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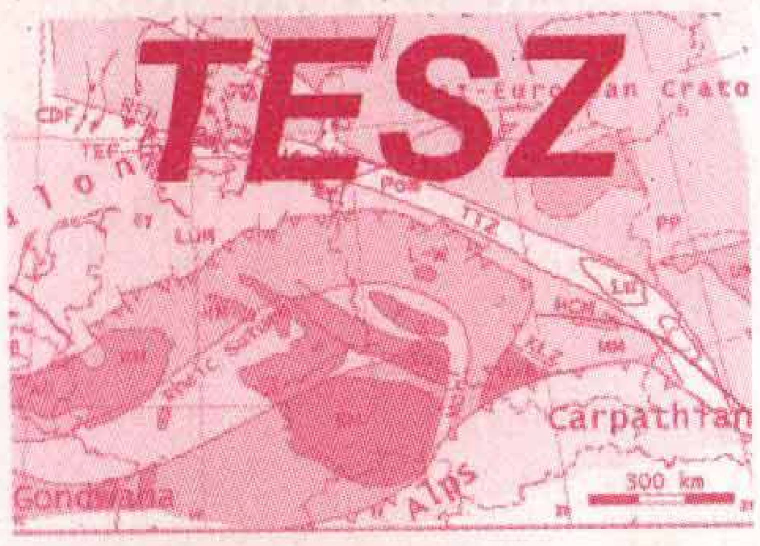

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PROGRAMME AND ABSTRACTS VOLUME

I.G.R. 45 N 24 E

Institutul Geologic al României

Bucureşti - 1999

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The editor has changed the name as follows: Institutul Geologic al României (1906-1952), Comitetul Geologic (1953-1966), Comitetul de Stat al Geologiei (1967-1969), Institutul Geologic (1970-1974), Institutul de Geologie şi Geofizică (1975-1993), Institutul Geologic al României (since 1994).

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Joint Meeting of

EUROPROBE TESZ, PANCARDI AND GEORIFT PROJECTS
Dobrogea – the interface between the Carpathians and the Trans-European Suture Zone

Tulcea, Romania
25 September – 6 October 1999

PROGRAMME AND ABSTRACTS VOLUME

Edited by

Liviu Maţenco – Bucharest University, Faculty of Geology and Geophysics
Dumitru Ioane – Geological Institute of Romania
Antoneta Seghedi – Geological Institute of Romania

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Bucureşti
1999

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CONFERENCE PROGRAMME

FIELDTRIPS AND INFORMATION

25-26 September
Arrival of participants in Bucharest

26 September
Workshop on borehole cores samples
8.00 Breakfast
9.00 Core Store – Workshop on borehole core samples
13.00 Lunch at the Geological Museum/ Introduction to geology of Dobrogea
17.30 Bus to Tulcea

Description
Borehole cores from the Middle and Late Proterozoic basement of the South Dobrogea (Moesian Platform) will be examined in the core store of the Geological Institute of Romania. The Middle Proterozoic is represented by a banded iron formation, while the Late Proterozoic includes a basic volcano-sedimentary formation with very low grade metamorphism. Lunch organized at the Geological Museum. An introduction to the geology of Dobrogea. Departure to Tulcea by bus at 5 p.m.

General Fieldtrips programme
8.00 Breakfast
8.30 Departure for the field trip
12.30 Lunch
18.00 Return from the field trip
19.30 Dinner

A. 27 - 29 September - First part of TESZ excursion in Dobrogea

Title: "Geology and structure of the Precambrian and Palaeozoic basement of North and Central Dobrogea"

27 September
Description
The Late Proterozoic basement of Central Dobrogea (Moesian Platform), represented by the Histria Formation, with very low grade metamorphism and well preserved sedimentary structures; 5 stops will present the sedimentology, facies associations of the midfan and distal turbidites three members and the structural style of the Cadomian deformation.

28 September
Description
Precambrian metamorphic basement of North Dobrogea; 6 stops introducing the lithology, metamorphism and deformation of the medium grade Orliga and Megina Groups, and the low grade Boclugea Group.

29 September
Description
The Palaeozoic formations and granitoids of North Dobrogea - 8 stops.

30 September and 1 October are common with days 1 and 2 of the next fieldtrip.

B. 30 September – 1 October - PANCARDI/TESZ/ GEORIFT excursion

Title: "Mesozoic history of North and Central Dobrogea"

30 September
Description
The main crustal faults of Dobrogea: Peceneaga-Camena and Capidava-Ovidiu Faults.
Sight-seeing tour of the Black Sea shore.

1 October
Description
The alkaline magmatism of North Dobrogea, ascribed to the Late Permian-Early Triassic; the extension-related Early to Middle Triassic rhyolitic and basaltic volcanism and associated sediments; the style of the Cimmerian deformation. Wine tasting party in Niculitel cellars.

1 October evening Arrival in Tulcea for the conference sessions

C. 2 October - Danube Delta fieldtrip

Programme
8.00 Breakfast
10.00 Start of excursion
13.00 Lunch on board
17.00 Arrival in Tulcea

Description
This excursion will take 8 hours on one or two ships. The route will follow the Sulina Distributary, then several minor channels and Lakes Fortuna, Baclanestii Mari and Nebunu, with return to the Danube along channel Sontea. Lunch will be served on board. Further details on the maps section on the web page.

D. Conference sessions details

Duration
- Early Morning session: 2h (09:00-11:00)
- Late Morning session: 2h (11:30-13:30)
- Early Afternoon session: 2h (15:00-17:00)
- Late Afternoon session: variable, between 1h and 1h:40 mins (starting at 17:30 or 17:20)

2 coffee breaks, first 30 min and second 20 or 30 mins
1 lunch break, 1h:30mins

General programme
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09:00-11:00 Early Morning session
11:00-11:30 Coffee break
11:30-13:30 Late Morning session
13:30-15:00 Lunch
15:00-17:00 Early Afternoon session
17:00-17:30 (or 17:00-17:20) Coffee break
17:30-variable Late Afternoon session
19:30-20:30 Dinner
20:30- Social events

Social events
2 October 20:30 Ice breaker party
3 October 20:30 "Mozart Evening", Imperioso String Quartet
4 October 20:30 "Farewell" conference party

Lectures Halls
Hall 1 Tulcea County hall
Hall 2 Delta Hotel
Hall 3 National Institute Danube Delta hall

SESSIONS PROGRAMME

Joint Session
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08:20-08:50 Special welcome session
- Local officialities welcome
- Message from Romanian presidency

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Convener: A. Seghedi

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J2. **09:40** THE NEOTECTONICS OF THE BALKANS, AEGEAN AND MIDDLE EAST, by Dewey, J.F.
J3. **10:20** THE NORTH DOBROGEA OROGENIC BELT: A REVIEW, by Seghedi, A.

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Lecture room: Hall 1
Convener: J.F. Dewey

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J8. **15:40** TECTONIC DEVELOPMENT OF THE WEST CARPATHIANS IN MESOZOIC AND CENOZOIC AS REVEALED BY GEOLOGIC. DEEP REFLECTION SEISMIC AND MAGNETOTELLURIC DATA, by Tomek, C., Hall, J., Stanley, D., Varga, G., and Vozar, J.
J9. 16:20 WHAT HAS GEORIFT BEEN UP TO: THE KEY LINKS BETWEEN GEORIFT, TESZ, AND PANCARDI, by Stephenson, R.A.

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Convener: C. Tomek

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PO2. **09:40** SEISMIC EXPERIMENT CELEBRATION 2000: FROM EAST EUROPEAN CRATON THROUGH CARPATHIANS TO PANNONIAN BASIN, by CELEBRATION 2000 Organizing Committee (Guterch, A., Grad, M., Keller, G.R., Thybo, H., Vozar, J., Hegedüs, E., and Hajnal, Z.
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Convener: A. Guterch

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Convener: J. Mosar

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PANCARDI oral session part 2
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Convener: T. Pharaoh

TO1. **09:00** TECTONIC SUBSIDENCE MODELLING OF THE POLISH BASIN IN THE LIGHT OF NEW DATA ON CRUSTAL STRUCTURE AND MAGNITUDE OF INVERSION, by Stephenson, R.A., and Narkiewicz, M.

TO2. **09:20** REGIONAL TECTONIC FRAMEWORK OF THE TRANS-EUROPEAN SUTURE ZONE FROM GRAVITY AND MAGNETIC DATA, by Lee, M.K., Wybraniek, S., Thybo, H., Williamson, J.P., Banka, D., and Wonik, T.

TO3. **09:40** A COMBINED 3-D DENSITY AND MAGNETIC MODEL OF THE EARTH'S CRUST OF THE SOUTH-WEST PART OF THE EAST-EUROPEAN CRATON, by Pashkevich, I., Buryanov, V., Makarenko, I., Starostenko, V., Legostaeva, O., and Orlyuk, M.

TO4. **10:00** HEAT FLOW, SEISMIC WAVE VELOCITY AND THE LITHOSPHERE STRUCTURE IN THE NOTH-WESTERN BLACK SEA REGION, by Veliciu, Ş.

TO5. **10:20** TRANS-CRUSTAL "TOMOGRAPHY" OF THE ROMANIAN TERRITORRY BASED ON GRAVITY AND MAGNETIC DATA, by Ioane, D., and Atanasiu L.

TO6. **10:40** OLD AND NEW GEOPHYSICAL IMAGES WITHIN NORTH DOBROGEA OROGEN, ROMANIA, by Besutiu, L., and Nicolescu, A.

11:30-13:30 – Late Morning session
Title: Seismics part 1
Lecture room: Hall 3
Convener: M. Lee

TO7. **11:30** DEEP REFLECTION AND REFRACTION SEISMIC CONSTRAINTS ON CALEDONIAN ACCRETION IN THE SOUTHERN BALTIC SEA, by Krawczyk, C.M., Eilts, F., Bleibinhaus, F., Beilecke, T., Bram, K., and the North German Basin Research Group

TO8. **11:50** LITHOSPHERIC STRUCTURE BENEATH THE TESZ DERIVED FROM POLONAISE'97, by POLONAISE WORKING GROUP (Grad, M.)

TO9. **12:10** INTEGRATED SEISMIC AND DENSITY MODEL OF THE EARTH'S CRUST AND UPPER MANTLE BENEATH THE LT-7 AND TTZ DSS PROFILES IN POLAND, by Kozlovskaya, E., and Yliniemi, J.

TO10. **12:30** TOR STATUS FALL 1999. TOR - A SEISMIC STUDY OF THE LITHOSPHERE AND ASTHENOSPHERE OF NORTHERN EUROPE., by Voss, P., Gregersen, S., and the TOR Working Group.

TO11. **12:50** CRUSTAL STRUCTURE OF WESTERN POLAND: PRELIMINARY GEOLOGIC INTERPRETATION OF POLONAISE '97 PROFILE P1, by Zelazniewicz, Z., Cwojdzinski, S., Guterch, A., and Grad, M.

TO12. **13:10** DEEP SEISMIC LINES IN THE ROMANIAN CARPATHIAN FORELAND, by Cristea, P., and Stanchevici, B.

15:00-17:20 – Early Afternoon session
Title: Seismics part 2, crustal stress, biostratigraphy and metamorphic suits part 1
Lecture room: Hall 3
Convener: S. Veliciu

TO13. **15:00** TECTONIC EVOLUTION OF THE ROMANIAN PART OF THE MOESIAN PLATFORM: AN INTEGRATED MODEL, by Rabagia, T., and Tarapoanca, M.

TO14. **15:20** FAR-FIELD STRESS TRANSMISSION INDICATIONS IN EARLY PALAEOZOIC STRUCTURAL EVOLUTION OF THE BALTIC BASIN, by Sliaupa, S.

TO15. **15:40** PROGRESS REPORT OF THE PALEONTOLOGY AND PALEOGEOGRAPHY SUBPROJECT, by Verniers J. et al.

TO16. **16:00** BIOSTRATIGRAPHY OF THE PALEOZOIC FROM THE FORELAND OF THE ROMANIAN CARPATHIANS, by Iordan, M.

TO17. **16:20** ANCHIMETAMORPHIC PRECAMBRIAN ROCKS ON THE FORELAND OF THE EAST-EUROPEAN PLATFORM., by Bula, Z., and Jachowicz, M.

TO18. **16:40** GEOCHEMISTRY AND DEFORMATIONAL HISTORY OF METABASIC VOLCANIC ROCKS FROM NORTHERN AND CENTRAL DOBROGEA, ROMANIA, by Crowley, Q.G., Baier, U., and Winchester, J.A.

TESZ - oral session part 2
Date: 5 October 1999

09:00-11:00 – Early Morning session
Title: Metamorphic suits part 2 and variscan orogeny
Lecture room: Hall 3
Convener: P. Voss

TO19. **09:00** ULTRAHIGH PRESSURE- VERSUS ULTRA-DEEP ORIGIN ROCKS - THEIR GEOLOGICAL SETTINGS, by Bakun-Czubarow, N.

TO20. **09:20** HEAVY MINERALS IN OROGENIC STUDIES, by Mange-Rajetzky, M.A., and Dewey, J.F.

TO21. **09:40** HP METAMORPHIC ROCKS AND VARISCAN COLISIONAL FRAMEWORK IN THE BASEMENT OF THE SOUTH CARPATHIANS, by Iancu, V., Medaris Jr., G., Ghent, E.D., and Maluski, H.

TO22. **10:00** PRECONDITIONS OF PALAEOZOIC OROGENIC DEVELOPMENTS IN SOUTHERN POLAND, by Zelazniewicz, A.

TO23. **10:20** THE DEFORMATIONAL HISTORY OF NORTH DOBROGEAN HERCYNIAN BASEMENT AS REFLECTED IN NEW $^{39}AR/^{40}AR$ DETERMINATIONS., by Seghedi, A., Lang, B., and Heimann, A.

TO24. **10:40** VARISCAN STRUCTURE AND HISTORY OF THE TESZ IN SOUTH-EASTERN POLAND, by Narkiewicz, M.

TESZ, Posters
Date: 3-6 October 1999

TP1. THE CAPIDAVA-OVIDIU FAULT SYSTEM (OVIDIU SECTOR) IN THE POARTA ALBA-NAVODARI CANAL, by Avram, E., Ion, J., Pană, I., Popescu, Gh., Baltres, A., Iva, M., and Bombiță, Gh. (Seghedi, A.)

TP2. MAGLODAN PROJECT, THE FIRST STEP IN MERGING THE NATIONAL GEOMAGNETIC MAPS OF ROMANIA, UKRAINE AND REPUBLIC OF MOOLDOVA, by Besutiu, L., Paschkevich, I., Orlyuk, M., Besutiu, G., Ivan, M., and Neaga, V.

TP3. GEOCHEMISTRY AND DEFORMATIONAL HISTORY OF METABASIC VOLCANIC ROCKS FROM NORTHERN AND CENTRAL DOBROGEA, ROMANIA, by Crowley, Q.G., Baier, U., and Winchester, J.A.

TP4. DEEP GEOLOGICAL STRUCTURE OF DANUBE DELTA AREA AS DEDUCED BY 3D INTERPRETATION OF GEOPHYSICAL DATA, by Dimitriu, R. G., Sava, C., Oaie, Gh., and Anghel, S.

TP5. REGIONAL TECTONIC FRAMEWORK OF THE TRANS-EUROPEAN SUTURE ZONE FROM GRAVITY AND MAGNETIC DATA, by Lee, M.K., Wybraniek, S., Thybo, H., Williamson, J.P., Banka, D., and Wonik, T.

TP6. DEEP REFLECTION AND REFRACTION SEISMIC CONSTRAINTS ON CALEDONIAN ACCRETION IN THE SOUTHERN BALTIC SEA, by Krawczyk, C.M., Eilts, F., Bleibinhaus, F., Beilecke, T., Bram, K., and the North German Basin Research Group

TP7. PERMO-CARBONIFEROUS TECTONO-SEDIMENTARY EVOLUTION AT THE NORTHERN MARGIN OF THE NORTHEAST GERMAN BASIN, by Kossow, D., Rieke, H., Krawczyk, C.M., McCann, T., Strecker, M., Negendank, J.W.F., and the North German Basin Research Group

TP8. MODES OF THE LATE MESOZOIC AND MIOCENE TECTONIC ACTIVITY ALONG THE TRANS-EUROPEAN SUTURE ZONE - FROM THE BALTIC SEA TO THE CARPATHIANS, by Krzywiec, P.

TP9. ROTLIEGEND CONGLOMERATES FROM THE NE GERMAN BASIN - PROVENANCE AND SIGNIFICANCE, by McCann, T.

TP10. THE NATURE OF THE VARISCAN DEFORMATION FRONT IN NE GERMANY - EVIDENCE FROM DEEP SEISMIC PROFILING, by McCann, T., and Krawczyk, C.M.

TP11. CALEDONIAN METAVOLCANICS FROM THE EAST CARPATHIANS: GEOCHEMISTRY AND TECTONIC SETTING, by Munteanu, M., Rosu, E., and Voda, A.

TP12. NEREITES ICHNOFACIES IN THE PALEOZOIC OF NORTH DOBROGEA, by Oaie, G., and Brustur, T.

TP13. DEEP MARINE SEDIMENTATION OF THE HISTRIA FORMATION, CENTRAL DOBROGEA (ROMANIA), by Oaie G.

TP14. TODAY'S TEMPERATURE FIELD OF THE NE-GERMAN BASIN – COMPARING TEMPERATURE MEASUREMENTS AND 3D-MODELING, by Ondrak, R., Scheck, M., Foerster, A., McCann, T., Gerisch, R., and the North German Basin Research Group

TP15. THE VARISCAN OROGEN IN BULGARIA - NEW ISOTOPE-GEOCHEMICAL DATA, by Peytcheva, I., Kostitsin, Y., Salnikova, E., Ovcharova, M., and Von Quadt, A.

TP16. LATERITIC PALEOWEATHERING CRUSTS FROM DOBROGEA - PALEOCLIMATIC, PALEOGEOGRAPHIC AND PALEOTECTONIC IMPLICATIONS, by Radan, S.

TP17. MARINE GRAVITY AND MAGNETIC DATA OVER THE BLACK SEA ROMANIAN SHELF, by Sava, C.S.

TP18. HERCYNIAN DEFORMATION AND VERY LOW GRADE METAMORPHISM OF THE PALEOZOIC FORMATIONS IN NORTH DOBROGEA, by Seghedi A., Ciulavu M., Oaie Gh., and Radan S.

TP19. LATE PROTEROZOIC-EARLY CAMBRIAN TURBIDITES FROM CENTRAL DOBROGEA – PROVENANCE AND SIGNIFICANCE, by Seghedi, A., Oaie, G., and Rădan, S.

TP20. REE BASED PROVENANCE STUDY OF SILURIAN SEDIMENTS IN THE BALTIC BASIN, by Sliaupa, S.

TP21. LATE CRETACEOUS INVERSION TECTONICS IN THE BALTIC REGION: CONSTRAINTS ON FAR-FIELD STRESS TRANSMISSION REGIME, by Sliaupa, S.

TP22. PALAEOMAGNETISM AND PALEOGEOGRAPHY OF PALAEOZOIC TERRANES IN THE VARISCAN AND ALPINE FOLD BELTS, by Tait, J.A., Schätz, M., Bachtadse, V., and Soffel, H.

TP23. PALYNOLOGICAL EVIDENCE FOR THE PALEOZOIC IN THE BASEMENT OF NORTH DOBROGEA, by Vaida, M., and Seghedi, A

TP24. TOR STATUS FALL 1999. TOR - A SEISMIC STUDY OF THE LITHOSPHERE AND ASTHENOSPHERE OF NORTHERN EUROPE, by Voss, P., Gregersen, S., and the TOR Working Group.

TP25. NEW VIEWS OF SELECTED EUROPEAN GEOPHYSICAL FIELDS, by Wybraniec, S., Perchuc, E., Thybo, H., Jankowski, J., Ernst, T., Praus, O., and Pecova, J.

GeoRift, oral session
Date: 5 October 1999

11:30-13:30 – Late Morning session
Title: Georift part 1
Lecture room: Hall 3
Convener: R. Stephenson

GO1. **11:30** *(Invited)* PALEOZOIC CIRCUM-BALTICA PLATE-TECTONICS, by Mosar J.

GO2. **12:10** MESOZOIC AND CENOZOIC EVOLUTION OF THE SCYTHIAN PLATFORM-BLACK SEA-CAUCASUS DOMAIN, by Nikishin, A.M., Ziegler, P.A., Panov, D.I., Nazarevich, B.P., Brunet, M.F., Stephenson, R.A., Bolotov, S.N., Korotaev, M.V., and Tikhomirov, P.

GO3. **12:30** CENTRAL-BALKAN NEOTECTONIC REGION NORTH OF THE AEGEAN: TECTONIC EXHUMATION ALONG LOW-ANGLE DETACHMENTS OR RIFTING AND NORMAL EROSIONAL DENUDATION AND UNROOFING?, by Zagorchev I. S.

GO4. **12:50** DRIVING FORCES, STRAIN AND TEMPERATURE NECESSARY FOR INTRACRATONIC RIFTING AND INVERSIONS FROM THE VIEWPOINT OF RHEOLOGICAL MODELS OF LITHOSPHERE, by Ershov, A., and Stephenson, R.

GO5. **13:10** THE BLACK SEA BASIN: TECTONIC HISTORY AND MODELLING, by Korotaev, M.V., Nikishin, A.M., Ershov, A.V., and Brunet, M.F.

15:00-17:00 – Early Afternoon session
Title: Georift part 2
Lecture room: Hall 3
Convener: A.M. Nikishin

GO6. **15:00** GEOLOGIC ENVIRONMENTS AND GEODYNAMICS OF THE SOUTHERN MARGIN OF EAST EUROPEAN CRATON, by Kostyuchenko, S.L

GO7. **15:20** INNER STRUCTURE AND EVOLUTION OF SALT MASSIFS IN THE PRIPYAT PALEORIFT, by Kovkhuto, A.M., Garetsky, R.G., and Konischev, V.S.

GO8. **15:40** THE INVERSION OF THE HYSTRIA BASIN - ROMANIAN BLACK SEA SHELF, by Morosanu, I.

GO9. **16:00** SOME KINEMATIC INDICATORS FOR THE TECTONIC EVOLUTION OF THE DONBAS FOLD-AND-THRUST BELT (UKRAINIAN PART), by Saintot, A., Privalov, V., Zhikaliak, M., Brem, A., and the EUROPROBE/INTAS team

GO10. **16:20** MECHANISMS OF SALT DIAPIR FORMATIONS: SOME MODERN IDEAS AND THEIR COMPARISON WITH OBSERVATIONS, by Stovba, S., and Podladchikov, Y.

GO11. **16:40** TRIASSIC VOLCANIC ACTIVITY IN THE EASTERN FORE-CAUCASUS (SCYTHIAN PLATFORM): NEW DATA ON THE PROBLEM OF NORTH-TETHYS VOLCANIC BELT, by Tikhomirov, P.L., and Nazarevich, B.P.

17:20-18:20 – Early Afternoon session
Title: Georift part 3
Lecture room: Hall 3
Convener: I.S. Zagorchev

GO12. **17:20** EARLY PERMIAN REGIONAL UPLIFT OF THE SOUTH-EASTERN PART OF THE DNIEPR-DONETS BASIN, by Shymanovsky, V., and Stovba, S.

GO13. **17:40** DEEP STRUCTURE OF THE LITHOSPHERE BELOW THE DNIEPR-DONETS BASIN AND DONBAS FOLDBELT ACCORDING TO GRAVITY AND SEISMIC DATA, by Yegorova, T.P., Kozlenko, V.G., Starostenko, V.I., Legostaeva, O.V., and Stephenson, R.A.

GO14. **18:00** CDP SEISMICAL AND OTHER GEOLOGICAL DATA RECEIVED IN THE CRIMEA - BLACK SEA REGION: INTERPRETATION AND USING FOR ESTABLISHING THE FORMING HISTORY, by Karpenko, I.V.

GeoRift, Posters
Date: 3-6 October 1999

GP1. 3-D ANALYSIS OF THE GRAVITY FIELD OF THE NW BLACK SEA AND THE ADJACENT LAND (DOBROGEA), by Buryanov, V.B., Makarenko, I.B., Orovetsky, Y.P., Starostenko, V.I., and Legostaeva, O.V.

GP2. THE INFLUENCE OF REMOTE EARTHQUAKES ON STABLE REGIONS (EXAMPLES FROM LITHUANIA), by Ilginyte, V.

GP3. THE BLACK SEA BASIN: TECTONIC HISTORY AND MODELLING, by Omelchenko, V.

GP4. NEW 3-D CRUSTAL DENSITY MODEL FOR THE EASTERN PART OF THE DNIEPR-DONETS BASIN AND DONBAS FOLDBELT: AUTOMATED METHOD AND RESULTS, by Starostenko, V.I., Legostaeva, O.V., Burianov, V.B., and Makarenko, I.B.

GP5. 3-D GRAVITY MODELLING OF THE CRUSTAL STRUCTURE FOR THE EUROBRIDGE'97 PROFILE AREA (BELARUS AND UKRAINE), by Yegorova, T.P., Kozlenko, V.G., and Starostenko, V.I.

JOINT SESSION

THE NEOTECTONICS OF THE BALKANS, AEGEAN AND MIDDLE EAST

J2

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The region displays a complete extant array of tectonic regimes with complex local variation and rapid tectonic facies changes from extension to strike-slip and shortening in the context of continental collision, wedge/escape tectonics, remnant oceanic holes and back-arc extension by subduction roll-back. The basic framework for analysis is the relative motion of the Eurasia, African and Arabian Plates. For the last 9 my, Africa has rotated anticlockwise by 0.94° with respect to Europe about a pole at Lat. 0.55°/Long. – 55.78° giving a relative motion of about 9 mma^{-1} to the northwest in the Aegean region. Arabia moves northwards at about 20 mma^{-1} with respect to Eurasia causing crustal thickening in eastern Turkey and Iran since about 14 my and the westwards motion (lateral wedging/escape) of Anatolia bounded by the right-lateral North Anatolian Fault and the left-lateral East Anatolian Fault, enhanced by Aegean back-arc extensional collapse caused by the roll-back suction of the Cretan forearc. The modern stress map of Europe is dominated by North-Atlantic ridge push and Alpine shortening giving a strong NW/SE compression, whereas to the east in the Aegean and Middle East stress regimes and consequent earthquake first motions are related more locally to tectonic regime and slip on major faults. Topography is a major weapon in our tectonic armoury and closely reflects tectonic regimes throughout the region. GPS data in Turkey and the Aegean give a clear and consistent pattern of the westward anticlockwise rotation and motion of Anatolia at about 20 mma^{-1} modified by north-south stretching in the Aegean. A new analysis will be presented of displacement rotation and strain throughout the region for the last 10 my using the finite difference/vector nest method. In eastern Turkey and Iran, the NW/SE motion of Arabia with respect to Eurasia is strongly partitioned into zone-parallel right lateral strike-slip and zone-orthogonal shortening. In east-central Turkey, relative motion is partitioned in a much more complicated way into north-south shortening, oblique thrusting and slip on major strike-slip faults. Sedimentary basins reflect local tectonic regimes. The Karliova Basin originates at the eastern wedge junction of the North and East Anatolean Faults as an 'arrowhead' escape basin which becomes progressively shortened, whereas the Adana Basin develops at the triple junction between the East Anatolian Fault, the Dead Sea Transform and the Misis Zone. The Mediterranean Ridge is an accretionary prism beneath which the subduction of sea-mounts causes mega-grooving parallel with the Plino/Strabo lineaments and the slip direction between the Africa Plate and Anatolia. Magmatism is systematically related to tectonic position from the calc-alkaline Aegean arc to the mafic volcanics associated with Adana Basin extension, the flood basalts along north-south 'cracks' in the Arabian foreland to the collisional calc-alkaline volcanics of eastern Anatolia. Balkan tectonics contrasts sharply in resulting from slow continental contraction causing splintering, sliding and rotation along weak zones and lineaments generated by Tertiary Carpathian and Hellenide orogeny.

THE NORTH DOBROGEA OROGENIC BELT: A REVIEW

J3

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Results of recent geological investigations indicate that the North Dobrogea orogenic belt represents a Late Permian-Early Triassic rifted basin that was inverted during the Late Triassic and Early Cretaceous phases of the Cimmerian orogeny.

Permo-Triassic rifting was accompanied by progressive deepening of the basin and bimodal volcanism. Inversion of this basin accounts for the development of south-west and north-east verging thrusted folds, high angle reverse faults and shear zones that are exposed in the uplifted Variscan basement. The intensity of Cimmerian deformation decreases and dies out towards the Northeast.

The North Dobrogea Permo-Triassic rifted basin is superimposed on the Hercynian suture between the Gondwana-derived Moesian Platform and the Precambrian East-European craton. Syn-rift sedimentation commenced during the Late Permian and earliest Triassic and records during the Lower Scythian the transition from a continental siliciclastic to a carbonate dominated environment. Spathian series are dominated by platform and turbiditic carbonates. Anisian to Ladinian series are represented by basinal pelagic carbonates that are offset by carbonate shelves. A Late Spathian pulse of subaerial, explosive rhyolite volcanism was followed by Spathian to Anisian extrusion of pillow basalts. Late Triassic to Middle Jurassic syn-inversion deposits are represented by terrigenous turbidites, derived from the Hercynian basement that was uplifted in the western parts of the belt, involving compressional reactivation of syn-rift extensional faults. Progressive thrust propagation into the basin fill was accompanied by eastward migration of the turbiditic depocentre. Late Jurassic resumption of platform carbonate sedimentation, indicates that inversion movements had ceased by this time. Kimmeridgian extrusion of basalts reflects transtensional reactivation of the south-western margin of the North Dobrogea. During the Early Cretaceous, mild inversion movements are recorded, terminating during the Albian. Late Cretaceous shallow marine sediments overlap the deeply truncated Cimmerian structures.

The stratigraphic and magmatic record of the North Dobrogea orogen is reviewed and a sequence of palinspastically not restored palaeogeographic maps is presented.

MANTLE BENEATH THE CPR: RESULTS FROM STUDIES OF ULTRAMAFIC XENOLITHS

J4

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Heterogeneity in the shallow subcontinental lithospheric mantle can occur over a wide range of length scales, from kilometers down to microns. If the lithospheric mantle is examined on a wide scale using mantle xenolith suites from different locations, numerous similarities emerge in lithology, mineralogy, and geochemistry. Significant differences among spinel-facies xenolith suites are then highlighted by this method and can be attributed to a variety of major mantle processes. In this review, I will discuss examples of spinel peridotites from the Carpathian-Pannonian region which give us insight into the shallow lithospheric mantle.

Xenoliths from the Eastern Transylvanian Basin display typical depleted mantle geochemistry (Vaselli et al, 1995). Despite the apparent proximity to recent subduction in the Carpathian arc, the vast majority of the xenoliths are depleted in Light Rare Earth Elements and their bulk rock chemistry shows no evidence of interaction with subduction-zone fluids. Instead, metasomatism is linked particularly to veins of amphibole, which are considered to be closely related to the Tertiary alkaline magmatism. Carbonatite metasomatism has recently been documented in some xenoliths from the CPR, although no carbonatite magmas have been erupted in the area.

In contrast, xenoliths from the central part of the neighbouring Pannonian Basin display strong evidence of interaction with subduction-related fluids and melts (Downes et al., 1992; Wilson et al., 1997). This enrichment affects Pb isotopes in constituent clinopyroxenes, with consistent high $^{207}Pb/^{204}Pb$ ratios at a given value of $^{206}Pb/^{204}Pb$ (i.e. deviation from the NHRL towards the field of sea-floor sediments). $^{87}Sr/^{86}Sr$ isotope ratios are also elevated during this interaction. The resulting isotopic composition field is unusual among mantle xenoliths from Europe. We consider that this enrichment is due to subduction of sediments during Tertiary subduction.

PALAEOZOIC BIOGEOGRAPHY

J5

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Biogeographic and palaeomagnetic data can now define the positions of the major continents during the Palaeozoic. It is only in the past ten yeas that these two lines of evidence have shown general agreement; palaeomagnetists now know more about remagnetisation of rocks, and palaeontologists now understand more how different faunas and floras have different abilities to migrate. There are, however, still some areas of uncertainty in defining the precise positions of some sutures and in the recognition of some smaller continental fragments. These uncertainties include the exact line of the Trans-European suture zone, where the Tornquist Sea closed between Avalonia and Baltica in the Late 0rdovician, and where Gondwana collided with these northern continents in the Early Devonian.

In the Early Cambrian (at 545Ma), after the Pan-African collisions, the components of Gondwana had come together, while the three smaller continents of Laurentia, Baltica and Siberia were situated together to the west of Gondwana having separated at around 600Ma (Torsvik *et al.* 1995). Siberia and Morocco have similar Early Cambrian faunas, suggesting that Siberia lay to the west of north-west Africa at low latitudes. Avalonia (which was attached to the South American part of Gondwana) has similar faunas to Baltica; and both were at high southern latitudes. Laurentia had similar, but more diverse, faunas to Baltica; this diversity fits with the carbonate facies and palaeomagnetic data from Laurentia, suggesting a low latitude position within the range of pelagic spat transported to and from Baltica (McKerrow *et al.* 1992).

In the Early Ordovician, Laurentia and Siberia shared the same shallow marine benthos, but they were faunally distinct from both Baltica and Gondwana (Cocks & Fortey 1990). During the later Ordovician, Avalonia separated off from Gondwana and moved north to collide with Baltica so that by the start of the Silurian all the major continents were within the range of transport of pelagic spat (i.e. within around 1,000km) of each other, so the distributions of most faunas with pelagic spat (e.g brachiopods, trilobites, molluscs) was governed more by climate (and latitude) than by isolation of individual continents.

Palaeomagnetism shows that, during the Silurian, Bohemia and Armorica both separated from the northern edges of Gondwana to collide independently with the northern continent of Laurussia (Tait *et al.* 1995). After the start of the Silurian, the only common fossils to show the effects of isolation by oceans were the benthic ostracodes (which had no spat) and the non-marine fish (Berdan 1990; Young 1990). These, and other non-marine faunas become ubiquitous after the Emsian, showing that the was more or less continuous contact between Gondwana and Laurussia after that time (McKerrow *et al.* in press). The Variscan oceans of central and southern Europe are thus more comparable to the present day Mediterranean Sea than to the Pacific Ocean.

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J6

PALAEOZOIC AMALGAMATION OF CENTRAL EUROPE: AVALONIAN AND VARISCAN BLOCKS ABUTTING THE EAST EUROPEAN CRATON ALONG THE TRANS EUROPEAN SUTURE ZONE.

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Recent geophysical traverses in the North European Plain and the Southern North Sea, together with re-interpretations of the Variscan Geology of the North Bohemian Massif, have enabled a new look at the margins of the principal crustal blocks attached to the East European Craton (EEC) along the Trans-European Suture Zone (TESZ). This combined approach has illustrated the major sutures dividing the principal microcontinental blocks, which can be traced beneath the Mesozoic cover of the North European Plain.

The largest Palaeozoic microcontinental block now abutting the EEC comprises basement extending eastwards from the eastern part of Avalonia, beneath the southern North Sea, N Germany and NW Poland. In these areas it is totally covered by late Palaeozoic and younger sedimentary rocks, so evidence for its presence therefore entirely arises from geophysical data and inherited age information from magmatic rocks. Further to the SE, the location and dip of reflectors along the TESZ, suggests that those blocks now SE of Avalonia forming part of the "Armorican Terrane Assemblage" have overridden the margin of the EEC on shallowly SW-dipping thrust planes. Sutures, with or without associated zones of deformation should mark the boundaries between these microcontinental blocks, and the principal boundaries which can be traced include:

1. The Thor-Tornquist Suture, approximating to the Caledonian Deformation Front;
2. The northern Variscan Deformation Front;
3. The Rheno-Hercynian (Lizard-Giessen-Harz) suture, extending eastwards towards Berlin;
4. A possible suture line linking ophiolitic lenses close to the western margin of the Moravian block.

Beneath the North European Plain the deep seismic reflection and wide angle record now provides a concise picture of the deep crustal structures which can be partly attributed to the docking of Avalonia. Beneath the Baltic Sea consistently north-dipping reflectors have been recorded below the Moho which extend far north into the EEC. Although these might be interpreted as a northward-dipping Caledonian subduction, their extent, together with the lack of arc magmatism on the EEC margin, argues that they probably have a Precambrian origin. However, further S, and extending N from the Elbe Line and close to the "Caledonian Deformation Front" a high-velocity lower crustal layer is clearly recognizable in all refraction and wide angle lines. Based on new evidence from the DEKORP Basin'96 lines, this high velocity layer shows features interpreted as characteristic of a passive margin, thought to represent the edge of the EEC, and overridden by East Avalonian crust. Also in Germany, Breitkreuz & Kennedy (1999) inferred the presence of Avalonian crust by obtaining old (i261 Ma) zircon ages preserved from the Penkun drill cores in the Halle Volcanic Complex.

The significance of the Variscan orocline is that at mid-crustal levels, blocks of Avalonian affinity may underlie the deformed Variscides in SW Poland, but provide a link at depth between the Avalonian beneath Berlin and the Moravian and Upper Silesian blocks, which may also be displaced portions of easternmost Avalonia. If the Upper Silesian and Moravian blocks possess late Proterozoic and Palaeozoic geological histories similar to Avalonia, they, along with blocks now situated even further to the SE (e.g. Dobrogea, Istanbul), may be relics of the easternmost extremity of the Avalonian microcontinent, which became detached by dextral shearing as Avalonia deformed as it collided obliquely with the EEC margin.

Structural re-assessments within the N Bohemian Massif, and in the Rhenohercynian deformation belt show a complex pattern of early Variscide deformation during the Devonian on the N side of the Variscan orocline. In the NE Bohemian Massif it was dominated by WNW-directed thrusting, whereas in the Rhenohercynian Massif NW-directed thrusting occurred early. This infers that the initial collision was with the S margin of Avalonia, by this stage accreted to and forming part of the "Old Red Continent", comprising Laurentia, the EEC and Avalonia. This also suggests that relative motion to the EEC margin further east was dextral, which is consistent with the development of major dextral strike-slip faulting along the NE margins of the Bohemian Massif. This deformation also marks the closure of seaways which originally opened between Ordovician and Devonian time, between both the trailing margin of Avalonia and the detached "islands" of the Variscan Terrane Assemblage. Subsequent N-S compression, indicated by the E-W trending F_3 folding in the Kaczawa Mountains, may mark later collision with the EEC margin, and wholesale deformation of the Variscides to produce the Variscan orocline. These motions could have superimposed Armorican blocks above Avalonian ones in the NE Bohemian Massif, suggesting that Avalonian, rather than EEC-related middle crust is present in the middle portion of the TESZ.

J7

EUROPROBE TESZ PROJECT – RECENT PROGRESS IN RESEARCH

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The Trans-European Suture Zone (TESZ) is a broad and complex zone of terrane accretion separating ancient lithosphere of the Baltic Shield and East European Craton (EEC) from the younger lithosphere of western and southern Europe. Stretching 2000 km from the North Sea to the Black Sea, it represents the most fundamental lithospheric boundary in Europe. The TESZ project is investigating the nature and evolution of this zone using a carefully planned and coordinated programme of multidisciplinary studies. Geophysical studies form an important part of the programme due to the thick post-Palaeozoic sedimentary cover. These include wide-angle reflection, refraction seismic (POLONAISE project) and teleseismic tomography (TOR) experiments recently carried out in the southern Baltic region.

Comparison of the most recent version of the TESZ project map (Pharaoh, 1999) with that published in the EUROPROBE Science Plan (Gee & Zeyen, 1996), provides a dramatic illustration of the progress being made within the project. The near surface expression of the suture between Avalonia and Baltica is now referred to as the Thor-Tornquist Suture, rather than the 'Caledonian Deformation Front', following Berthelsen (1998). Deformation of 'Caledonian' (Scandian-Acadian) age is now known to extend well to the north of this suture, which is related to closure of the Tornquist Sea in late Ordovician time. The new name also avoids potential confusion with the Sorgenfrei- and Teisseyre-Tornquist Zone, which is a post-Caledonian rift structure within the crust of Baltica well to N of the suture. Recent isotopic studies on deep borehole cores in the Rügen area (Dallmeyer et al., 1999) have enabled revision of the suture's location in N Germany. It is anticipated that similar studies of deep boreholes on the Mid-North Sea/Ringkøbing-Fyn High will help to locate the suture in this region, poorly constrained by the existing seismic coverage. The Thor Suture is depicted as truncated by the slightly younger Iapetus Suture, between Avalonia and Laurentia. Recent interpretations of deep seismic reflection data favour a gently inclined, SSW-dipping boundary to Baltica (MONA LISA Working Group, 1997; DEKORP-BASIN Research Group, 1999), overthrust by Avalonia, with no evidence for a steep fault such as the previously inferred Trans-European Fault Zone (Berthelsen, 1992).

