EUROBRIDGE extended:

FROM THE BALTIC SEA TO THE BLACK SEA

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In early September 1997, the EUROBRIDGE deep seismic sounding (DSS) and wide-angle reflection seismic profiling (CMP) was successfully finalised. The new, 1500-km long high quality transect starting at the southeastern shores of Sweden, crossed the Baltic Sea, Lithuania, Belarus and the western Ukraine. Geophysicists from Belarus, Denmark, Finland, Germany, Lithuania, Poland, Sweden, the Ukraine and the U. K. have provided new data to reveal the structure of the crust and lithosphere in this region of very diverse crustal tectonics - the juvenile Palaeoproterozoic crust of Svecofennia assembled through the collision of different terranes and the Archaean continent of Sarmatia. EUROBRIDGE transected a major boundary within the East European Craton, the one between its Fennoscandian and Sarmatian crustal segments (Bogdanova et al., 1996). Financial constraints limited the profiling to the western part of the Ukrainian Shield, in Southern Sarmatia (Fig. 1) where the oldest crust in the East-European Craton is found, containing rocks of 3.8-3.4 Ga.

The spatial relationships in Sarmatia of the oldest crust with adjacent terranes are not well known. They are based on interpretations of, the DSS Geotraverse VI, which was shot in the western Ukraine in the early 1980s. In Ukraine, Geotraverse VI strikes NW along the line Yalta - Odessa -Vinnitsa - Rovno mainly over the southwestern margin of the East European Craton within the Ukrainian Shield (100-910 km), being crossed at the 640th km by the EUROBRIDGE-97 transect (Fig. 1).

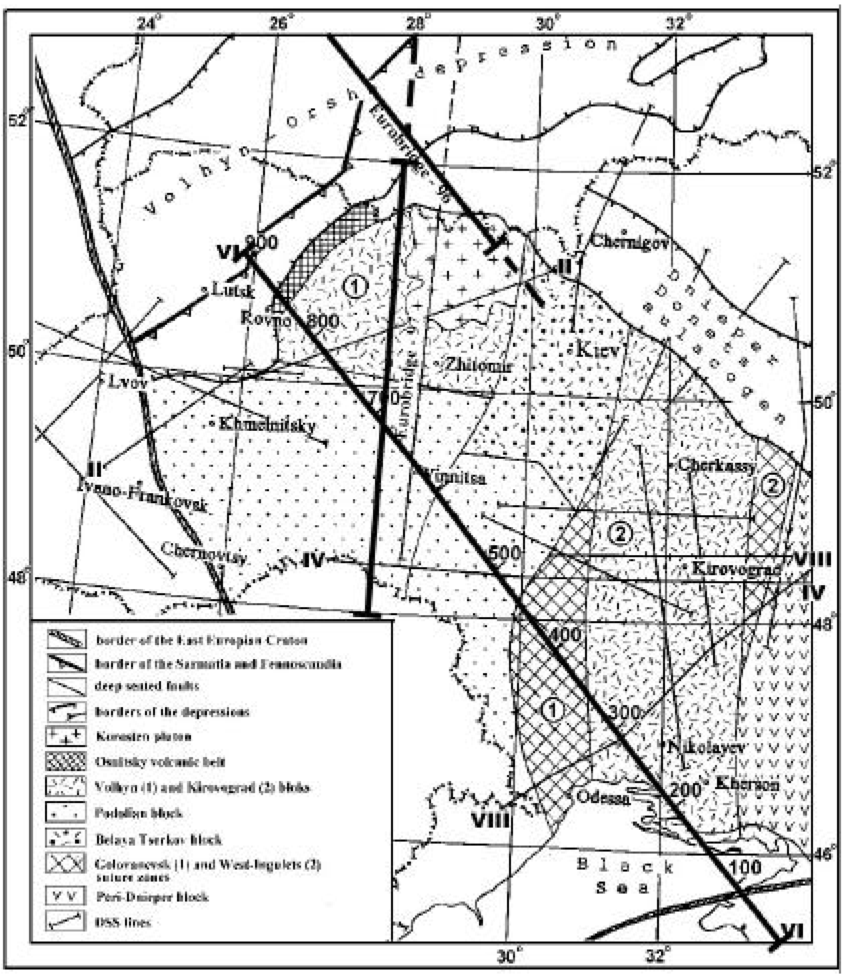

Fig.1. Geological zoning and DSS profiles for the central and western parts of the Ukrainian Shield.

Geotraverse VI offers the following geophysical observations.

SEISMICS. In 1981-82, detailed continuous wide-angle reflection and refraction studies (DSS) were made along Geotraverse VI with shot-point spacings of 30-50 km and maximum offset lengths of 300-400 km. Observation from one shot covered a ca. 30 km long interval. Only the vertical component in a frequency band of 7-15 Hz was recorded by seismographs placed every 200 m. These registration conditions provided a reliable phase correlation on seismograms. The experimental records are available now on paper seismograms with a time scale of 0.01 s/mm and will be digitised soon within an INTAS collaboration between Kiev, Milan, Moscow and Uppsala.

