocks. Particular emphasis will be given to determining the kinematics of the fault zones separating the Precambrian and overlying younger rocks. Also planned is a deformation analysis of the various Palaeozoic granites that intrude both the Precambrian and Palaeozoic rock units.

11. Kinematic history of the Main Uralian Fault *(Aachen [RWTH], Potsdam [GFZ], Ekaterinburg [RAS]).*
The role of orogenic collapse and re-equilibration in the Uralides is being addressed. An attempt will be made to 1) determine the geometry and kinematics of the Main Uralian Fault and associated structures in the southern Urals, 2) relate the tectonic fabrics to the metamorphic conditions and deformation processes, and 3) estimate the age of the different fault movements. Using existing seismic reflection data, the geometry of the Main Uralian Fault at depth will be studied. Extrapolation of surface geological data into the lower crust may lead to a new interpretation of the Uralides root zone and its relationship to Palaeozoic collision, extensional collapse and subsequent uplift.

12. Exhumation of ultra-high pressure terranes in the southwestern Uralides *(Montpellier [U], Darmstadt [TU], Ufa [RAS]).*
Some of the world's best preserved high-pressure metamorphic assemblages outcrop along the length of the Urals. At certain locations, rocks have undergone high-P/ low-T metamorphism (blueschist and eclogite facies), but were not affected by subsequent high-T thermal events. Detailed structural, petrological and $^{39}Ar/^{40}Ar$ radiometric studies will help define the age of the high-pressure metamorphism and subsequent uplift, thus establishing a P-T-t path for the exhumation and uplift of these rocks from depths of 50-80 km.

13. Fluid induced high-P metamorphism and geodynamics of orogens *(Oslo [MGM], Miass [RAS]).*
Volume reduction during eclogite formation may influence tectonism by promoting subduction and surface subsidence. Changes in petrophysical properties associated with high-P metamorphism (eclogite facies) in the Uralides will be compared with similar data from deep crustal rocks exposed in the Variscides and Caledonides. These data, which are fundamental for interpretation of certain geophysical experiments of the deep crust, will be used to constrain models of crustal root evolution.

14. Urals' Ophiolites *(Udine [U], Moscow [GIN]).*
Ophiolites may offer key information on the past configuration of plate boundaries. In addition, their petrology and geochemistry reflect the tectonic environment in which the ophiolites were generated. Detailed structural, petrological and geochemical investigations of dismembered ophiolites in the southern Urals, in particular the sequences near the proposed crust-mantle boundary and the overlying plutonic and volcanic units, will contribute to a better understanding of their original tectonic setting.

15. Petrology and geochemistry of magmatism *(Granada [U], Ekaterinburg [RAS], Halle [U]).*
A systematic study of plutonic rocks, gabbro-granite complexes and granitoids across the southern and middle Urals will be conducted. To be investigated are: 1) the evolutionary and isotopic trends of the granitoids, 2) internal structures of plutons, and 3) changes in composition, age and emplacement mechanisms of the various magmatic bodies intruded during the history of the Uralides, from early subduction to the final phases of collision and compression.

16. Tectonic framework of mineralisation in the Uralides *(Utrecht [U], Aachen [RWTH], Ufa [RAS], Ekaterinburg [RAS]).*
The range of Uralian mineral deposits is, at first sight, comparable to that of other European orogenic belts. However, apart from mineral deposits associated with mafic and ultramafic complexes of oceanic and island arc origin, the tectonic settings of Uralian mineral accumulations are often not as clear as elsewhere in Europe. In addition to processes pertaining to the orogenic regime itself, older structures of the East-European Craton may have played a role in the generation and location of major ore deposits. Four specific components of this sub-project are planned: 1) suture zones of the southern Urals and their gold mineralisation, 2) nature of mineralisation within granites of the southeastern Urals, 3) tectonic setting of diamond and gold mineralisation in the middle Urals, and 4) tectonic setting of porphyry copper deposits in the northern Urals.

17. Palaeontological, mineralogical and isotopic features of vent fauna assemblages in the Urals *(Scheelit [RAS], Ekaterinburg [RAS], Keyworth [NERC]).*
The vent faunal assemblages of the type occurring at Yaman Kasi and other sulphide deposits in the Urals have not been described from any other locality so far. The faunal assemblage, the nature of mineral assemblages, isotopic features of minerals and organic matter as well as the organic geochemical characteristics throw light on the surficial conditions at the time of deposition and the subsequent geological history. The first is totally unknown and the second is poorly known in the areas of low heat flow particular in this area.

18. Lead isotope studies and ore genesis *(Stockholm [U], Moscow [VIGAC], Ekaterinburg [UGK]).*
It is commonly assumed that the Precambrian basement within the Uralides has significantly influenced the mineralogy and geochemistry of overlying strati-form base metal deposits. New lead isotope studies will further explore these potential relationships.

19. Geothermal modelling of the lithosphere in the Uralides *(Prague [CAS], Espoo [GSF], Ekaterinburg [RAS], Ufa [RAS]).*
The Urals are characterized by extremely low heat flow. Such anomalously low heat flow may be evidence for a crust that is highly depleted in radioactive elements and/or a relatively narrow zone of low heat outflow from the subcrustal lithosphere. Critical objectives will include a review and interpretation of available temperature logs from Uralian boreholes and a comparison of heat flow with near-surface radiogenic heat production.

20. Stress measurements *(Karlsruhe [U], Potsdam [GFZ], Jaroslavl [NEDRA]).*
Information on the present state of stress in the Uralides is sparse. New stress measurements using high-resolution logging tools have been initiated in the SG-4 superdeep drillhole. This work is part of a regional scientific investigation aimed at determining stress patterns throughout Europe. Specific questions to be addressed are: 1) does the dominant northwestern orientation of stresses in western Europe continue across the East-European Craton and 2) are the Uralides characterized by a separate and distinct stress regime? Initial measurements in the superdeep drillhole suggest only a minor rotation of the stress vector relative to those of Western Europe. If further measurements confirm this result it would indicate that the Uralides, even though they are a major tectonic element, do not have a significant influence on regional stress orientations.

21. Palaeomagnetism *(Trondheim [NGU], München [U], St. Petersburg [VNIGRI]).*
The palaeomagnetism of late Precambrian and Palaeozoic rocks of the Siberian Craton and the microcontinents of the Uralide hinterland will be studied. Ongoing investigations of the Palaeozoic polar wander paths of the East-European and Angara Cratons will be expanded to include studies of the microcontinents within the Uralide orogen.

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