A number of important geophysical lineaments, e.g. the Dowsing-South Hewett Fault Zone, Lower Rhine Lineament, and Elbe Fault Zone within Avalonia indicate that the latter may be composite in nature, with juvenile early Palaeozoic crustal material of the Southern North Sea Terrane accreted to Neoproterozoic crust in southern Britain. Inclined zones of seismic reflectivity in the lithospheric mantle in this region, and the preservation of arc volcanic suites. In southern Britain, favour southward-directed subduction of the Tornquist Sea along at least 2 subduction zones, as previously inferred by Van Grootel et al. (1997). Similar features beneath the southern margin of Baltica have been interpreted in terms of northward-directed subduction (MONA LISA Working Group, 1998), but the absence of preserved associated arc magmatic rocks favours a pre-Palaeozoic age for these structures.

East of Rügen, the Thor Suture, like the Sorgenfrei- and Teisseyre-segments of the Tornquist Rift Zone, may be offset by a lineament extending southward from the Rønne Graben. Recent geophysical experiments of the POLONAISE project promise to resolve the nature and geometry of this crustal boundary in N Poland. The suture emerges from beneath an allochthonous cover of Rhenohercynian nappes in SW Poland, where it is generally agreed that the Kraków-Lubliniec Zone represents the likely suture between Baltica and Gondwana-derived terranes (Dadlez et al., 1994). The status and affinity of the inferred terranes here remains controversial, however. For example, it has been suggested (Bełka et al, 1996) that the Małopolska Terrane may have been derived from Gondwana and amalgamated to Baltica by mid-Cambrian time, perhaps even before the Iapetus Ocean had opened. The affinities of the Moravo-Silesian Terrane lie with Gondwana, but it is presently unclear if the closest links are with Avalonia or Armorica. The structural position of the terrane within the Variscan foreland is certainly comparable to that of the Rhenohercynian Zone in western Europe (Franke et al., 1999). The amalgamation of these terranes to Baltica involved significant components of dextral strike-slip and anti-clockwise rotation.

The geologically complex internide zones of the Variscides (exposed in the Bohemian Massif) comprise components of the 'Armorican Terrane Assemblage' derived from Gondwana, and amalgamated into the accretionary collage of the Trans-European Suture Zone following the closure of still younger, Rheic, Rhenohercynian, Saxothuringian and Massif Central oceans interspersed with this archipelago of microcontinents (Matte et al., 1990; Franke et al., 1999). The TESZ project map has been revised to reflect the complexity of this collage. Early high pressure metamorphic events record subduction-related collisions between these terranes prior to incorporation into the Variscan orogenic collage in late Devonian/early Carboniferous time.

Geophysical data indicate that the Tornquist-Teisseyre Zone emerges from beneath the Carpathian Front in the Dobrogea province of Romania (Seghedi, 1998). The limited isotopic dataset available in this region show that the Palaeozoic basement of the North Dobrogea Orogen has Gondwanan affinities and a strong Variscan overprint, comparable to the Variscide Saxothuringian Zone. If this is so, Avalonian crust is absent in Romania and the Rheic Suture defines the SW margin of the East European Craton here. It is however clear that post-Palaeozoic tectonism, e.g. rifting of the Tethyan margin and Cimmerian and Alpine inversion, has dismembered the TESZ collage and relocated its original components along the Tethyan margin from Romania, through the Pontides of Turkey and beyond.

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J8

TECTONIC DEVELOPMENT OF THE WEST CARPATHIANS IN MESOZOIC AND CENOZOIC AS REVEALED BY GEOLOGIC. DEEP REFLECTION SEISMIC AND MAGNETOTELLURIC DATA

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150 years of intensive geological research led by generations of excellent geologists including giants like D. Stur, V. Uhlig, M. Lugeon, A. Matejka, D. Andrusov and many others and 50 years of enormous activity in geophysics in Poland, Czechia, Slovakia and Hungary brought extensive general knowledge about the West Carpathians. We will show here the crustal structure of the West Carpathians on two transects crossing the mountain chain from foredeep to the Pannonian basin. The first one passes through the Carpathians in their westernmost part from the Bohemian Massif to the Danube basin (part of the Pannonian basin). The second one passes through the mountaineous area of the Choc Mts. and Low Tatra Mts. to the Pannonian basin into the Pliocene basalt area of Lucenec-Nograd.

Common feature of both transect is the reflection seismic image of relatively steep bend of the European plate beneath the Carpathians. It is evident that final subduction of the European passive margin happened not very elastically. The efective elastic thickness of the lower plate varies between 4-8 km. All other features are different. Whereas in the west the transect shows that the Neogene (Krosno-Tarcau) and Paleogene (Magura) accretionary wedges are of full crustal thickness, in the central transect they are cut by the underthrust European platform. The west line ends within the frontal parts of the Hronic, Fatric and Tatric Mesozoic nappes and shows them in more or less subhorizontal position. The central line continues more southwards and shows a spectacular image of the whole crustal suture of these nappes and underlying South (Middle(?), North (?)) Penninic (Vahic) nappes. Upper plate of this suture is made of the South Veporic crystalline complex with overlying Gemeric, Meliatic and Silicic complexes that were most probably strongly extended during the subductional events of the above mentioned suture in the Upper Cretaceous. Subhorizontal reflections dominate within these complexes.

Magnetotelluric profiles exhibit three important high conductivity anomalies. The first one is all-Carpathian and is connected probably with very conductive and relatively massive occurrences of graphite. This anomaly reaches to Romania. The second conductivity zone is connected with the Penninic (Vahic) suture and is not so pronounced. The third high conductivity anomaly in the Lucenec-Nograd alkaline volcanic area is again very intensive. Whole crust is highly conductive there and magmatic fluids with possible crustal active magma underplating is responsible for this.

West Carpathians are a complex orogen where different Variscan and Cadomian fragments are incorporated in a series of tectonic units exhibiting complicated Alpine history. The Mesozoic history of the West Carpathians was identical to that of the East Alps. The Alpine terminology will be therefore mentioned in brackets behind the Slovak one. The oldest are the Upper Jurassic uppermost tectonic units of the Silicicum (Juvavicum), Meliaticum and Gemericum (Grauwackenzone and the Graz Paleozoic) that tectonically (probably on late extensional faults overlie the Lower Cretaceous Hronic (lower Tirolic ans upper Bajuvaric) and South Veporic (Mittelostalpinic) nappes. These were underthrust in the Cenomanian to Santonian by the above mentioned Fatric (lower Bajuvaric), Tatric (Unterostalpinic) and Vahic (Penninic) tectonic slices or nappes.

The Cenozoic history of the West Carpathians was different than this of the East Alps. This difference is generally characterized by more oceanic subductions and less collisional and extensional events. The Paleogene Magura wedges existed probably as well in the Alps as north Penninic and Ultrahelvetic subductional wedges that were in the Upper Eocene and Oligocene strongly tectonized, metamorphosed and uplifted, whereas in the West Carpathians they still form huge imbricated unmetamorphosed systems. The Neogene Krosno-Tarcau subduction has not an analogue in the Alps. West Carpathians rotated about 60° CCW in the lower and middle Miocene and are not parallel with the Alps from that time. Small but sometimes intensive collision occurred in the Tatras area after the mid-Miocene subduction and gave rise to the central West Carpathian mountains.

J10

FINAL STAGE OF A PLATE DETACHMENT? TOMOGRAPHIC INVESTIGATION TO SNAPSHOT THIS PROCESS AT THE CARPATHIAN BENDING ZONE

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CALIXTO '99 (Carpathian Arc Lithosphere X-Tomography) is an on-going project carried out as close international cooperation of research and education. This first extensive seismic tomography experiment over the Carpathian Bending Arc is an outcome of multiple meetings and previous programs developed under EUROPROBE/PANCARDI umbrella.

The Pancardi region evolved during Mesozoic-Cenozoic collision between "stable" Eurasia and migrating continental fragments such as African Italo-Dinaric microplate and reflects tectonic escape, arc rollback, and eastward collision of the proceeding arc with stable platform. Southward subduction of Eurasia in the Eocene produced a discontinuous volcanic arc beneath the Pannonian basin, followed by rapid extension and basin subsidence in the Miocene and continued underthrusting and calkalcaline volcanism in the northern and northeastern Carpathians. The Vrancea Bending Zone of the Eastern Carpathains is confined by strike-slip fractures - left-lateral to the north and right-lateral to the south.

Vrancea is characterized by an unusually narrow, near-vertical zone of intense seismicity, between 70 and 220 km in depth, matched by a gap in the Volcanic arc. Surface-wave tomographic results in the Pannonian basin clearly show low seismic velocities between 80 and 200 km depth, indicating that this apparently continental region is underlain by thick asthenosphere which may have acted to decouple surface and deeper mesosphere during extrusion-related translation.

Active subduction of oceanic lithosphere at convergent plate boundaries is well understood as processes associated to the oceanic lithosphere (metamorphism, seismicity), interaction with continental crust (accretion, erosion, seismic coupling) and process related to dehydration of the oceanic lithosphere (andesitic volcanism) are concerned. The slab detachment appears when plates convergence reaches a halt and the suction force of the sinking plate vanishes the oceanic slab, if subduction develops in an arcuate geometry.

The ocean closure, and therefore the vanishing oceanic lithosphere could not produce the later continental lithosphere, which is much more rigid and cold, force to bend and follow the descending previous plate. The geometry, when arcuate, also plays an important role. Suction forces are much less associated to that process, than corner flows, though there is a buoyancy effect for the 'cold' subduction plate remnant.

The terminal phase of plate break-off is hardly understood. The processes associated with the very last moment before the subducted slab is separated from the overlying lithosphere and sinks/melts into the mantle remain elusive. The Southeast Carpathians is probably the site beneath such a process is right now developing. Recent tomographic inversion of regional and teleseismic P-wave arrival times indicate some important new results:

(i) indication for break-off in about 120 km depth;

(ii) two dip angles of about 50-60 degrees for the upper part (70-110km) and roughly 80 degrees for the lower part (>130km);

(iii) two thicknesses about 50km for the upper part, 70-80 for the lower;

(iv) a downward counter-clockwise rotation of the subducted slab from southwest-northeast orientation to south-north orientation. The slab model is an image of the Eastern Carpathian 'subduction' zone which has probably retreated towards the east during middle Miocene and changed its direction southeast during the final stage in late Miocene.

(v) the complex shaped structure of high-velocity material (+4%) is surrounded by low-velocity (-1%) stuff.

The tomography experiment is consisting of about 130 passive stations (both broadbands and short period sensors) operating from May to November 1999. They record local, regional, and teleseismic events enabling to get details boundaries and structural heterogeneities from the receiver functions and mantle anisotropy. The very active deforming slab is most probably introducing a significant mantle flow to be observed into SKS data. Inversion of teleseismic and local seismic phases travel times, P-S - reflections will hopefully allow a structure resolution of less then 10-20 km. Thus, utilization of tomographic images for hazard assessment will be possible in area that experienced four strong earthquakes just this century: 1940 (M_W = 7.7), 1977 (M_W = 7.5), 1986 (M_W = 7.2), 1990 (M_W = 6.9). Inversing for S-wave velocities and attenuation will offer the possibility to simulate the propagation of destructive waves from potential future earthquakes to Bucharest.

A continuation is envisaged for the two years (2001-2003) with a different coverage, about 30 mobile stations (only broadband) to be deployed in the main tectonic units surrounding Vrancea, from the Pannonian Basin to the East European Platform, from central Eastern Carpathian to south Moesian platform and the Dobrogean orogen. This second part of the tomographic experiment will be performed in close cooperation with Northwestern University, Evanston, USA and is mainly devoted to constrain upper mantle deformation fabrics, hence mantle flow, via S-wave splitting observations, and to determine crustal and upper mantle structure precisely through receiver functions. S-wave splitting will provide a unique opportunity to infer mantle flow regimes around an intercontinental subducted slab characterized by rapid slab rollback during the Cenozoic, and by very high current rates related to slab detachment beneath Vrancea.

PANCARDI SESSION ORAL PRESENTATIONS

PANCARDI: AT THE CROSSROAD OF THE ATLANTIC AND TETHYS OCEAN SYSTEMS

PO1

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The areas investigated by the Pancardi research program include remants of different parts from different ocean systems. The evolution of these terranes is linked to the birth and the demise of the Tethys s.l. oceans and the opening of the Atlantic ocean. The development of the Tethys ocean system involves the formation of several mid-ocean ridges as well as their subsequent subduction. Active since Silurian times, Paleothetys and subsequently, since Permian, Neotethys, are the two main oceans causing the transition of the exotic terranes – now forming the Carpathians/Alps/Dinarides/Cimmerides/Hercynides and pertaining formerly to Gondwanaland - towards the Eurasian continent. The subduction of these oceans - mainly northward under Eurasia - led to the development of collisions between the Gondwanaland-derived terranes (Hercynian, Alpine, Cimmerian), as well as to the opening and closing of a series of back-arc oceans along the southern margin of the Eurasian continent.

After opening in Early Jurassic, the Central Atlantic ocean attempts to propagate towards the East, leading to the development of the Alpine "Tethys" and subsequently to the isolation of Ibera. After this aborted attempt of crossing the Eurasian continent eastward, the Atlantic finally propagates northward (North Atlantic, Labrador, Rockall).

The rotational convergence of Africa towards Eurasia leads to the demise and final closure of the Alpine Atlantic and the Tethys s.l. The development of the Carpathian and Dinarides fold and thrust belts and the Pannonian basin is related to the complex indentation and imbrication of the remnants of these two ocean systems and a series of micro-continents.

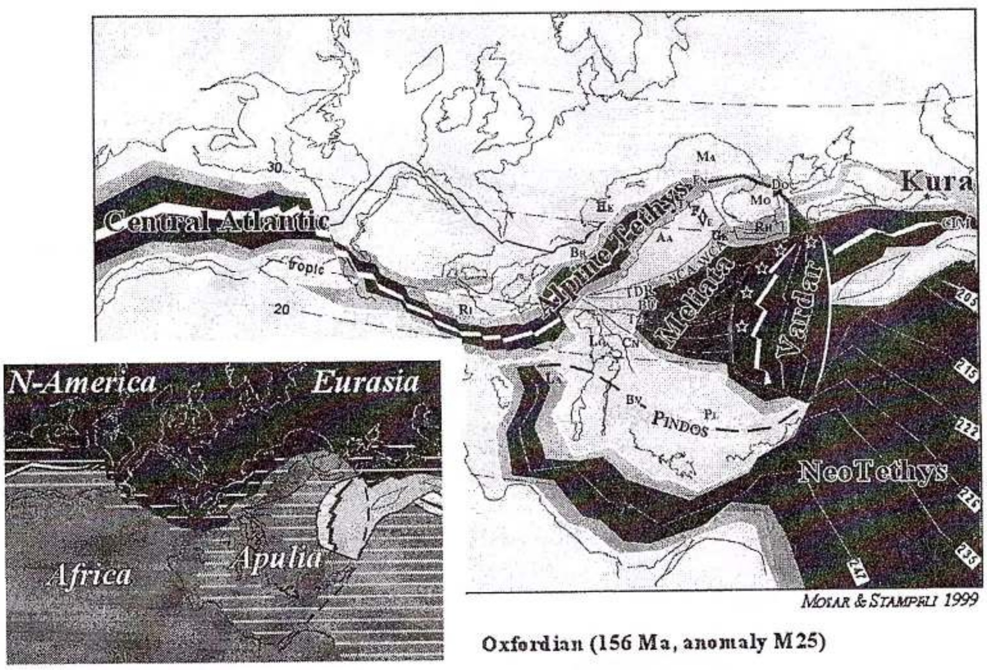

Figure1: Late Jurassic plate reconstruction of the Atlantic-Tethys domain.
AA=Austroalpine; BR=Brianconnais; BÜ= Bükk; BV=Budva; CIM=Cimmerian; Terranes; DO=Dobrogea; CN=Carnic; FA=Fatric; GE=Getic; HE=Helvetic; LA=Lago Negro; LO=Lombardian; MA=Magura; MO=Moesia; NCA=N-Calcareous Alps; PL=Pelagonian; PN=Pieninic; RH=Rhodope; RI=Rif; TDR=Trans-Danubian; TT=Tatric; TZ=Tizia; VE=Veporic; WCA=W-Calcareous Alps.

SEISMIC EXPERIMENT CELEBRATION 2000: FROM EAST EUROPEAN CRATON THROUGH CARPATHIANS TO PANNONIAN BASIN

PO2

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One of the major tectonic problems in Europe concerns the south-west margin of the East European Platform. In general, this margin is assumed to be the Tornquist-Teisseyre Zone (TTZ), running across Europe approximately from north-west to south-east. The Polish segment of TTZ is a part of the Trans European Suture Zone (TESZ), a first order geotectonic unit, stretching from Black Sea to the British Islands. Determination of deep crustal structure of the contact zone between the Precambrian Platform, the Palaeozoic Platform and Carpathian Mts. was the main aim of the deep seismic sounding (DSS) programme in SE Poland in 1965-1982. In the study area the crustal thickness varies, being 46 km within the Precambrian Platform, about 55 km in the TTZ, about 45 km in the Holy Cross Mts. and 30-35 km in the Palaeozoic Platform. In the region of the Carpathian Foredeep, it is about 40 km.

In the framework of the new programme of deep geological and geophysical investigations in SE Poland, Slovak Republic and Hungary, closely connected with EUROPROBE TESZ and PANCARDI Projects, there are planned new deep seismic refraction and wide angle reflection profiles. The profiles intersect well known tectonic units and tectonic lines in this part of Europe, e.g. SW margin of the Precambrian Platform, Holy Cross Mts., Małopolska Massif, Grójec Dislocation, Kraków-Lubliniec Tectonic Zone, Carpathian Mts, and Pannonian Basin. New international seismic operation named CELEBRATION 2000 (Central European Lithospheric Experiment Based on Refraction 2000) will be carried out during 2 weeks in June 2000. It will include contributions from the geophysical and geological communities in Poland, Slovak Republic, Hungary, the USA, Canada, Denmark, Finland and Sweden. This large lithospheric seismic experiment CELEBRATION 2000 is going to collect about 1200 seismic refraction stations to record shots from about 90 shot points along 5 profiles with a total length of about 2600 km. The spacing between recording stations will be 1-2 km. Distances between shot points will vary from 20 to 40 km.

PRESENTATION OF RODOPI: A NEW EUROPROBE PROJECT PROPOSAL

PO3

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A new project called RODOPI (after the name of the Rhodope Mountains) is proposed to EUROPROBE with the aim to contribute to solution of pending and controversial problems with importance for European and world geology.

The Rhodope (Rodopi) Region occupies parts of Bulgaria, Greece, and the former Yugoslav republics of Macedonia and Serbia. Many controversies concern important geological features, and namely: lithostratigraphy and age of the protolith(s) of the amphibolite-facies metamorphics; age and character of the metamorphic event(s); age and origin of the diabase-phyllitoid complexes at the periphery of the Rhodope massif, and their relations to the amphibolite-facies basement; age of the granites; the internal structure of the massif; the structural position in the Alpine orogenic belt; the Palaeogene evolution; the neotectonic history and structure (the role of rifts and/or low-angle detachments). Other important features are the presence of a core of thickened continental crust (up to 55 km to Moho) with high seismicity in the western and northern margins; high geothermal gradient and abundance of thermal mineral waters; large areas occupied by marbles with extensive karst neighboured by areas of Palaeogene sediments and volcanics that create considerable geotechnical hazards. A great part of the region is underdeveloped, and possesses considerable possibilities for development of tourism, recreation and balneological and climatic treatment. High pollution due to mining and enrichment industry in some areas needs a complex geochemical study. Geotourism and educational visits of students are favoured by the richness and variety of the geological features and the good exposure. The sustainable development of the region may be enhanced by a better understanding of its geological features.

The importance of the Rhodope Region for the geology of Europe and the world comes mostly from: 1) the place of the massif in the Alpine orogenic edifice, and its role and behaviour during the considerable plate motions relative to closure of the Tethys; 2) the presence of pre-Alpine and pre-Ordovician metamorphic complexes and tectonic entities, and their behaviour during the Phanerozoic orogenies; 3) the thickened continental crust, its evolution, and recent behaviour with increased seismicity; 4) possibilities for application and perfection of existing methods in complexly built metamorphic terrains. The solution of most of the problems may be achieved through a wider involvement of the international geological community, with application of modern geological and geophysical methods and techniques. Therefore, the geologists from the countries concerned decided during the 16th Congress of the Carpathian-Balkan Geological Association (Vienna, September 1998), and with the support of the whole Association, to propose to EUROPROBE to launch a new RODOPI project centered on the geology of the Rhodope Region and the surrounding orogenic belts of Balkanides and Dinarides-Albanides-Hellenides.

MANTLE DYNAMIC IMPLICATIONS FOR TETHYAN HAZARD ASSESSMENT: A NEW IGCP PROGRAM

PO4

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The Tethyan belt extends through Europe, the Mediterranean, and central Asia, to the southwestern Pacific, and is the premier global example of a colliding plate margin. The Tethyan region is home to nearly half the earth's population, abiding at various levels of health and economic risk, and includes over ten of the world's 'megacities'. Tethyan seismicity and explosive volcanism caused nearly a million deaths and catastrophic economic losses in the 20th century alone. The most damaging earthquakes are caused by lithospheric plate motions associated with post-collision subduction and strike-slip faulting while destructive volcanism result from the eruption of viscous volatile-rich magma, generated and fractionated in the suprasubduction asthenosphere and lithosphere. Here, we ponder a new approach to hazard mitigation and introduce an exploratory program for studying Tethyan mantle-lithosphere dynamics.

IGCP 430 will start in January 2000 and focus on collision-related mantle dynamics and their role in defining Tethyan seismic and volcanic risk scenarios into natural laboratories: PANCARDI (Pannonia-Carpathians-Dinarides) and SEAWPAC (Southeast Asia Western Pacific) regions. This will be accomplished by interdisciplinary research involving:

- Seismic tomography and share-wave splitting - to characterise the lithospheric structure and mantle flow,
- Paleomagnetic, geodetic, geological studies - to resolve collision-related lithosphere kinematics, and
- Petrologic, geochemical, and age dating studies of volcanics - to interpret mantle thermal and chemical character.

Identified problem areas include:

- Asthenospheric flow associated with lateral escape, subduction, and inelastic deformation of lithospheric plates: to what extent are collision-related extrusion and crustal thickening caused by forces transmitted through the upper mantle?
- Thermal structures associated with intraplate and suprasubduction melting: does syn- and post-orogenic magmatism result from transtension, deep plumes, or local (e.g. collision or subduction induced) upwelling asthenosphere?
- Petrologic and rheologic character of the lithosphere-asthenosphere boundary: what are the respective effects of temperature and dehidration reactions in determining rheologic changes?

The project will coordinate the natural lab results with those from studies of orogen collapse and exhumation in the Alps and Himalayas, and with models of arc-rollback and marginal basin formation in the Mediterranean, Philippine Sea, and Indonesian regions. Models synthesizing subduction- and collision- induced mantle flow, mantle volatile budget and dehydration reactions, and flow-induced lithospheric strain will serve as a basis for ranking natural hazard categories for display in map form.

Topical working groups will provide means of comparing geodynamic and geochemical models and allow direct integration of relevant results into hazard models for the two areas. It will also link programs such as PANCARDI with research in Asia Minor, The Himalayas, East and Southeast Asia, and Western Pacific margins.

Annual workshops will bring together field, theoretical, and experimental evidence and are planned as follows:

- 2000: Romania (‚Post-collision slab detachment and potassic magma genesis')
- 2001: Vietnam (‚Tectonic escape kinematics'')
- 2002: Turkey (‚Seismic risk assessment')
- 2003: China (‚Crustal thickening')
- 2004: Philippines (‚Volcanic risk assessment')
- 2005: Chicago/Evanston (‚Plenary symposium').

3-D VELOCITY MODELS OF THE MANTLE BENEATH CONTINENTS AND OCEANS AND THE DISTRIBUTIONS OF EARTHQUAKE FOCUCES

PO5

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Three large-scale 3-D *P*-velocity models of the mantle beneath Europe, central Asia and a region from Indonesia to Solomon Islands to 850 km depth and more have been represented. The massive collection containing first-arrival times of *P*-waves from strong seismic events exploits as initial observed data set. The traveltime tomography method developed by V. Geyko was used for data recovering. Results present as follows: map of true *P*-velocity distribution in Moho depth, a set of horizontal section from 50 to 850 km depths by 25 km step and maps of averaging about depth velocity distribution within eight mantle layers. They are called conditionally as the mantle uppermost (50-100 depth km), mantle upper part (50-250 km), upper tectonosphere (50-400 km), tectonosphere (50-650 km), 'astenosphere' depths layer (100-250 km), lower part of the upper mantle (250-400 km), lower tectonosphere (400-650 km) and lower mantle Uppermost (650-850 km). Analysis of the models deduces the following general solid properties. (1) The mantle falls into two shells by the global boundary situated at 550-680 km depth. The upper shell (tectonosphere) is notably inhomogeneous laterally, while the lower one is almost radials-symmetric (deeper 750-780 km). (2) The boundary between the upper and lower tectonosphere is situated at 390-450 depth km as the astenosphere do not global. The former is peculiar to the ancient and formed tectonic structures and later to those presently active. (3) Age and genetic type of the tectonic structures reflect in the thickness and structure of the tectonosphere. The tectonic structures of the first order (plates) have 'roots' piercing the entire tectonosphere, while those of higher order are clear-cut in the upper and unclear in the lower tectonosphere. (4) Separated great tectonic structures, belts and assemblies tectonic structures which images as unit distinguish motley heterogeneous inner pattern. (5) Into velocity inhomogeneities find contrast mapping major tectonic structures and locates and traces sutures and boundaries between great structures. Into zones flanking to sutures and boundaries immediately observes usual anomalous velocity varying that reflects effect of the smoothness, diffusing of the contact region stipulated by coupling, interacting and collision of the associated structures. (6) Greet tectonic structures distinguish almost opposite image into velocity inhomogeneities of the upper and lower tectonosphere. (7) Seismic belts correspond usual by areas of lower velocity into 'astenosphere' depths layer. Velocity heterogeneity reflects density ones that induce at different depths diverse scale gravitational unsteadiness that is a principal cause and effect of tectonic phenomenon. Recovered *P*-wave velocity values are the comparatively precise determined physical characteristic of the mantle that reflects objectively its true material composition and *PT* conditions. They can be considered as original basic data for proving of combine interpreting of a different geological and geophysical information and for meaningful tectonic and physical explaining. It is key result of this paper.

SYNSEDIMENTARY TECTONICS DURING TERTIARY ACCRETION IN THE POLISH SEGMENT OF THE OUTER CARPATHIANS - STRUCTURAL AND CARTOGRAPHIC APPROACH

PO6

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Polish segment of the Outer Carpathians is a north-verging thrust-and-fold belt comprising (from south to north): Magura, Dukla, Silesian, Subsilesian and Skole nappes. Main tectonic features of the belt were formed during Tertiary times when the belt was an accretionary wedge related to southward-directed subduction of the European Platform under the ALCAPA unit.

We report new structural data from the Magura, Silesian and Skole nappes. In the Magura nappe, Tertiary accretion started during Paleocene. This is evidenced by results of analysis of deformation bands and small-scale hydroplastic thrusts. These results show that folding and northward in-sequence thrusting took place during sedimentation of Paleocene and Eocene strata. The synsedimentary folding and thrusting were accompanied by strike-slip faulting along faults of two conjugated sets: NNW striking dextral set and NNE striking sinistral set. Numerous faults of both sets show features of hydroplastic deformation. Spatial relationships between small-scale and map-scale folds and deformation bands show that in the central part of the studied segment of the Magura nappe the synsedimentary folding was completed during Eocene times.

Our pilot observations show that in the Silesian nappe, accretion-related synsedimentary folding, thrusting and strike-slip faulting took place during Oligocene to early Miocene. However, we have not enough data to date the completion of synsedimentary folding in the Silesian nappe.

Through the Magura and Silesian nappes, spatial relationships between joints, folds, sandstone dykes and hydroplastic faults show that the cross-fold joints are early synsedimentary features. It follows that the joints recorded the stress arrangement which occurred during deposition of the strata involved. Similar orientation of cross-fold joints in the whole Tertiary stratal sequence indicates that the overall stress arrangement remained constant during the Tertiary accretion. This was a compression stress regime with $\sigma1$ oriented horizontal and perpendicular to present day map-scale fold axes.

An anomalous situation has been observed in a portion of the Skole nappe where the deposition of the Oligocene strata took place in extension stress setting in which horizontal $\sigma3$ was oriented perpendicular to present day map-scale fold axes. This is evidenced by spatial relationships between map-scale folds, clastic dykes, vein structures and small-scale slump folds. These early extension-related features are overprinted by later structures formed in compression stress regime in which $\sigma1$ was horizontal and perpendicular to the present day map-scale fold axes. Due to scarcity of data we are not able yet to date the transition from the extension to compression stress arrangement.

The discussed structural data show that the age of the accretion-related synsedimentary folding, thrusting and faulting is younging outwards across the studied segment of the Outer Carpathians.

Discussed synsedimentary tectonic activity is confirmed by distribution of numerous map-scale Upper Eocene to Middle Miocene olistostromes. Most of the olistostromes underlie major thrusts including frontal Carpathian overthrust and/or crop-out in front of the nappes.

NORTHWARD MIGRATION OF NORTH ALCAPA BOUNDARY DURING TERTIARY ACCRETION OF THE OUTER CARPATHIANS - PALEOMAGNETIC APPROACH

PO7

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We are reporting pilot paleomagnetic results from a transect across Polish segment of the Carpathians. The sampled tectonic units comprise (from the south to the north): Central Carpathian Paleogene (Podhale Flysch basin), Outer Carpathian nappes, inner (folded) part of the Carpathian Foredeep (Zgłobice unit) and, outer (unfolded) part of the Foredeep. All these units resulted from the Tertiary southward directed subduction of the European Platform below the ALCAPA unit. The subduction-related accretion migrated northward since Paleocene in the innermost part of the Outer Carpathians until at least Badenian in the Zgłobice unit.

Paleomagnetic data from the Podhale Flysch basin are geographically distributed, consistent and exhibit in average 60 degrees counterclockwise rotation, with respect to the present north, which is definitely younger than mid-Oligocene. From the Outer Carpathian nappes Albian through Oligocene rocks were so far studied from 13 localities. Less than half of them yielded results, all exhibiting counterclockwise rotations of variable magnitude. We have too few data to decide if the magnitude of the rotation changes with time or space or is dependent on both. In the folded part of the Carpathian Foredeep, three lower Badenian localities yield in average 30 degrees counterclockwise rotation, a single lower Sarmatian locality practically no rotation. A single Badenian locality from the unfolded Foredeep shows a slight clockwise rotation which is consistent with the Stable European "reference" declination.

It is generally accepted that during Tertiary times the northern boundary of the ALCAPA unit has been situated along the Pieniny Klippen Belt, south of the Outer Carpathians. In this interpretation, the Podhale Flysch basin belongs to the ALCAPA unit whereas the Outer Carpathians and the Carpathian Foredeep are situated north from this unit. It is well evidenced, that during the Miocene the North Hungarian Paleogene Basin underwent about 80 degrees counterclockwise rotation. Our data from the Podhale Flysch basin are in line with these results. However, our data also suggest that the Outer Carpathian nappes were subjected to CCW rotation after the Oligocene. The post-early Badenian CCW rotation of the Zgłobice unit is 30 degrees and must have occurred before the Sarmatian.

Basing on the above paleomagnatic data, we suggest that during the Tertiary accretion, the Outer Carpathians nappes and the Zgłobice unit became successively incorporated into the ALCAPA unit. The incorporation of the Outer Carpathian nappes took place before the onset of the Miocene CCW rotation, whereas the incorporation of the Zgłobice unit occurred after the Ottnangian. It follows, that during the Tertiary times the northern boundary of the ALCAPA unit migrated northward.

PRESENT-DAY STRESS FIELD OF POLAND: THE TRANSITION FROM THE WEST EUROPEAN STRESS PROVINCE TO THE SPECIFIC PERI-CARPATHIAN REGION

PO8

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In a junction zone between the Palaeozoic and Precambrian Platform (EEP) and the Carpathian orogen on the other side, present-day stress field was investigated. The main task was to describe the nature of stress distortion from the general trend NW, which predominates in West and North Europe. Directions of horizontal compression (SH_{max}) were determined by mean of breakout analyses for 80 boreholes located in Poland.

For the Western Outer Carpathian segment (the cover of Upper Silesian Massif) anticlockwise stress rotation with increasing depth was interpreted. Namely, NNE-oriented SH_{max} in the Carpathian flysch nappes turns to NNW and NW in the autochthonous basement. In contrary, the basement of the Eastern Outer Carpathian segment (the cover of Malopolska Massif) is under stable NNE compression. For southernmost segment of EEP constant N-S trend of SH_{max} was determined for Palaeozoic sedimentary sequence of the Lublin Trough. In the northern segment of the EEP (Palaeozoic complex of the Baltic Syneclise) SH_{max} distorts systematically from N-S to NNW as reaches the edge of the EEP. Thick sedimentary cover of the TTZ is characterised by SH_{max} rotations in vertical well sections and its distortion towards the trend of the zone NW. For wells piercing Permo-Mesozoic complex of the north-easternmost part of the Peri-Sudetic Monocline, NNE-oriented SH_{max} was determined. Poor quality data from folded Carboniferous complex of the inner part of the monocline suggests NW trend of SH_{max}.

Distribution of the SHmax orientation for Poland can be explained assuming interaction of three main factors: 1) Mid-Atlantic ridge push in NW direction; 2) tectonic push of the Carpatho-Pannonian plate towards NNE; 3) tectonic structure of the foreland plate comprising passive buoyancy forces (acting orthogonal to the orogen belt) and structural anisotropy due to folding and faulting. For the sake of simplicity, these three factors are called: plate stress, tectonic stress and structural anisotropy (or buoyancy stress), respectively. These factors control on the stress field for separate regions was evaluated from dominant stress orientation and its relation to tectonic structure.

In the Carpathians, Carpatho-Pannonian micro-plate moving along Mur-_ilina strike-slip fault exerts N-S to NNE-directed compression on the flysch nappes and also on the Malopolska Massif basement. Thus for these units following relation can be derived:

- tectonic stress + buoyancy stress >> plate stress.

Tectonic stresses are transmitted across the stiff basement of the Carpathian Foredeep into the sedimentary cover of the southern segment of the EEP, causing stable N-S orientation of SH_{max} that ignore predominant strike of faults NW. Above suggests:

- tectonic stress >> plate stress + structural anisotropy.

As being transmitted farther to the north through the cover of the EEP, tectonic stresses weaken. Therefore in the Baltic Syneclise SHmax direction drifts towards NNW, implying:

- tectonic stress ~ plate stress.

Within the TTZ, SH_{max} parallels the trend and internal structure of the zone NW, what suggests:

- plate stress + structural anisotropy >> tectonic stress.

For the Upper Silesian and the Bohemian Massifs beneath the Carpathians and also for folded Variscan complex of Pery-Sudetic Monocline, the same NW SH_{max} direction imply:

- plate stress + buoyancy stress (structural anisotropy) >> tectonic stress.

In the younger Mesozoic complex of the monocline, NNE-oriented SH_{max} is hypothesised to result from strata inclination over the weak salt layer.

In general, present-day tectonic stresses of reactivated Carpathian arc influence the stress field of the foreland plate along the EEP at a distance of 700 kilometres away from the suture. Neither passive buoyancy forces nor inhomogeneity of the plate alone can be accounted for phenomena of this range.

TECTONIC CONTEXT OF QUARTZ-CALCITE VEINS IN THE MAGURA NAPPE (POLAND)

PO9

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Origin of the quartz-calcite mineralization has been studied in the context of structural development of the Magura nappe during the Tertiary times. This mineralization has been studied in the Eocene, Paleocene and Upper Cretaceous sandstones of the Magura nappe. This has been supplemented by study of this mineralization within the Oligocene sandstones of underlying Dukla nappe.

Joints are filled by blocky and drusy quartz and calcite forming veins up to 2 cm thick, whereas fault surfaces are covered by fibrous quartz and calcite seals up to 5 mm thick. The mineralization is more abundant in the proximity of exposure-scale faults. In some joints, the quartz-calcite association post-date columnar calcite and is followed by still later blocky and/or drusy calcite.

Primary fluid inclusions are abundant in the blocky and drusy quartz. Variable phase ratios in the inclusions point to a heterogeneous trapping of immiscible methane and aqueous liquids. Coeval calcite occasionally contains CH_4-rich inclusions along with dominant aqueous inclusions. Salinities of the aqueous inclusions in quartz are very consistent (1.2-1.4 wt. % NaCl eq.) in Oligocene sandstones of the Dukla nappe and in Cretaceous sandstones of the Magura nappe. In contrast, salinity fluctuations (0-3.1 wt. % NaCl) have been reported in Paleocene-Eocene sandstones of the Magura nappe. Formation temperatures during precipitation of the blocky and drusy quartz fall from 200-220°C in the Dukla nappe, to 160-210°C in the Magura nappe. Fluid pressures decrease from 2.1-3.7 kbar in the Dukla nappe to 0.75-2 kbar in the Magura nappe.

Cross-cutting relationships show that the quartz mineralization of the Magura nappe and underlying Dukla nappe was formed during a thermal event coincidental with post-orogenic collapse of the region. The high temperature quartz from joints and small-scale faults is linked with an external source for the hot, CH_4-bearing aqueous fluids, percolating the Magura nappe along normal faults. Vertical PT variations attest to a fluid ascent from beneath of the Magura nappe.

Strong salinity fluctuations and its decrease to essentially 0 wt. % NaCl eq. in the upper part of the section suggest an influx of freshwater, probably of meteoric origin. At the base of the Magura nappe, significant portion of the aqueous phase might represent marine and/or connate waters.

Depths of quartz precipitation derived from microthermometry data (8-15 km in the Dukla nappe and 3-8 km in the Magura nappe) are not supported by recent tectonic models. This suggests that pressures of hot fluids during the regional collapse have been higher than those corresponding to a lithostatic load.

PO10

KINEMATICS AND TIMING OF THRUST SHORTENING IN THE POLISH SEGMENT OF THE WESTERN OUTER CARPATHIANS

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The Polish part of the Western Outer Carpathians is a generally north-verging fold-and-thrust belt composed of Early Cretaceous to Early Miocene Flysch sediments. It comprises the following main tectonic units (from south to north): Magura, Submagura, Dukla (and its equivalents), Silesian, Subsilesian and Skole Nappe. The Galicia T. Group has carried out structural analyses on 115 outcrops in the western and eastern part of the Polish Outer Carpathians. According to the observed structures, the formation of the fold-and-thrust belt occurred in two distinct events of (1) NNW-directed and (2) NE-directed thrust shortening.

The first event is characterised by N- to NNW-directed piggy-back in-sequence-thrusting. Thrusts are connected with meso- and large-scale folding around E to ENE-striking fold axes. Small-scale structures constraining shortening directions include ramp-flat and duplex arrays, kinematical folds such as fault-propagation folds and ramp anticlines, and shear bands in shale sediments. In the southern/upper tectonic units, thrusting initiated during the Palaeocene as indicated by soft-sediment deformation structures in Palaeocene flysch strata of the Magura tectonic unit. N- to NNW-directed thrusting presumably terminated in the Subsilesian unit during the Early Miocene.

N(NW)-directed thrust faults and related folds were overprinted and refolded during the second event of NE-directed thrust shortening. This event is characterised by the reactivation of older thrusts and by the evolution of out-of-sequence thrusts which are kinematically linked to NE-striking sinistral tear faults and lateral ramps. In the western part of the Polish Outer Carpathians, older (E)NE-striking thrust faults were reactivated as sinistral wrench faults which terminate in major out-of-sequence thrusts where thrust contacts of young strata over older sequences as well as thrust ramps cutting down-section indicate out-of-sequence thrusting. Middle Badenian Molasse sediments cut by tear faults related to NE-directed thrust shortening, and early Late Miocene (Pannonian) Molasse sediments cut by thrust faults serve as time constraints for this second deformational event.