The principal elements of the observed wave field are refracted and reflected waves originating in the crystalline crust (the sedimentary cover being thin here) and uppermost mantle. The crustal refracted waves recorded as first arrivals are associated with the upper 15-20 km. Mantle refractions start at an offset of 200-220 km and, because of their low intensity, can only be correlated along intervals of no more than 30-50 km. Therefore, they image only short parts of the Moho discontinuity (crust-mantle boundary) proper and cannot reveal structures in the deeper lithosphere. The observed reflections are mainly post-critical and originate at boundaries lying at depths between 10 and 80 km. Though Moho reflected phases are generally stable, with a high signal-to-noise ratio, the length of their uninterrupted correlation intervals varies widely from 20 to 80 km. Nevertheless, the observation network density has provided an amount of these reflections tied in reciprocal points sufficient to constrain the lower crust velocity model and Moho discontinuity position.

The Earth's crust and upper mantle velocity model for the considered part of Geotraverse VI (Fig. 2) have been developed by 2-D forward modelling (Ilchenko, 1985, 1988). The uncertainty of the model parameters was determined as difference between their maximum and minimum values permissible for the following inaccuracy of the observed travel times: ±0.03-0.04 s for the refracted and ±0.05 s for the reflected phases.

The travel times of upper crustal refractions always enable us to define an accurate velocity distribution. Limits of a possible vertical shift for velocity isolines were estimated to be less than 0.5 km. The maximum sampling depth of these waves (marked by the wavy line in Fig. 2) varies along the profile from 15 to 25 km. For the deeper crust, velocity isolines are only constrained by Moho reflections increasing their depth uncertainty to 2-3 km. Accordingly, the vertical uncertainty of Moho depth is 2-4 km. The velocity model presented in Fig. 2 is simplified and illustrates only the main features of the interpretation. Average velocity isoline depths are given and Moho reflectors are shown as strips with a thickness corresponding to the calculated uncertainty intervals.

According to geological data, Geotraverse VI cuts several blocks of the Ukrainian Shield which differ in size, rock composition and evolution. This is often manifested by sharp lateral changes in the upper crustal velocity (see the high velocities in the Golovanevsk block in Fig. 2). For the crust as a whole, the following three large segments with different thickness and averaged velocity characteristics of the crust and velocity in the uppermost mantle are marked out (Fig. 2):

1. The Kirovograd block (100-350 km), where the crust is 37-38 km thick, crustal velocity increases with depth from 5.8-6.0 to 6.8 km/s and velocity at the mantle top is 8.1 km/s;

2. The Golovanevsk zone (350-490 km), which reaches 30 km further NW in the seismic model than the geologically defined Golovanevsk suture zone. Here the same parameters are 60-65 km, from 6.2-6.4 to 7.7 km/s and 8.4 km/s.

3. The Podolian-Volhyn-Osnitsk segment (490-910 km), where the same parameters are 55 km on average, from 6.0-6.2 to 7.2 km/s and 8.4-8.5 km/s. In the NW, the Osnitsk volcanic belt (840-910 km) shows somewhat higher crustal thickness and velocity compared with the rest of this segment.

Thus, the Kirovograd block is characterised by the lowest, the Golovanevsk zone by the highest and the Podolian-Volhyn-Osnitsk segment by generally intermediate seismic parameters. Besides, while the former two have a relatively smooth relief of the Moho discontinuity, the Moho topography of the latter has a very complicated shape.