In sum, our data suggest heteroaxial shortening of the Polish Outer Carpathians including (1) Palaeocene to Early Miocene N(NW)-directed and (2) Early-Late Miocene NE-directed shortening.

PO11

THE SOUTH CARPATHIANS: ALPINE POLYSTAGE TECTONO-METAMORPHIC EVOLUTION

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The structural model of the South Carpathians is based on the idea of a polystage tectono-metamorphic, magmatic, sedimentary evolution and mountain building of this Alpine segment. The main tectogenetic events responsible for the compression and crustal thickening processes took place in the Mid-Cretaceous ("Austrian phase") and Upper Cretaceous ("Laramian phase"), the main nappe piles including: Danubian, Severin-Arjana, Getic and Supragetic units. The younger history of the belt is dominated by the Miocene tectogenetic events, including thrusting of the older nappe stacks onto the Moesian platform, orogen-parallel faulting and extension related (detachment) movements, connected with different types of sedimentation processes, dynamically controlled in time by the main paroxysmal events. The present day structural features of this branch of the Carpathian belt are strongly supported by structural, petrologic and geochronological constraints. Successive extensional to compressional tectogenetic events, affecting the same crustal domains, alternated from the Lower Jurassic to Upper Cretaceous, with a period of quiescence in the Paleogene. The main paroxysmal compressional events alternated with longer periods of extension, magmatism or erosion in some areas, while sedimentation continued in important troughs and in the frontal zone of the fold and thrust belt; thus, the continent - ocean crust type collision on both sides of the belt was followed by continent - continent type collision, the Alpine mobile belt being attached to the eastern European platforms by the "post-tectonic" sedimentary cover units in Neogene times.

- The polystage nappe stacking, in the mid-Cretaceous (Albian) and upper-Cretaceous (intra-Senonian) tectogenetic phases had a discontinuous character, proved by the different ages of the corresponding shear zones, as was doccumented by complex criteria and field maps (Iancu, 1985, 1986; Balintoni et al., 1986; Berza et al., 1994); significant conceptual differences are underlined in respect with a unitary, continuous displacement model of the same "Getic nape" of Murgoci (1905), Codarcea (1940).
- The subsequent high angle thrusting of the older nappe piles, during the Miocene (pre-Sarmatian) resulted in a collisional particular fan-like model of the regional cross-section, strongly asymmetrical in shape to the east (Iancu et al., 1998), as an effect of the Moesian plate indenter; the late Alpine compression in Miocene times corresponds to the convergence of the allohtonous units and the European foreland (Săndulescu, 1988);
- The metamorphic evolution of the Alpine cycle has a polystage character in the units of the Danubian domain (lower geometrical position), from the eo-Alpine (medium pressure?), mid-Cretaceous stage (prograde in cover, with chloritoid-pyrophyllite-chlorite-illite blasthesis and meta-anthracite to pre-graphite transition) to late Cretaceous low-grade metamorphism (prehnite-pumpellyite facies).
- The known ages, corresponding to compressional events, responsible for the changing of the tectonic style from thick skinned to thin skinned translation, is strongly supported by sedimentary and magmatic markers which are now confirmed by some Ar/Ar age determinations (118,6 and 117,9 Ma, for Supragetic/Getic tectonic line, cf. Dallmeyer et al. (1998) and U/Pb zircon ages (75,5+/-1,6 Ma and 79,6+/-2,5 Ma, cf. Nicolescu et al., in Nicolescu, 1998); the preserved late Cretaceous fission track data and thermal modelling are relevant for rapid cooling processes (100-60

Ma), followed by a period of thermal stability in the Paleogene (Sanders, 1998).

- In the upper nappes (Getic-Supragetic) the superposed effects of the Alpine metamorphism are related to high thermal and low-pressure gradients, spatially associated with repeated magmatic-arc intrusions, named "banatitic magmatites" (subduction-related magma genesis, with an extensional regime of emplacement); their ages are concentrated in two main periods: pre- and post-Maastrichtian (the tectogenetic marker being the intra-Senonian, Laramian tectonic planes), the corresponding K/Ar ages and U/Pb data supporting this discrimination (81-68 and 62-45 Ma intervals, cf. Russo-Sandulescu et al., 1994). Thermal histories based on apatite data are relevant for the time span 75-30 Ma (Bojar et al., 1998; Sanders, 1998) coresponding to the late collisional history of the South Carpathians.
- Eocene post-nappe extension and orogen-parallel N-S stretch (Schmid et al., 1998) were followed by: Oligocene dextral wrenching and pull-apart sedimentation and a renewed extension (and post-nappe folding?) (Chattian-Badenian, Berza, Drăgănescu, 1988); Miocene high-angle thrusting of the older nappe complexes onto the Moesian platform (pre-Sarmatian) and pro-wedge sedimentation; Pliocene uplift, cooling and erosion in destructive stages (Sanders, 1998).

THE LATE CRETACEOUS - PALEOCENE EXHUMATION AND COOLING HISTORY OF THE ȚARCU-RETEZAT DOME (SOUTH CARPATHIANS): STRUCTURAL GEOLOGY AND FISSION TRACK DATING

PO12

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The South Carpathian orogen is built up by two continental blocks and remnants of an oceanic basin in between them. The upper plate is represented by the Supragetic and Getic nappes which are separated from the lower plate (Upper and Lower Danubian nappes) by the Late Jurassic - Early Cretaceous Severin ophiolite. Closure of the oceanic basin and subsequent stacking of the continental units appears to have commenced during the Aptian as indicated by isotope and stratigraphic data. Convergence was accommodated by top-to-the ENE-ESE thrusting of the hangingwall units. Crustal thickening and related greenschist to locally epidote-amphibolite facies metamorphism was followed by the formation of the Țarcu-Retezat metamorphic core complex. Core complex formation is apparently closely related to subsidence in the adjacent Hațeg extensional basin. New structural and fission track data put constraints on the tectono-thermal evolution of the Țarcu-Retezat Dome, the Hateg basin as well as on the timing of the stacking event.

Field geological investigations revealed that extensional structures, which we relate to the exhumation of the Țarcu-Retezat metamorphic dome overprint older, compression related structures. On outcrop-scale, ductile to semi-brittle faults within Lower and Upper Danubian nappes document normal displacement of the hangingwall. Partitioning of deformation into sectors of coaxial and non-coaxial deformation is shown by the development of conjugate as well as single sets of normal faults. Locally, normal faults are closely spaced and define an extensional crenulation cleavage. On map-scale, extensional deformation is marked by a considerable reduction of the metamorphic profile along the northern and southeastern margin of the Tarcu-Retezat Dome. Normal faulting was probably coeval with dextral strike-slip faulting and associated deposition of Maastrichtian-Paleogene red conglomerates along the northern margin of the dome. Additionally, a dramatic change in deformation behavior from ductile - semi-brittle in the lower plate to purely brittle in the upper plate argues for large amounts of displacements along the plate boundary.

Apatite fission track dating on Santonian, Campanian and Late Maastrichtian sediments of the Hațeg basin yielded 102±12, 84±12, 56±4 Ma, respectively. These ages are interpreted to reflect rapid uplift and erosion of the source area during the Santonian-Campanian and partial annealing of the Late Maastrichtian sample due to burial underneath ca. 2 km thick Paleogene sediments. Additionally, an Early Maastrichtian sandstone sample yielded a zircon fission track age of 259±15 Ma, pointing to the dominance of a pre-Alpine source area. From zircon fission track dating of upper and lower plate rocks we infer that emplacement of the Getic unit on the Danubian unit must have occurred prior to ca. 81±7 Ma and post metamorphic cooling through ca. 240°C occurred in the Upper Danubian nappes between 70 and 57 Myrs and in the Lower Danubian nappes between 64 and 54 Myrs.

Our structural and fission track data demonstrate that (1) emplacement of the upper plate on the lower plate occurred prior to ca. 80 Ma; (2) exhumation of the Tarcu-Retezat Dome was governed by normal faulting on various scales and was subsequently followed by cooling of the lower plate rocks below ca. 240°C during the Maastrichtian-Paleocene.

TECTONIC MODELLING AND KINEMATIC EVOLUTION OF THE EXTERNAL CARPATHIAN-MOESIAN PLATFORM REGION DURING TERTIARY TIMES

PO13

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The Miocene - Pliocene subsidence evolution of the Romanian Carpathians foreland platforms was analysed using a standard 1D backstripping technique along individual wells, or combined in two regional sections and six contour maps. The subsidence patterns were analysed together with previously paleostress and kinematic studies, in order to derive the Tertiary kinematic of the buried platform faults in the frontal part of the Carpathians.

Time-step rheological modelling allow for the definition of the Danubian exhumation and rotation along the Moesian corner and of the definition of the mechanical paremeters of the

Moesian plate. This revealed that the Moesian plate is still thermally unrelaxed after the Eocene followed by Early Burdigalian large scale extension to transtension. 3D definition of the rheological parameters allows for the regional definition of the thermal state of the Moesian plate as well as of the geometry of the Early Tertiary extensional episodes.

The study revealed accelerated subsidence during the Lower Miocene in the western part of the Moesian platform/Getic Depression, in direct relationship with the opening of an WSW-ENE trending extensional basin. The largest subsidence recorded in the front of the Carpathians took place during the Late Miocene, due to final E-ward emplacement of the thrust sheets. The Late Miocene subsidence show anomalous high values between the Intramoesian and Trotus faults as a result of collision with East-European platform northward, and acceleration of the subduction process in the SE Carpathians corner. Further Pliocene subsidence continued only in the later region, the depocenter being shifted southward, nearby the juction with the South Carpathians foreland.

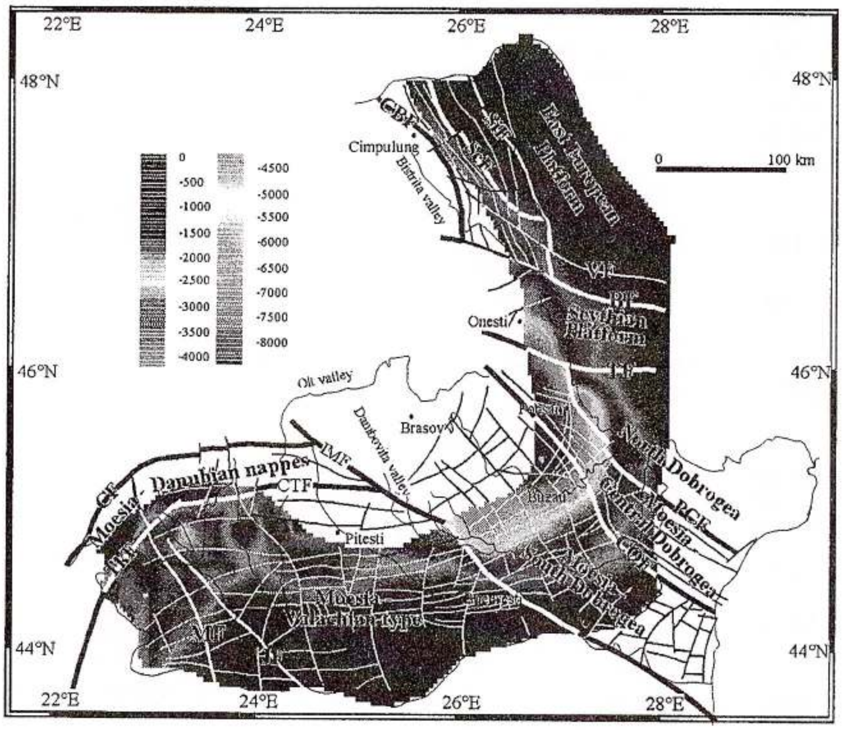

Figure 1. Simplified structural map of the autochthonous units in the frontal part of the Romanian Carpathians and contour map of the pre-Miocene basement of the foreland platforms. CBF- Câmpulung-Bicaz Fault, ScF - Solca Fault, SiF - Siret Fault, VF - Vaslui Fault, BF - Bistrita Fault, TF - Trotus Fault, PCF - Peceneaga-Camena Fault, COF - Capidava-Ovidiu Fault, IF - Intramoesian Fault, JF - Jiu Fault, MF - Motru Fault, CF - Cerna Fault, TkF - northern extension of Timok Fault, CTF - Călimăneşti-Tg. Jiu Fault. Note the high depth values of the basement in the Focsani depression and the apparent dextral offset along the Intramoesian fault and sinistral offset along the Trotus fault.

TERTIARY TECTONIC AND SEDIMENTOLOGICAL EVOLUTION OF THE SOUTH CARPATHIANS FOREDEEP: TECTONIC VERSUS EUSTATIC CONTROL

PO14

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A detailed seismic sequence stratigraphy study based on a dense network of seismic profiles is integrated with structural observations from interpreted geological sections to derive a tectonic and sedimentological model for the Miocene-Pliocene evolution of the South Carpathians foredeep (Getic Depression). Following Paleogene and older orogenic phases, the first tectonic event which affected the studied area was characterised by Early Miocene large scale extension to transtension which is responsible for the opening of the Getic Depression as a dextral pull-apart basin. Further Middle Miocene contraction caused WNW-ESE oriented thrusts and associated piggy-back basins. The last tectonic episode recognised in the studied area relates to general transpressive deformations during the Late Miocene - Early Pliocene interval, a first NW-SE oriented dextral episode is followed by second N-S sinistral deformations. The detailed sequence stratigraphy study allow for the definition of the dominant tectonic control of the sedimentary sequences in foreland basins. The eustatic control may be associated, but has a clear subordinated character.

STRUCTURES ASSOCIATED WITH LOW-ANGLE NORMAL FAULTING IN THE DANUBIAN UNITS (SOUTH CARPATHIANS)

PO15

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Orogen parallel extension has play a key role in Alpine tectonic evolution of the South Carpathians, as demonstrated by recent studies (e.g., Schmid et al., 1998). Un-roofing of the Danubian Units in respect to Getic and Supragetic takes place along a well marked detachment roughly following the former Late Cretaceous Getic/Danubian thrust. Severin unit is squeezed in between and frequently completely cut off by normal faulting. Although main movement occurs along this generally east dipping detachment by means of down throwing the getic domain towards east, important internal shearing may occur in the Danubian units as well. As Danubian rocks record the extensional event at significantly higher temperatures than the Getic ones (which exhibits only brittle deformation), internal deformation is mainly ductile and provides numerous structures suitable for cinematic interpretation, indicative for temperature- and strain regime.

Large mylonitic zones along contacts among main Danubian Units as well as complex patterns of anastomized shear zones within each unit indicate significant amouns of Top E shearing postdating nappe stacking.

Most of the samples taken from Danubian basement show stretching lineation consistently striking in the NE-SW quadrant, former microstructure related to nappe emplacement being entirely obliterated. For those we estimated temperature ranges based on active deformation mechanisms identified in thin sections. However few of them show two sets of lineation an early one marked by biotite flakes scattering around SSE orientation and a late one, more pronounced, marked by quartz ribbons and white mica flakes, scattering around NE orientation. Active deformation mechanisms show approximately the same temperature conditions for both stages. Progressive transposition of the structures related to Late Cretaceous top SE thrusting by those related to Eocene top E extension is most obvious at one locality (Coasta lui Rus) along the thrust of Urdele nappe nappe on to the Lainici nappe (both Danubian basement+cover nappes). The contact is well marked by a mylonitic zone comprising the base of Urdele nappe, the cover of Lainici Nappe, (Lower Jurasic arcoses and Upper Jurasic-Lower Cretaceous carbonates) and top of Lainici basement. Several profiles along the contact show progressive overprint of the top SE thrust related structure by top NE shearing. Early top SE lineation gets progressively folded as the rock undergo isoclinal microfolding until it is completely obliterated by the newly formed stretching lineation parallel to the fold axis. Subsequently foliation is transposed along the axial plane cleavage.

Reference

S. M. Schmid, T. Berza, V. Diaconescu, N. Froitzheim, B. Fugenschuh, 1998, Orogen-paralell extension in the South Carpathians , Tectonophysics 297, 209-228

PO16

UPPER MANTLE ANISOTROPY BENEATH VRANCEA AREA - ROMANIA AS DERIVED FROM POLARIZATION OF TELESEISMIC S-WAVES RECORDED IN POLAND

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Vrancea area - Romania represents an extremely well individualized seismic cluster, with the epicentral area roughly elongated along a N 48 E direction. It is located at the sharp bend of the Eastern Carpathians, having an almost North South direction to the Southern Carpathians, aligned mainly from East to West. The maximum focal depth ever recorded in the area is approximately 221 kms. The purpose of our paper is to investigate the polarization of teleseismic S - waves generated by several Turkish events as recorded by the Polish network. The rays traveling just beneath Vrancea present a very clear pattern, with a first onset of a medium amplitude S-wave polarized along a North-South direction. It is immediately followed by a similar amplitude wave polarized on East-West. The maximum amplitude arrival is polarized very closed to the azimuth 53 degrees. The results are extremely clear at KSP, at a distance of 8.64 degrees from Vrancea and approximately 20 degrees from the analyzed events. But they are still clearly seen at closer stations, down to 5.74 degrees from Vrancea. The pattern of the other rays (not beneath Vrancea) is quite different. Our preliminary results should indicate the anisotropy of the upper mantle beneath Vrancea (to depths around 400 - 500 kms) matches the geometry of the focal volume as revealed by seismicity data. They support the assumption of a descending subduced slab as a source of Vrancea earthquakes.

PO17

THE SEISMIC-REFRACTION PROJECT VRANCEA-99 THROUGH THE SE CARPATHIANS – A FIRST REPORT

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In May 1999 a seismic-refraction project was performed in southeastern Romania to study the crustal and uppermost mantle structure to a depth of about 70 km underneath the Vrancea epicentral region in the southeastern Carpathians. The project is a contribution to the joint German-Romanian research programme "Strong earthquakes - a challenge to geoscientists and engineers" installed by the Sonderforschungsbereich 461 at the University of Karlsruhe, Germany, in collaboration with various research institutions in Romania. The seismic-refraction investigation of subproject A1 comprises three lines: (1) a 230 km long main line from the northeastern edge of the city of Bucharest to Bacău traversing the Vrancea epicentral region in SSW-NNE direction, (2) a 70 km long fan line from Mărăşeşti to Tîrgu Secuiesc along the Putna valley north of the Vrancea epicentral region and (3) a 50 km long NNE-SSW directed extension of the main line from the southeastern edge of the city of Bucharest to the Danube river SW of Giurgiu. 14 shotpoints were established, 11 along the main line with charges from 300 kg to 900 kg and an average spacing of 20 km, 2 of 30 kg charge at the endpoints of the fan line and 1 shot with 300 kg south of Bucharest. 134 recording stations were emplaced with an average spacing of 2 km. 114 stations of type PDAS-100 and REFTEK were provided by the GeoForschungsZentrum Potsdam (organised and supervised by Dr. J. Bribach before and during the fieldwork), and 20 stations of type PDAS came from Leicester University (organised and supervised by Dr. P. Denton). The crustal and uppermost mantle study of this subproject A1 is being performed in conjunction with a teleseismic tomographic study (subproject A2), presently carried out until end of November 1999. The detailed investigation of the crust and uppermost mantle to about 70 km depth and the upper-mantle tomography study of the velocity structure to 200 km depth aim to contribute to the understanding of the causes of the occurrence of deep earthquakes in the Vrancea epicentral region. In this contribution, some technical details and selected data of the seismic-refraction study will be presented.

COMPRESSIONAL FORMATION OF THE NEOGENE TRANSYLVANIAN DEPRESSION

PO18

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The shape of the Neogene Transylvanian Depression (TD) is roughly circular with radius 60 km and sediment thicknesses increasing towards the centre where it reaches more than 4000 m. The surface heat flow is relatively low with a minimum of 35 mW/m^2. Correction for the effects of Neogene sedimentation increases the heat flow by 5 mW/m^2.

The Neogene subsidence can be modelled by three compressional phases: Old Styrian (20-17 Ma), Young Styrian (16-15 Ma) and Moldavian (13-11.5 Ma). The numerical model applied is a rotational symmetrical rheological finite element model. The modes of deformation comprise power law creep, plastic flow and elastic deformation. Temperature, pressure, deviatoric stress and rock types determine the mode of deformation.

That compression produces subsidence is related to the fact that the lithosphere of the TD is strong compared to the surroundings. The low heat flow combined with an elevated Moho and the presence of ophiolites in the crust ensures a strong Transylvanian lithosphere that does not yield much to compression. The surroundings, however, yield and thicken in response to compression as is evidenced by thrusting and mountain building in the Carpathians. In this process the Moho under the Carpathians deepens and thereby initiates subsidence in the TD by dragging down the Moho here. Sediment loading and upper mantle flexure under further compression finally deepens the TD towards the centre.

The moment active compression stops, deviatoric stresses, which are set up during the compression to balance buoyancy forces, surface loads and boundary forces start to relax viscously in the weaker parts of the lithosphere. This results in basin inversion because the buoyancy forces regain their influence. The process of inversion is much enhanced by relaxation of the compressional regime by means of the boundary condition at the perimeter of the model.

MIDDLE MIOCENE EXTENSION AT THE SOUTHWESTERN CORNER OF THE PANNONIAN BASIN: SURFACE DATA ON FAULTS AND PALEO-STRESS FIELD

PO19

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Middle Miocene (Badenian-Sarmatian) is a period of broad extension in the Pannonian Basin system when numerous basins opened or widened to accommodate convergence in the outer East Carpathians. Most of the basins were generated along large NE-SW trending strike-slip fault zones or master normal faults and generally acquire elongated, variably deep, half-graben shape. At some places low-angle normal faulting contributed to exhumation of basement rocks and to the formation of metamorphic core complexes (e.g. Rechnitz metamorphic core complex). Basin opening was accompanied by considerable calc-alkaline volcanism dispersed almost across the entire Basin system. During the same period several basins opened or re-opened at the southwestern corner of the Pannonian Basin, southwestward of the Periadriatic and the Drava Lineament, as marginal basins or troughs which terminate to the southwest at the Pannonain Basin – Dinarides boundary. These basins are recently parts of two larger Neogene basins in Croatia, i.e. Hrvatsko Zagorje and Sava Basin that experienced quite complex tectonic history since Late Cretaceous-Paleogene times. This work analyses two fault populations thought to be responsible for the opening of basins in the Middle Miocene time. Both are recorded in the highest structural unit of pre-Neogene tectonic assemblage at Samoborsko gorje Mt., a moderately (up to 900 m) high mountain elevated at the southwestern edge of the Pannonian Basin. One comprises a system of NE-SW striking, normal faults characterized by a set of smoothly curving, listric surfaces. It generates major rotated fault blocks, often dissected into smaller blocks by a set of high-angle, planar, antithetic faults. This fault system creates a series of half-grabens filled with Middle Miocene rocks. At one location faulting was accompanied by extrusion of volcanic dacite-andesite rocks of the same age. Computed paleostress axis orientation indicate that these faults accommodate NW-SE directed extension, mostly perpendicular to their strike. The other fault population is characterized by two sets of moderate to high angle strike-slip NE and NW-striking faults, generally accommodating N-S directed compression. The relative age between these events is still ambiguous. Overprinting relations suggesting that early normal-sinistral and normal-dextral movement is followed by sinistral slip on the same fault plane (i.e. earlier NE-SE extension is followed by N-S compression) are observed only on two locations. Comparison with data recorded in other parts of the Pannonian Basin as well as with some results obtained from experimental models leaves the possibility that both populations acted more or less synchronously.

PRE-MESOZOIC TECTONOSTRATIGRAPHIC UNITS OF THE DINARIDES AND SOUTH TISIA

PO20

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In the investigated area which is included within the intra-Alpine/Variscan domain, four zones with distinctly different Paleozoic tectonostratigraphic units can be distinguished.

- Post-Variscan formations of the External Dinarides are represented by fossiliferous Moscowian limestone, Gzelian Auernig beds, Ruttendorf limestone and conglomerates with redeposited older Carboniferous pebbles, neoschwagerina carbonates and, locally, evaporites.
- Paleozoic complexes of the Sava nappe, which is thrust on the NE margin of the External Dinarides, are composed of fossiliferous Namurian-early Westphalian metaclastics. More

widespread are post-Variscan formations represented by Groeden beds, Rattendorf limestones, Trogkofel clastics and Upper Permian limestones and gypsum-bearing dolomites.

- Variscan formations of the Internal Dinarides, parts of the Noric-Bosnian zone, build up several larger isolated complexes which are included in the Pannonian nappe. In all of them characteristically occur fossiliferous Devonian platform carbonates frequently underlain by fossiliferous Silurian, in some areas even by fossiliferous Cambrian-Ordovician metaclastics with subordinate carbonates, tuffs and metabasics. However, the most widespread are fossiliferous Carboniferous metapsammites, metapelites, lydites and limestones interlayered with metarhyolites. All these formations were affected by Variscan deformation (ca 340 Ma) and very low- and low-grade metamorphism. Overstepping post-Variscan formations are represented largely by shales, sandstones, rarely interlayered with volcanics, carbonates, conglomerates and breccias in which redeposited lydites and metarhyolites are very common. In some areas, upper parts of the Permian are represented by Bellerophone limestones and Red beds with evaporites.
- Paleozoic complexes of the South Tisia, in eastern Slavonian block are represented by a) low- and medium-grade Barrovian sequences composed of metapsammites, metapelites interlayered with tholeiitic orthoamphibolites and marbles. The lowest grade metapsammites contain Silurian-Devonian palynomorphs, whereas on hornblende concentrates from higher grade rocks K-Ar ages of 376 to 262 Ma were obtained. On a few samples from the same metamorphic sequence K-Ar ages of 659-421 Ma were obtained. On mica concentrates from paragneisses of the Barrovian sequences most of Ar-Ar ages range between 337 and 324 Ma, two are decreased (264-237 Ma) and one is increased (430 Ma). All these radiometric ages suggest that in the predominant Barrovian sequences are included remnants of unmapable pre-Variscan units. In eastern Moslavina block crop out medium-grade Abukumo-type sequences, petrographically, of the same composition as in Slavonija which are characterized by pervasive overprint ages mainly of 90 to 50 Ma; b) Migmatites and S-type granites which occur in both blocks have Rb/Sr and K/Ar ages of 336-277 Ma in Slavonija and 73-57 Ma in Moslavina; c) I-type granites associated with monzodiorites, gabbros, and serpentinized alpine-type ultramafics. K-Ar ages range from 339-321 Ma on granites and from 527-507 Ma on amphibolites interlayered with the alpine-type ultramafics.

Paleozoic formations of the External Dinarides and Sava nappe, paleogeographically, were related to the northern passive Gondwana margin, whereas the crystalline complexes of the South Tisia were related to the active Laurasian margin. Allochthonous Paleozoic formations of the Internal Dinarides originated, alternatively, either in open, oceanized Prototethys or in a system of "en-echelon" basins. The presented model fits with the global geodynamic evolution of the Variscan Europe.

DEEP LITHOSPHERIC DENSITY VARIATIONS AND THEIR RELATION TO STRUCTURES IN THE PANCARDI REGION

PO21

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The contribution focuses on density modelling and interpretation of long-wavelength gravity anomalies in the PANCARDI region. It offers a review on all hitherto results obtained in frame of PANCARDI research "Gravity field of the PANCARDI region". Color-shaded gravity image map of Poland and Slovak Republic will be shown. Re-calculated new model of deep lithospheric density variations and their relation to structures in the Vrancea region will be presented too. Based on these results together with the results obtained in terms of integrated modelling and prediction of lithospheric rheology the contribution discusses about the following questions: How is the role of the lithosphere-asthenosphere boundary for density modelling? What is real depth of the lithosphere-asthenosphere boundary? And what are the surface structures associated with the deep-seated density inhomogeneities?

DEEP GEOLOGY BOUNDARIES IN THE EAST CARPATHIAN BEND ZONE AS SUGGESTED BY GRAVITY AND MAGNETIC DATA

PO22

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According to the actual geotectonic models of the East Carpathians, their alpine structures override as a broadly advanced belt, the foreland paltforms: the Epialgomian Platform (?) and the Epihercynian Platforms (the Scythian and the Moesian Platforms).

The gravity information apllied to by attempting to show the relation between the two foreland platforms, is represented by a residual Bouguer gravity map (the figure), prepared as the result of a stripping process. This stripping process included a 3D modelling of the gravitational effect of the nappes and the Carpathian foredeep covering the foreland platforms and the usual removing of this effect from the observed Bouguer anomaly.

For the proposed investigation, it has been thought that there are 3 main tectonic units producing the main gravitational effect in the East Carpathian bend zone. This units are the Neogene foredeep, the Marginal Folds Nappe and the Tarcău Nappe. The gravity modelling of these main units has been performed by using borehole density data and isobath maps prepared with the aid of published geological profiles, at scale 1:200.000.

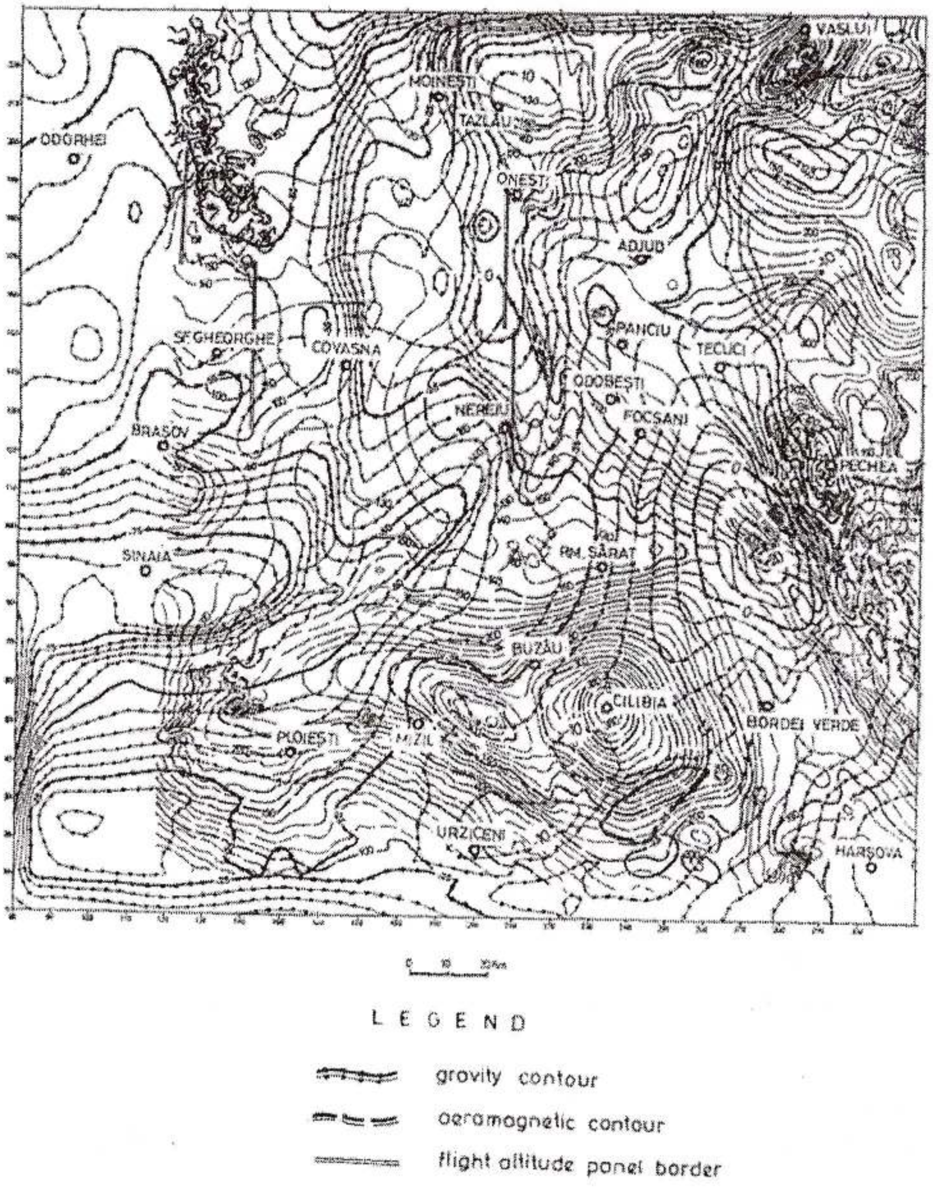
The magnetic information is represented by an aeromagnetic map orginally drawn at scale 1: 100,000 (the figure).

Although a stripping process is not able to remove completely the effect of a cover, the comparison between the residual map and the observed map showed that most of the regional low, produced by the foredeep and the nappes, has been compensated by replacing those tectonic units with a volume of rocks having the same density as the underlay, that means the density of the foreland platforms.

It can be assumed that by tracking the boundary between the different foreland platforms beneath the Carpathian Orogen, one may hope to explain certain strange features of this orogen. One of these features is certainly the bend zone of the East Carpathians. It is a zone of a large gap of the Carpathian crystalline belt and the realm of a singular seismicity.

For the above shown reason, an attempt has been made to decyphre the track of the boundary between the Scithyian and the Moesian Platform, by appealling to gravity and magnetic information.

RESIDUAL GRAVITY AND AEROMAGNETIC MAP
OF THE EAST CARPATHIAN BEND ZONE



By correlating the gravity and the aeromagnetic maps, one can hardly suggest any connection between the anomalies present on these two maps. It is rather a signature similarity to be outlined when the maps are presented together.

On the aeromagnetic map, the very Carpathian bend zone, that means an area outlined by the places: Coavasna, Oneşti, Tecuci, Râmnicu Sărat, shows very low intensity anomalies. In the same area, the residual gravity map, shows a conspicuous regional low, with a singular high that has a local character.

The sources of the aeromagnetic anomalies are to be sought within the underlay of the flysch units. The regional gravity low indicates a sunk platformial underlay. Among the weak magnetic anomalies, the most important, pinpointed by the place Nereju, seems to pertain to an alignment with an orientation different from the strong anomalies which characterise the foreland. It is suggested that the deep geology of the Carpathian bend zone is a puzzle of fragments pertaining to the two platforms, denoting a singular history.

PROGRESS REPORT ON ACTIVITIES IN THE PANCARDI SUBPROJECT "PALEO HEAT FLOW AND FLUID FLOW IN THE TRANSYLVANIAN AND PANNONIAN DEPRESSIONS". NEW GEOTHERMAL MEASUREMENTS AND MODELING CONCERNING LITHOSPHERIC THERMAL STRUCTURE AND EVOLUTION OF THE TRANSYLVANIAN DEPRESSION

PO23

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A joint cooperation between the Institute of Geodynamics – Bucharest and the Geophysical Laboratory - The University of Aarhus on the heat flow and lithosphere evolution of the Transylvanian Depression (TD) started in 1996 as a contribution to the subproject "Paleo heat flow and fluid flow in the Transylvanian and Pannonian depressions". New geothermal measurements were performed during two field campaigns in 1996 and 1997 and modeling studies were undertaken to elucidate several aspects of the thermal regime and evolution of this tectonic unit.

The surface heat flow density pattern of the Transylvanian Depression represents a marked high amplitude short wavelength low in a region of generally elevated heat flow. Detailed temperature-depth profiles obtained by continuous temperature logging in 24 thermally stabilized wells to a maximum depth of

1400 m, combined with a finite element modeling of topographic and fluid flow effects support the conclusion that the observed thermal gradient in the TD truly represents the rate of heat loss of the subsurface. Modeling results show that the transient effects of sedimentation and erosion mean an overall 5-7 mW/m^2 reduction in heat flow compared to the steady state value and that a low mantle heat flow and a low crustal heat production rate in the TD are necessary to explain the heat flow anomaly.

The shape of the Neogene depression is roughly circular with radius 60 km with sediment thickness increasing toward the centre where it reaches more than 4000 m. A system of roughly circular faults borders the basin. The TD has a length scale in all directions which is similar to the thickness of the lithosphere and calls for three-dimensional modeling. As a first approach we invoke a rheological lithosphere model of alternate radial compression and extension to model the Neogene subsidence. The compressional phases are related to the Old Styrian (20-17 Ma), Young Styrian (16-15 Ma) and Moldavian (13-11.5 Ma) tectogeneses active in the Carpathians, while weak extensional phases account for the uplift of the basin in Pannonian (5.5-0 Ma).

GEOTHERMAL FIELD AND STRUCTURALLY CONTROLLED REGIONAL-SCALE FLUID CONVECTION SYSTEM IN THE EASTERN CARPATHIANS AND ITS FORELAND, ROMANIA

PO24

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In the Eastern Carpathians of Romania and its foreland structural investigations, studies of superficial fluid discharges, and high resolution temperature measurements in boreholes of oil fields were carried out.

The chemistry of the fluid and gas occurrences (water with CO_2, H_2S, NaCl, HCO_3^{-}, hydrocarbons, methan) is an indicator of their source area. It is possible to demonstrate a good correlation between the composition of the fluids, their regional distribution with respect to the superficial geologic structures, and the structural correlation with expected source rocks in depth (p.ex. lower Cretaceous and Oligocene black shales or Miocene evaporites). Isotopic data of Berner (work in progress) and geologic considerations make it possible to distinguish fluids originating from superficial precipitation (whole working area) and from diagenese/very low grade metamorphism (hydrocarbons, area of flysch nappes and foreland basin) and to prove the inflow of fluids and gases of mantle origin (area of Neogene/Quaternary volcanism).

The measured borehole temperature-depth-profiles of the foreland can be separated into two different classes. In the area west of a NNW-SSE oriented line passing through the city of Focsani the temperature profiles show gradients below 20 K/km from the surface to a depth of 1500 m. To greater depths the gradients increase and approach values of 30 K/km. East of this line the gradients are of 30 K/km from the surface to a depth of about 1000 m and increase to above 30 K/km at depths between 1000 m and 1300 m. The results of a simple mathematical model describing the effect of sedimentation in a basin do not match the temperature profiles measured for depths until at least 2500 m. Instead, the measurements can easily be explained by a stationary fluid convection system. The fluids are moving downward west of the NNW-SSE oriented line and upward east of it. This line can be correlated with the Capidava-Ovidiu fault zone.

From the totality of the data it is possible to define several hydrologically significant aquifers (p.ex. Oligocene and Miocene Kliwa sandstone, Miocene Doftana molasse) and to deduce a regional-scale fluid flow in the Eastern Carpathians and its foreland. The increased precipitations in the topographically high areas of the East Carpathians lead to a forced convection of groundwater, whose flow is strongly influenced by the geological structures. Cold surface water from these high areas move down to the low-lying foreland areas respectively Quaternary intramontanous basins, where they rise back to the surface. From the distribution of the hydrocarbon occurrences and zones of artesic water it is possible to confine these areas of upwelling fluids, which are partly connected with an increased heat flow. Minor advection of mantle fluids and gases in the area of young volcanism is probably connected with faults related to the Quaternary intramontanous basins between Covasna and Brasov.

HEAT FLOW IN ALBANIA IN A BROADER CONTEXT OF GEOTHERMAL MAPPING IN PANCARDI REGION

PO25

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On the basis of detailed borehole temperature logging in fourteen selected localities, completed with numerous industrial temperature-depth records from deep holes, the regional patterns of temperature at 100-m depth and of characteristic near-surface temperature gradient were constructed. After assessing the effect of the topography, altogether 49 heat flow values were determined.

A generally low geothermal activity is typical for most of the Albanian territory with temperature gradients ranging from 7-11 mK/m in the synclinal belt, 11-13 mK/m in southernmost Albania to a maximum of 18-20 mK/m in the central part of the Pre-Adriatic depression. Low heat flow zone of 30-45 mW/m^2 extends from north to south along the Adriatic coast. Geothermal activity increases landwards from west to east and generally corresponds to the tectonic evolution of the whole region. Low heat flow zone well copies the belt of thick crust (40-50 km) and the extended low gravity anomaly. From the east and south the Albanian territory is surrounded by considerably higher heat flow data.

Heat flow field of all Balkan region is characteristic by generally very complex geothermal conditions and typically broken to a number of local heat flow anomalies produced by both hydrogeological conditions as well as structural inhomogeneities. Crustal temperatures at the MOHO depth thus may vary at an extremely broad range of 400-450 (e.g. Adriatic coast, Transylvanian depression) to 800+ degrees Celsius (e.g. Pannonian basin). Moho heat flow then varies from 20 to 35-40 mW/m^2.

GEOELECTRIC MODELS RELATED TO THE PANNONO-CARPATHIAN SYSTEM

PO26

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In the framework of the PANCARDI project, an extensive program of magnetotelluric survey has been developed in the last years, along a geotransect crossing eastwards of the Pannonian Depression, southwards of the Apuseni Mountains, the Transylvanian Basin and the Carpathian Arc Bend Zone. The goal of this paper is to show how magnetotelluric data can provide valuable information about physical state of the geotectonic structure, by means of the conductivity distribution within the crust and upper mantle. The tensor impedance decomposition technique was used to derive both the regional 2D geoelectric responses corresponding to the electromagnetic induction parallel and perpendicular to the strike direction of the main geotectonical units into lithosphere and the dimensionality parameters of the regional structure, for which 2D modeling should be carried out. The final models reveal the following aspects:

- Existence of two large conductive zones, approximately collocated with collisional orogenic belts belonging both to the remnants of the Tethyan oceanic crust (ophiolitic suture) and the palaeo-plane of "consumption" beneath the Eastern Carpathian Flysh Nappes System (sedimentary formations);
- The presence of the intermediate depth seismogenic volume (60-200km) in the Carpathian Arc Bend zone, characterized by a block of low conductivity, surrounded by high conductivity areas, which may represent a strong evidence of a lithospheric slab embeded in the mantle during collisional processes. The volume of low conductivity displays a peculiar structure, its main feature being a change of strike direction from top (orientated NE-SW) to bottom (mostly orientated N-S).

INTERPRETATION OF MAGNETOTELLURIC DATA ALONG THE RADOSZYCE-PRZEMYSL LINE – EASTERN PART OF THE POLISH CARPATHIANS

PO27

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Deep magnetotelluric soundings were made by the Geophysical Exploration Company, Warsaw, in 1998 in the eastern part of the Polish Carpathians along the Radoszyce-Przemysl line crossing the flysch orogen in the transition zone between Western and Eastern Carpathians. The measurement line was ca 80 km long with sounding sites distributed about 3 km apart. Data acquisition was made with the use of MT-1 magnetotelluric system designed and produced by Electromagnetic Instruments Inc. (EMI), Richmond, California, USA. Measurements were made in a frequency range of 300 – 0.0005 Hz. The remote magnetic referencing was applied to eliminate the influence of electromagnetic noise. Field data were processed with the use of MTR15 computer program incorporated in the MT-1 system. The results of data processing were amplitude and phase MT sounding curves, impedance polar diagrams, and skew. They were then subjected to qualitative and quantitative interpretation. At the first stage of interpretation apparent resistivity and phase pseudosections were obtained. A type of curves, polar diagrams and skew were analysed in qualitative interpretation. 1D inversion was made with Bostick, Occam and LSQ methods. Based on Bostick 1D inversion, pseudo 2D resistivity cross-sections were computed with the use of kriging method. Results of 1D LSQ inversion were used to obtain 2D input resistivity section. Additional data including geological information on the flysch orogen, refraction seismic data, and results of 2D inversion with RRI method were also applied.

Results of magnetotelluric data interpretation provided new elements in recognition of the structure of the flysch orogen and its basement and confirmed earlier interpretation of the roof of the high-resistivity horizon. A considerable resistivity differentiation was observed in the Precambrian formations in NE part of the cross-section where the high-resistivity platform-type basement occurs beneath the autochthonous Miocene sediments. In the roof of that complex two wide depressions are observed in the high-resistivity horizon. They are filled with relatively low-resistivity deposits and are likely cut by tectonic zones in SW. It is possible that those deposits are younger, however their geological identification is problematic because deep borehole data are unavailable there. The zone of low-resistivity rocks occurs to SW of the Kuzmina-1 well. It is likely connected with a great alpine compressional structure. In SW portion of the section, the high-resistivity horizon is buried deep under a thick low-resistivity complex. In the final part of the section, close to the state border, the high-resistivity block is overthrust onto those low-resistivity deposits. Its roof is interpreted to be at a depth of 8-10 km. The arrangement of those high and low-resistivity complexes suggests that a subduction zone is present where low-resistivity deposits are impressed under a high-resistivity block overthrust from the south.

Resistivities of the flysch orogen differ over a narrow range. In the southern part of the section the flysch is underlain by thick low-resistivity complexes whose geology cannot be clearly identified. The position of the surface of the Carpathian overthrust is not clear as well. Results of the presented study show that the magnetotelluric method provides great possibilities in recognition of the geology of the Carpathian orogen and its basement.

THE POSSIBLE ZONE OF SUBDUCTION IN THE EASTERN PART OF THE POLISH CARPATHIANS IN THE LIGHT OF MAGNETOTELLURIC SOUNDING INTERPRETATION

PO28

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In common opinion, the subduction zone in the northern part of the Carpathians is connected with the Pieniny Klippen Belt, i.e. with the border between Inner and Outer Carpathians. However, the location of this subduction zone is not so evident in the transition zone between Western and Eastern Carpathians. The axis of the minimum gravity depression, usually connected with subduction zones, runs several dozens kilometres north of the Pieniny Klippen Belt. The line of inversion of Wiese vectors is translated to north as well. The results of magnetotelluric and geomagnetic investigations that have been made in the Polish Carpathians for years, indicate that the deep depression of the orogen basement filled with low-resistivity deposits exists under the so-called Central Carpathian Depression. The southern edge of the depression occurs under the frontier of the Dukla Unit. Interpretation of magnetotelluric soundings located close to the Polish-Slovakian border allows a low-resistivity layer, 2-5 km thick, to be identified in that zone. The layer steeply dips towards south-west under the elevated high-resistive complex. The arrangement of high and low-resistivity complexes suggest the existence of a subduction zone shifted towards north in relation to the Pieniny Klippen Belt in the area between Krynica and Baligród. The course of the subduction zone east of that area is not clear. The zone of deeply buried basement becomes narrower and shallower but the axis of gravity minimum is shifted to north. Analysis of geophysical data suggests the existence of large transversal tectonic zone.

FLUID SOURCES IN OROGENIC AREAS, TWO EXAMPLES: NORTHERN APENNINES AND EASTERN CARPATHIANS

PO29

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Nature, origin, chemical and isotopic ($\delta^{18}O$ and δD in waters and $^3He/^4He$ and $\delta^{13}C$ in CO_2 and CH_4 in gas samples) composition of natural fluids from two active orogenic areas, Northern Apennines and Eastern Carpathians have been compared. The two areas show similar characteristics in their back-arc and fore-deep areas. The peri-Tyrrhenian back-arc sector in the Apennines and the south-eastern part of the Transylvanian depression are characterized by a relevant CO_2 flux. Such CO_2 greatly affects the composition of both deep thermal, mineral and shallow waters. In Italy, being the back-arc area interested by a regional reservoir (Mesozoic limestones), relatively deep in the crust with evaporites at the base, thermal spring compositions vary from Ca-HCO_3 to Ca-SO_4 with travertine deposition. In Romania, the main aquifers interfere with CO_2 in volcanic formations and the resulting water composition is prevalently Na-HCO_3 (soluble component), with no travertine deposition.

The gas composition in back-arc areas of both countries is mostly CO_2 with minor contribution of N_2, related to air-saturated descending waters. The isotopic signature of waters is meteoric, suggesting for the two areas a gradient of (water table) topographically driven origin.

As suggested by Neogene post-orogenic basins, the two back-arc areas are interested by tensive tectonics. Such tensive tectonics, associated with the rising of mantle material, is also confirmed by the $^3He/^4He$ ratios in the gas phases. In the peri-Tyrrhenian sector, values of R/Ra ($=^3He/^4He_{measured}/^3He/^4He_{air}$) are as high as 3.0 in the Larderello geothermal field, whereas they reach 4.62 around the volcanic Harghita Mts. Assuming that the mantle R/Ra ratio below the Apennines and the Carpathians resembles that of the European Mantle (6.1-6.7 R/Ra), we can assess a mantle contribution of 50 and 75%, respectively.

Passing the Apenninic thrust belt, CO_2 emissions disappear and several CH_4-rich emissions discharge from the flysch formations along the watershed. In the foredeep basin (Po Valley), mud volcanoes characterizes the boundary limit between the Apennine formations and the Po Valley sediments. Similarly, crossing the Carpathian watershed, though with a more reduced CH_4 emissions, CO_2-rich gases lack. The difference between the Apennines and the Carpathians is that the geothermal fields in Italy contribute to the production of abundant thermogenic CH_4 (150 ton/d at Larderello geothermal wells) which is not present in the Eastern Carpathians. As observed for waters associated to CH_4 emissions, their chemical composition is Na-Cl in the two areas, suggesting a leakage of brackish waters associated with oil-fields.

Morphologically, CO_2 emissions have the shape of small mud basins, whereas CH_4 gases are generally related to mud cones. A relation between orifice morphology and gas pressure at depth exists. CO_2 vents consist of mud basins with high gas-rate emission where the rising fluids move upwards through diatremes (high gas pressure). Methane emissions seep out with a reduced gas flow-rate where fluid motion is likely related to saline diapire extrusions (low pressure).

ORGANIC FACIES VARIATIONS AND SOURCE ROCK POTENTIAL IN THE DYSODILIC SHALES, ZEMES-SLANIC AREA

PO30

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Oligocene lower dysodilic shales and Miocene upper dysodilic shales outcrops of the Tarcau nappe and Marginal Folds nappe of the East Carpathians Outer Flysch in the Zemes-Slanic area were investigated with organic - geochemical analyses. Our investigations were able to differentiate organic facies types, to estimate their source rock potential and to integrate these facies into the sequence stratigraphic network.

The total organic carbon contents (TOC of the bulk sediment) and the Rock-Eval pyrolysis data (Espitalie, 1977; Peters, 1986) define mainly a high preservation rate of the organic matter in poorly oxygenated or anoxic conditions in the bottom-water column and a low stage of thermal maturity.

Four organic facies types C, BC, B and D (sensu Jones, 1987) were recogized. They define the position of the organic-rich deposits in a depositional sequence, the rate of the terrestrial input in the marine organic matter and can show the signs of oxic decomposition or reworking processes.

MIOCENE AND PLIO-PLEISTOCENE VOLCANIC ROCKS FROM TWO NEOGENE SUB-BASINS OF THE PANNONIAN SYSTEM (STYRIA AND CARINTHIA): PETROGENESIS AND GEODYNAMIC IMPLICATIONS

PO31

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The Styrian (SB) and Lavanttal (Carinthia) (LB) Basins are the only Miocene intramontane basins of Austria where the lithospheric extension was so important to allow the eruption of mantle-derived magmas. In the LB only one volcano (Kollnitz) was formed (14.9 Ma), whereas several volcanic centres developed in the SB during two separated phases (16.3-14.0 Ma and 3.8-1.7 Ma). The Miocene and Plio-Pleistocene volcanic activity of the SB and LB has contrasting affinities with rocks belonging to the high-K calcalkaline/shoshonite and Na-alkaline series, respectively. In terms of age of eruption and, in first approximation, also general affinity the studied SB and LB volcanic rocks are respectively comparable with phase 2 and 3 of the CPR, defined by Downes (1996) as "subduction-related" and "extension-related" volcanism, respectively.

A detailed comparison of major and trace elements as well as Sr, Nd and Pb isotopes shows that I) the Plio-Pleistocene volcanic rocks have a similar petrogenetic affinity with Phase 3 volcanics of the whole CRP, whereas II) the Miocene volcanic rocks of SB and LB are clearly distinguishable from coeval volcanic rocks of the Western and Eastern Carpathians.

The volcanic rocks of the Western and Eastern Carpathians are widely considered to be related to Miocene subduction of the oceanic lithosphere of the European plate and its subsequent detachment as a consequence of soft collision between the Carpathian arc and the European platform. By contrast, the petrogenesis of the more primitive lavas of SB and LB indicate that their mantle sources contain a component derived from subducted continental crust materials, particularly at Weitendorf (Styria), and there is no evidence of the presence of a component derived by dehydration of the oceanic crust. Modelling based on the geochemical and isotopic data of the whole Miocene lavas from SB and LB shows that crustal contamination is not a significant process during the upraise and the evolution at shallow level of mantle-derived magmas.

The SB and LB volcanism (16.3-14.0 Ma) took place during the main eastward extrusion period of the Eastern Alps (18-15 Ma, Frisch et al., 1998) in connection with extensional collapse of the Eastern Alpine orogenic prism leading to the formation of the intramontane basins of Austria. During this period there is no evidence of active subduction of European plate under the Eastern Alps.

Therefore, the subduction/incorporation of continental crust material in the mantle source required by petrogenesis of the SB and LB volcanism should have occurred earlier, most probably during the Paleogene N-S subduction/collision leading to the formation of the Eastern Alpine orogenic prism. In this geodynamic scenario, the SB and LB volcanism is considered to be related to delayed melting of a recently enriched lithospheric mantle sources activated by Miocene extensional tectonics.

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PETROGENETIC PROCESSES IN A SUBDUCTION-RELATED POST-COLLISIONAL VOLCANIC ARC SEGMENT: THE UKRAINIAN CARPATHIANS

PO32

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Calc-alkaline lavas erupted in the SW Ukraine in Miocene times (13.8-9.1 Ma) form an integral part of the complex subduction-related volcanic arc of the Inner Carpathians in Eastern Europe. Magmas were erupted simultaneously in two parallel arcs (here termed Outer Arc and Inner Arc) in the Ukrainian part of the Carpathians. Compositional differences between volcanics in the two parallel arcs were produced by the introduction of a variable proportion of slab-derived sediments and fluids into the underlying mantle wedge, and by upper crustal contamination.

Outer Arc rocks, represented mainly by andesites, are characterized by LILE enrichment (e.g. K and Pb), depletion of Nb, low compatible element abundances, higher Sr, O, lower Nd isotopic ratios (0.7085-0.7095; 7.01-8.53; 0.51230-0.51245). Inner Arc rocks are mainly dacitic and rhyolitic with some andesitic lavas. Both high-Nb and low-Nb lithologies are present, which show low compatible element abundances and lower Sr, O, and higher Nd isotopic ratios (0.7060-0.7085; 6.15-6.64; 0.5125-0.5126). Based on the LILE enrichment (especially Pb) a higher fluid flux is suggested for the Outer Arc as compared with Inner Arc lavas.

Combined trace elements and Sr-Nd-O modelling suggests that the factors which control the generation and evolution of magmas is complex. The most primitive magmas belong to the Inner Arc. Isotopic modelling shows that they can be produced by adding 3-8% subducted terrigenous flysch sediments to a combination of depleted (DM) and enriched (EM) local asthenospheric mantle sources. Further lower crustal and up to 5% upper crustal contamination has been modelled for fractionated products of Inner Arc and Intermediate Zone areas. The similar geochemical features of Outer arc lavas suggests that they were generated from similar melts as the Inner Arc and Intermediate Zone primitive magmas, but have been strongly affected by upper crustal contamination and fractional crystallization. 10-20% upper crust assimilation is required in the AFC modelling, starting from an Innner Arc parental magma. We suggest that magma genesis is in closely related with the complex geotectonic evolution of the Intracarpathian area. Several tectonic and kinematic factors are significant: (1) hydration of the asthenosphere during subduction and plate rollback directly related to collisional processes; (2) thermal disturbance caused by ascent of hot asthenospheric mantle during the back-arc opening of the Pannonian Basin; (3) clockwise translational movements of the Intracarpathian terranes, which facilitated decompressional melting of an already hydrated and heated asthenosphere.

HOW TO EXPLAIN CALC-ALKALINE MAFIC ERUPTIONS IN ABSENCE OF ANY OCEANIC SUBDUCTION? EXAMPLE IN THE SOUTHERN EASTERN CARPATHIANS

PO33

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Since 9.4 Ma, the internal part of the SE Carpathians is the site of calc-alkaline mafic eruptions (Calimani-Harghita volcanic chain), synchronous in the last 2 Ma with alkaline mafic eruptions (Persani volcanoes). However the convergence between the Tizia-Dacia and European plates stopped around 12 Ma. Besides the crustal seismic profiles evidence that the recent volcanic zone crosscuts the major suture between both plates such that calc-alkaline and alkaline magmas necessarily originated from the mantle below the lower, and not upper, plate.

For understanding this unusual sheme and the genetical link between the deep and shallow processes, only an integrated study enables to find an acceptable solution.

At surface, volcanism started in a crustal uplift context and at the time of a dramatic increase of the subsidence of the Focsani foreland basin. Then, the uplift rate dramatically accelerated, hinterland basins began to form at the periphery of the volcanoes while the internal part of the foreland basin began to be folded. Both volcanoes and basins formed in an uplift-induced NW-SE extension context by gravity spreading towards SE above a detachment horizon within the crust. This hinterland extension was compensated by folding of the internal part of the foreland. The primitive feature of mantle magmas and the alignement of craters, more and more recent towards SE, suggest a rapid ascent along deep NW-SE crustal fractures.

At depth, the strong seismicity is confined to a narrow vertical slab hanging below the Focsani basin between 70 and 200 km depth and at 130 km southeastward far from the Africa-Europe suture. This slab would be the result of the delamination of the lower mantle lithosphere, while the Focsani basin would be the isostatic response to the slab loading. Below the volcanic zone characterized by a very high heat flux, the lithospheric mantle thickness is strongly reduced, which suggests an asthenospheric rise inside the newly created space. A low velocity zone exists within the mantle just below the Moho. This subcrustal mantle, sampled by the alkaline lavas, is rich in partial melting micropockets and petrographically rather heterogeneous. The chemical and isotopic compositions of the different lithologies fit with those of possible source-rocks for the calc-alkaline and alkaline lavas, while melting pockets attest for a fast decompression at mantle depth. The LVZ would represent a partially molten zone underlining, in the uplift context, a crust-mantle mechanical decoupling. Indeed, while crust deforms flexurally, mantle deforms in a ductile way, expands and partially melts. Locally the crust fractures enabling rising and eruption of magmas.

All these events are linked as follows: lithospheric mantle delamination -> asthenospheric rise -> density decrease and uplift of the thinned lithosphere -> crust-mantle decoupling -> mantle melting and crustal fracturation -> magma ascent and eruptions. At surface uplift induced extension, fracturation and hinterland basin formation by gravity spreading above a intracrustal detachment. Mantle delamination would have begun 16 Ma ago as the Focsani basin formation, i.e. some millions years before the end of plate convergence.

GEOCHRONOLOGICAL APPROACH OF NEOGENE CALC-ALKALINE VOLCANIC ROCKS FROM TRANSCARPATHIA, SW UKRAINE

PO34

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Along the Inner part of the Carpathians there is a subduction-related magmatic arc, extending from Slovakia to Romania. The Transcarpathian region of SW Ukraine is situated in the central part of this arc and was active during the Middle-Late Miocene. The volcanic structures of the Transcarpathian region can be divided into three major areas: a. Outer Arc; b.Intermediate zone; c. Inner Arc. This division reflects the basic tectonic features of the Ukrainian Carpathians. The Outer Arc consists of a number of overlapping stratovolcanic structures, generally composed of lava flows, domes, dykes/sills, volcanic necks and lahars of basaltic andesite, andesite and dacite composition. In the Inner Arc, primary and reworked ash-flow tuffs and fall-out tuff deposits of dacitic, rhyodacitic and rhyolitic composition are abundant. Lava flows of andesitic and basaltic-andesitic composition are also present, together with domes of dacite and rhyolite. The Intermediate zone is composed of lava domes and small andesitic shield volcanoes.

New K-Ar data obtained on 58 volcanic rock samples has yielded K-Ar ages of 13.4-9.1 Ma. This time interval (~ 4.5 million years) is identical to that of the neighboring Carpathian volcanic regions to the west (Tokaj Mts., Hungary) and to the east (Calimani, Romania). Thus, there is no evidence in this area for any along-arc migration of volcanism, unlike in the East Carpathians of Romania.

Volcanic activity started simultaneously in both Outer Arc and Inner Arc volcanic areas (13.4 Ma). Different peaks of volcanic activity were observed: (a) between 12.3-11.6 in the Inner Arc, interpreted as the major period of generation of a complex of resurgent domes related to formation of a caldera, probably situated toward the central part of the Pannonian depression, and (b) between 11-10.4 Ma in the Outer Arc, representing the main period of volcano generation. The end of the volcanic activity (9.5-9.1 Ma) was scattered and less voluminous.

RELATIONSHIPS BETWEEN GEOCHEMICAL FEATURES AND AGE OF THE NEOGENE VOLCANIC ROCKS IN THE APUSENI MTS., ROMANIA

PO35

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Unlike most of the Carpathian Volcanic Arc, which is spatially related to the Alpine fold-and-thrust belt, the Neogene volcanic area of the Apuseni Mountains is situated within the Tisia-Getia microplate, some 200 km behind the Carpathian Flysch zone. Apart of this peculiar tectonic setting, it is petrochemically indistinguishable from the subduction-related calc-alkaline volcanics of the Carpathians. The obvious subduction signature of this volcanic zone has not yet been explained satisfactorily.

High-quality major element, trace element and isotope geochemical analyses has been obtained on volcanic rocks of the Apuseni Mts., along with a set of new K-Ar age determinations, in addition to published data (Rosu et al., 1998). According to all available radiometric age data, the volcanic activity in the Apuseni Mts. started in Upper Badenian times and ended in the Early Pleistocene (14.7-1.6 Ma), with most of the eruptions occurring between 10-13 Ma. The rocks can be separated in several age groups. Four age groups are separated arbitrarily and represent a continuous volcanic activity, ranging between 14.7-7.4 Ma, whereas the fifth (Uroiu shoshonites) occurs after a ca. 6 Ma time gap.

Except for the southernmost body of volcanic rocks (Uroiu Hill) displaying shoshonitic compositions, all the studied volcanics are calc-alkaline, few of them high-K calc-alkaline. Geochemically, the volcanics characteristically cluster in three groups according to their Nb content (low-, medium-, and high-Nb). Interesting correlations between age and chemistry of the volcanic rocks can be observed. Mg number and P_2O_5 gradually increase with decreasing age in the calc-alkaline series. Na_2O+K_2O increases across the whole compositional range, except for one age group (7-10 Ma) which does not show this trend. Among the trace elements, Nb, Cr, V and Sc increase and Y decreases with decreasing age throughout the whole age range, while Ni, Sr, Ba and La increase with decreasing age only along the oldest three age groups. $^{86}Sr/^{87}Sr$ decreases and $^{143}Nd/^{144}Nd$ increases with decreasing age. The two oldest age groups belong to the low-Nb volcanics, while the youngest shoshonites are high-Nb. The two intermediate age groups (10-12 and 7-9.5 Ma, respectively) contain rocks that belong to both the low-Nb and medium-Nb groups. The Nb/Zr ratio increases significantly in the forth age group as compared with the three oldest age groups of calc-alkaline rocks. Although Zr displays an overall-increasing trend with decreasing age, it decreases with age within the low-Nb and medium-Nb groups. These features suggest that the relative contribution of mantle components to the Neogene magmagenesis in the Apuseni Mts. increase with decreasing age, whereas the influence of the crust diminishes. Beyond this general trend, there is an obvious change in the evolution of the geochemical features at ca. 10 Ma. Between 14.7-10 Ma increasing Ba/Zr vs. Nb/Zr ratios indicate increasing fluid involvement in magmagenesis, while after ca. 10 Ma source mixing between lithospheric and asthenospheric mantle components seems to be the major petrogenetic process.

References

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TERTIARY BASALTOID ROCKS OF SERBIA: AGE, RELATIONSHIPS AND GEOCHEMICAL AND PETROLOGIC FEATURES

PO36

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Tectonic activity in Serbia during the Tertiary period produced ENE-WSW fault system and simultaneously reactivated ancient dislocation zones oriented NNW-SSE. Here, voluminous intermediate to acid magmatism accompanied by various basaltoid volcanism took place. This work presents a geochemical and petrological study on 28 occurrences of different basic rocks which crop out in all major geotectonic units of the Serbian part of the Balkan Peninsula. On the basis of the composition and K/Ar age determinations of the 21 selected basaltoid rocks, we recognized at least four different basaltoid episodes.

The oldest basaltic rocks (61.97 to 39.48 Ma) are spatially restricted to the composite terrane of the Carpatho-Balkanides. These rocks show a clear basanite affinity with restricted SiO_2 range (41.44-42.64 wt.%), medium to high Mg# (0.37-0.53) and Na-alkaline character with K_2O/Na_2O=0.29-0.62. They are characterised by apparent presence of mm to cm sized dunite, lherzolite and pyroxenite xenoliths. Compatible trace elements contents (Cr up to 652 ppm and Ni up to 400 ppm) indicate their near primitive character, whereas LILE and HFSE abundances display substantial similarities to the average OIB-type lavas. All these characteristics, together with the Sr and Nd isotopic ratios of the basanite of Soko Banja (0.70302 and 0.51293, respectively), resemble those of the alkali basalt lavas from Poiana Rusca (Romania).

Potassic suite is the most appropriate name for the second group of the basaltoid rocks occurring in almost all the major terranes of the Serbian part of the Balkan Peninsula. This heterogeneous group consists of lamproitic, minette to leucititic rocks. Their radiometric ages range between 35.15 and 21.85Ma. They show rather high Mg# (up to 0.60) and K_2O/Na_2O ratios (>0.7) and sometimes they can even be considered as ultrapotassic (K_2O/Na_2O up to 20) products. Chromium and and Ni are relatively high, up to 440 and up to 260 ppm, respectively. LIL elements (Rb, K, Ba, Cs ± Sr) and U and Th are often up to 1000xPrimordial Mantle, whereas HFSE contents and ratios (Zr/Nb = 7-21; Zr/Y = 6-33) show differences probably due to heterogeneities in the lithospheric mantle source. The Sr and Nd isotopic composition of the phlogopite trachybasalt of Mionica (0.71078; 0.51225) indicates time-integrated enrichment.

Roughly contemporaneously to the potassic suite, basaltoid rocks of medium to high K-calc-alkaline features emplaced. They mostly occupy the basaltic field of the TAS diagram, but some occurrences also show basaltic andesite, basanite and trachybasaltic affinity. They have variable SiO_2 (43.49-55.50 wt.%), Mg# (0.41-0.48), K_2O/Na_2O (0.20-1.39) values. Their medium- to high-K character is reflected by a frequent presence of K-feldspar either as macrocrysts or microlites within the groundmass.

The youngest basaltoid rocks (15.8-3.86Ma) are represented by basanites, rare analcimites, trachybasalts to trachyandesites. Generally speaking, they have silica-undersaturated to saturated character: SiO_2 (40.85-53.73%), with moderately to high Mg# (0.35-0.80), predominantly sodic affinity (K_2O/Na_2O<1) and high Na_2O (up to 5.00 wt.%) abundances. Chromium and Ni are lower with respect to the previous suites (up to 273 and 231 ppm, respectively), but ratios of selected LIL and HFS elements approach typical values of OIB-like source.

OCCURRENCE OF THE ALKALI BASALT LAVA FLOW IN THE VILLAGE DRUZETICI NEAR CACAK, (SERBIA)

PO37

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Alkali basalt lava flows were found in the area of Druzetici, near Cacak (Western Serbia) and here, their petrology is presented. They are situated on the NW margin of the Tertiary Pranjani basin, in the Western zone of the Vardar Zone Composite Terrane. Two K/Ar age determinations gave 15.8±1.8 and 23.9±2.1 Ma. The complete stratigraphic sequence of the study area, including final members of the Tertiary volcaniclastic psammitic lacustrine sediments, indicate that the first explosive volcanic phases (phreatomagmatic?) were followed mainly by mild effusions of alkali basalt lava.

Alkali basalt of Druzetici is a black to dark-brown colored compact porphyritic holocrystalline to hypocrystalline rock. It mainly shows massive structure whereas in the lowermost lava flows of the volcanic succession vesicular texture is noticeable. Within the uppermost lava flows small (up to 5 mm in diameter) coarse-grained nephelinitic enclaves regularly appear.

Mineral phases were qualitatively and quantitatively studied by using standard electron microprobe and X-ray Rietveld refinement technique (when >3 wt. %). Alkali basalt of Druzetici is composed of phenocrysts of salite (56.6 wt.%, $Wo_{49.7}En_{38.4}Fs_{11.8}$ and Al^{VI}/Al^{IV}–0.24, showing low-pressure origin), analcime displaying primary igneous characteristics [40.2 wt.%, a_0=13.7233(8)Å; FeO^t=0.52-0.59 %] and fluorapatite (3.2 wt.%). The groundmass consists of microlites of the same mineral components. Rare mineral phases are: Ti-magnetite (46.3 % ulvöspinel component) and hyalophane ($Or_{53.4}Cn_{34.6}Ab_{8.6}An_{3.4}$). Basaltoid rock from Druzetici is therefore classified as analcimite.

Average mineral composition of granular enclave found in analcimite lava of Druzetici, is obtained by modal analyses: nepheline (56.3 vol.%), K-celsian (21.7 vol.%; Ba=24.01 vol.%), salite (17.21 vol.%; $Wo_{50.8}En_{34.4}Fs_{14.7}$), Ti-magnetite (4.7 vol.%; 53 % of ulvöspinel component) and fluorapatite (less then 1 vol.%). These enclaves possibly suggest sidewall or in situ fractional crystallization processes within the magmatic chamber.

The Analcimite of Druzetici displays silica-undersaturated character: SiO_2 (40.85-45.03%), with high Na_2O (3.23-4.62%), MgO (7.72-10.39%), P_2O_5 (1.43-1.55%), low K_2O (0.12-0.56%) and moderate TiO_2 (1.40-1.48%). Initial $^{87}Sr/^{86}Sr$ ratio is 0.7065.

Relatively low Mg# (up to 59.9%) and Cr and Ni contents (150 and 158 ppm, respectively) suggest that Druzetici lavas do not represent primary mantle melts. These rocks have high and variable content of Ba (938-4904 ppm), which is not followed by an appropriate increase of other LILE (especially K and Rb). Abundant K-celsian occurrences in the nephelinitic enclaves suggest that the high Ba content is most likely a primary feature. The analcimite of Druzetici shows high HFSE contents. Zirconium and Nb contents (up to 413 and 52 ppm, respectively) and selected LILE and HFSE ratios approach the typical values of OIB-like source with an unusual enrichment of Ba.

FEATURES OF DOMES FROM OAŞ-GUTÂI MTS, ROMANIAN EAST CARPATIANS AND THEIR IMPLICATIONS

PO38

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Oaş-Gutâi Mts are part of the Romanian East Carpatians. They show a complex volcanic structure still rising up a lot of questions.

A series of extensions had been emphasized during the last years either in Oaş Mts. where they prevail and in Gutâi Mts. They may be classified, as a whole, according to their shape, lithology and internal structure suggesting genetic processes.

Domes and coulées, endogene and exogene domes and intrusive domes or cripptodomes have been identified. They are composed mainly of dacites and subordinately of andesites, more or less glassy, showing both flow banding and massive textures.

Internal structure shows composite domes, complexes of domes, faulted domes, asociated with volcaniclastics. Both in situ and resedimented hyaloclastites are present suggesting subaqueously extruded magma bodies. (Fülöp and Kovacs, 1996).

Tephra deposits found on the flanks of the domes developed from explosive disintegration of the extruded lava either closely following or years after its extrusions. (Merapian explosive dome collapse) (Fülöp and Halga, 1996).

Domes are associated with major faults and are disposed on different alignements, more or less clearly pointed out. A liniar alignment has been emphasised by Fülöp and Kovacs, 1996, 1997; E-W aproximately trending, on the southern border of Gutâi Mts.

Ongoing research could emphasive other aligments with significant tectono-magmatic and economic implications.

TERTIARY CALC-ALKALINE VOLCANISM AND GEOTECTONIC EVOLUTION IN NORTHWESTERN PART OF ROMANIAN TERRITORY (GUTAI MTS., EASTERN CARPATHIANS)

PO39

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A continental margin arc type volcanism took place in the northwestern part of the Romanian territory (Gutai Mts.) during the Upper Miocene. It was related to the Tertiary subduction of the oceanic crust attached to the European plate beneath the Alcapa microplate. A typical CA magmatic series, from basalts to rhyolites, consisting of effusive and explosive volcanics and associated intrusive rocks has been developed during the main volcanic activity (13.4 - 9.0 Ma). A later stage (8.5 - 6.9 Ma) consisting of small intrusions ceased the volcanism. No significant migration took place during the Gutai Mts. volcanic activity. Major and trace elements geochemistry emphasized the CA and medium K character of the volcanism and his affinities with the high Ce/Yb arcs. REE, LILE, HFSE and Sr-Nd-Pb isotopes distribution asserts an upper mantle source (depleted MORB type mantle wedge, slightly metasomatised by subducted slab components) for the parental magmas and the presence of the crustal assimilation as a major petrogenetic process for the Gutai volcanic arc.

Our geochemical investigation yields magmatic constraints for a geotectonic model in northwestern part of the Romanian territory. We have focussed on the relationship between Miocene subduction and Gutai volcanic arc generation. The nature of the subducted slab and of the overriding plate, the type and mechanisms involved in the subduction related to the generation of the magmas are also discussed. According to the geotectonic model, the Gutai Mts. volcanism started at aprox. 7 Ma after the beginning of the subduction in the Carpathian arc (20 - 22 Ma, Csontos, 1995). This time interval has been necessary both for the subducted slab to reach the asthenospheric magma-generating zone and for the parental magmas generation and crosscutting through the overriding continental plate. The volcanism developed continuously during the complete sinking and partial consumption of the oceanic lithosphere. The end of the main volcanic activity, at aprox. 9 Ma, coincides with the beginning of the collision of the Alcapa and European plates (9 Ma, Peresson & Decker, 1997).

PANCARDI SESSION POSTER PRESENTATIONS

RHEOLOGICAL IMPLICATIONS OF THE THERMAL STRUCTURE OF THE LITHOSPHERE IN THE CONVERGENCE ZONE OF THE EASTERN CARPATHIANS

PP1

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Four different thermal models for the tectonic evolution of the convergence zone of the Eastern Carpathians are studied, in which processes like the pre-collisional subduction of an oceanic lithosphere, the underthrusting of the East-European continental margin in collision and the post-collision thermal relaxation control the long term thermal structure of the study area. The strategy of the thermal modelling is based on the results obtained in the thermal studies of the convergence areas. The thermal parameters of the models are chosen in connection with information provided by the tectonic models about the convergence process on the Romanian territory.

The thermal results obtained by modelling have been used to evaluate the rheological structure along a NE-SW representative lithospheric profile crossing the East Carpathians structures.

The investigation of the rheological profiles indicates remarkable changes with depth and laterally in the rheological behaviour of the crustal and mantle material, for all studied cases. A process of mechanical decoupling between crustal and mantle layers of the lithosphere has been noticed in front of the convergence fault (strike). This process could explain the lack of the intermediate depth earthquakes along the most part of the cross-section by interruption of the stress transfer to the deeper depths in the lithosphere. In contrast, in the models simulating the pre-collisional subduction the crustal layer seems to be still coupled with the mantle in a narrow volume of the convergence area. The values of the effective elastic thickness (EET) obtained by profile analysis confirm these conclusions. Also, the mechanical strong lithosphere (MSL) reaches depths of about 220 km, close to the maximum depth of the seismic activity in Vrancea region only in the models including an oceanic subduction process, followed by the convergence of the continental lithosphere.

The main conclusion of this paper is that the peculiarities of the seismic activity in the subducting slab in the Vrancea area could be interpreted in terms of the rheological behavior of the crustal and mantle material only in case an episode of pre-collisional subduction of an oceanic lithosphere is included.

AN INTEGRATED GEOPHYSICAL MODEL IN THE EAST CARPATHIAN BEND ZONE AND ITS FORELAND

PP2

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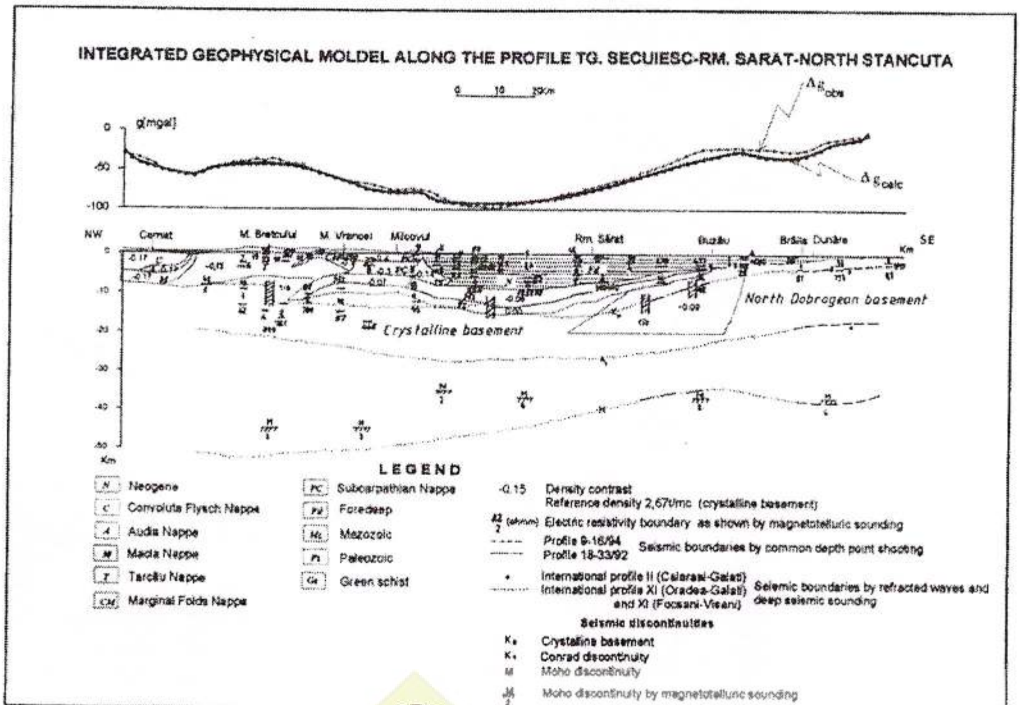
A crustal integrated geophysical model has been prepared along a profile crossing the bend zone of the Eastern Carpathians, from the inner depressions to the Danube (Tg. Secuiesc – Stancuta). It integrates the information offered by magnetotelluric sounding, seismic and gravity data.

The magnetotelluric data indicate the presence of several crustal fractures. A broad high conductivity zone, situated under the Subcarpathian Nappe (the place Monteoru), crossing the whole crust, is considered as representing the most important feature connecting those fractures and the source of the "Carpathian high conductivity anomaly". Besides, the magnetotelluric data give a general image of the depth of the crystalline basement and the presence of the underthrusted foreland platform at a depth of approximately 17 km, underneath the Carpathian nappes.



The seismic data show that the crystalline basement, from a depth of approx. 5 km in the Stancuţa area, descends at a depth of 16 km in the middle of the foredeep and rises to a depth of 10 km inside the bend zone. From seismic and magnetotelluric data, depths to the Conrad and Moho discontinuities are also inferred.

The gravity data are generally allowing the drawing of a model based on the geological model. This model seems to denote merely density contrasts situated above the basement. The density contrast has been considered for the upper crust density (2,67 t/m^3) as reference density.

That means that the gravimetric information is confined to the upper crust zone. This information includes some detail features:
- the inner nappes (Convolute, Audia and Macla) have a similar lithological constitution and they are 9 Km thick;
- the Marginal Folds Nappe and the Tarcau Nappe have similar densities;
- the thickness of the flysch nappes which is shown by the geological model, is in agreement with the gravity model where the densities are plausible;
- for modelling the Neogen Depression, a density increase with the depth is necessary;
- the gravimetric model shows an extension of the "green schist" in the Platform basement, more important than the one indicated by the geological model.

The integrated geophysical model shows a good agreement between the seismic and gravity data concerning the thickness of the flysch and the slope of the external side of the foredeep. For all the three kind of integrated data, an agreement is observed as regarding the presence of an important step at the level of the support of the flysch nappes. This step, shown in the zone of the Breţcu Mountains, corresponds to a rise of the inner side of the underthrusted nappes.

LITHOSPHERE-ASTHENOSPHERE BOUNDARY AS A DENSITY DISCONTINUITY

PP3

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Recent extensive gravimetric study involving integrated application of other geophysical and geological constraints in different European collisional and extensional regions indicates that lithosphere-asthenosphere boundary is also observed as a density boundary. Geophysical characterization of the lithosphere-asthenosphere boundary in the Western Carpathians and the Pannonian basin is also presented. Modelling of gravity anomalies by isostatically balancing effects of topography, the crust-mantle boundary and the lithosphere-asthenosphere boundary for the lithosphere-asthenosphere system as a whole suggests a relatively small (about -30 kg m^{-3}) density contrast. The results of integrated interpretations in the Eastern Alpine-Carpathian-Pannonian basin-Transylvanian basin region and Scandinavian Caledonides clearly show that the lithosphere-asthenosphere boundary is necessary to take into consideration for density modelling of long-wavelength gravity anomalies. This boundary is playing an important role in analysis and better understanding of the observed gravity anomalies in different tectonic setting.