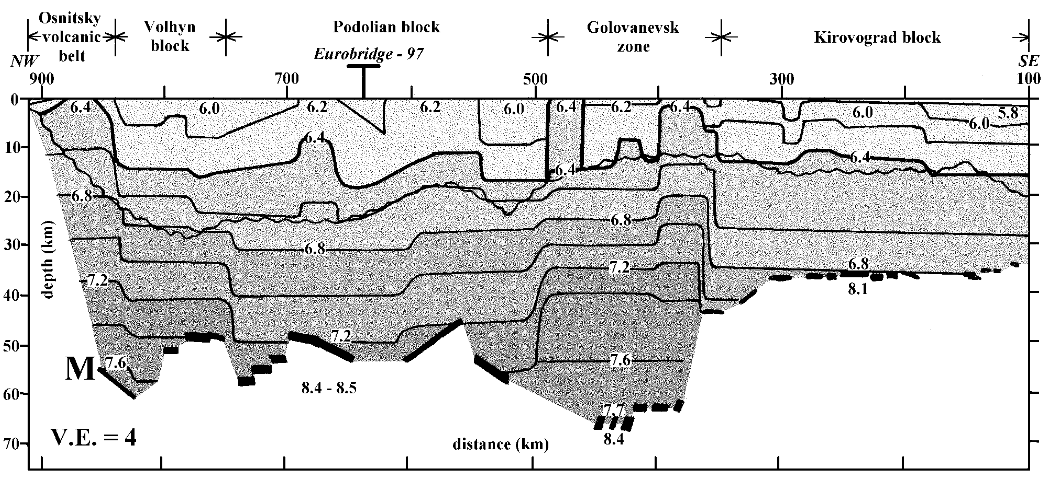

Fig.2. P-wave velocity model of the Earth's crust and uppermost mantle for the central and western parts of the Ukrainian Shield (Geotraverse VI). Velocity isolines are shown by lines, with isoline "6.4" being shown by thick line. Moho discontinuity (M) is indicated by strips corresponding to uncertainty intervals of the reflector depths. Wavy line divides the crust areas studied from refraction (up) and reflection (down) data. Velocity units are km/s.

GRAVITY AND MAGNETIC FIELDS. The obtained velocity model served as a basis for density and magnetic modelling. In the gravity field of the study area, the most significant are the decreased Bouguer gravity anomaly values of the Kirovograd block and the strikingly increased ones over the Golovanevsk zone. Interestingly, the negative anomaly corresponds to the shallowest position of the Moho discontinuity and a low velocity crust, and, contrarily, the positive one correlates with the greatest crustal thickness and high crustal velocities. A 3-D density model (Starostenko & Zavorotko, 1980; Koifman, 1988) shows that for the crystalline crustal rocks in the considered region of the Ukrainian Shield, the relation between density ρ and P-wave velocity Vp can be described by $\rho = 0.3\ Vp + (0.85 + 0.01)$, except for the edges of the Shield in the SE (100-300 km) and NW (840-910 km) of Geotraverse VI where the second term had to be diminished to 0.78.

The anomalous magnetic field contains short- and long-wavelength components the sources of which reside in the upper (to 10 km depth) and lower crust, respectively. The uncertainty of the long-wavelength separation is +(40- 80) nT. It results in no more than 20% error of estimating the lower crustal magnetisation. The magnetic model along Geotraverse VI reflects the subdivision of the Ukrainian Shield crust into large blocks. At 100-350 km (the Kirovograd block), the lower crustal magnetisation is 2A/m and the upper crust one averages 0.1 A/m. At 350-600 km, a segment with the most magnetic lower (4 A/m) and upper (0.8 A/m) crust coincides with the Golovanevsk suture zone and the eastern half of the Podolian block, while the crust of the western part of the latter is practically non-magnetic. Magnetisation begins to increase again near the Volhyn block and reaches (750-840 km) 3.5 A/m for the lower and 0.3 A/m for the upper crust.

HEAT FLOW and MAGNETOTELLURICS. Geothermal measurements have been made in a 50 km wide zone to both sides of Geotraverse VI at 80 points. The heat flow is relatively low, varying from 25 to 44 mW/m^2 without showing important variations. The northwestern part and centre of the profile are dominated by low values (25-30 mW/m^2) and the Kirovograd block by somewhat higher ones (38-44 mW/m^2). The crust and subcrustal mantle temperatures were determined by solving a 2-D and a non-stationary 3-D problem (Gordienko et. al., 1996; Kutas, 1988). The temperature at the Moho discontinuity results at 600^oC.

Magnetotelluric sounding covered both Geotraverse VI itself (63 points) and a 100 km wide stripe (97 more points) around it. The interpretation of the data has discovered three large areas with good conductors in the crust. With a background resistivity of 2000 Ωm, these have 25 Ωm at 800-910 km in the depth ranges of 5-10 and 30-50 km, 80 Ωm at 600-750 km at 15-30 km depth and 10 Ωm at 300-550 km from the surface to 10-15 km depth (Burakhovich et al., 1996).

FUTURE WORK. An integrative interpretation of the different geophysical data obtained on EUROBRIDGE-97 and Geotraverse VI involving the newly reinterpreted DSS data of Geotraverse II (Fig. 1) provides a good opportunity for regional geophysical-geological modelling of the Ukrainian Shield. Of specific interest will be the construction of 3-D geophysical models of the Earth's crust and upper mantle (with outcome to petrological prognosis) of the Korosten pluton and the Volhyn block. The same type models can be developed for the Podolian block, using data of EUROBRIDGE-97 and Geotraverses II, IV and VI (Fig. 1). The method of solving such a problem has already been worked out during areal studies of the Golovanevsk suture zone and Kirovograd block of the Ukrainian Shield, made on the basis of Geotraverses IV, VI and VIII (Fig. data (Chekunov, et al., 1994).

The geologic-geophysical modelling planned here will provide a comprehensive extension of the EUROBRIDGE profile to the southern boundary of the East European Craton, notably increasing its transcontinental significance. These results will be of importance for the assessment of metallogenic prognosis in the Ukrainian Shield.

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