K-AR DATING OF THE MIOCENE ANDESITE INTRUSIONS, PIENINY MTS, WEST CARPATHIANS, POLAND

PP4

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The Miocene volcanic rocks of the Pieniny Mts. occur as small hypabyssal intrusions-dykes and sills of basic to normal to acidic andesite composition.They are emplaced in the Jurassic through Upper Cretaceous sedimentary rocks of the Grajcarek Unit along the northern margin of the Pieniny Klippen Belt, and in Upper Cretaceous to Eocene deposits of the Magura Nappe (Outer Carpathians).The intrusions represent two phases of subvolcanic activity; the first phase andesite intrusions are oriented parallel/subparallel (WNW-ESE; W-E); the second phase andesite intrusions follow transversal faults (NNW-SSE) which displace the first phase ones. A detailed geochronological study of the andesite intrusions has been carried out, using the conventional K-Ar age determination. Seventeen representative rock samples from four selected areas were dated, using whole rock and monomineral (hornblende and feldspars) fractions. In some cases ground mass of the andesites were dated, as well. The analytical work has been performed at the Institute of Nuclear Research of the Hungarian Academy of Sciences (ATOMKI) in Debrecen, Hungary. Amphiboles containing excess ^{40}Ar yielded anomalous old K-Ar dates with no chronological significance (21-16 Ma). Similar results for feldspars separated from the same rock sample have been determined. On the other hand it cannot rule out completely that the reheating by the "second generation" caused a portion of the glassy ground mass to degas. The concordant radiometric ages indicate that the andesite intrusions were emplaced into the sedimentary rocks from approximately 13.0 to 11.5 million years ago. Therefore the most probable age of the andesitic magmatism in the Pieniny Mts. corresponds to the Sarmatian. However, based on the analytical data available, the emplacement of the two phases of andesite intrusions cannot be distinguished in time, because of the respective error bars overlap.

STRUCTURAL STYLES OF THE TRANSYLVANIAN BASIN REFLECTED IN SEISMIC LINES

PP5

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Structures interpreted in the seismic lines from the Transylvanian Basin reveal a very complex tectonic history with several superposed depocenters resulting from successive but different tectonic processes.

Subsurface data image a late Early to early Late Cretaceous nappe pile in the northern sector of the basin. Subsequent north-trending late Cretaceous extensional basins developed, without major border faults.

After the late Cretaceous extensional episode, shortening was continuous until the Oligocene, in the northern part of the basin. Continuous tectonics induced the thrusting of metamorphic basement and pre-Oligocene series, which are sealed by overlying Oligocene. In the northern part of the basin, most of the faults indicate a transpressional tectonic regime.

A southward thinning wedge is developed in the northern part of the basin. Its age is Burdigalian.

During the early Badenian the whole basin was subsiding. No faults of regional importance where found during this time span.

Since the Late Badenian, the inherited structures were either reactivated or controlled the new ones. Thrust faults, with salt acting as decollement horizon or transpressive strike-slip faults, represent the main structures of the Transylvanian Basin since the late Badenian. The North Transylvanian Fault represents the best example of reactivation of inherited structures. Pliocene strike-slip movement in a transpressional regime is documented along it. The discontinuities between the metamorphic basement and the pre-Badenian sedimentary sequence were also reactivated. The best exemple of inherited structure which control the new ones is the Cenade Fault. A short-cut block was created above it, with the salt acting as the decollement horizon.

VERY LOW GRADE METAMORPHISM IN THE DANUBIAN WINDOW, SOUTH CARPATHIANS (ROMANIA): PT CONDITIONS INFERRED FROM CLAY MINERALS STUDY

PP6

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The structure of the South Carpathian orocline is the result of Cretaceous nappe-stacking (top SSE) and Oligocene orogen-parallel extension (top ENE). The lowest (Danubian) and the uppermost (Getic) nappe systems consist of continental basement and Mesozoic cover. Between them are sandwiched the Severin-Cosustea ophiolite+flysch units. The samples analyzed come from the: 1) metapelitic and marly Jurassic to Cretaceous rocks of the Danubian nappes; 2) Upper Jurassic to Lower Cretaceous pelagic and flysch formations of the Severin nappe; 3) Upper Cretaceous turbidites from the Cosustea nappe.

The mineralogy of Cretaceous samples consists of illite + chlorite + quartz +/- mica/paragonite interstratification +/- hematite. The Danubian Jurassic formation shows the same mineralogy in the southwestern part of the area, while in N and NE a more complex mineral association was identified: illite + paragonite + chloritoid + pyrophyllite + quartz +/- chlorite +/- mica/paragonite interstratification.

The illite crystallinity varies from diagenetic to epizonal values. It shows two trends, increasing 1) from SW to NE and 2) from S to N. The same trends are observed for the coherent scattering domain size. The mineral associations and IC correlate well with the: 1) metamorphic facies identified in associated volcanic-volcaniclastic rocks and 2) vitrinite reflectance values.

From microprobe analyses of chlorite and mica/phengite, temperatures of 340-400 degree C and minimum pressure of about 3 kbar were deduced for the northeastern Danubian units. Higher pressure conditions (~5 kbar) are inferred for an early mica/phengite generation. 4.5 kbar are given as first approach in the Severin nappe.

INTERPRETATION OF MAGNETOTELLURIC DATA ALONG THE LINE BUKOWINA TATRZANSKA-NIEPOLOMICE, WESTERN PART OF THE POLISH CARPATHIANS

PP7

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The goal of magnetotelluric investigations that are currently carried out in the Polish Carpathians is achieving information on the geological structure of the Carpathian Flysch Orogen and its basement. Knowledge of these data is essential to oil and gas prospecting. For this purpose magnetotelluric field variations are recorded in the frequency range 0.001-200.0 Hz, thus giving information on features at a depth of about 30.0 km. The presented magnetotelluric investigations were made along the line Bukowina Tatrzańska-Niepołomice that was the first of several transversal profiles designed in the area of the Western part of Polish Carpathians to make survey with the use of new high-frequency equipment. The data were acquired with MT-1 system of ElectroMagnetic Instruments Inc. (EMI), Richmond, California, USA. Time series of MT field components were processed using programme MTR15 joined to MT-1 system. The qualitative and quantitative interpretation of sounding curves was made. As a result of qualitative interpretation the general character of geoelectric medium was recognized. Results of 1-D inversion made with the use of LSQ algorithm was used as a base of construction of initial 2-D cross-section. The 1-D Bostick's inversion was used to construct of initial 1-D models for LSQ method as well as for computation of 2-D distribution of resistivity along measurement line. Interpretation of MT soundings allowed the verified geological section to be constructed along the line. In particular, new information was obtained in relation to basement structure.

PROGRESS REPORT ON ACTIVITIES IN THE PANCARDI SUBPROJECT "PALEO HEAT FLOW AND FLUID FLOW IN THE TRANSYLVANIAN AND PANNONIAN DEPRESSIONS". NEW GEOTHERMAL MEASUREMENTS AND MODELING CONCERNING LITHOSPHERIC THERMAL STRUCTURE AND EVOLUTION OF THE TRANSYLVANIAN DEPRESSION

PP8

See PO22

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PP9

JURASSIC TO PALEOGENE PALEOMAGNETIC DATA FROM THE BUCEGI AND PIATRA CRAIULUI MASSIFS (SE CARPATHIANS, ROMANIA): CONSTRAINTS FOR THE DRIFT HISTORY OF THE TISIA-DACIA UNIT

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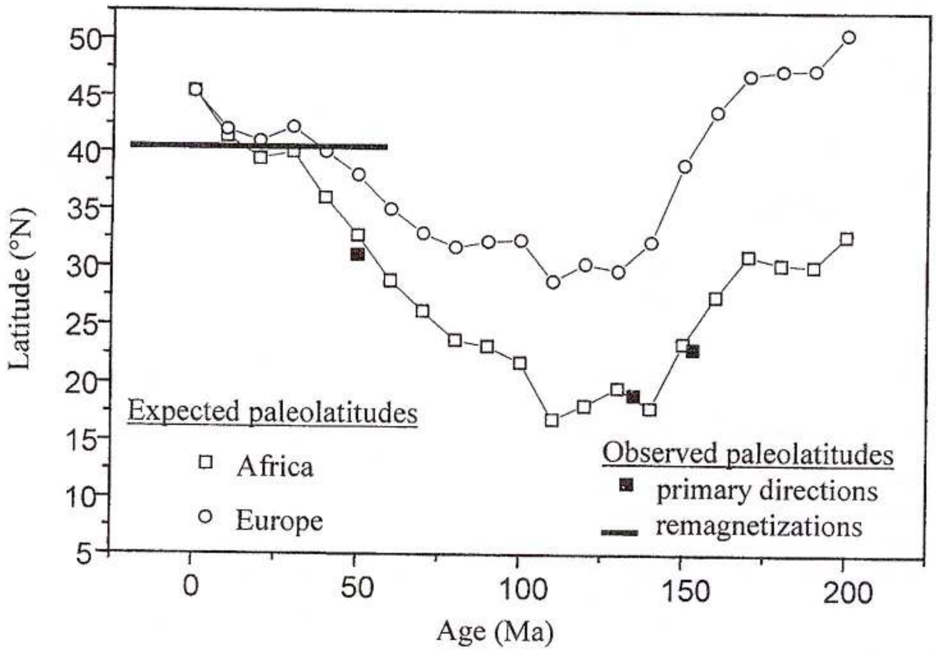
The formation of the tectonic puzzle today forming the Intra-Carpathian area is one of the important questions of Tethyan geodynamic. The so-called Tisia-Dacia unit comprises the Apuseni Mts., the South and the East Carpathians and is characterized by a common Tertiary tectonic evolution. The pre-Tertiary drift history of this unit is hardly known. In a hierarchy of arguments for the paleogeographic position of a tectonic unit at a certain time the results of a well-documented paleomagnetic study is surely the topmost. The well-known geometry of the Earth's magnetic field provides a coordinate system from which we can read the paleolatitude and the paleo-north direction of the rock unit at the time when the corresponding magnetization component was acquired. Paleomagnetism can therefore quantify the sum of both latitude-normal translations and rotations around vertical axes of tectonic blocks experienced in their geological history.

After a careful fieldwork, we selected several sites suitable for a paleomagnetic study in Middle Jurassic to Paleogene sediments from Piatra Craiului and Bucegi Mts and in the strongly faulted area between them. Sampled formations are considered to be a part of the Getic tectonic unit. Progressive thermal and alternating field demagnetization analyses reveal the natural remanent magnetization of Jurassic limestones and Jurassic limestone boulders from Bucegi Conglomerates (Albian age) being dominated by a pervasive overprint which shows mainly a normal polarity. However the primary Jurassic component can also be isolated in 4 of 11 sites. Paleomagnetic and rock magnetic analyses indicate that the Jurassic component is carried by hematite and the remagnetization by magnetite. No remagnetization was found in Lower Cretaceous limestones (3 sites). The primary magnetization in these limestones is carried by magnetite, showing both normal and reverse polarities. In the Paleogene site (sandstones) we identified both a primary component carried by magnetite and a secondary component carried by hematite.

Expected paleolatitudes in the reference frame of Europe and Africa and observed paleolatitude in this study are represented in the figure. The results of the paleomagnetic study reveal Mesozoic and Tertiary paleolatitudes, which are in agreement with a position South of Europe. These new data corroborate Upper Cretaceous paleolatitudes obtained from the Apuseni Mountains, Banat area and Hateg Basin that show also 'African' affinities. The new paleolatitudes imply a position of this part of the Getic unit between 24°N and 19°N during Middle Jurassic and Lower Cretaceous. This result imposes the review of present paleogeographic reconstructions.



The paleolatitude of remagnetizations point to a Neogene age of this event. Paleodeclinations of the Neogene remagnetization and of Paleogene sandstones show large (84° - 119°) and systematic clockwise rotation. This result show for the first time that the southeastern corner of the Tisia-Dacia unit is also affected by the Miocene clockwise rotation characterizing the western part of the Transylvanian Basin, the Apuseni Mts and western parts of the South Carpathians. The rotation took place after the cessation of the drift to the North.

PP10

EXHUMATION OF THE DANUBIAN NAPPES SYSTEM (SOUTH CARPATHIANS) DURING THE EARLY TERTIARY: INFERENCES FROM KINEMATIC AND PALEOSTRESS ANALYSIS AT THE GETIC/DANUBIAN NAPPES CONTACT

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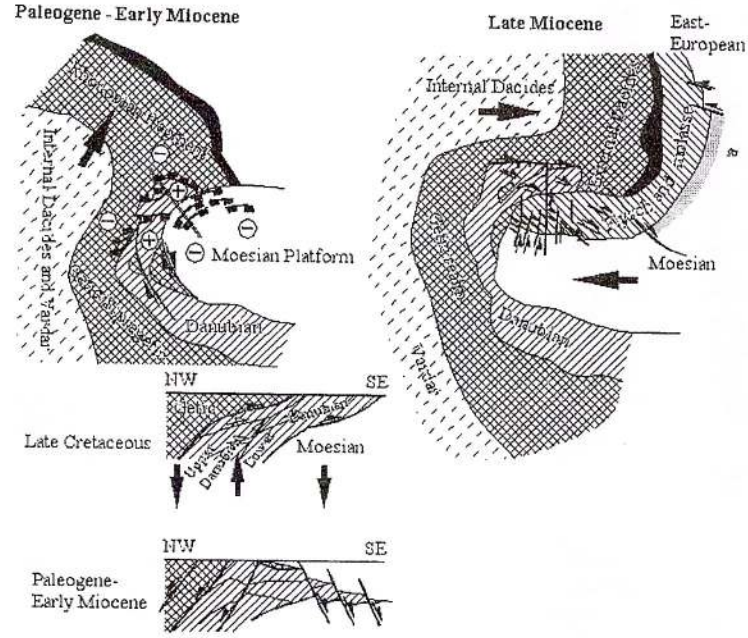
A detailed kinematic study based on the analysis of brittle structures, combined with the description of structures in the adjacent foredeep, allow for the definition of three major tectonic episodes during the Late Cretaceous - Tertiary evolution of the central part of the South Carpathians.

Following Middle Cretaceous and older orogenic phases, the first tectonic event that affected the studied area was a Late Cretaceous NNW-SSE oriented contraction, which lead to the



final major emplacement of the Danubian and Getic nappes. During the Paleogene-Early Miocene an extension event induced rapid exhumation of the Danubian units, leading to the formation of large normal faults dipping both towards the foreland and the hinterland. This extension, together with dextral rotation of the South Carpathians around the western corner of the Moesian Platform, allows for the NE-ward movement of the internal continental blocks with respect to the foreland platforms. In the Late Miocene, E-ward translation of the internal South Carpathians units with respect to the Moesian Platform was accommodated through a large scale E-W oriented strike-slip corridor within the South Carpathians.

The general Paleogene - Early Miocene NE to E-ward rotation and the Late Miocene E-ward translation of the Rhodopian fragment allowed for the accommodation of roll-back and contraction taking place in the East Carpathians.

THE INTERNATIONAL CARPATHIAN ARC LITHOSPHERE X(CROSS)-TOMOGRAPHY EXPERIMENT 1999

PP11

The CALIXTO Group:

Geophysical Institute, University of Karlsruhe, Germany;
National Institute for Earth Physics, Bucharest, Romania ;
Faculty of Geology and Geophysics, University of Bucharest, Romania;
Ecole et Observatoire des Siences de la Terre, Strasbourg, France;
Institute of Geophysics, ETH Hönggerberg, Zurich, Switzerland;
Istituto Ricerca Rischio Sismico, Milan, Italy;
GeoForschungsZentrum Potsdam, Germany.

The large scale passive high resolution seismic tomography experiment is operated by an international group investigating the Romanian Vrancea Zone. Between April and November 1999 about 150 mobile acquisition systems, including special broadband systems are deployed in an area between 24°-28° E and 44°-47° N, known as an extraordinary earthquake area with very high seismic activity in intermediate-depth range.

We present first data examples from selected events of local, regional and teleseismic distances. We discuss the possibilities of later on data processing and modelling methods, taking into respect the specific station distribution. The major type of acquisition equipment is explained briefly, as their specific advantages for our purpose. The high resolution of the final tomographic images that can be expected for the used experimental layout is demonstrated with synthetic calculations. The knowledge of the present velocity structure is the base for the understanding of geodynamic processes and should help developing realistic seismic hazard assessment scenarios for this area and especially the nearby megacity of Bucharest.

A PRELIMINARY REPORT ON THE BREAKOUT INFERRED STRESSES IN THE TRANSYLVANIAN BASIN – ROMANIA

PP12

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The Transylvanian Basin, situated on the Romanian territory, has been intensivelly explored for hydrocarbon resources. A lot of gas reservoirs were discovered in the Badenian and Sarmatian formations during the last 30 years.

However, the stress related geological information is very scarce and the few present day stress indicators coming from earthquake focal mechanism determinations have not been included in the World Stress Map (WSM).

Because on the World Stress Map the Transylvanian Basin zone is a void space, during the last 3 years, a study of borehole breakouts, following the standard procedures and techniques, was undertaken by the Romanian Institute of Geodynamics.

In the same time, it was also considered that the study results will bring an important and useful data volume for the future geodynamic modellings of the Eastern Carpathians region, in which several geological processes act simultaneously.

With this aim in view, the available dipmeter oriented caliper measurements of 30 exploration and exploitation – gas wells, whose bottom hole depths were less than 10,000 ft have been collected and processed.

These boreholes uniformly distributed on the Transylvanian Basin, are all located in an area in which no previous works, concerning the present-day stresses, have been performed and published.

In order to reveal the first order horizontal stresses we divided the Transylvanian Basin in 4 sectors (quadrants) based on geographical considerations.

Supposing the basin to have a circular shape (and this approximation is not too far from reality), two orthogonal diameters were drawn, crossing each other in the longitude of 24°50' East and the latitude 46°30' North.

In such a way, we defined 4 quadrants designated as being the NE, SE, SW and NW domains of the basin.

The N-E azimuth values of the maximum horizontal stress for each domain are indicated below:
NE domain: 130° - 160°; SE domain: 110° - 140°; SW domain: 20° - 100°; NW domain: 120° - 145°.

Some anomalous horizontal stress directions possibly associated to the faults crossed by the boreholes came into notice. The observed stress rotations were related to the sealing capacity of these faults, but an adequate study concerning this subject was not undertaken, so far.

The data quality of the 30 determinations, assigned according to the World Stress Map quality ranking scheme, may be placed between A and D (A=18%; B=46%; C=23%; D=13%).

Although our study did not reach its final aim, the following conclusions with geodynamic significance may be issued:

The analysis of stress directions in the Northern and Eastern parts of the Transylvanian Basin shows a considerable resemblance to the Western Europe (Midplate Stress Domain) where the average value of maximum horizontal stress component is N 145° E ±25°.

But in the southwestern part of the basin (where five determinations indicated N 25°E directions) we anticipate some perturbations of the regional stress field, possibly due to some local fault processes.

In this zone, the larger horizontal stress seems to be perpendicular to the South Carpathians mountain chain.

The analysis of stress magnitudes have shown that the maximum principal stress is vertical while the minimum horizontal stress is approximately 62% of the vertical stress. The average values of these two stress gradients are respectively 2.3 MPa/km and 1.42 MPa/km.

PP13

INCOMPLETE ASSIMILATION PHENOMENA ON THE ENCLAVES OF THE CALC-ALKALINE NEOGENE INTRUSIVE ROCKS FROM THE EAST-CARPATHIAN SUBVOLCANIC ZONE

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In the East Carpathians, calc - alkaline intrusive magmatism took place in the Pannonian - Pontian time span (8.5 Ma - 11.7 Ma). This area includes the Rodna and Bârgău Mountains where many shallow intrusions (rhyolites, rhyodacites, dacites, andesites, microdiorites) penetrated either a Precambrian metamorphic basement or a Paleogene sedimentary one. The intrusions occur in two alignments parallel to the Transcarpathian Flysch Fault. Most intrusive bodies contain enclaves. The presence and the abundance of the igneous enclaves depend on the petrographic type of the host rocks: they are rare in dacites, rhyodacites and rhyolites while in andesites (especially in the quartziferous ones) and in microdiorites they are abundant.

The occurrence of the enclaves was used to decipher the genesis and evolution of the calc-alkaline magmas. The enclaves belong to the metamorphic and sedimentary basement or to deep-seated magmatic rocks.

Mechanical, thermic and chemical interactions between the enclaves and their host rocks had been observed. The addition of these effects led, finally, to the occurrence of the assimilation processes. It seems the magma had not the power to assimilate completely the enclaves. Partial assimilation of the enclaves was observed on sedimentary enclaves, on metamorphic enclaves, on the monomimeral siliceous enclaves and on the garnets of metamorphic origin. The assimilation of the enclaves is accompanied by the formation of new minerals (diopside, calcite, quartz, biotite, sillimanite), new structures and textures. At the contact, the reactions between the enclave and the host rock led to the disappearance of the mineralogical limits and to the change of the initial ratios of the initial minerals.

In a first stage melting zones occur around the enclave (sometimes two compositionally different liquids formed around the enclave). As the assimilation progressed, local contamination and hybridizations occured. The ionic and thermic diffusion led to mineralogical transformations (reaction corronas) and to the change of the initial features of the enclave and host rock. The new mineralogical phases formed in this stage are: amphibole, pyroxene, plagioclase, tridimite, apatite.

The mineralogical, petrographical and chemical features of the enclaves and host rocks as resulted from the optical study completed with the electron microprobe analyses, indicate that assimilation of the enclaves by the calc-alkaline magma have occurred at relatively shallow levels in the crust at about 15- 20 km depth, (6.43- 6.83 kbar), and at 700°- 800°C .

PP14

HP/LT ASSEMBLAGES IN THE BLACK-FLYSCH NAPPE (EAST CARPATHIANS, ROMANIA)

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The innermost unit of the flysch nappes, currently grouped in the external Dacides, (Săndulescu, 1984) – the Black Flysch Nappe - consists of several mid–Cretaceous imbricated scales built up of Upper Jurassic-Lower Cretaceous areno-siltites underlain by and partly interbedded with a mafic complex. In the basaltic flows, pillow-lavae and dikes, displaying a within-plate geochemistry that belong to the mafic complex a very-low grade HP/LT metamorphic overprint was recognised (Russo-Săndulescu, 1981).

Neomineralisation is usually confined to the groundmass, vesicles and veinlets, seldom rimming some of the phenocrysts. The magmatic relics are represented by clinopyroxene, plagioclase, amphibole and ilmenite. Clinopyroxene is a relatively iron-rich augite frequently displaying an hour-glass structure. Ca reaches at most 0.8 p.f.u., while the esseneite ($CaFe^{3+}AlSiO_6$) component amounts up to 15% and X_{Mg} ranges between 0.65-0.75. Plagioclase is typically An_{40}. Rare primary amphibole is kaersutite. Ilmenite is quite frequent, forming skeletal crystals containing 5-8% hematite and 8-10% pyrophanite in solution.

The neoformation phases are chlorite, epidote, pumpellyite, phengite, titanite, albite and amphibole, stilpnomelane also appearing in veinlets. Chlorite and epidote are the most abundant phases; epidote is homogenous Ps_{78-95}, while chlorite is represented by an older Fe-Mg variety (X_{Mg}=49-53), followed by a Fe-richer term (X_{Mg}=38-42). Pumpellyite-(Fe) is quite frequent in vesicles, where it forms coarse grained radiating aggregates; it may also form fine-grained intergrowths that rim pyroxene phenocrysts or appear in small quantities together with albite replacing plagioclase. Fine-grained pumpellyite is iron-richer. Phengite is less abundant. Its Si content ranges between 3.27-3.35 p.f.u.. Titanite corrodes magmatic ilmenite; it contains 1-3 wt% of both Al_2O_3 and Fe_2O_3.

Amphibole is abundant, being represented by several Al-poor species evolving from alkali amphibole to actinolite. It forms rugged aggregates displaying an intricate overgrowth zonation. The first composition to crystallise is riebeckite, which builds skeletal and hour-glass aggregates. These are overgrown by ferrowinchite and ferrorichterite, sometimes rich in F and containing up to 0.2 p.f.u. K. Rim compositions are actinolites. Homogenous crystals also appear, especially bluish actinolite coexisting with chlorite, epidote and phengite. Ferroglaucophane and actinolite overgrowths may form on magmatic augite or kaersutite.

The coexisting phases are indicative for very-low grade, low thermal gradient metamorphic conditions. As no lawsonite has been identified coexisting with amphibole, chlorite and pumpellyite implies pressures below 0.7 GPa at maximum temperatures of ca. 325° C. Extrapolating the phase relationships depicted by Evans (1990) to alkali-amphibole compositions in the studied samples yields the most probable peak-pressure metamorphic conditions at 0.5 GPa, 270-300° C. Amphibole zonality indicates moderate heating and presumably decompression during a late stage. Characterisation of the exact timing and mechanisms of both exhumation from depths of ca. 15 km and involvement in the East-Carpathian flysch-nappes depends on additional information still to be gathered.

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Russo-Săndulescu D. (1981) in Săndulescu M. I. V., Kräutner H., Balintoni I., Russo-Săndulescu D., Micu M.: Carp.-Balk. Geol. Assoc., 12th Congr., Guidebook B1, Inst. Geol. Rom.
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THE NEOGENE FOHNSDORF BASIN: BASIN FORMATION AND BASIN INVERSION DURING LATERAL EXTRUSION IN THE EASTERN ALPS (AUSTRIA)

PP15

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The Miocene evolution of the Eastern Alps is characterized by lateral tectonic extrusion of crustal wedges towards the east. Movements of crustal blocks occurred along sets of conjugate strike-slip faults. Faults which bound major extruding wedges are the Salzach-Enns fault, the Mur-Mürz fault system and the Periadriatic Lineament. The dextral Pöls-Lavanttal fault system displaces the Periadriatic Lineament.

The sinistral Mur-Mürz fault system is associated with early to middle Miocene sedimentary basins, which formed as pull-apart basins or as extensional halfgrabens. The largest of these is the Fohnsdorf Basin located at the intersection with the Pöls-Lavanttal fault system. It is more than 2 km deep and covers an area of about 120 km². The Fohnsdorf Basin is separated from the Seckau Basin in the north and the Feeberg Basin in the southwest by basement highs.

Sedimentation in the Fohnsdorf Basin started within a pull-apart-setting with the deposition of fluvio-deltaic sediments. Thick coal with a high methane potential accumulated in the northwestern basin. After coal deposition subsidence rates increased dramatically and a several hundred meter deep lake originated. The lake was filled mainly from northern directions with more than 1500 m thick sediments showing a coarsening-upward trend due to southward prograding deltaic lobes. The Fohnsdorf, Seckau and Feeberg basins were connected during the deposition of the lacustrine sediments.

More than 1000 m thick boulder gravels in the southern part of the basin are interpreted as the upper part of a coarse-grained fan delta succession, which accumulated at a normal fault along the southern basin margin. They suggest a younger phase of basin formation, which was probably controlled by N-S extension and the formation of halfgrabens. Microstructural data indicate that former E-W trending, sinistral strike-slip faults were reactivated as normal faults during this time.

The present-day southwestern margin of the Fohnsdorf Basin is a young feature, which is related to the dextral Pöls-Lavanttal fault system. It is formed by reverse faults forming the northeastern part of a flower structure. Miocene sediments in the Feeberg valley, southwest of the main basin, are preserved along its southwestern part. Uplift of the central part of the flower structure was at least 2.4 km. Post-depositional N-S compression deformed the basin fill and is at least partly responsible for the uplift of the basement ridge separating the Fohnsdorf Basin from the northern Seckau Basins. Basin inversion resulted in erosion of up to 1750 m thick sediments in the Fohnsdorf area.

Miocene heat flow was about 65-70 mW/m² and significantly lower than in other basins along the Mur-Mürz-fault system. Consequenty the coal seam reached only the subbituminous stage in spite of a great thickness of the overburden. Coalification temperatures up to 90 °C are too low to explain the detected high methane content. Most probably, the high methane content and the coal-bed methane potential of the basin are due to bacterial activity.

THE 1ST ATLAS OF DEEP SEISMIC PROFILES OF THE WESTERN CARPATHIANS

PP16

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At a European scale, Slovakia belongs among the countries with the densest network of deep seismic sections relative to its area. More than 1260 kms of seismic lines with the time registration of 12 and more seconds enabling a visualization and interpretation of the earth crust down to a depth between 35 - 60 km fall to the area of 49 030 km² of the Slovak republic. During the years 1995 and 1998 the Atlas of deep seismic sections of Western Carpathians was constructed.

Several objectives were achieved through realization of this method:

- All available data from the deep seismic sections made in Slovakia were summarized and processed using a common approach so that four versions (original-nonmigrated, migrated, original coherent and migrated coherent) could be used as a background for further application, assessment and interpretation. The sections were worked out at common length, depths and time scales as to suit the data obtained using other methods,
- The sections were interpreted and constructed as a coloured version based on the modern and most up-to-date concept of the deep structure of the Western Carpathians and paying a particular attention to the contact between the Carpathian orogenic belt and the European platform of Variscan age, on structural setting and the character of the Klippen belt, on the structure and tectonics of the Flysch zone, on the structure of the upper crust in the Central and Inner Western Carpathians, on the setting and structural character of Tertiary basins and

on the structure and outlines of the deep crust and the MOHO discontinuity (the crust - mantle boundary),

- To solve the deep geological structure on the basis of seismic sections, important geological and geophysical data were processed in an areal and in the map forms. For these purposes the Geological map of Slovakia at 1:1 000 000 scale was prepared and published, the first of its kind in Slovakia to serve not only the atlas compilation, but also to become a general purpose map for use by both, specialists and laymen. Furthermore, a geomagnetic map of Slovakia, specially with characteristic of anomalies in Tertiary and pre -Tertiary basement, a Complete Bouguer anomaly map (CBA) and gravity anomaly map with characteristic of diferrent anomalies of Slovakia and an orthophotomosaics of Slovakia were compiled on the basis of satellite imagery,
- Information on the structure of Slovakia is supplemented by more than 440 kms of shallow seismic sections with the time registration up to 6 s, focusing on the filling and basement of the Tertiary basins (Vienna b., Danube b., Eastern Slovakian b.) with the objective to characterize their structure and to solve their hydrocarbon potential.

Atlas of deep seismic sections through Western Carpatians represents a special piece of scientific work compiled in written and graphic form and also comprising an Electronical atlas with a full database ranging from raw data to written reports and figures. Electronical atlas was prepared with GIS software – TNTmips and distributed with TNTatlas. This atlas was built by Hyperindex (HI) structure, where HI arranges objects and files in a specificed hierarchy called a stack. TNTatlas allows users to select and view seismic profiles from within a GIS which includes a spatial view containing a variety of themes. These profiles are linked by TNTlink option from the map view and can be accessed by cliking on line locations. A series of metadata (textual data) links have been designed to allow users to navigate easily between images and text. As far as we know, this atlas, composed of the deep seismic sections and of an electronic database, is the first of its kind not only in Slovakia, but also in Europe. The compilation method was designed by the authors themselves.

Both parts – the written/graphic and the electronic one are suitable to serve as an editing, printing and publishing medium (1999, Dionýz Štúr Publ., Bratislava). A bilingual Slovak - English version was proposed for publication and for an inclusion in the Internet information system.

Main regional tectonic results: Atlas of deep seismic sections present a synthesis of deep structure of the Western Carpathians which is interpreted on basis of gravimetric and deep seismic sections. MOHO discontinuity in Western Carpathians is in level between 10,5 and 12,5 sec. The seismic and gravimetric sections dominating express the structural character of Central Western Carpathians (main tectonic units: Tatricum, Veporicum and higher rootles nappes of Hronicum) and Inner Western Carpathians (tectonic units: Gemericum, Meliaticum and higher nappes of Turnaicum and Silicicum). Alpine tectonic units are characteristic with dominant northern vergency. Evidence of Variscan tectonic structures are very sporadic in the crystalline basement. Complicated structure of Klippen Belt represents a system of Tertiary transform fault zone along the tectonic contact between the units of Central and External Western Carpathians. Tectonic contact between Inner Western Carpathians and Pelsö megaunit is situated on Miocene fault zone Rába-Hurbanovo-Diosjenõ.

GEODYNAMICS OF THE (EASTERN) CARPATHIANS

PP17

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Intermediate-depth seismicity of the Carpathian arc is mainly concentrated at its southeastern bending area, suggesting that the Miocene continental collision was not a frontal one, but started in the northern part of the Carpathians and successively proceeded towards the SE and S. New insights into this final stage of a collision zone are given by the combination of two views, from top down (kinematic data) and from bottom-up (seismicity, tomography).

Analysis of kinematic data reveals the tectonic evolution of the intra-Carpathian crustal blocks which formed the upper plate during middle Miocene subduction. Strike-slip zones laterally guided the northeast- and eastward movements of these blocks, while frontal accretion (and later collision) was accompanied by thrusting. Continental collision during middle and late Miocene was followed by slab break-off. Similar to collision, break-off started first in the northern part and then proceeded towards the SE and S. Thus the northernmost slab segments already sank deep into the mantle, which would explain the lack of recent seismicity in that area. Only in the youngest, southeasternmost part of the Carpathian orogen a relic of the originally west-dipping subducted plate remained. In this region earthquakes occur under strong vertical extension in a small, almost vertical volume with depths between 70 and 220km and a width of 30km x 70km. However, this seismogenic volume is not located beneath the Miocene collisional suture zone, but is shifted about 80-100km towards the SE.

This offset is also visible from seismic tomography which shows a high-velocity body enclosing all subcrustal earthquake locations. Two different orientations of this body can be distinguished: at larger depths (> 130km) it trends N-S, thus reflecting the orientation of the middle Miocene subduction zone beneath the Eastern Carpathians. At shallower levels its orientation is NE-SW and the downdip length of this part is identical with the distance between the earthquake zone and the Miocene collisional suture. Thus the southeastward offset of the slab relative to the west-dipping suture zone can be explained by post-collisional delamination of the lower lithosphere (Girbacea & Frisch, 1998). Lateral boundaries of the delaminating body have been pre-existing crustal fracture zones, the Intramoesian fault in the SW and the Trans-European Suture Zone in the NE. Both fracture zones show weak recent seismic activity. The delamination theory is supported by the spatial distribution of alkaline and calc-alkaline volcanism.

Mechanical coupling of the subducted and delaminated parts with the crustal parts of the lithosphere is still strong enough to enable large deformations inside the slab which are manifested in large intermediate depth earthquakes. Focal mechanism solutions indicate vertical extension and radial horizontal compression. On the other hand, no large earthquakes are recorded from the overlying crust thus indicating that the coupling with the slab is not strong enough to transmit large deformations from the slab into the crust.

Reference:

Gîrbacea, R. & Frisch, W. (1998): Slab in the wrong place: Lower lithospheric mantle delamination in the last stage of the Eastern Carpathian subduction retreat. - Geology, 26 (7), 611-614

TECTONOSTRATIGRAPHY OF THE DINARIDES

PP18

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Personal field observations and comprehensive study of many published and unpublished data provide a relevant basis for tectonostratigraphic division of the Dinarides. Foredeep fill deposits preset as more or less narrow outcrop tracts are the key evidence for timing of thrusting. Well defined age and type of volcanism and associated sediments define major tectonic events: Triassic rifting of Pangea, Late Jurassic subduction and partial obduction of Vardar oceanic plate under the Eastern Dinarides, Maastrichtian – Eocene subduction of Tisza oceanic plate under the Northern Dinarides and Miocene and younger underthrusting (subduction?) of Adria beneath the Western Dinarides.

Rather complicated present day tectonic setting is a result of : a) prealpine tectonic extension and b) alpine compression (continental convergence and ultimate collision) of Dinaridic thrusting affected older thrusts and flysch deposits, which are in places completely underthrust beneath the younger thrust sheets. Miocene climax of alpine orogeny (PHASE V) designed the final outlook of the Dinarides and its surrounding by transcurrent (transtensive and transpressive) faulting, tectonic inversion and underthrusting of Adria.

PHASE I (Late Jurassic): Inner thrust composed of prealpine deposits and obducted ophiolites. Foredeep filled with eroded ophiolites and flysch. In External thrust tectonic plunge and global sea level rise reflected as "Lemeš" intraplatform trough.

PHASE II (Early and Late Cretaceous): Central thrust of Jurassic and Cretaceous platform carbonates. Foredeep filled with flysch deposits. In Northern Dinarides (Maastrichtian to microplate with Tisza – Vardar oceanic plate and Adriatic indenter.

PREALPINE UNIT:

Disintegration of Pangea is marked by Early and Middle Triassic graben and half-graben deposits and volcanism as the result of ultimate astenospheric break-through (PHASE I). During Late Triassic - Mid Jurassic time extensive carbonate platform built up over pre-existing grabens and tilted blocks (PHASE II)

ALPINE UNIT:

Continental convergence was progressive from Mid to Late Jurassic through the present day. Four major thrust belts were created through the time, starting with Late Jurassic Inner thrust (PHASE I), and followed by Early and Late Cretaceous Central thrust (PHASE II), Late Eocene External thrust (PHASE III) and Eocene – Oligocene Frontal thrust (PHASE IV). Each thrusting was accompanied with flysch filled foredeeps, that evidence the time of thrusting. Each younger Eocene - PHASE IIa) partial subduction of Tisza resulted in accretionary wedge and back arc trench systems.

PHASE III (Late Eocene): External thrust of Dinaridic carbonate platform. Foredeep filled with tectogenic breccia and flysch deposits. Structural elements: fault propagation folds within hanging wall.

PHASE IV (Eocene – Oligocene): Frontal Thrust of exclusively Cretaceous and Eocene carbonates caused by early underthrusting of Adria. Structural elements: fault bend folds, fault propagation folds, intraplate tear faults, basement related tear faults, normal faults controlled by location of footwall ramp in thrust system,

PHASE V (Miocene) wrenching and tectonic inversion affected the entire Dinarides due to further underthrusting of Adria and Pannonian basin. Structural elements: pull apart basins, flower structures, tear faults and "piggy back" basins.

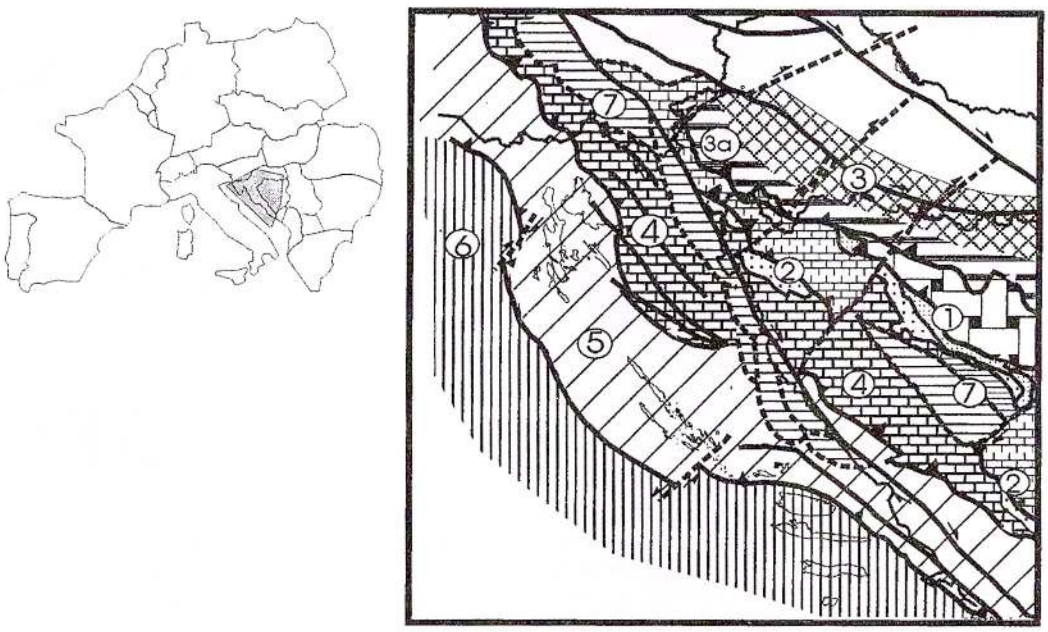

Figure:
1- Inner thrust
2 - Central thrust
3. Accretionary wedge
3a. Back-arc trench related to Tisza subduction
4 - External thrust
5 - Frontal thrust and folded flysch of External thrusts
6 – Adriatic indenter
7 – Tectonic inversion
7a. Wrenching

DEEP SEISMIC PROFILE ACROSS SREDNA GORA MOUNTAIN: PRELIMINARY RESULTS

PP19

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The new regional deep seismic reflection profile SR1 is carried out in the end of 1997 for obtaining information about geological preconditions for oil and gas prospecting in the Central Sredna Gora tectonic zone as well as to investigate deep crust structure and the interrelation between the Sredna Gora and Stara Planina tectonic zones in depth. It crosses the eastern end of Sredna Gora mountain and ends just northern of the deepest borehole in Stara Planina mountain Pchelinovo-1 which penetrates the Middle-Early Triassic boundary several times. The received field records are processed in 1999.

The geological mapping and some structural boreholes show presence of north vergent thrusting and very complicate subsurface structure.

The seismic section indicates large scale north vergent thrusting followed by Early Tertiary extension. The seismic picture under the outcropped Palaeozoic granites and Precambrian metamorphites obviously shows that they are in allochthonous position. The large thrust sheets are accumulated over the southern end of the Moesian plate producing thick layered section probably created mainly by Mesozoic and Palaeozoic sediments up to 20 km total thickness. The Sredna Gora gravitational minimum obviously coincides with this zone of the seismic reflectors up to 8 s.

The morphology of the seismic reflectors near to the borehole Pchelinovo-1, where are found out up to 80° sloping Triassic sediments, can not explains the repeated crossing of the Middle-Early Triassic boundary but shows prolonging the Moesian plate to the southern under the Stara Planina and Sredna Gora mountains.

STRESS FIELD OF THE POLISH OUTER CARPATHIANS: INSIGHTS FROM THE STUDY OF EARLY FRACTURES

PP20

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We have analysed >380 stations spread throughout the Polish segment of the Outer Carpathians. Most of them are located in the Magura (246), Silesian (58) and Dukla (52) nappes, the remaining units being represented by infrequent stations. Nearly 80% of our data pertain to Paleocene through lower Miocene strata; the upper Cretaceous strata have been sampled chiefly in the medial segment of the Magura nappe (62 station). In all the units, except Dukla, stations located in thick-bedded flysch sandstone strata dominate.

Joints are ubiquitous in the upper Cretaceous-Tertiary flysch strata of the Polish Outer Carpathians. Kathetal joints compose 1-3 sets of cross-fold joints and 1-2 sets of fold-parallel joints. The cross-fold joints form two sets (labelled D_1 and D_2), intersecting one another at 60-70°, whose acute bisector is perpendicular to map-scale folds, and a single set of transversal joints T, which is also perpendicular to the map-scale folds. The surfaces of D joints are planar and their traces on bedding surfaces are rectilinear; they also terminate one against another. These sets are accompanied by feather fractures and some of them pass laterally into en echelon oriented cracks, the latter being filled by material derived from host strata or lined by calcite contamined by this material. Feather fractures indicate tendency to right- (D_1) and left-lateral (D_2) motion, respectively. The D joints are, hence, shear or hybrid-shear joints that were formed when the host strata were in horizontal position and not fully lithified, i.e. at an early stage of regional folding. The surfaces of T joints are rough and non-planar, and their traces on bedding surfaces are curvilinear. They are commonly lined by calcite. These joints are extension fractures. Abutting relationships indicate that the D joints are roughly coeval and form a conjugate system. The age of T joints remains unknown, although their orientation parallel to the acute bisector of D joints points to the same time of formation of all the sets. On the contrary, the fold-parallel joints are younger, they usually terminate against surfaces of cross-fold joints, are frequently lined with calcite mineralization, and their orientation is much more consistent as compared to that of the cross-fold joints. They were probably formed due to extension following the regional folding.

The position of shear joints-related maximum stress axis was horizontal, its orientation changing from NW through NNE to NE in the western, medial, and eastern portions of the Outer Carpathians, respectively. On the other hand, extension associated with the T joints was oriented, respectively, NE, E-W, and NW, whereas that related to the formation of fold-parallel joints was NW, NW to N-S, and NE. Orientation of σ_1 related to the cross-fold shear joints coincides with that of recent horizontal stresses (recorded by breakouts) in the medial and eastern segments of the Outer Carpathians (NNE to NE), whereas in the western segment it is aligned NW to NNW, i.e. parallel to the recent horizontal stress recorded in the autochthonous basement of the flysch cover. Breakouts in that segment of flysch nappes point to recent horizontal stress oriented NE to N (cf. Jarosinski, 1998).

Reference:

Jarosinski, M. 1998. Contemporary stress field distortion in the Polish part of the Western Outer Carpathians and their basement. Tectonophysics, 297: 91-119.

RATES OF FLUVIAL DOWNCUTTING AS INDICATORS OF YOUNG TECTONIC UPLIFT IN THE OUTER CARPATHIANS (POLAND)

PP21

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Analysis of rates of fluvial downcutting helps to understand landscape evolution which is controlled both by climatic and tectonic factors. Differentation in downcutting of a river along its long profile enables one to reconstruct the spatial distribution of young uplifted structures. Fluvial erosion depends principally on climatic changes in successive glacial-interglacial cycles, although its spatial variability is also controlled by tectonic tendencies.

Main valleys of the Outer Carpathians in Poland bear 5 to 9 Quaternary terrace steps. Most of Pleistocene terraces are strath or complex-response terraces, whereas the last glacial and Holocene ones are cut-and-fill terraces, except for those located in axial zones of young uplifted areas. Longitudinal profiles of individual straths frequently show convergence, divergence or tilting, indicating tectonic control. Moreover, both the amount and rate of downcutting of strata of comparable age are different for different morphotectonic units, despite regionally consistent Quaternary climatic conditions throughout the Outer West Carpathians and more or less uniform bedrock resistance to erosion.

Long-term rates of fluvial downcutting of successive Quaternary strata tended to increase in the periods of 800-472 ka, 130-90 ka, and 15-0 ka, ranging from 0.18 to 0.40 mm/yr. Rates calculated for individual Quaternary stages have varied from 0.04 to 2.00 mm/yr, being different for neighbouring morphotectonic units. The late Pleistocene increased rates of fluvial incision into solid bedrock are particularly well noticeable in frontal parts of some nappes and slices, both in the western (Raca slice of

Magura nappe, Silesian nappe) and eastern segments of the Polish Carpathians (Dukla unit). Average rates of fluvial downcutting for the whole of Quaternary (0.06 to 0.22 mm/yr), in turn, are compatible with those of isostatic uplift of that area during the last 10 million years, which has been from 0.03 to 0.11 mm/yr.

STRONG EARTHQUAKES IN ROMANIA: A CHALLENGE FOR GEOSCIENCES AND CIVIL ENGINEERING

PP22-PP25

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Strong earthquakes in the Romanian Vrancea area have caused a high toll of casualties and extensive damage over the last centuries. The average recurrence rates make another strong event within the next 2 decades highly probable and provide a challenge to mitigate its impact. Romanian and German groups of scientists from various fields (geology, seismology, civil engineering, operation research) organized themselves in the Collaborative Research Center (CRC) 'Strong Earthquakes: A Challenge for Geosciences and Civil Engineering' (Karlsruhe, Germany) and the Romanian Group for 'Strong Vrancea Earthquakes' (Bucharest, Romania) in a multidisciplinary attempt towards earthquake mitigation. Our poster collection highlights recent achievements and specifies research objectives of the forthcoming years.

Key objectives of joint research activities are:

- Understanding of the tectonic processes that are responsible for the strong intermediate depth seismicity beneath Vrancea.
- Developing realistic models and predictions of ground motion.
- Prognosis of potential damage in case of a strong earthquake.
- Risk reduction by appropriate civil engineering concepts.

Specific targets within the next 3 years are:

- Development of a consistent geodynamic model of the Neogene evolution of the Southeast Carpathians. This model should explain the specific features of Vrancea seismicity (intermediate depth, small seismogenic volume, high activity) and provide boundary conditions for hazard assessment.
- Development of damage projections for Bucharest based on seismological data, quantification of site effects and analysis of the built environment.
- Detailed experimental study of the entire sequence relevant in engineering seismology: source physics, wave propagation, site effects, soil-structure interaction, building performance. The Multidisciplinary Seismic Test Site INCERC, in the eastern part of Bucharest serves as focus to verify theoretical predictions by experimental data. Non-linear soil behavior is a key issue in this context.
- Development of novel approaches for mitigation such as dynamic disaster management, new techniques for rescue and retrieval, retrofitting with fiber glass materials, rapid assessment of damage with photogrammetric methods and post-event shake maps.

Webpage: http://www-sfb461.physik.uni-karlsruhe.de/

TESZ SESSION ORAL PRESENTATIONS

TECTONIC SUBSIDENCE MODELLING OF THE POLISH BASIN IN THE LIGHT OF NEW DATA ON CRUSTAL STRUCTURE AND MAGNITUDE OF INVERSION

TO1

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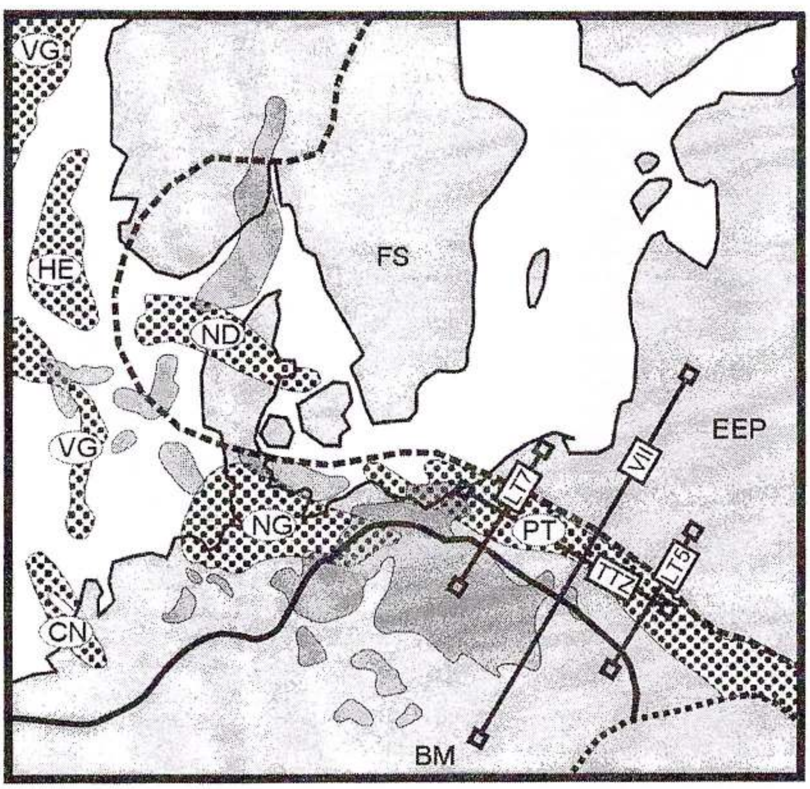
The Polish Basin (PB) is one of numerous basins developed on the Palaeozoic platform of western Europe (Figure). It was formed in the late Palaeozoic between the Variscan Orogen and the East European Craton (EEC = Baltica plate/continent). The main depocentral axis of the Polish Basin, called the Mid-Polish Trough (MPT), was active during most of the basin development as a maximum subsidence zone with almost uninterrupted (continuous) sedimentation. The present base of the Permian in the MPT is located at depths ranging from ca. 3000-3500 m near Baltic coast, to 5000 m in the Pomeranian (central) segment, to maximum up to 8000 m in the Kujawy (south-east) segment.

The MPT lies parallel and adjacent to the edge of the EEC, therefore along the boundary between the Phanerozoic and Proterozoic European crustal domains, and appears to be related to a distinct structural zone within the crust, termed the Tornquist-Teisseyre Zone (TTZ), comprising part of the more extensive Trans-European Suture Zone. Basement is heterogeneous: in the south-west it comprises the outer zone of the Variscan belt, in the north-east the Precambrian craton; in the central part, basement is probably a complex mosaic of crustal blocks of Caledonian origin (consolidation) and/or built of reworked Precambrian crust.

Subsidence of the MPT is explained in terms of crustal extension/transtension and related lithosphere cooling coupled with a structural pre-determination of the underlying TTZ (Dadlez et al., 1995, van Wees et al., 1999). Tectonic subsidence analysis of the preserved and reconstructed stratigraphic record indicates the occurrence of an initial Late Permian-Early Triassic "rifting" phase. This was followed by subsequent episodes of increased tectonic subsidence during the Oxfordian-Kimmeridgian and beginning in the Cenomanian. The former can be correlated with intensified rifting and wrench activity within the Arctic-North Atlantic rift system and along the northern Tethyan margin. The Cenomanian event is a precursor of compressional deformations in the basin that culminated in basin inversion.

During the latest Late Cretaceous and earliest Tertiary, the inversion processes affecting the MPT formed the Mid-Polish Swell (MPS), which on sub-Cenozoic maps is visible as a belt of Jurassic subcrops rimmed by troughs filled with Cretaceous deposits. Inversion processes (as in other basins in the central and western Europe) are correlated with the Alpine folding: the stresses in the mobile Alpine belt were transmitted into its distant foreland. Taking the inversion into account, the maximum depth of base Zechstein structural surface by the end Cretaceous is estimated to have ranged to 5000 m, 7500-8000 m, and more than 10000 m, for the Baltic, Pomeranian, and Kujawy segments respectively.

Several problematic issues having to do with the origin and evolution of the MPT includ (1) the deficit of geologically observable extensional features (faulting) during the main, apparently initial, Late Permian-Early Triassic "rifting" phase and the relationship between this phase of basin subsidence and earlier (post-Variscan "collapse") Late Carboniferous-Early Permian tectonism; (2) the possible misfit of basin modelling predictions (crustal thinning associated with rifting) with the available crustal structure data from Deep Seismic Sounding (DSS) studies; and (3) constraints on Cretaceous subsidence, which appears from the reconstructions used in the subsidence modelling to have accelerated in the Late Cretaceous prior to basin inversion, and - accordingly - the magnitude and exact timing of Late Cretaceous-Palaeogene inversion of the Polish Trough.



Regional setting and location of the Polish Basin. Stippled regions represent the main Mesozoic basins of north-central Europe (CG - Central Graben of the North Sea; CN - Central Netherlands Basin; HE - Horda-Egersund basins; ND - North Danish Basin; NG - North German Basin; PT - Polish Trough); occurrences of Permo-Carboniferous volcanic rocks are indicated by darker shading. The thick solid line indicates the position of the Variscan deformation front, the thick dashed line the Caledonian deformation front, and the thick dotted line the Alpine deformation front. BM, EEP, and FS are Bohemian Massif, Eastern European Platform, and Fennoscandian Shield respectively. Locations of certain Deep Seismic Sounding (refraction/wide-angle reflection) lines are given by ornamented lines labelled LT7, VII, TTZ, and LT5.

References:

R. Dadlez, M. Narkiewicz, R.A. Stephenson, M.T.M. Visser, and J-D. van Wees, 1995. Tectonic evolution of the Mid-Polish Trough: modelling implications and significance for central European geology, Tectonophysics, 252, 179-196.

J-D. van Wees, R.A. Stephenson, P.A. Ziegler, U. Bayer, T. McCann, R. Dadlez, R. Gaupp, M. Narkiewicz, F. Bitzer, and M. Scheck, 1999. On the origin of the southern Permian Basin, Central Europe. Marine and Petroleum Geology, in press.

REGIONAL TECTONIC FRAMEWORK OF THE TRANS-EUROPEAN SUTURE ZONE FROM GRAVITY AND MAGNETIC DATA

TO2

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The present-day structure of the Trans-European Suture Zone evolved through a complex sequence of events comprising the Ordovician-Silurian triple continental collision between Laurentia, Baltica and Eastern Avalonia, further accretion/collision of Gondwana-derived terranes from the south and episodes of extension. Whilst the basic structural elements are reasonably well known, there is considerable debate regarding the deep structure, the position of the margins of the palaeo-continents, the disposition of smaller terranes and the provenance of much of the concealed basement. Major new compilations of gravity and magnetic data have been assembled for the TESZ project, and a suite of new image maps have been generated, to assist in resolving some of the uncertainties.

The basic Bouguer anomaly and magnetic total field anomaly maps define the broad-scale structural elements of the TESZ. Digital processing and the application of various transforms have further enhanced the structural information within the gravity and magnetic fields and thus define the major structural boundaries. Colour shaded-relief gravity transform maps have been generated of (i) the isostatically-corrected Bouguer anomaly (which corrects for variations in crustal thickness due to topographic load), (ii) the horizontal gradient of the Bouguer anomaly (which highlights shallow structural boundaries), (iii) the horizontal component of the gravity field (which highlights deeper structural boundaries), and (iv) the residual Bouguer anomaly (which removes the effects of deep structure). In the case of the magnetic field, transform maps have been generated of (i) the horizontal gradient anomaly (which highlights shallow structural boundaries), (ii) the pseudo-gravity field (which represents the theoretical gravity field based on a linear relationship between density and magnetisation, and (iii) the horizontal gradient of the pseudo-gravity field (which highlights deep structural boundaries). Euler solutions have also been calculated for both the gravity and magnetic fields to provide information on the depth to the source of the major anomalies.

Between them, these new maps provide important new information on the crustal structure and tectonic framework of the TESZ and surrounding region (see poster for details). The current phase of the project has moved on to integrated 2D whole-crust seismic-gravity-magnetic modelling along major profiles across the North Sea in order to define the concealed structure and terrane boundaries in more detail. This will be followed by three-dimensional modelling in key areas.

A COMBINED 3-D DENSITY AND MAGNETIC MODEL OF THE EARTH'S CRUST OF THE SOUTH-WEST PART OF THE EAST-EUROPEAN CRATON

TO3

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The study region is the south-western part of the East-European Craton (EEC) and includes the western slope of the Ukrainian Shield and parts of the Lviv Palaeozoic and the Pericarpathian Troughs. The Precambrian basement surface gradually plunges west and south-westwards to 6 km in the Lviv Trough.

A residual gravity field for this area was calculated using a 3-D model of the sediment cover of the crust on a 5 x 5 km grid with a crustal reference density of 2.65 g/cm^3. Sediment densities ranged 2.30-2.40 g/cm^3. The residual field clearly reflects the effects of near-surface and deep-seated density inhomogeneities of the crust. In particular, two large zones (one 80 km and another ca. 130 km wide) of positive anomalies striking NE and NW are distinguished.

The magnetic field of the region is not complicated by the effect of the sediments and the estimation of the effect of Riphean-Palaeozoic effusives shows that it is no more than 40 nT and covers the north-west part of the territory. The anomalous magnetic field consists of the short- and long-wavelength anomalies due to basic rocks in the Precambrian basement and other deep-seated basic sources. The long-wavelength magnetic anomalies have been obtained from observed field by using of a special method controlled by reducing the effect of the sources of the upper crust.

The spatial distribution of the near-surface magnetic sources and deep-seated density and magnetic inhomogeneities has been analysed together with fracture tectonics, DSS data along three geotraverses, and temperature within the crust. The distribution of short- and long-wavelength magnetic anomalies allows the tracing of faults of different ranks. Two main fault systems are respectively associated with the boundary of Sarmatia and Fennoscandia striking NE and the south-west boundary of the EEC striking NW. It is these directions in which large zones of positive anomalies of the residual gravity field and corresponding density inhomogeneities of deep origin are situated. Geologically, the NE striking zone corresponds to the Ukrainian part of the Osnitsa-Mikashevichi Igneous Belt (OMIB). The NW striking zone of deep density and magnetic inhomogeneities is almost orthogonal to the first fault system. It is observed further to the north-west in Poland and marks the marginal part of the EEC and the Trans-European Suture Zone (TESZ). The two main fault systems are complicated by faults of meridional and latitudinal strike that define the inhomogeneity of the OMIB and the marginal zone of the EEC on the basis of inferred densities and magnetic parameters, as well as the morphology of deep-seated density and magnetic inhomogeneities under the Palaeozoic Lviv Trough.

An analysis of the spatial relation of the deep-seated density and magnetic inhomogeneities shows that in the most part of the study area they are well correlated. This suggests a common geological nature and association with basic rocks. However, a 50-60 km wide region with a large, lower crustal magnetic source of submeridional strike observed from the latitude of Lutsk southwards to the EEC boundary is reflected in the reduced gravity field by anomalies of different signs. This suggests that the high magnetization of the crust in this region is caused by magnetic minerals formed in an extensive submeridional zone of fluid activation.

In both large structural zones of the south-west part of the EEC, density and magnetic inhomogeneities are generally associated with an increased basic component in the Earth's crust.

HEAT FLOW, SEISMIC WAVE VELOCITY AND THE LITHOSPHERE STRUCTURE IN THE NORTH-WESTERN BLACK SEA REGION

TO4

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The studied area is located in the North Western Black Sea region covering six degrees of longitude (from 27-East to 33-East) and four degrees of latitude (from 42-North to 46-North).

New heat flow observations from 44 on-shore and 10 off-shore wells were added to the previous data reported by Erickson & Von Herzen (1970), Ducikov & Kazantzev (1985), Boiadgeva (1987) and a Heat Flow Map at the scale of 1/2,500,000 has been compiled. The heat flow values range from 28 to 72 mW/m^2 in the North Eastern Black Sea basin and from 32 to 93 mW/m^2 in the surrounding on-shore regions depending upon the different tectonic units. So, the North Dobroudja intra-cratonic Alpine area and its prolongation toward the abyssal-plain exhibit surprisingly low heat flow values (32-46 mW/m^2). In the adjoining tectonic units (Moesian and Scythian platforms) an average heat flow of 61 to 66 mW/m^2 has been respectively recorded which was considered as "normal" for the epi-Hercynian terrains. A system of deep faults trending NW-SE and NNE-SSW, most of them still active, strongly influences the shape and geographic distribution of the local positive heat flow anomalies. The correlation between the North Dobrogea and Alpine Crimea is emphasized not only by the similar Mesozoic formations and the gravity and magnetic anomaly but also by the same thermal regime.

It is worthwhile to notice that the average heat flow computed for the entire Western Black Sea region is increased by a factor of approximately 1.5 if the new observed values were inserted into the calculation. This is mainly due to the higher heat flow values observed in the deep off-shore wells as compared with the values obtained previously for the same locations with the marine probe heat flow technique.

Correlation of the Heat Flow Map with a map showing the distribution of the seismic wave velocity at the base of the crust, derived from travel time of the teleseismic events, indicates the same negative linear trend depicted for the Central and Eastern Europe first by Cermak and then by others authors: the low seismic velocities (8.00 km/s) correspond to the highs of heat flow while the high seismic velocities values (8.18-8.20 km/s) are connected with the lows of heat flow.

Experimental evidence on the relationship between seismic wave velocity and radiogenic heat production was used to estimate the vertical distribution of heat sources in the lithosphere. A calculated family of geotherms, having the heat flow as parameter, indicated a depth of 100-150 km for the base of the lithosphere. However, the seismic data revealed only 20-30 km for the crustal thickness in the abyssal region of the Black Sea, where heat flow is very low (32-38 mW/m^2).

The typical rocks less endowed with radiogenic heat producing elements and geotectonic evolution of this area since the Middle Cretaceous offered arguments for some models of transitional crust. A such model involves an essentially upper crust ("granitic" layer) only in the marginal regions of the Western Black Sea basin and a well developed lower crust ("basaltic" layer) in the central part of the basin.

TRANS-CRUSTAL "TOMOGRAPHY" OF THE ROMANIAN TERRITORY BASED ON GRAVITY AND MAGNETIC DATA

TO5

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The first gravity maps, obtained in late '50 and early '60 at the scale of the Romanian territory, offered new insights for the crystalline basement - sedimentary cover boundary in deep basins and on the platforms, and more important, determined important crustal studies related to isostasy or to the Conrad and Moho discontinuities (Socolescu et al., 1956; 1963; 1964).

The magnetic maps built at regional scales have been mainly utilized for structural interpretations mostly implying the crystalline basement and the magmatic provinces, due to their significant magnetic properties comparing to the sedimentary deposits (Airinei, 1957; 1959; 1964).

A first attempt to derive geophysical interpretations related to deep structures from both gravity and magnetic regional maps provided the first model of the crystalline basement in Romania, the strike of the main faults crossing the territory as well as uplifted or downlifted blocks resulting from the analysis of gravity data, the magnetic ones offering the possibility of contouring basement compartments having different petrographic compositions, which have been ascribed to different geological ages (Gavăt et al., 1963).

Our study, benefiting of the completion during the '80 of the gravity and magnetic maps of Romania, offers information regarding the mass inhomogeneities for the whole lithosphere, by using gravity (mean 5' x 7.5' Bouguer and free-air) and geoidal data as well as quantities derived from their adequate processing (filtering, horizontal gradient). The "detrending" procedure (Featherstone, 1992), applied to gravimetric geoidal anomalies included in the EGM96 global geopotential model, gave valuable information regarding the mass distributions within different crustal levels, coming this way towards the excellent results offered lately by seismic tomography.

In order to enhance the processing of the magnetic data in view of regional structural interpretations, the ΔZ magnetic map has been used to evaluate mean values of the vertical component in 5' x 7.5' blocks. Besides the resulted residual maps, which analyzed in close correlation with the gravity ones, offer valuable information regarding shallow geological structures, the horizontal gradient maps depicts clearly the strike of the main faults and fractures which separate different geotectonic units, especially those associated with the TTZ.

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OLD AND NEW GEOPHYSICAL IMAGES WITHIN NORTH DOBROGEA OROGEN, ROMANIA

TO6

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The paper presentats geophysical images, especially gravity and geomagnetic ones, within North Dobrogea Orogen (NDO) and surrounding areas. It tries to emphasize the importance of choosing of the most appropriate form for data presentation in interpreting geophysical information.

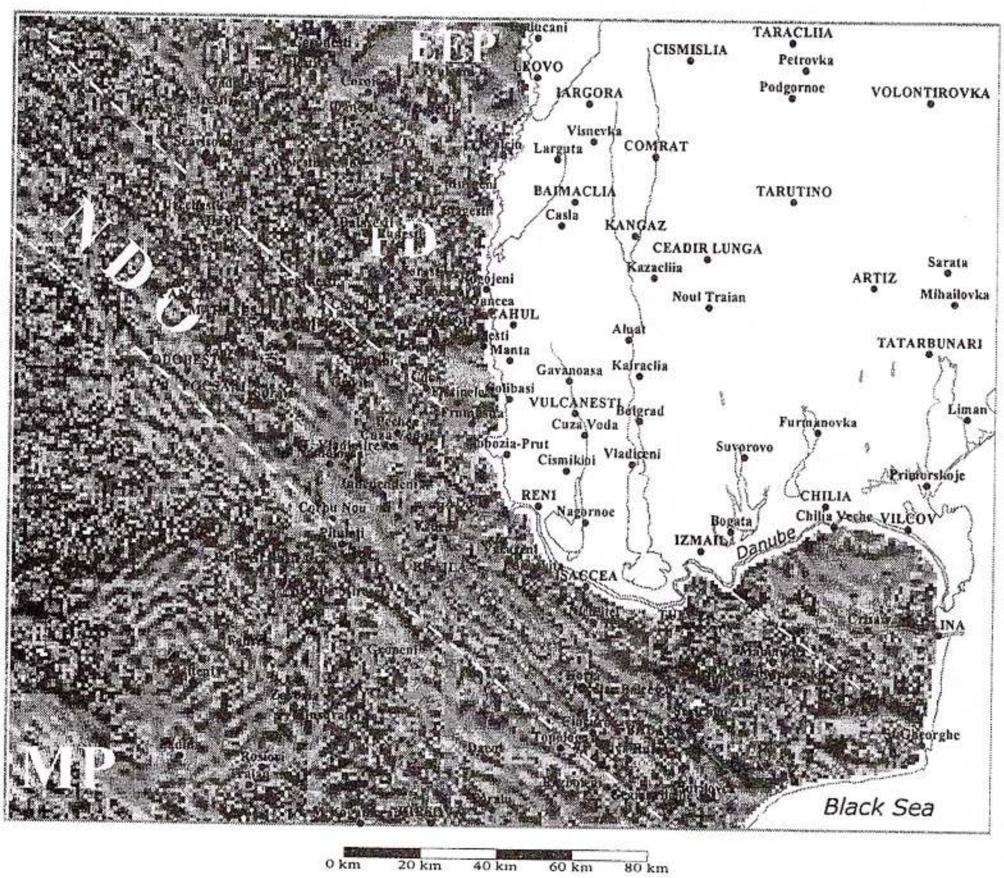
Based on a consistent gravity and geomagnetic data set organized in a computer data base, Bouguer anomaly and aeromagnetic images have been achieved and exhibited as contour maps and by using special imaging approaches as well. The advantages of shaded relief technique in revealing fault areas are obvious when comparing basic approaches to the latest techniques in data presentation.

On the other hand, in order to separate cumulative effects, often met in geopotential fields mapping, special data processing as horizontal and vertical derivatives or wavenumber domain filtering has been applied to the raw material. Accordingly, gradient, regional and residual maps have been obtained and visualized by using previously mentioned modern techniques.

Comparing geological ideas to thus obtained by geophysical models interesting mis/good correlation have been found. Among others, mentions should be made to the following aspects.

- NDO developed into a narrow strip squeezed between East European Platform and Moesian Platform. The distinct geomagnetic overprint easily allows pointing out its spreading area.
- Beyond the Danube, the NDO westward extension was more appropriated revealed by the image of the horizontal gradient of the geomagnetic anomaly. The Peceneaga-Camena fault, clearly outlined by a narrow strip of gravity gradient east of the Danube river, may be accurately followed far away to the west, below the Carpathian foredeep sediments, due to the discordant aspects in the geomagnetic gradient pattern between NDO and Moesian Platform. It is worth mentioning that geomagnetic and gravity behavior strongly suggests its strike-slip features.
- Unlike its southern limit, the northern flank of the NDO is not so sharply outlined. Fault elements seem to appear both southern and northern Danube arm. Gravity and geomagnetic images present Sf. Gheorghe fault more likely as a transient zone along which NDO steps down toward the Predobrogean Depression (PD).
- There are no geomagnetic nor gravity evidences for the presence of the Moesian Platform deposits between East Carpathian and NDO.
- Structural aspects inside NDO are well emphasized by gravity data. Shaded relief map of Bouguer anomaly sharply outlines the main fault areas.
- The pattern of the geomagnetic anomaly clearly preserves its main features east of the Luncaviţa-Consul fault (the only difference between the two areas stands in the intensity of the revealed anomaly, which obviously decreases toward east). This seems to demonstrate the eastward extension of the Paleozoic structures, below the Triassic deposits, thus confirming older geological hypothesis.

Actually, there is a difference in the general strike of the gravity and geomagnetic trend elements to be noticed, but this does not represent a conflict between the two types of geophysical information. The apparent miscorrelation is due to the fact that gravity mainly reflects structural aspects, connected to latest tectonic events, while geomagnetic pattern is strongly related to the basement petrography, whatever its position might be. It is interesting to remark the common strike of some downthrown compartments belonging to Triassic units of NDO or Predobrogean Depression, that could be the result of a common tectonic event affecting the two geotectonic units.



HORIZONTAL GRADIENT OF THE GEOMAGNETIC ANOMALY WITHIN NDO AND SURROUNDING AREA

Hillshaded from North

MP=Moesian Platform, EEP=East European Platform, PD=Predobrogean Depression

assumed southern and northern limits of the NDO

DEEP REFLECTION AND REFRACTION SEISMIC CONSTRAINTS ON CALEDONIAN ACCRETION IN THE SOUTHERN BALTIC SEA

TO7

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Important tectonic lineaments north of the Northeast German Basin (e.g. Trans-European Suture Zone, Tornquist Zone, Caledonian Deformation Front-CDF) are investigated in the south-west Baltic Sea to decide how and when Paleozoic and Mesozoic units were attached to Precambrian Europe. While continental Europe shows clear changes in crustal depth and mantle velocity, the situation in the Baltic Sea is much more complex, with Mesozoic fault zones, inversion structures and Caledonian thrusts from Avalonia onto Baltica being observed.

The Northeast German Basin is part of the Central European Basin System, extending from the Tornquist Zone to the Harz Mountains, and from the North Sea to Poland. The DEKORP-BASIN '96 deep-seismic reflection profiles in the Baltic Sea locate the northern boundary of this intracontinental basin immediately north of Ruegen island in the transition zone towards the Baltic Shield.

The reflection seismic data also reveal the offshore continuation of fault structures already mapped onshore, sedimentary inversion structures, the Moho depth, and deep crustal and upper mantle structures. The data further confirm the idea of a bivergent collision between Avalonia and Baltica. A similar compressional style is also observed in the Proterozoic crust farther north, and would appear to be connected to major tectonic lineaments.

On the main NE-SW trending profiles crossing the CDF, good correlation between refraction and reflection seismic data exists. A series of reflections dipping SW-ward below the NE German mainland is observed on both marine and land seismic data, and is interpreted as a wedge of Baltica crust extending below the NE German Basin. This interpretation is corroborated by the refraction velocity model which is based on a 3-layered crust typical of shields and platforms. The model not only facilitates the recognition of Baltica derived crust, but also the determination of both crystalline basement and Moho depths.

LITHOSPHERIC STRUCTURE BENEATH THE TESZ DERIVED FROM POLONAISE'97

TO8

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A large seismic experiment POLONAISE'97 targeted the deep structure of the Trans European Suture Zone (TESZ), between the Phanerozoic and Proterozoic European crustal domains. Detailed system of seismic measurements permitted to determined details of the structure of the Palaeozoic belt and East European Craton.

The crustal structure of the East European Platform is characterised by nearly horizontal uniform structure. The crystalline crust consists of three parts: upper, middle and lower with P-wave velocities of 6.1-6.4, 6.5-6.7 and 7.0-7.2 km/s, respectively. The crystalline basement lies at the depth 0.5-5 km. The depth of the Moho boundary ranges from 39-45 km in north-eastern Poland up to 50 km beneath Lithuania. The sub-Moho P-wave velocity is 8.05-8.1 km/s.

The crustal structure of the Polish Basin and Palaeozoic Platform is represented by POLONAISE'97 profiles P1, P2, P4, as well as profiles LT-7 and TTZ. In general, the P-wave velocities of the upper crust in the Polish Basin are low (< 6.0 - 6.2 km/s) down to 20 km of depth. It can be interpreted as an evidence for their being originally of sedimentary with a volcanic intrusions. The basin is distinctly asymmetric. The lower crust has a P-wave velocity 6.5 - 6.8 - 7.3 km/s, high velocity gradient, and strong, ringing reflectivity. The TESZ in the P4 profile is associated with a crustal root in which the thickness of the crust reaches 50 km. The velocity of the sub-Moho uppermost mantle is high (> 8.2 - 8.3 km/s). A very distinct asymmetry, between the maximum thickness of the sedimentary cover and the crustal root associated with TESZ, is observed.

Besides intracrustal and Moho phases, correlated phases from the lower lithosphere, beneath the Moho was recorded. Particularly very good quality groups of reflections were recorded in the TESZ. They could be interpreted as reflections from seismic boundaries at depths about 70, 90 and 100 km in the lower lithosphere.

INTEGRATED SEISMIC AND DENSITY MODEL OF THE EARTH'S CRUST AND UPPER MANTLE BENEATH THE LT-7 AND TTZ DSS PROFILES IN POLAND

TO9

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Determination of deep lithosphere structure of the Trans-European Suture Zone (TESZ) between the Precambrian Platform of Eastern Europe and the Palaeozoic Platform of Central and Western Europe was one of the main tasks of the LT-7 and TTZ seismic refraction and wide reflection experiments across the part of TESZ called the Teisseyre-Tornquist zone (TTZ) in Poland. Experiments were carried out in 1987-1990 and 1993, respectively, by an international team of researchers from the Institute of Geophysics of the Polish Academy of Sciences, the Institute of Seismology, University of Helsinki and the Department of Geophysics, University of Oulu, Finland, GeoForschungsCentrum Potsdam, Germany and Department of Geophysics of Uppsala University, Sweden. Both experiments showed that the TTZ structure could be characterized by anomalous character of seismic waves field that cannot be interpreted by some unique way. The first interpretation of P-wave arrivals along the LT-7 and TTZ profiles did not solve all the problems concerning the lithosphere structure beneath the Teisseyre-Tornquist zone. Previous geophysical investigations have also revealed anomalous character of potential fields in this area. That is why integrated interpretation of DSS and potential field's experimental data can be used to obtain more reliable and informative model.

For this purpose the method of integrated interpretation of observed DSS and gravity data that is based on the concept of a non-linear relationship between density and seismic waves velocity was applied. This relationship can be obtained as a solution to inverse gravity problem. The data on other geophysical and geological measurements are used as a-priory information necessary to find reliable solution. Then the density distribution within the geological section can be calculated with the use of the equation obtained.

The combined velocity-density models of the LT-7 and TTZ models are in better agreement with the gravity data as the initial one. The regional high of the gravity field in the NW part of the TTZ obviously correlates with the upper boundary of a layer composed of rocks with velocity more than 6.0 km/sec and density about 2.75 g/cm^3. Such values correspond to the crystalline crust rather than to the consolidated sediments. As modeling of both profiles has shown, the depth to this layer varies from 10-12 km in the northwest and southeast of TTZ profile to 15-16 km in its central part. It is significantly less than it has been estimated by previous interpretations of LT-7 and TTZ profiles. The rapid decrease of the gravity field to the southeast of TTZ line can be explained not only by descending of this boundary, but also by increase of the Moho depth. The layer with velocities more than 7 km/sec in the lower crust is absent from the central part of the TTZ profile. All this details show that the lithosphere structure beneath the Teisseyre-Tornquist zone is significantly inhomogeneous and the former probably consists of several tectonic units.

TOR STATUS FALL 1999. TOR - A SEISMIC STUDY OF THE LITHOSPHERE AND ASTHENOSPHERE OF NORTHERN EUROPE.

TO10

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Report from the largest seismic antenna to this time in Europe. The Field work was undertaken in half a year 1996 to 1997, where mobile short period and broad band seismographs collected data continuously in Germany, Denmark and Sweden. 273 earthquake records have been extracted from the data set. The TOR project involved around 120 seismographs with a horizontal resolution of 20-30 km. Investigations of the TOR data set can be called two-and-a-half dimensional being a 900 km profile with 100 km width plus a few seismographs off the profile. Teleseismic tomography, receiver functions, S-wave splitting and surface waves are research areas that have been studied within the TOR data set. The TOR line goes along a well studied crustal profile of earlier projects, so that the sediments and crustal structures are assumed well known, and the inversion efforts are concentrated on the deep lithosphere and asthenosphere differences to depths around 300 km. Surface waves studies find a 80 km thick lithosphere in the SW part of the profile but in the NE part surface wave inversion has not been able to define the thickness of the lithosphere which is an indication of a very thick lithosphere. Ray tracing through a synthetic 3D crust and upper mantle model, based on existing data, show that the observed travel time anomalies of 1-2 seconds can be divided almost equally between known crustal effects and lower lithosphere/asthenosphere differences. Rays coming from the NE has a more sharp transition than rays from other directions. This indicates a steep NE slope of a sharp transition in the lower lithosphere.

CRUSTAL STRUCTURE OF WESTERN POLAND: PRELIMINARY GEOLOGIC INTERPRETATION OF POLONAISE '97 PROFILE P1

TO11

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The NW- trending, c. 300 km long POLONAISE'97 profile P1 is located in western Poland, inward the s.c. Variscan deformation front drawn arbitrarily between the Odra Fault Zone and the East European Craton. However, neither a frontal thrust nor a foredeep basin can be demonstrated in this region by geological evidence because of a thick Permo-Mesozoic cover (Cwojdziński & Żelaźniewicz, 1999). Earlier obtained seismic data have not be conclusive either. A high-resolution velocity profiling has revealed the presence of relatively low velocity rocks (<6.1 - 6.2 km/s) of sedimentary or volcanic origin down to the depth of 20 km, high velocity (6.7 - 7.5 km/s) lower crust, Moho at the depth of c. 30-33 km and a high-velocity (>8.3 km km/s) lithospheric mantle (Jensen et al. 1999). The c. 3 km thicker crust in the southeast is isostatically compatible with c. 3 km thinner sediment cover.

The P1 profile was shot to the NE of the Dolsk Fault Zone and the Wolsztyn-Leszno high flanked by this zone on the northeast. The high exposes subsurface quartz-sericite phyllites with 2 cross-cutting foliations of unknown, yet pre-Late Devonian age, occurring directly under Rotliegend strata at the depth of 2.6 - 2.2 km. Nearly 2 km thicker Permo-Mesozoic deposits (4.6-5.2 km/s) NE of the high point to faulting related to the development of the Polish trough. The underlying unconsolidated Palaeozoic sediments (4.9-5.5 km/s), extending down to the depth of 6.5 km, are c. 2.5 km thick pile of likely Upper Devonian-Carboniferous strata. These might be taken as a Variscan foredeep. However, similar thickness show Upper Devonian-Carboniferous sediments belonging to platform deposits, supposedly epi-Caledonian, laid down on the slope of the East European Craton, much to the north of the alleged Variscan Deformation Front. The top of the consolidated basement along the profile P1 is, according to the velocity model, much uneven indicating tectonic activity during late Palaeozoic subsidence. Remarkable evidence for syn-sedimentary block faulting has been recognized in boreholes. Along the profile P1 there was sedimentation controlled by basement trough rather, than by genuine Variscan foredeep. Accordingly, the underlying c. 10 km thick layer characterized by 6.1 km/s seismic velocity is not considered as a Variscan foreland system either. It is too thick and too far from the inner part of the Variscan orogen, and it does not have an analogue further west, where the foreland basin was controlled by a collision of Avalonia and

Saxothuringian terrane bringing about a magmatic arc known as the Mid-German Crystalline High. This high does not continue to Poland (Oberc-Dziedzic et al. 1999), where the Saxothuringia did not collide with the East European Craton but moved in a wrench manner past the border with it.

To understand the nature of this unusually thick low-velocity layer of low-grade metamorphic rocks of likely silicoclastic/volcanogenic protolith it is necessary to consider the provenance of the underlying high-velocity lower crust into which the former passes via a c. 4 km thick transition zone. This lower crust cannot be taken as Avalonian basement (1) because Avalonia is bordered on the NW by the Elbe Line (Cocks et al. 1997) coinciding in Poland with the Dolsk Fault Zone, hence it occurs to the SW of the P1 profile area, (2) this crust, although discretely attenuated, is still a 3-layered structure typical of Baltica as revealed by the seismic profile LT-7 (Guterch et al. 1994; Dadlez 1997) intersecting orthogonally the P1 profile.

Therefore, the lower crust along the P1 profile is interpreted by us as a thinned out Baltica crust as also supposed by Abramowitz et al. (1998) and Berthelsen (1998). This thinning out has to be related to rifting of pre-Baltica along the future Teisseyre-Tornquist zone in post-Grenvillian (post-Sveconorwegian) times while supercontinent Rodinia broke-up (Żelaźniewicz 1999) c. at 0.8 - 0.7 Ga.

Judging from the LT-7 seismic image, the pre-Baltica crust was extended by both normal faulting at the top and underplating at the base over a mantle wedge. A sagging rift basin was being filled up with sedimentary-volcanogenic succession until the continental lithosphere eventually failed and an oceanic crust may have started to develop further southwest (in the present-day configuration). The question is what type of basin it actually was and when this basin was effectively closed: during Early Palaeozoic (Ordovician) or still in Neoproterozoic times in connection with the Cadomian orogeny occurring at the periphery of Pannotia supercontinent as prompted by a spectrum of U-Pb (zircon) and Ar-Ar (mica) ages of detrital grains with minumum at 600 Ma (Tschernoster et al. 1997). The answer heavily relies on a strict knowledge of the palaeogeographic position of Baltica within Pannotia. From geologic premises further southeast it is probable that Cadomian foreland basin system encroached Baltica (Żelaźniewicz et al. 1997; Żelaźniewicz, 1999). Accordingly, it is possible that the low-velocity upper crust overlying in western Poland (P1 profile) the attenuated Baltica basement represent basically the Cadomian accretionary wedge with some Ordovician additions. The latter were accreted during an Early Palaeozoic splitting of former supercontinent in a persistently weakend crustal zone further developing into the Teisseyre-Tornquist Zone and the Trans-European Suture Zone.

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DEEP SEISMIC LINES IN THE ROMANIAN CARPATHIAN FORELAND

TO12

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A few deep seismic reflection lines were performed dominantly in the Romanian Carpathian foreland, within the framework of crustal geophysical studies promoted by the Romanian Geological Institute, in the last few years.

The specific data were gathered by conventional hydrocarbon seismic exploration, in according with up-to-date field and processing techniques (Hall et al.,1989) and complementary to the foregoing similar seismic lines (Raileanu et al., 1994, Diaconescu et al., 1995).

The adopted field technology was the near-vertical incidence with recordings collected to 20sTWT, which did not allow to use the interval velocities information, but did not diminish the emphasizing of potential reflection elements situated in the deeper crust. In these circumstances, the features of the time sections consist in the reflectivity status differentiations associated with the main intervals of the geological section.

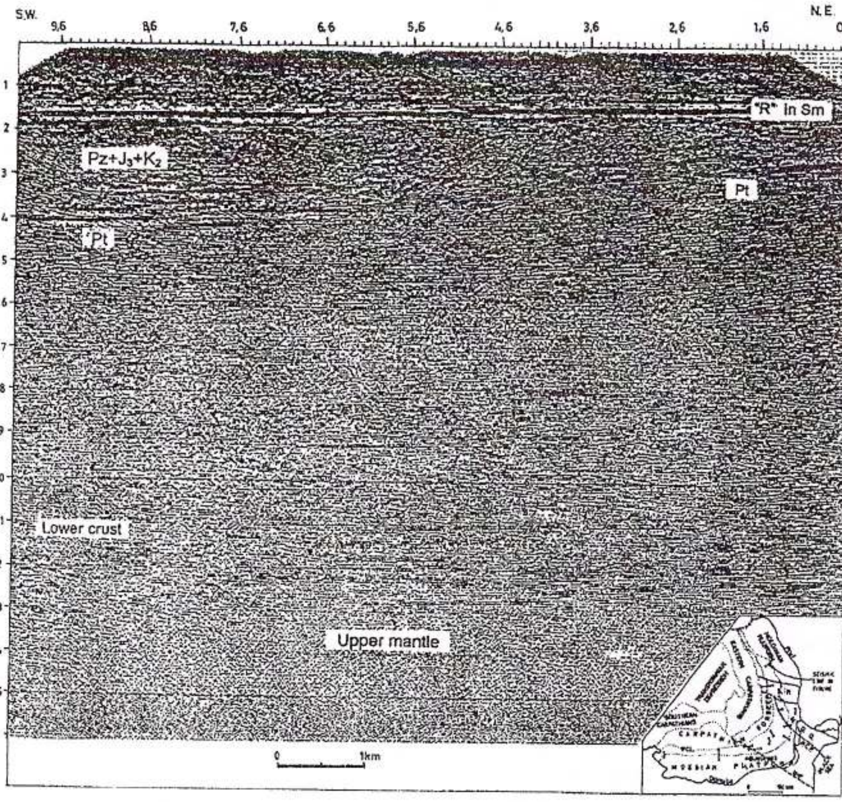
Certain aspects are illustrated in the enclosed time section, achieved eastward of the Pericarpathian line, in the western margin of the Moldavian Platform. The recordings were obtained with conventional reflection technology: 2200 m spread length; 2-4 kg dynamite, average charge size into hole at 20-30 m deep for shot point, 48% normal fold coverage and 2 ms sampling rate.

The seismic image (Figure 1) describes a medium reflective upper crust overlying more intensive reflection events, especially toward the crust base. The Moho discontinuity is interpreted as the bottom of lower crustal reflections at about 13s TWT (roughly 40 km deep).

All the other seismic lines located in the Carpathian foreland have been examined under the same reflectivity concept concerning the constitutive blocks of the crust.

Summarily, the most important element of the deep seismic analysis is represented by some reflectivity differences with reference to the level Moho discontinuity, as follows:

- a narrow highly reflective sequence onto the transparent background, including the crust base and the upper mantle, in the central-west part of the Moesian Platform ;
- reflective interval, during about 2s TWT, with discontinuous and stronger signals in the northward and the west side of the Moesian Platform;
- extended bands of subparallel reflection events, with accentuated dips towards the Carpathian orogen, revealed into inner zone of the foredeep ;
- longer correlable reflections (1-1,5 km) in the east-central part of the Moesian Platform.;



sources, can allow to enhance the results regarding the researched objectives, at economical costs.

Figure1. Deep seismic line-time section in the western margin of the Moldavian Platform. Legend: Pt-proterozoic basement; $Pz+J_3+K_2$-undivided seismic sequence for Paleozoic, Upper Jurasic and late Cretaceous, "R" in Sm – guide mark in Sarmatian. Inset - simplified tectonic map of Romania shows the location of the analysed deep seismic lines. Legend of symbols: dotted line-boundaries between main tectonic units; heavy dashed line-crustal fault; segment-seismic line. Legend of abreviations: SP-Scythian Platform; NDO-North Dobrogea Orogen; PCL-Pericarpathian line; PCF-Peceneaga Camena fault; IMF-Intramoesian fault.

- short subhorizontal reflections, like as laminated bedded crust, in the eastern Moesian Platform and partly in the North Dobrogean Promontory;
- unexpressive and nonconclusive reflections in areas wich belong to the border between Moldavian Platform and Scythian Platform and in the vicinity of the Intra-Moesian fault

The obtained information suggest the possibility to improve the structural models of the deep crust by the subsequent increase of the reflection multiple coverage data on seimic lines controlled by the hydrocarbon exploration.

Additionally, the field measurements based on the seismic deep soundings, with massive blastings in quarries as seismic

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TECTONIC EVOLUTION OF THE ROMANIAN PART OF THE MOESIAN PLATFORM: AN INTEGRATED MODEL

TO13

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The Moesian platform represents an autochthonous unit in the frontal part of both Romanian Carpathians and Balkans. Classical definition of this unit refers to a Precambrian block incorporated in the Epihercynian European platforms.

The Moesian Platform extends S and SW of the Trotus and Peceneaga-Camena faults, and it is composed by two main domains, the "Dobrogean" and "Valachian" parts. The studied area comprises both areas, separated by the Intramoesian Fault, a deep crustal fracture extending northward at least up to below the Getic nappe. It is the site of a large number of shallow to deep earthquakes, and has 20-30 km of right-lateral movement during the Tertiary, as demostrated by seismic reflection studies. 6 major tectonic periods can be defined in close connection with the development of associated sedimentary basins.

- During Permian – Middle Triassic, the Moesian block underwent an extensional episode, characterised by the development of NW-SE elongated extensional basins.
- During Upper Triassic - Early Jurassic, the NW-SE trending normal faults were inverted, the contraction inducing piggy-back and flexural-associated basins
- During Upper Jurassic – Early Cretaceous, Moesia evolved as a stable region coeval with the N to NW-ward evolution of the Outer Dacidian trough.
- Late Cretaceous contractional episodes in the Romanian Carpathians induced dextral transpression, right-lateral movements being associated with Moesian flexure in the frontal part of the Carpathians.
- During Middle Miocene (Badenian) ESE-WSW strike-slip deformation and transtensional structures are recorded especially in the eastern part.
- Strike-slip movement also occured in Upper Miocene (Sarmatian) and Early Pliocene, but that time on NW-SE trending faults.
- The Pliocene – Pleistocene contraction from Carpathians produced an important sinistral deformation which involved also the former ENE-WSW strike-slip faults. The sinistral offset could be over 10km.

FAR-FIELD STRESS TRANSMISSION INDICATIONS IN EARLY PALAEOZOIC STRUCTURAL EVOLUTION OF THE BALTIC BASIN

TO14

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The Baltic Basin (BB) is situated on the western margin of East European Craton (EEC). During Early Palaeozoic both the subsidence pattern and structuring style were strongly affected by tectonic processes in adjacent Caledonides. The structuring style was mainly governed by stress originated in adjacent orogenic belts. The far-field stress transmission effect is traced as far into the stabile platform interiors as ca. 1000 km. This influence was just a minor during Cambrian. The structural differentiation was rather miserable, implying weak tectonic activity in the Baltic area during this time.

In Ordovician time the increasing stresses, transmitted from Scandinavian Caledonides, evoked crustal-scale long-wave folding that dominated the whole architecture of the BB. The structural trend was persistent through the whole Ordovician, showing WSW-NEN and SW-NE orientation of folds. The wavelength ranges in order of 80 km, the amplitudes are of 60-100 m (against the background Ordovician thickness of 100-200 m). The buckling processes were most intense in Middle Caradocian time, that is related to some collision processes that occurred between the Finnmarkiana and Scandian orogenies.

The regular structural pattern was obliterated in middle Silurian due to flexural banding of the Baltica plate margin along the North German-Polish Caledonides (NGPC). Still, in Late Silurian the Scandinavian stresses increased enough to initiate the family of forced folds (flexures) and faults along the ancient basement faults striking SW-NE and WSW-ENE. In earliest Devonian it climaxed in the extensive rapture of the sedimentary pile and establishment of regular network of transpressional faults. Fault amplitudes exceed locally 200-500 m. A gradual concentration of the strains along the major faults is stated. In Middle Sillurian the fault activity was dispersed along the minor faults which ceased by the end of Silurian, and most prominent thrusting in Earliest Devonian was confined just to regional-scale fault zones. This tectonic maximum in the Baltic basin was contemporaneous to Scandian orogeny in Scandinavian Caledones. The extensional collapse in the latter during the late Early Devonian led to inversion (extensional fault activity) of the prior established reverse faults.

The structural evolution of the Baltic Basin reveals the dominant influence of the Scandinavian Caledonides, whereas the basin subsidence was governed mainly by NGPC development (e.g. Late Vendian rifting and Late Ordovician-Silurian flexural bending). It implies strong tectonic coupling between the Laurentia and Baltica plates, whereas it was much weaker between E.Avalonia and Baltica during Early Palaeozoic. Stresses generated in Scandinavia and transmitted into the plate interiors evidently increased in a course of Early Palaeozoic time.

BIOSTRATIGRAPHY OF THE PALEOZOIC FROM THE FORELAND OF THE ROMANIAN CARPATHIANS

TO16

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Faunal assemblages from the main tectonic units of the Romanian Carpathian foreland – the Moldavian, Scythian and Moesian Platforms and the North Dobrogea orogenic belt – are reviewed and biogeographic and paleoecological correlatios are attempted.

In the Moldavian Platform, representing the south-western termination of the East European Platform, two lithological complexes separated by breaks are differentiated in the Paleozoic succession: a lower, detrital complex, representing the Vendian – Cambrian - Ordovician, and an upper, calcareous complex, ascribed to the Silurian ± Early Devonian. The Vendian is attested palaeontologically by *Vendotaenia antiqua*, the Cambrian by *Sabellidites cambriensis*, the Silurian by a shelly fauna facies, consisting mainly of brachiopods and subordinately by ostracods, trilobites, gastropods, corals, bivalves, bryozoans, crinoids and palynomorphs. The paleontological assemblage proves the similarity with Podolian and Baltic faunas.

The Predobrogea Depression, representing the Scythian Platform and its possible north-westward prolongation beneath the Carpathian flysch nappes, is a highly controversal unit. The presence of the Silurian is attested by the presence of graptolites in the north-west (west of the Siret Fault), as well as of assemblages of forams, chitinozoans and scolecodonts identified in borehole cores. Characeea, forams and ostracods attest the Devonian and the Carboniferous in this area.

The Moesian Platform displays a very thick cover of Paleozoic sediments, starting with the Cambrian and overlying the Cadomian or older basement. The Cambrian is attested by trilobites; the Ordovician and especially the Silurian are attested by graptolites; the Silurian shelly fauna shows close affinities with that of the Barrandian. The Devonian is attested by a rich assemblage consisting mainly of trilobites, tentaculites, brachiopods, placodermi fishes and subordinately of bivalves, crinoids, corals, psilophytal plants, conodonts, forams and palynomorphs. The Carboniferous is attested by brachiopods, bivalves, goniatites, forams, conodonts, plant debris; the Permian is attested by a microfaunistic assemblage of forams, ostracods and conodonts.

In the North Dobrogea orogenic belt, the Paleozoic shows a shallow marine (detrital and calcareous) facies in the western, Macin zone, and a deep water facies (siliceous pelagites and distal turbidites) in the northern part of Tulcea zone. These areas also differ in their faunal assemblages. In the Macin zone, the Silurian is attested by scarce fossil remains (*Rastrites*, crinoids, corals), while the Early Devonian is attested by a brachiopod dominated macrofaunal assemblage, rich in crinoids and tentaculitids, with subordinate trilobites, corals, briozoans and ostracods. The biocenosis, as well as the lithological association suggest shallow water deposition in a benthic, open shelf environment. The succession from the Tulcea zone yielded Middle-Late Ordovician palynological assemblages and Silurian - Devonian associations of conodonts, abundant recrystallized radiolarians, subordinate ostracods and scolecodonts as well as chitinozoans.

The Paleozoic macrofauna and palynological assemblages of the Moldavian Platform show a good correlation with the fauna of Baltica. The Silurian bivalvian assemblages from the Moesian Platform sediments are closely related to those known from the East European Platform sediments of Eastern Poland. A connection during the Silurian between these areas with epicontinental sedimentation might explain the migration of bivalves, either by epiplanktonic transport on algae or a better larval dispersal by oceanic currents from regions with high adaptive radiation like the orthoceras limestone facies in the Bohemian Paleozoic. The Silurian graptolite faunas attest the large spreading of the euxinic depositional environment all around the world. Elements of both Rhenish and Bohemian faunas are present in the Moesian Devonian, as in Poland, Moravia and north-western Turkey, the gastropod assemblages being characteristic for the tropical-subtropical marine conditions of the Old World Realm. Carboniferous brachiopods enable correlations with the Dinant and Namur basins from Western Europe, as well as with the East European Platform and Poland. The macrofauna from the Macin zone of north Dobrogea correlates with Ardennes and Rhenish massif, as well as with Poland and Turkey.

ANCHIMETAMORPHIC PRECAMBRIAN ROCKS ON THE FORELAND OF THE EAST-EUROPEAN PLATFORM

TO17

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In the south-eastern Poland, two tectonic units are distinguished, namely Upper Silesian and Małopolska Blocks.

The Upper Silesian Block together with Brno Block are situated in the area of Czechs and partially Austria. They make a larger tectonic unitt, which is called Brunovistulicum by Dudek (1980) and Brno-Upper Silesian Massif by Kotas (1985) (vide Buła *et al.*, 1997). This wide tectonic unit (which will be called here Brunovistulicum), the south part of which comprises Western External Carpathian Mountains, is built of two assemblages of rocks which differ from each other in terms of the degree of metamorphic transformations.

The older assemblage, located in the southern, Sub-Carpathian part of Brunovistulicum is represented by crystalline schits, gneiss, magmated gneiss and olivine gabbro. These rocks represent the lower part of epi zone and mezo zone of the regional metamorphism.

The younger assemblage in the Brunovistulicum is built of phyllites, metapelites, metapsammites and metaconglomerates, which originated from flysch sediments. Anchimetamorphic rocks of Brunovistulicum occur N and NE of the outcrops of crystalline rocks on sub-Cambrian surface (alternatively, sub-Devonian, sub-Mesozoic or sub-Miocen surface). The Cambrian rocks, which represent structural cover complex of Brunovistulicum, occur discordantly on the cristalline and anchimetamorphic rocks.

Flysch character is also associated with anchimetamorphic lithologies (stylitised metapelites, metaleurites and metapsammites) which have been recognised in the southern part of the Małopolska Block (S of Kielce region of the Holy Cross Moutains). They are discordantly overlain by Ordovician, Silurian, Devonian or Mesozoic and Miocene sediments. The interface of anchimetamorphic rocks with non-metamorphised Cambrian lithologies which occur in Kielce region of Holy Cross Mountains (which also belongs to Małopolska Block - Pożaryski *et al.*, 1992) has not been recognised. Brochwicz-Lewiński *et al.* (1983) states that Małopolska Block underwent Grampian consolidation in early Cambrian. In contrast, Dadlez *et al.*, 1994) suggests that flysch or flysch-like Vendian sediments continues into Cambrian sediments, which became deformed in Sandomierz phase before Arenig.

The Cadomian age of Brunovistulicum consolidation is unquestionable, which is indicated, for example, by age of the detrital mica from Lower Cambrian clastics in the Upper Silesian Block (Bełka *et al.*, 1997). In Małopolska Block, the Precambrian age of anchimetamorphic rocks (which earlier was compared with Vendian green schist of Dobrogrea (Głowacki, Karwowski, 1963) has been documented by acritarchs in two boreholes located E of Kraków (Moryc, Jachowicz, in press).

According to Żelaźniewicz *et al.* (1997), the crystalline rocks recognised in the southern, sub-Carpathian part of Brunovistulicum, represent an internal part of Cadomian orogen (Internides). The Vendian Flysch and flysch - like anchimetamorphic rocks recognised both in Brunovistulicum and Małopolska Block would represent, therefore, the foreland of this orogen. Thus, the foreland would be located between its internal part located in the southern part of Brunovistulicum and eastern-European craton. Having documented the genetic associations between the Vendian anchimetamorphic rocks recognised in the SE Poland and Dobrogea in Romania, the range of Cadomian orogen in eastern Europe at the forefield of Eastern European craton, would be determined. To solve this problem, an attempt is made to carry out complex investigations of Vendian anchimetamorphic rocks from SE Poland and Dobrogea. These investigations will be financed by the Committee of Scientific Research.

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GEOCHEMISTRY AND DEFORMATIONAL HISTORY OF METABASIC VOLCANIC ROCKS FROM NORTHERN AND CENTRAL DOBROGEA, ROMANIA

TO18

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New geochemical data is presented for metabasic volcanic rocks from northern (Megina & Orliga) and central (Altîn Tepe) Dobrogea. The two separate areas are characterised by metamorphic pre-Variscan rocks, anchimetamorphic Palaeozoic sedimentary and volcanic formations, and both pre-Variscan and Variscan granitoids. The pre-Variscan rocks form the Moesian Platform and represent Cadomian basement accreted to the south-western margin of Baltica during the Palaeozoic. Mesozoic sediments and volcanic rocks overlie these basement lithologies.

The Orliga Group crops out in the northwestern extremity of northern Dobrogea and is also known from drillings in the North Dobrogea Promontory. It exhibits tectonic contacts with neighbouring formations and comprises gneisses, micaschists, quartzites, calc-silicates and meta-basic volcanic rocks of tholeiitic to enriched tholeiitic composition. At least three metamorphic and deformational events affected these rocks.

The Megina Group crops out on the Priopcea and Dâlchi Bair hills and also on the Bugeac Promontory. Distinct differences exist between the Orliga and Megina groups, not only in lithology but also in metamorphic evolution. The Megina Group is composed mainly of metabasic volcanic rocks of tholeiitic composition and quartz-feldspar mica schists (currently interpreted as acid meta-tuffs). Four separate metamorphic and deformational events can be recognized within the Megina Group.

Northern and central Dobrogea are separated by the Mesozoic Peceneaga-Camena Fault. Meta-tholeiitic volcanic rocks occur at Altîn Tepe (Pre-Cambrian). Deformation of these rocks may be correlated with the medium grade D1 event that affected the Megina Group.

The northern margin (Măcin unit) of the Moesian microcontinent was strongly sheared and metamorphosed under greenschist facies conditions during the final stages of its migration. The Boclugea Group, which is devoid of volcanic rocks, was thrust over the Megina and Orliga groups. The resulting nappe pile was subsequently folded in an event which clearly predates the Silurian. This represents initiation of a compressional event between the East European platform and the Moesian microcontinent. The D3 deformation in Megina (D2 in Boclugea) is characterized by a change in compressional direction. This deformation, which affects rocks as young as Carboniferous (Carapelit Formation), represents a final collisional event. In some areas, like the Orliga and the Bugeac promontories, this D3 deformation with its NW-SE striking structures is absent or E-W striking parallel to D2. This can be explained by decoupling and rotation of sections of the compressional fold belt during late stages of collision.

Even though lithological associations differ across the area from northern and central Dobrogea and a range of late Proterozoic to early Palaeozoic ages exist, all the meta-basic volcanic rocks are tholeiite to enriched tholeiite in composition. These geochemical characteristics are consistent with their development in a rift environment. There is little or no evidence of significant crustal contamination or of any plume influence in these meta-basalts. This contrasts with analogous early Palaeozoic rocks in the Central European Variscides and ultimately records the initiation of development of an early Palaeozoic rift zone during fragmentation of Avalonia from the Gondwanan margin. This is envisaged to have occurred prior to separation of other "European Variscan" terranes (e.g. Armorica, Bohemia, Iberia) finally culminating in the docking of an "Avalonian terrane assemblage" with Baltica in late Ordovician - early Silurian times.

ULTRAHIGH PRESSURE- VERSUS ULTRADEEP ORIGIN ROCKS - THEIR GEOLOGICAL SETTINGS

TO19

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Ultrahigh pressure (UHP) rocks were metamorphosed under pressure greater than 28 kbar, in the coesite stability field, usually at the asthenospheric depths in the mantle. They outcrop in the continental collisional zones. UHPM rocks contain either coesite and/or diamond or other equivalent HP mineral assemblages. On the other hand, the rocks of ultradeep origin (UDO)are considered to be originated within the transition zone (TZ) of the Earth's mantle and/or at the depths below 300 km within the lowermost part of the upper mantle. TZ is delineated by major density and seismic discontinuities located at the depths of 410 and 660 km. Regardless whether peridotitic or eclogitic model of TZ is considered, the key in understanding nature of this zone is the following series of phase transformations: alpha-olivine (Fo90)->beta-spinel (wadsleyite)->gamma-spinel (ringwoodite), which occurs with increasing pressure. At the depths of 410 km olivine transforms to wadsleyite, which at a depth about 520 km transforms to ringwoodite. The latter disproportionates into perovskite $MgSiO_3$ and magnesiowustite at the depth of 660 km. Within the upper mantle pyroxene->garnet transformation start at a depth of 300 km. This transformation results in formation of majorite being new class of supersilicic garnet end-members, in which one quarter of silicon atoms are octahedrally coordinated. Pyroxenes disappear in the mantle at a depth of about 500 km. During decompression majorite garnets usually exsolve rods or needles of pyroxenes. The findings of supersilicic majorite garnets included in diamonds from kimberlites of South Africa (Moore, Gurney 1985) and Brazil (Wilding et al. 1989) initiated the search for terrestrial UDO rocks. The first UDO rocks were discovered among ultramafic xenoliths in Jagersfontain kimberlite, South Africa (Haggerty, Sautter 1990) and in Koidu kimberlite, Sierra Leone (Hills, Haggerty 1989), on the basis of pyroxene exsolutions in garnets. These UDO rocks represent both the peridotitic and eclogitic assemblages. In many cases the UDO xenoliths from African kimberlites underwent two-stage uplift, first by plume transport, then by volcanism. The first UDO rocks outcropping within UHPM complexes were described by Dobrzhinetskaya et al. (1996) in Alpe Arami, mainly on the basis of topotaxial exsolutions of abundant tiny $FeTiO_3$ rods in the first-generation olivine of garnet lherzolite. The precursor mineral (wadsleyite or ringwoodite) was rich in TiO_2, which was first exsolved in the form of perovskite structured $FeTiO_3$. Another unusual exsolutions of oxides were described recently in olivine of Kokchetav garnet peridotites and in the olivine from the Maowu harzburgite in Dabieshan. The clinopyroxene exsolutions in eclogitic garnets from UHPM Sulu terrane in China were also found. Although the direct access to UDO rocks is extremely limited, there can be recognized two different geological settings of these rocks on the Earth's surface. One of them is explosive environment of kimberlite diatremes, the other one is connected with continental collision zones and sutures between continental plates. The uplift mechanism in the first environment (plume transport & kimberlite volcanism) is much better documented than in the case of UHPM complexes, where ultramafic- and their host voluminous felsic rocks should be first subducted to great depths and then educted back to the surface by buoyant upwelling. In the northeastern Bohemian Massif, in the West Sudetes the areas with signs of UHPM: the eastern part of the core of Orlica-Snieznik Dome, located in the hanging wall of the Moldanubian thrust zone and Sowie Mountains, where garnet lherzolites occur within granulites, can be perspective in the search for UDO rocks. The other perspective areas may be occurrences of peridotites of non-ophiolitic provenance. In the UHPM terranes, all kinds of epitaxial exsolutions should be carefully studied in order to recognize preexisting minerals, among which majorite, wadsleyite and/or ringwoodite could be deciphered.

HEAVY MINERALS IN OROGENIC STUDIES

TO20

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Erosion and sediment accumulation, concomitant with the growth of orogenic belts, imply that the mineralogy of tectonogenic sediments provides a record of tectonic pulses experienced by their evolving source region. Shortening in the mountain belt results in time-varying provenance, as successively deeper crustal levels are brought to surface and eroded. The sequential analysis of heavy minerals of basin-fill sediments enables reconstruction of the lithology and tectonic phases of their dynamic hinterland. Therefore, this petrographic technique, integrated with structural and sedimentological data, is instrumental for constraining the timing of uplift and erosion of orogenic regimes. Results of such an integrated approach have proved highly informative in studies on the Caledonides and on the peri-Alpine molasse of France and Switzerland.

The British and Irish Caledonides occupy a key position between the Appalachian orogen of western North America to the south and the Caledonides of East Greenland and Scandinavia to the north. Definitive new detrital heavy mineral evidence obtained from a study on most of the Ordovician and Silurian stratigraphical units in the South Mayo Trough in western Ireland, supports and enhances our model of a short-lived orogenic event, involving ophiolite obduction and the rapid development and unroofing of a Grampian Barrovian metamorphic complex over about 10 my. We show that ophiolite unroofing began during the Arenig and that, by the early Llanvirn, a Barrovian complex was being eroded. We regard the problem of timing the Grampian deformation and metamorphism of the Dalradian as now solved. It was an Arenig/Llanvirn event, lasting about 10 my, which is recorded faithfully by the detrital heavy mineral assemblage in the conformable Ordovician sequence of the South Mayo Trough.

In the Lower Oligocene to Lower Miocene Molasse of Savoy, France and western and central Switzerland the progressive advance of Alpine-derived detritus and the presence of high-pressure low-temperature (HP-LT) index blue sodic amphibole, lawsonite and carpholite played a key rôle in the reconstruction of the unroofing episodes of the Alpine tectonic domains. The first appearance of HP-LT index minerals in the molasse indicates that some of the Penninic subduction complexes (102-80Ma) were uplifted by the early Upper Oligocene (~24Ma). A relative tectonic quiescence during the Aquitanian is mirrored by impoverished heavy mineral suites and by the almost complete absence of the HP-LT index minerals. Tectonic rejuvenation in the Burdigalian (21-22Ma) is shown by the diversity of heavy mineral assemblages. The re-appearance of the HP-index suite, but this time with different blue sodic amphibole chemistry, was complemented by abundant Ca-amphiboles, derived from the emerging External Massifs.

HP METAMORPHIC ROCKS AND VARISCAN COLISIONAL FRAMEWORK IN THE BASEMENT OF THE SOUTH CARPATHIANS

TO21

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The South Carpathians resulted from Alpine polystage collision characterized by: a double verging orientation of the crustal bodies, delimited by thrust/overthrust planes, in an asymmetric, fan like, nape pile; a strong heterogeneity due to the alpine building and the inheritance of a strong pre-Alpine structural anisotropy; important contrasts in the physical parameters of the metamorphic conditions correspond to the Alpine, Variscan and Pan-African cycles; the widespread occurrences of HP/HT rocks occur only in the Variscan units of the Getic-Supragetic basement.

Pre-Mesozoic basement of the South Carpathians includes: Upper Carboniferous-Permian sedimentary deposits; Paleozoic (pre-Upper Carboniferous) orogenic granitoids; pre-orogenic, lower Paleozoic mafic-ultramafic magmatic rocks; sedimentary and volcano-sedimentary rock sequences affected by prograde Variscan metamorphism, in low-grade conditions; medium-high grade metamorphic rock assemblages, of pre-Upper Carboniferous age (Proterozoic +/-Paleozoic), with a complex and diversified polymetamorphic (polystage or polyorogenic) history; and structural building.

Variscan HP rocks are related to:

- Dynamo-thermal (regional) Paleozoic metamorphism which can be attributed to the Variscan orogeny, older than Upper Carboniferous-Permian, corresponding to the deposition of the sedimentary, discordant, molasse type deposits. Recent isotopic geochronological data from the Getic-Supragetic basement support this timing, as $^{40}Ar/^{39}Ar$ cooling ages are of 309-320 Ma (Dallmeyer et al., 1996) and older ones are of 354-346 Ma (Maluski, in Iancu, 1998).
- Dynamic, shear zone related metamorphism of Paleozoic age, spatially associated to the main tectonic contacts separating the pre-Alpine litho-tectonic units.

Some isotopicaly dated occurrences of mylonitic rocks and syn-tectonic pegmatites give Paleozoic, Variscan ages 346-331 Ma ($^{40}Ar/^{39}Ar$, cf. Maluski, in Iancu, 1998) and respectively, 338-332 Ma (Pb/Pb, single crystal zircon ages, Cocherie, in Ledru et al., 1997). The dated minerals are from blastomylonitic rocks and syn-tectonic pegmatites characterizing the tectonic boundaries between the main litho-tectonic units of the Getic-Supragetic basement (Iancu et al., 1998).

The aim of this presentation is to emphasize the spatial distribution and position of the HP and medium-HT rocks in the uppermost alpine units, with a sub-horizontal crustal tectonic layering. The Variscan polystage crustal thickening and subsequent thinning due to collapse (recently $^{40}Ar/^{39}Ar$ ages are 354-331 Ma) produced the structural anisotropy and tectono-metamorphic inversion of the pre-Alpine basement and exhumed the high-grade rocks from the roots of the belt.

Well constrained PT conditions for eclogites and granulites are 550-700^{0}C and 11-15 kb, while for garnet peridotites are 1160-1295^{0}C/25-32 Kb, which are comparable to those for similar rocks in the Variscan Bohemian Massif. The Paleozoic crustal anisotropy can be explained by a complex, polystage tectono-metamorphic evolution, involving a "tectonic collage" or "mixing" of the crustal bodies; the exhumation processes of the HP rocks can be understand only by deciphering of the whole pre-Alpine history. Further uplift and erosion (cooling ages of 309-320 Ma, Dallmeyer et al., 1996) followed the pre-331 Ma effects of thickening-thinning processes.

PRECONDITIONS OF PALAEOZOIC OROGENIC DEVELOPMENTS IN SOUTHERN POLAND

TO22

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The Cadomian orogeny in central Europe terminated at c. 540 Ma (Linnemann et al. 1997) with voluminous intrusions of post-orogenic granodiorites into an earlier sedimentary and magmatic arc rocks of c. 585-540 Ma age (Kröner et al 1994). These rocks are either directly exposed at the surface or known from subsurface (e.g. Lausitz, Brno, Upper Silesia). They are also identifiable as xenoliths and by zircon inheritance ages in lower Palaeozoic granitoids (e.g. Izera, |nie¿nik, Erzgebirge), or recognizable as detrital material (zircons) within clastic sequences of early Palaeozoic platforms (Upper Silesia, Małopolska, Holy Cross Mts). Fragments of the internal portions of the Cadomian orogen occur in the Sudetes, Moravia and Upper Silesia, whereas fragments of the Cadomian foreland occur between the inner domains and the nearest craton, that is the East European craton (Żelaźniewicz et al. 1997). This palaeogeographic configuration was achieved during the waning stage of Rodinia-Pannotia supercontinent (Dalziel 1997, Żelaźniewicz 1999) that finally broke up at the onset of the Phanerozoic. Among others also its Cadomian portion was subjected to extension and rifting and it is this portion whose fragments are now identified in central Europe as Avalonia, Armorica, Perunica etc. Because the southern boundary of Avalonia coincides with the Rhenohercynian/Saxothuringian border and its NE boundary is defined by the s.c. Elbe Line (Cocks et al. 1997) conforming to the Hamburg-Kraków Fault or Dolsk fault zone, Avalonia is actually located almost out of Poland. Accordingly, southern Poland has to belong to Armorica terrane, or rather to an Armorican assemblage of mutually rotating terranes as put forward by Tait et al. (1997) on account of incompatible palaeomagnetic data from various parts (e.g. Saxothuringia vs. western Armorica or Tepla-Barrandian) of what is supposed to be Armorica.

In case of southern Poland yet another palaeogeographic assignment cannot be excluded since palaeomagnetic data from the Sudetes seem to deny their linkage with western Armorica and instead point to the proximity to Avalonia and Baltica since the Ordovician (Nawrocki & Żelaźniewicz 1996). Nevertheless, whatever their affiliation can be, the terranes were produced by rifting of larger fragments of the former supercontinent. Effects and distances of mutual separations of the rifted off lithospheric blocks are controversial and palaeomagnetism-based estimations exceed significantly palaeoclimatic ones (Lewandowski 1998). Moreover, single terranes show clear evidence or at least tendency for further breaking-up. For instance the Saxothuringian terrane during Ordovician became additionally splitted inside by the Vesser rift zone (Kraichgau-Vesser magnetic anomaly) branching toward the western Erzgebirge and Görlitz-Kaczawa-East Karkonosze (Rudawy Janowickie-Lasocki Grzbiet)-South Karkonosze (Rychor*, *elezn* Brod) rift zone rimming the Lausitz-Izera high, with offsets toward Bardo and Hradec Kralove. Evidence for this intra-terrane rift zone ('Saxothuringian ocean') comes also from Mönchberg and Mariansk* L*zne. An obscured border to the Moldanubian zone (Perunica, Havli*ek et al. 1994) with Barrandien and the Islet zone shows that it follows roughly the same pattern yet in a more abbortive way.

Accordingly, there was a network of rifts evolving within the Saxothuringian terrane. Its easternmost manifestation occurred in the Stare Mesto belt at the border with the Variscan Moravo-Silesian Zone. The latter also contains a well identified Cadomian granitoid-dominated basement of c. 680-540 Ma age (Fritz et al. 1994), which however was not involved in rifting until early Devonian. In Upper Silesia, southern Poland, the Cadomian basement of the Bruno-Vistulicum was overstepped by Lower Cambrian clastic platform deposits (Buła et al. 1997), with detritus derived from the basement, and then again by Devonian platform. The Cambrian platform in Upper Silesia also unconformably overlies Vendian phyllites. Further east, in Małopolska, the phyllitized basement, approaching the East Europan Craton, is otherwise overlain by carbonate-carrying Ordovician-Silurian platform (Buła et al. 1997). In contrast to the Variscan Europe, both the Małopolska and Upper Silesia blocks were largely tectonothermally inactive during the Phanerozoic apparently remaining with their Precambrian basement on the Baltica side. The boundary between them and strongly tectonothermally reworked Cadomian crust follows the Moravo-Silesian Zone and then continues into the Dolsk Fault Zone further NW.

Summing up the preconditions of Palaezoic orogenic developments in southern Poland are as follows:

- Extensive presence of the Cadomian orogen, with (i) its inner part now exposed in the Sudetes, Moravo-Silesicum and Bruno-Vistulicum, and (ii) foreland part known from subsurface in Upper Silesia and Małopolska, eventually encroaching the East European Craton.
- Configuration of the Neoproterozoic supercontinent on its breaking-up at the Precambrian/Cambrian turn.
- A rift network splitting the Cadomian crust around more stable cooler cores/blocks during the Early Palaeozoic.
- Distribution of successful and failed rift arms.
- Mantle-controlled configuration of tectonothermally active and inactive crust/lithosphere during the Palaeozoic.

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THE DEFORMATIONAL HISTORY OF NORTH DOBROGEAN HERCYNIAN BASEMENT AS REFLECTED IN NEW ^{39}AR/^{40}AR DETERMINATIONS

TO23

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Mineral concentrates of five samples from the Precambrian - Hercynian Basement and one basalt sample from the Niculitel Triassic Formation were dated. The obtained spectra are shown in Figure 1. The results can be summarized as follows:

RID 1 – *muscovite* (Orliga Group mica-schist). The 281.8±2.7 Ma age is given by a slightly disturbed plateau calculated for more than 90% of the ^{39}Ar released. The presence of two, possible three generations of muscovite determined under microscope may cause the observed disturbances.

RID 1 – *biotite* (Orliga Group micaschist). The plateau age (250.6±2.4 Ma) was calculated for circa 80% of the released ^{39}Ar. The low temperature increment indicates a process of argon loss. Slightly de-colored rims observed under the microscope may suggest that biotite crystals were affected by a low thermal event circa 205 Ma before our time.

The RID 1 biotite and muscovite mineral concentrates were separated from the same whole rock sample. Nevertheless, the apparent age of the biotite is some 30 Ma younger than the age of the muscovite. Since the argon closure temperature of biotite is lower by several tens of degrees than those of the muscovite, the above mentioned time interval may represent either the cooling time spent between the closure of muscovite and biotite respectively, or the occurrence of a low temperature, younger thermal event which affected only the biotite.

RID 7 – *biotite* (Greci granodiorite). The apparent plateau age (242.2±2.1 Ma) was calculated for almost 90% of the released gas. This value is almost similar with the one recorded by the RID 1 biotite, both values indicating the Late Permian-Skythian time span, when extensional deformation of the basement rocks and dyke emplacement are geologically indicated.

RID 10 – *muscovite* (Boclugea Group quartz-micaschist). The obtained spectrum indicates the non-homogeneity of this concentrate caused by the presence of different generations of muscovite, or the contamination of the separated mineral fraction, or both.

RID 12 – *biotite* (Megina gneiss). The plateau age of 271.7±2.6 Ma was calculated for almost 90% of ^{39}Ar released. A slight saddle shape of the increment spectrum may suggest the presence of excess argon. In such a case the apparent age of the youngest increment located in the middle of the spectrum (circa 265 Ma) may be closer to the age of this mineral concentrate.

RID 5 – *whole rock* (Niculitel Fm. Basalt). The Niculitel Basalts are considered Triassic in age because of stratigraphic relation with paleontologically datet sedimentary rocks. The measurement was performed in order to find out whether younger than Herycian thermal events were recorded by the basalts. In thin section, both melanocrates and plagioclase appear partly altered. The obtained spectrum indicates that various K-bearing minerals have different ages. The

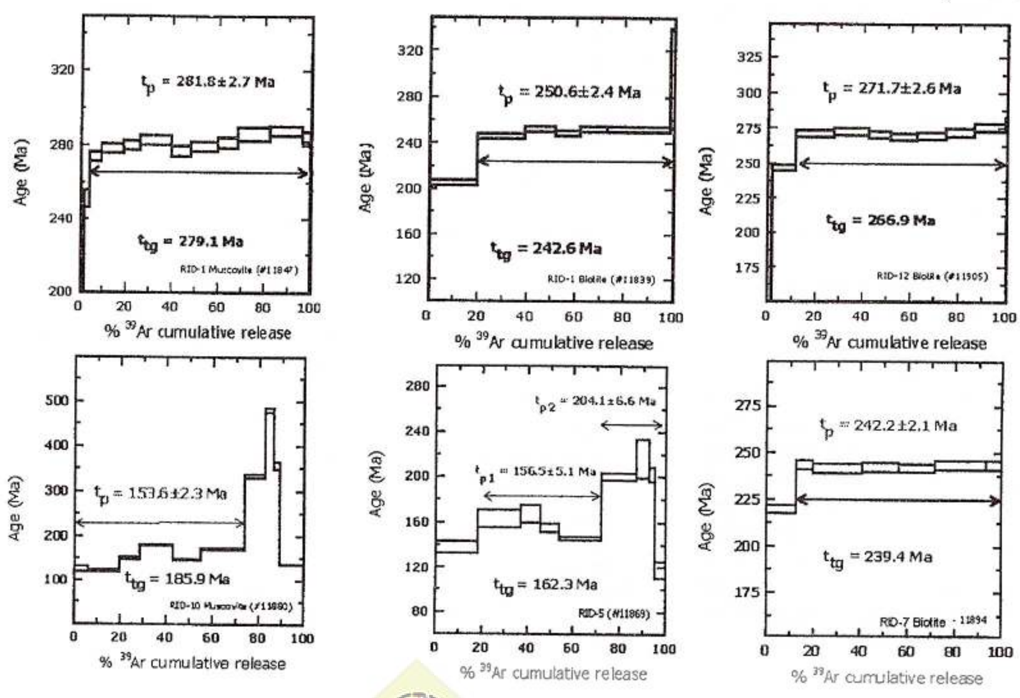

Figure 1. Ar-Ar spectra from North Dobrogea samples

two apparent plateau ages of 156.5±5.1 Ma and 204±6.6 Ma respectively, are only indications of the degrees of Ar resetting suffered by the K minerals. They correspond to the Oxfordian and Hettangian ages respectively, when compressional deformation affected both the basement and the Triassic sediments of North Dobrogea.

Two close plateau ages (RID 1 muscovite - 281.8±2.7 Ma and RID 12 biotite - 271.7±2.6 Ma) may indicate an Early Permian event; this correlates with the time of retro-arc thrusting in North Dobrogea, accompanied by a progressive metamorphism in low to very low grade conditions. Plateau ages of two biotites (RID 1 - 250.6±2.4 Ma and RID 7 - 242.2±2.1 Ma), corresponding to the Permian/Triassic boundary, may indicate the time of extensional ductile shearing and dyke emplacement. Two ages of about 150 Ma (RID 10 muscovite and RID 5) correspond to the Jurassic-Cretaceous boundary and can be correlated with the last compressional deformations which took place in North Dobrogea.

VARISCAN STRUCTURE AND HISTORY OF THE TESZ IN SOUTH-EASTERN POLAND

TO23

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The course of the TESZ between the Grójec Fault (central Poland) and the Carpathian Foredeep (SE) is not clearly defined. During the Variscan times (late Gedinnian - Westphalian) TESZ may have included entirely or partly the area stretching between the southern region of the Holy Cross Mts. being part of the Małopolska Massif (MM) from SW, and the elevated part of the East European Craton (NE). At present, the epicontinental Devonian and Carboniferous deposits of this area are folded and block-faulted, with reversed faults and positive flower structures in places, and regional strike WNW to NW. They are either exposed in the surface (HCMts.) or unconformably overlain by the Permian and/or Mesozoic.

Major tectonic zones trending parallel to the TESZ include: (1) Holy Cross Fault (HCF), corresponding to the boundary between the MM and Łysogóry Block, (2) elevated Radom - Kraśnik Zone with the Kazimierz-Ursynów Fault at its NE flank framing the Lublin Trough (LT) from SW, (3) Kock Fault Zone (= NE margin of the elevated ECC) bounding the LT from NE. The above zones are near-surface expressions of crustal discontinuities as may be inferred from previous geophysical studies (both DSS and potential fields measurements).

The strongest crustal contrasts seem to be associated with the HCF (6-7 km difference in crustal thickness). The Łysogóry Block area, with a thicker crust, differs from the southern margin of the MM also in displaying considerably larger Devonian tectonic subsidence and lacking Carboniferous deposits (possibly due to later erosion). However, the tectonic subsidence shows similar pattern of gradual decline during the Devonian. Southern margin of the MM shows continuous late Early Devonian to late Visean subsidence development with areally restricted evidence of insignificant extension (small-scale block-faulting, neptunian dykes) in the Late Devonian and Tournaisian.

The LT displays contrasting history of the tectonic development, with several episodes of accelerated subsidence (starting Frasnian, Asbian, late Namurian) separated by phases of uplift and subsequent basaltic volcanism (early Dinantian) or shift of the basin depocentre (mid-Namurian). In general, structural development of the LT during the Late Devonian to Carboniferous is interpreted in terms of intermittent pull-apart regime. It shows similarity to the evolution of the Dneper-Donets Rift which suggests common regional crustal deformation mechanism (Narkiewicz et al. 1997, Terra Nostra 97/11).

Basing on the available stratigraphical data and on tectonic subsidence analysis it seems most probable that, considering three above named structural zones, the Radom-Kraśnik Zone played the most important role in the structural and sedimentary development of the described area in the Devonian to Carboniferous. It separated crustal blocks of the Variscan foreland responding in a contrasting way to changing stress fields related to the orogenic compression from the (present) south and west. At present it forms the narrow (10-20 km) belt of strongest uplift/erosion and most complex structural deformations of probable transpressional character, related to the Late Carboniferous compression. Thus, it may be conceived as the most active part of the TESZ during the Variscan times.

TESZ SESSION POSTER PRESENTATIONS

THE CAPIDAVA-OVIDIU FAULT SYSTEM (OVIDIU SECTOR) IN THE POARTA ALBA-NAVODARI CANAL

TP1

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The Capidava-Ovidiu fault, representing the contact between Central and South Dobrogea (two major tectonic units of the eastern Moesian Platform), is exposed in the walls of the Poarta Albă-Năvodari canal. Some 4 km W of the Ovidiu-Hârşova highway bridge exposes fossiliferous Valanginian calcarenites (the Cernavoda Formation, Alimanu Member), Upper Barremian-Lower Aptian calcarenites, conglomerates and red marls (top of the Ramadan Formation), Maastrichtian glauconitic sands/sandstones and chalky marls (the Nisipari Formation), in South Dobrogea; Upper Jurassic dolostones and oncolitic calcarenites, which support Aptian deposits of the Gherghina Formation (mainly kaolinitic clays), then the Santonian-lowermost Upper Campanian basal conglomerate, glauconitic sandstone and massive chalk (the Murfatlar Formation), and also uppermost Lower Paleogene chalky marls and thin sandstones with marly interbeds, in Central Dobrogea; in between, several tectonic compartments preserve Upper Jurassic, Aptian, Santonian-Campanian and Paleogene deposits (the last ones including biocalcarenites with *Nummulites* - the Cetate Formation - but also spongolithes and chalky marls). The Maastrichtian and, in places, the Paleogene deposits constitute large elements in tectonic breccias, identified both in northern bank and in southern slope of the canal (see the anexed map). All these formations are discontinuously covered by fossiliferous Basarabian calcarenites in almost horizontal position.

The age of lithostratigraphical units was established especially by micropaleontological studies: top of the Lower Paleogene in the sites F1, F2, F3, F5 and, partly in F7, Valanginian in F6, Santonian-lowermost Upper Campanian in F4 and F2, respectively, and Maastrichtian in F7.

The tectonic evolution of the region, as observed from the areal spreading of the various lithostratigraphical units, includes an active subsequence and sedimentation in South Dobrogea during the Lower Cretaceous time-span up to the uppermost Aptian, when the kaolinitic sequence sealed the contact with the Central Dobrogea; a subsequent tectonic phase, during the late Early Paleogene, produced the folding near the contact and faulting of the Santonian-Campanian deposits and also the different succesions of Paleogene sequences in neighbouring areas; finally, the compartments preserving Maastrichtian and Paleogene breccias, in lower position as against both the Central and South Dobrogea, were brought to their actual position (probably due to an almost horizontal shifting from lower areas of the region) during a poorly constrained moment – between the Middle Paleogene and Basarabian.

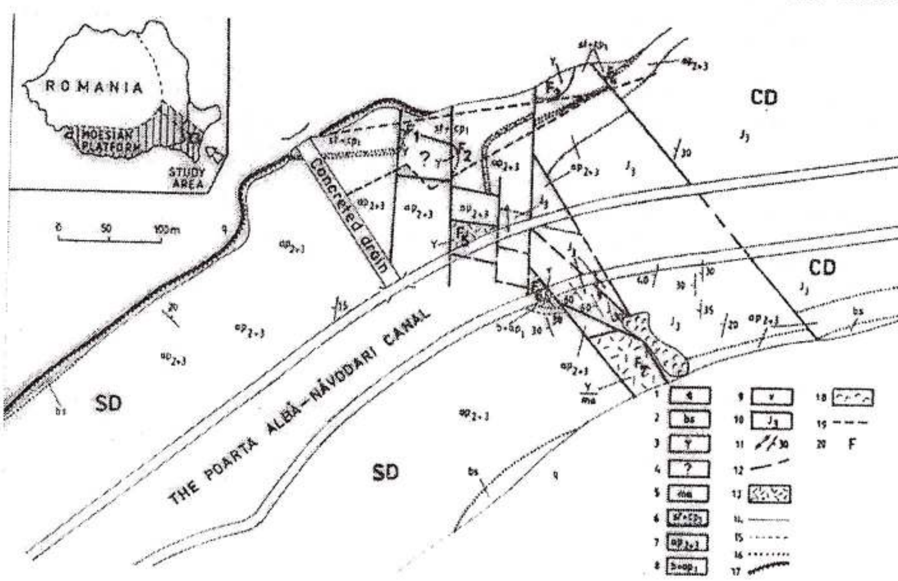

Figure 1. Map of the Central (CD) and South Dobrogea (SD) joining area, in the Poarta Albă-Năvodari Canal. Legend: 1, Quaternary; 2, Basarabian; 3, Upper Ypresian; 4, questionable Upper Ypresian (succession of the member"7" under the fossiliferous site F1); 5, Upper Maastrichtian; 6, Santonian-lowermost Upper Campanian; 7, Middle-Upper Aptian; 8, Upper Barremian-Lower Aptian; 9, Valanginian; 10, Upper Jurassic; 11, bed position; 12, fault; 13, tectonic breccias; 14, boundary of the Quaternary deposits; 15, geological boundary (s. l.); 16, uncomformity; 17, escarpment; 18, landslide; 19, topographic/compass sight; 20, fossiliferous site. Inset showes the location of the study area within Romania.

MAGLODAN PROJECT. THE FIRST STEP IN MERGING THE NATIONAL GEOMAGNETIC MAPS OF ROMANIA, UKRAINE AND REPUBLIC OF MOLDOVA

TP2

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There is a general trend in the Earth's sciences world to join geophysical images over the state borders in order to help in solving large-scale geological problems.

At the beginning of 1998 a joint venture between the Geological Institute of Romania, Subbotin Institute of Geophysics of the Ukrainian Academy of Sciences and the Institute of Geophysics and Geology of the Moldavian Academy of Sciences was started. The main aim of the project is the joining of the national geomagnetic maps of the three neighboring countries: Romania, Republic of Moldova and Ukraine.

The main project was scheduled for two phases. The first step was the achievement of a pilot geomagnetic map for the Low Danube area that encompasses confined regions belonging to the participant countries.

Research made within MAGLODAN (MAGnetic LOw DANube) sub-project were intended to solve basic problems of the merging operation such as:

- to compare national geomagnetic standards
- to provide a common reference level
- to remove the secular variation effect
- to overpass administrative problems
- to train scientists from various countries for a future more developed common research, etc.

COMPARING THE NATIONAL GEOMAGNETIC STANDARDS

To compare the national geomagnetic standards common geomagnetic determinations were performed at the Surlari Geomagnetic Observatory (Romania) and Stepanovka-Odessa Geomagnetic Observatory (Ukraine). Republic of Moldova has no geomagnetic observatory and actually all determinations used for the geomagnetic mapping of its territory were carried out by an Ukrainian team.

A GEOMETRICS proton magnetometer and an MP-01 proton magnetometer were used to compare the reference level of the two above-mentioned observatories.

Except for small scattering within the range of the instrument accuracy no systematic difference was found.

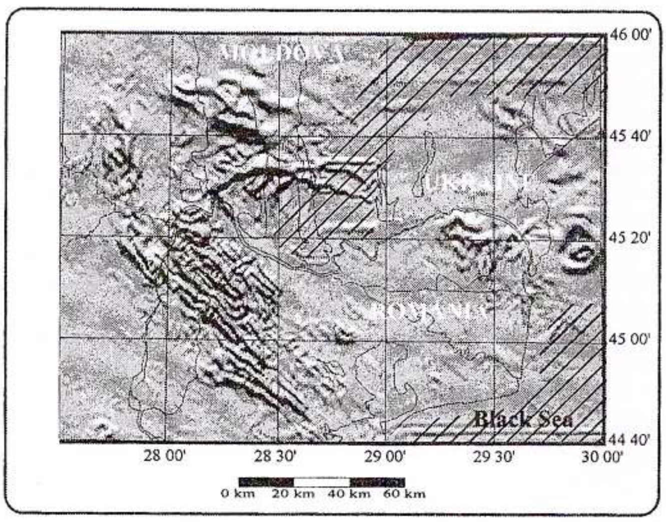

Fig. 1 Horizontal gradient of the geomagnetic anomaly within Low Danube area

Hillshaded from North under 40 degrees

missing data area

SETTING UP THE REFERENCE LEVEL OF THE GEOMAGNETIC MAP

As in any composite geomagnetic map, one of the main problem was to ensure a common reference level to data provided by surveys carried out at various epochs, with different instruments and base stations.

In order to overpass such inconveniences a common international reference network covering the area of the future pilot-map have been achieved. It consisted of 8 base stations (4 in Romania, 2 in Ukraine and 2 in Republic of Moldova). A consistent data set of ground total intensity scalar of the geomagnetic field, as annual mean values for the epoch 1998.0, was then obtained by referring the gathered results to the geomagnetic level of the Surlari observatory.

To compare the reference level of the geomagnetic surveys used in the construction of the composite pilot-map, micro-panels (100 meters by 100 meters) have been measured for every base station of the reference network and upward continued to flight altitude of the airborne measurements.

CONSTRUCTION OF THE MAGLODAN GEOMAGNETIC MAPS

1. Computer database

As row data for the Ukrainian and Moldavian territories were not available (materials provided by the Ukrainian and Moldavian partners were contour ΔT_a maps only) the first step was to digitize the anomaly maps and to create a computer database with all the available information.

2. Gathering a common reference level

To compare and correct the various reference levels of the previously carried out surveys to the common level provided by the international geomagnetic reference network absolute values of the normal geomagnetic fields (ngf) have to be added to ΔT_a values. Consequently, numerical ngf models had to be first created starting from the graphical LO-IZMIRAN models used in the construction of the anomaly maps. Fourth order polynomials successfully approximated graphical models within the range of ± 2.5 nTs.

After the correction of the reference level, a consistent geomagnetic data set for the epoch 1998.0 was gathered and total intensity scalar maps could be constructed.

3. Checking up the joining accuracy

To check up the quality of the joining operation horizontal gradient maps have been performed. No gradient trends within the state border area have been pointed out, thus proving the high accuracy of the gathered geomagnetic maps.

4. Geomagnetic anomaly images

To get more intuitive images, regional trends have been removed from the total intensity scalar maps by using polynomial regression technique.

CONCLUDING REMARKS

As previously stated out MAGLODAN sub-project represents the first step in joining the national geomagnetic maps of Romania, Ukraine and Republic of Moldova. The quality of the pilot-maps is the best evidence for the correct algorithm used and a guaranty for the final success of the operation.

GEOCHEMISTRY AND DEFORMATIONAL HISTORY OF METABASIC VOLCANIC ROCKS FROM NORTHERN AND CENTRAL DOBROGEA, ROMANIA

See TO18

TP3

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TP4

DEEP GEOLOGICAL STRUCTURE OF DANUBE DELTA AREA AS DEDUCED BY 3D INTERPRETATION OF GEOPHYSICAL DATA

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The Danube Delta is located on the Romanian coast of the western Black Sea Basin, in the northern part of Dobrogea. The relatively unconsolidated sediments of the delta edifice lie and totally cover the older geological formations that belong, from North to South, to Scythian Platform, North Dobrogea folded belt and Moesian Platform. Each of these main geotectonic units has a quite different lithology and geological history.

The Scythian Platform represents the downthrown compartment of the Predobrogean Depression, conventionally bordered southward by the Sf. Gheorghe Fault, with a pre-Vendian basement pierced by boreholes in Moldavia and Ukraine and a Vendian to Quaternary sedimentary cover. The North Dobrogea folded belt, confined between the Sf. Gheorghe and Peceneaga-Camena Faults, shows a western uplifted Hercynian basement block (Macin zone), overthrusting the eastern, Tulcea zone (exposing mainly Triassic-Jurassic formations), along the steep, NW trending Luncavița-Consul Fault. For the internal structure of this belt both a nappe structure and a high-angle thrust and fold model are infered. The Early Alpine structures of North Dobrogea are covered by the Late Cretaceous shallow water formations of the "Babadag Basin", that prolongates beneath the sediments of the southern Danube Delta towards the Histria Depression from the Black Sea continental shelf.

Located South of North Dobrogea, Central Dobrogea represents an uplifted compartment of the Moesian Platform, with the Cadomian basement exposed between the bordering Peceneaga-Camena and Capidava-Ovidiu Faults.

The unconsolidated sediments of the Danube Delta complex consist of marine and lacustrine littoral deposits, fluvial deposits, marsh deposits and loess-like deposits of ages ranging from 11,700 years BP to present (Panin, 1996). The thickness of delta sediments, determined by high-resolution seismics (Spânoche & Panin, 1997), ranges between 10 to over 200 m, with the greatest sediment thickness attained east of Lake Razelm.

Earlier regional scale gravity and magnetic (vertical component) measurements covered the entire Danube Delta (Airinei, 1968). The national aeromagnetic project (Cristescu & Ștefănciuc, 1968) covered most of the Romanian territory, including the Danube Delta area. Later, detailed gravity and magnetic surveys were carried out in the southern Danube Delta (Dimitriu, 1996; Dimitriu & Eufrosin, 1997; Beșuțiu, 1998). Seismic data have been recorded until 1981 along approximately 450 km of seismic lines. Several stratigraphic and deep structural wells have been drilled within Danube Delta area. The results of the completed drilling project, synthesized by Pătruț et al. (1983), compiled with results of the above mentioned seismic surveys, practically ended the process of deciphering the deep structure of the Predobrogea depression (up to approximately 3,000 m depth).

The main aim of the new, enhanced 3D interpretation is to fully utilize the valuable structural and lithological information offered by gravity and magnetic investigation methods. Gravity effects due both to Conrad and Moho discontinuities relief (according to Cristea et al., 1994) and to relatively poor consolidated Danube Delta's quaternary sediments have been computed by 2D and 3D modeling in order to constrain the interpretation within a certain depth domain. Regional-residual effect separations for both gravity and aeromagnetic data have been also computed. An integrated interpretation of all available geological and geophysical data resulted in the following main conclusions:

- The deep boundaries between the main geological units are more accurately pointed out in an area with very few available geological data.
- The existence of two main fault systems is pointed out. The older system with a NW-SE trend includes some of the most important faults that constrain the geotectonic units and crustal blocks of the region (Peceneaga-Camena, Capidava-Ovidiu, Ostrov-Sinoe, Histria and Sf. Gheorghe Faults). The younger system shows a N-S trend in the Scythian Platform (Neaga & Moroz, 1987; Zelinski et al., 1987; Rogoza et al., 1988), gradually changing to the NE-SW trend of the Moesian Platform (Visarion et al., 1990; Dimitriu & Eufrosin, 1997).
- The presence of a high-density anomalous body, with over average magnetic properties, within the Moesian metamorphic basement.

Some previous geotectonic models (Săndulescu, 1984; Visarion et al., 1990) favour the nappe structure of the North Dobrogea folded belt, which overthrusts in its turn the Paleozoic and Mesozoic deposits of the Scythian Platform.

The important bulk of mixture of sedimentary and volcanic origin, composed mostly of basaltic rocks, that corresponds, according to geophysical data, to Niculitel-Consul Unit, represents an buried and squeezed paleorift that was active during the Triassic.

A thick, relatively low density Paleozoic succession and the presence of a granite body in the basement of Tulcea Unit both fully justify the amplitude and the extension of the North Dobrogea gravity low and also the presence of the regional aeromagnetic anomalies.

The shallow boundary between the orogenic unit and the Scythian Platform (i.e. the Sf. Gheorghe Fault) is now traced, by geophysical bases, more northward that it has been previously considered. The deep boundary between the same geotectonic units may be traced on-shore, in full accord with off-shore geophysical data interpretation (Moroșanu & Sava, 1998), southward of Tulcea and Periteașca.

In the basement of the Predobrogean Depression, beneath the geological knowledge limit reached previously by structural wells and prospecting seismic interpretation, the new gravity and magnetics based interpretation, indicates the existence of a graben-like structure (i.e. Sulina graben) filled with Paleozoic deposits, of a horst-like structure (i.e. Chilia horst) and also the presence of a large and differentiated magmatic body. In the Scythian Platform, the extension of the Paleozoic formations is an object of increasing interest due to its already known hydrocarbon potential (Matchoulina, 1998).

TP5

REGIONAL TECTONIC FRAMEWORK OF THE TRANS-EUROPEAN SUTURE ZONE FROM GRAVITY AND MAGNETIC DATA

See TO2

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DEEP REFLECTION AND REFRACTION SEISMIC CONSTRAINTS ON CALEDONIAN ACCRETION IN THE SOUTHERN BALTIC SEA

TP6

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See TO7

PERMO-CARBONIFEROUS TECTONO-SEDIMENTARY EVOLUTION AT THE NORTHERN MARGIN OF THE NORTHEAST GERMAN BASIN

TP7

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The intracontinental Northeast German Basin (NEGB) forms part of the southern Permian Basin. This series of interconnected basins extends from England to Poland over more than 1500 km. The basin is located between the stable Precambrian Baltic Shield to the north and areas which were influenced by the Caledonian and Variscan orogenies to the south. In the central parts of the basin, the Phanerozoic strata are up to 10 km thick. The study area is situated in the northeasternmost part of Germany. During Permo-Carboniferous times this was the northern NW-SE orientated margin of the Southern Permian Basin. The Upper Carboniferous and Lower Rotliegend is characterized by the extrusion of large volumes of volcanic rocks (up to ca. 2000 m thick), mainly rhyolites, acid and basic andesites, and tholeiitic and alkali basalts. The Lower Stephanian and Upper Rotliegend sedimentary strata are represented by continental red clastics, deposited under semiarid to arid conditions. The depositional environment comprises a perennial lake in the basin center, mudflats and sandflats in the transitional zone and alluvial fans at the basin margin. The drilled profiles of the central and transitional area shows an overall fining upward trend.

Deep seismic data (DEKORP-campaign Basin'96), together with industrial profiles from the northern margin of the basin, facilitate the detailed analysis of the Carboniferous and Rotliegend sedimentary succession of the region. A network of seismic profiles cover an area of about 40x80 km along the northern margin of the NEGB. More than 30 deep hydrocarbon exploration wells penetrate the Permo-Carboniferous succession. Selected wells provided the stratigraphical calibration of the seismic reflection data. Additional data included geophysical logs and 400 m of Rotliegend core material.

The tectono-sedimentary evolution of the northern part of the NEGB was initiated during the Late Carboniferous. The sedimentary succession of the study area consists of predominantly clast-supported, fine to medium gravelly conglomerates, which are interpreted as proximal fluvial fan facies. Isopach maps of Stephanian and lower Upper Rotliegend Formations show depocenters with length of about 40 km and width of 30 km aligned in a SE-NW trend across the region. Up to 700 m of Rotliegend conglomerates and more than 300 m of Stephanian strata were drilled within these centers. Rapid variations in sediment thicknesses are observed and are interpreted as due to coeval normal faulting. The depositional pattern suggests that sedimentation occurred within an NW-SE trending array of pull-apart basins. The alignment of these basins indicates a dextral NW-SE trending master fault. Its position suggests a link with the intraplate Tornquist Zone where Permo-Carboniferous dextral transtensional movements are known. These movements are related to Early Stephanian dextral strike slip movement of the European versus the African plate.

MODES OF THE LATE MESOZOIC AND MIOCENE TECTONIC ACTIVITY ALONG THE TRANS-EUROPEAN SUTURE ZONE - FROM THE BALTIC SEA TO THE CARPATHIANS

TP8

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Orogenic processes can be responsible for variations in evolution of sedimentary basins located in the far-field of the evolving orogenic belt. Also, development of various foreland inversion structures can often be connected to evolution of orogenic belts and related transmission of compressional stresses into the foreland plate. Numerous seismic examples of such processes were identified within the foreland plate of the Carpathians, along the broadly defined Trans-European Suture Zone. They allowed for spatial and temporal interpretation of various aspects of the Polish Trough (PT) inversion and later reactivation of inherited foreland structures during subduction processes.

First group of such structures is related to the Late Cretaceous/Tertiary inversion of the PT and development of large basement inverted faults. Their development was most probably to at least some degree controlled by thickness of ductile Zechstein evaporitic successions that may have acted as detachment level between brittle Palaeozoic basement and Triassic to Cretaceous sedimentary infill. In the N part of the PT, in the Baltic and partly Pomeranian segments where Zechstein evaporites are either absent or of small thickness, these faults cut both Palaeozoic basement and Mesozoic basin infill. More to the south, especially in the central part of the PT where evaporites are of considerable thickness (e.g. Piła - Szubin area), presumed inversion of older extensional faults was restricted to pre-Zechstein section. It has resulted in basement block rotation, development of inverted faults and basement highs, and initiation of related salt structures. Along the NE edge of the PT, in places characterised by Mesozoic transtensional activity and relatively thin Zechstein cover, series of inverted faults formed that cut high into the Cretaceous section (Koszalin-Chojnice anticline). Numerous seismic unconformities observed above this anticline combined with well information allow for precise dating of inversion of this part of the PT. Oblique collision of the Carpathian belt with NW-SE orientated PT has also led to tectonic movements along faults perpendicular to the PT, like Grójec fault. Several seismic lines clearly show typical flower structures developed within the Mesozoic section along this fault that prove its strike-slip character.

During Miocene subduction of the foreland plate below the Carpathians another group of foreland structures formed. In SW part of the PT located in Kraków area (so-called Nida Trough) numerous SW-NE inverted faults developed above the areas of earlier extension. Slightly towards the S, below the Miocene sediments of the Carpathian Foredeep Basin (CFB) small-scale reactivation of Mesozoic NW-SE extensional faults can be observed. In the eastern part of the Polish segment of the CFB (Przemyœl - Lubaczów area) large extensional faults formed due to flexural extension of the downgoing foreland plate. They were interpreted as reactivated inherited fault that were initially formed during extensional phase of Jurassic(?) development of this part of the PT. Also, some strike-slip activity also took place along some of these faults, that was due to oblique collision of the Carpathian orogenic wedge in respect to major NW-SE orientated foreland plate structures related to the PT evolution.

ROTLIEGEND CONGLOMERATES FROM THE NE GERMAN BASIN - PROVENANCE AND SIGNIFICANCE

TP9

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The NE German Basin, containing more than 10-12 km of Phanerozoic strata, is part of the southern Rotliegend Basin, a series of connected basins extending across northern Europe from England to Poland. The southern Rotliegend Basin, with a N-S extension of 200-400 km and an E-W extension of >1500 km, developed between the northern foreland of the Variscan mountain belt and the Ringkøbing-Fyn High. The NE German Basin contains an approximately 2.5 km thick Rotliegend sedimentary section, subdivided into four formations. These were deposited following the cessation of the Late Carboniferous/Early Permian volcanic episode and a suggested ca. 20 Ma period of erosion and non-deposition. The volcanic succession is up to ca. 2 km thick, with a total volume of ca. 48,000 km^3. It was formed subsequent to the syn-late tectonic magmatism of the continent-continent collision of the Variscides and prior to the onset of broad regional sedimentation.

The most important hydrocarbon reservoir unit in the NE German Basin is the Lower Permian Rotliegend sequence of continental clastics. The succession is similar to that of western Germany and is also sourced from the underlying Upper Carboniferous (Westphalian) coal measures. Initial deposition was confined to two location, but with increasing thermal subsidence the basin extended to the south.

Sandstone composition is a sensitive recorder of climatic and physiographic variations in source area. Previous petrographic work in the area has indicated that the Rotliegend-age sandstones are quartz-rich and derived predominantly from cratonic or recycled sources. Volcanic and sedimentary rock fragments form most of the labile grains. The succession was deposited in a relatively stable tectonic environments with sediment input derived largely from the Lower and Upper Palaeozoic strata of the Variscan hinterland and the Upper Carboniferous and Lower Permian volcanics.

The present study is concentrated on a suite of more than 50 conglomerates from the Rotliegend in order to examine, in detail, individual clast composition and derivation. This was then related to the underlying geology to provide a more detailed picture of the lithological distribution, transport pathways and source areas.

THE NATURE OF THE VARISCAN DEFORMATION FRONT IN NE GERMANY - EVIDENCE FROM DEEP SEISMIC PROFILING

TP10

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The Variscan Deformation Front (VDF), extending from Ireland to Poland, is a significant Late Palaeozoic feature across NW Europe. Its precise expression, however, changes according to the geographical location. Location of the precise position of the VDF in NE Germany is a much more complex matter, complicated by the ca 10,000 m of post-Variscan sediments and associated volcanics that occupy the basin. While there are a large number of exploration wells in the region, relatively few of them core Carboniferous strata. Furthermore, existing gravimetric, magnetic, magnetotelluric and geoelectric data are inconsistent. Despite this, a number of interpreted structures from deep-seismic profiles have been used to define the trend of the Variscan Deformation Front in the region.

Reexamination of older deep seismic profiles, together with the BASIN '96 profile, has revealed the nature of deep crustal structures in this poorly understood region. Basement structures were traced across the northern margin of the NE German Basin using three deep seismic profiles (BABEL A, DEKORP-BASIN 9601, NIZUSE) and through the main part of the basin using four additional profiles (GLG 04, PLG 10, KYRZ 9004, ELG 14; made available by EE Gommern GmbH). Based on these data, there is no evidence of any major thrust features which could be definitively termed Variscan in origin in the area where the Variscan Front trend had been indicated. Furthermore, critical examination of the published seismic profiles, together with unpublished ones, would further confirm the lack of any real evidence in deep-seismic profiling for thrust features, as noted elsewhere in Europe, which could be related to the Variscan orogenic event.

The lack of these structures in eastern Germany may suggest that the style of Variscan deformation in the region was different to that in western Germany. Certainly the geological evidence, particularly that in outcrop, indicates that Variscan-age deformation did occur. However, the northerly extent of this deformation is not clear.

CALEDONIAN METAVOLCANICS FROM THE EAST CARPATHIANS: GEOCHEMISTRY AND TECTONIC SETTING

TP11

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Acidic metavolcanics (porphyroids) occur in the East Carpathian Tulghes Group, Cambrian-Lower Ordovician in age, with a Caledonian metamorphism under greenschist facies PT conditions. The porphyroids of Tulghes Group are built up by a fine-grained groundmass (quartz + feldspar + muscovite) in which quartz, K-feldspar, plagioclase and, seldom, biotite phenocrysts occur. Quartz and K-feldspar may show corrosion shapes.

The porphyroids are peraluminous rocks (asi=1.12-2.6) with up to 8% normative corundum. Their geochemical features indicate a crustal origin of the magmas. The trends of the major components plotted against silica indicate non-minimum melt compositions. Mg and Ca have similar trends and seem to have fractionated together in the earliest stages of magma differentiation either as restites or by fractionate crystallization.

Chondrite-normalized REE patterns show steep trends for LREE, flatter trends for HREE and pronounced Eu anomalies. REE patterns indicate differentiation when normalized to NASC, too, suggesting metagraywacke source materials rather than metapelite. The high SiO_2 content (70-82% with nearly half of the samples between 76 and 78% SiO_2) suggests the presence of quartzite intercalations in the source rocks.

The correlations between REE on the one hand and P_2O_5, TiO_2 and Zr, on the other hand, indicate that the concentration of REE was controlled mostly by apatite for Fundu Moldovei and Dealul Rusului porphyroids, and by zircon for Puiu porphyroids.

Rb vs. Y+Nb, Rb vs. Yb+Ta, Nb vs. Y and Ta vs. Yb diagrams indicate that the parent magmas were generated in a volcanic arc environment. This diagnostic is consistent with the occurrence of associated mafic rocks, both depicting accumulation of the Tulghes Group pile in a mobile belt-related tectonic environment.

NEREITES ICHNOFACIES IN THE PALEOZOIC OF NORTH DOBROGEA

TP12

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In the northern part of North Dobrogea, the Bestepe Formation (Devonian) of Tulcea zone in North Dobrogea contains a distal turbiditic member, very rich in traces of organic activity. The trace fossil assemblage is characterized by a high diversity (*Chondrites, Helminthoida, Helminthopsis, Protopalaeodictyon, Scolicia, Nereites*, etc.) and low abundancy, belonging to the "Nereites ichnofacies" in Seilacher's model, with typical sinuous and complex planar forms. This assemblage suggests an abyssal area, in a distal turbiditic fan environment, with oxigenated waters, situated at depths of several hundreds of meters.

Anchimetamorphic Paleozoic formations of the Măcin zone (Cerna, Bujoare, Beştepe and Carapelit formations) contain rare traces of organic activity. Slates of the Cerna Formation (Silurian) in the Măcin zone show faecal pellets deposited in pelagic or hemipelagic sediments. Shelf sediments (Bujoare Formation), limestones and mudstones, include milimetric endichnial and hypichnial channels. Fine grained sandstones and siltstones of the continental Carapelit Formation (Permo-Carboniferous) contain only ichnogenus *Planolites* and several bioturbated sediment beds.

DEEP MARINE SEDIMENTATION OF THE HISTRIA FORMATION, CENTRAL DOBROGEA (ROMANIA)

TP13

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The basement of the north-western part of the Moesian Platform consists of a 3200 m thick succession of Late Proterozoic – Early Cambrian turbidites (Histria Formation) exposed in Central Dobrogea. Histria Formation includes sandstone dominated coarse members, with subordinate conglomerates and fine-grained rocks (siltstones, musdtones), showing a large diversity of well preserved sedimentary structures.

Sedimentological studies documented various lithofacies, associated in channels, depositional lobes, interchannel and distal fan-abyssal plain environments. Vertical facies associations in coarsening and thickening upward sequences, typical for channel progradation, separated sometimes by fining and thining upward sequences, indicating aggradation of depositional lobes, suggest accumulation in a foreland basin with depths up to 4500m (Carbon compensation depth) with longitudinal sediment transport.

A south location of the main source area of the turbiditic suite results from paleoflow directions measured in the coarse members, which indicate a northward directed transport, normal to the longitudinal axis of the depositional basin. Finer grained sediments have been transported westward (from east to west), parallel to the longitudinal axis of the depositional basin, west to east paleoflow directions being the main transport direction in the basin. Secondary flow directions, from east to west and north to south, respectively, would indicate the presence of tectonic highs within the depositional basin.

The stratigraphy of the Histria Formation includes two coarse members of midfan turbidites, with a thick lower member (2000 m) and a thinner upper member (700 m), with conglomerate facies directly overlying the middle, dominantly fine-grained member (500 m) of distal fan-abyssal plain turbidites. The regional stratigraphy of the Histria Formation can be related to the global sea level changes during Late Precambrian – Early Cambrian, belonging to the oldest first order cycle.

Biogenic structures, scarcely occuring on bedding planes in pelitic intervals, include various types of meandered trails, bioturbations and a medusoid structure (mould) very similar to the Ediacara fauna from Australia and the East European Platform.

TODAY'S TEMPERATURE FIELD OF THE NE-GERMAN BASIN - COMPARING TEMPERATURE MEASUREMENTS AND 3D-MODELING

TP14

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For the past four decades the Northeast German Basin has been drilled extensively in search of natural resources. Part of this data set, which includes well data, isopach, thickness and depth maps, is available for research and was used to construct a 3D structural model of the Basin. The model covers an area of

230x330 km extending down to 33 km depth and focuses on the post-Devonian sedimentary basin fill. Although spatial resolution of this large-scale basin model is limited because of a 4x4 km grid spacing which cannot resolve all details, it includes important geological features e.g. large salt diapirs.

The digital model provides the framework to calculate the conductive thermal field using a 3D-FEM model. For the simulations, the stratigraphic units of the model are assigned average physical properties according to the dominant lithology of each unit. The resulting physical model is then used to calculate the present day conductive temperature field of the basin assuming that advection of heat does not play an important role on the scale of the model. The modeling results are compared with temperature data obtained from a large number of wells throughout the basin.

In general, the agreement between modeling results and measured temperature data is good but requires improvement in certain regions. Towards the northeast the model is warmer while in the center it is colder than the measured temperatures. It can be shown that the deviation is partly due to oversimplification of the model in terms of facies distribution, thickness of pre-Carboniferous sediments and inadequate physical rock properties. The model should be improved with respect to the pre-Carboniferous sediments particularly in the Ruegen area. The observed discrepancies between modeled and measured temperatures in the NE part of the region may be elucidated by this more comprehensive model. The present model will be improved with respect to facies-dependent lithological variations and temperature-dependent physical rock properties.

THE VARISCAN OROGEN IN BULGARIA - NEW ISOTOPE-GEOCHEMICAL DATA

TP15

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The Variscan orogen in Bulgaria is traditionally connected with the granites in the Balkan Mountain. The formation of these granites is considered as result of the collision of the Moesian Platform (Moesian terrane), to the North, and the Balkan terrane to the South (Haydoutov, 1989, Haydoutov and Yanev, 1997). In the last 15 years new publications reported about Carboniferous-Permian age of granitoids and metagranitoids in Sredna Gora and the Rhodopes: Zagorchev and Moorbath (1986) determined an age of 340 Ma, 300-320 Ma and 270-240 Ma for the three granite complexes in Sredna Gora; Quadt, Peytcheva (1995) and Peytcheva et al. (1998) suggested ages from 300 to 350 for metagranites in Eastern Rhodopes, exposed in the cores of the Byala Reka and Kessebir Domes.

We present here new Rb-Sr and U-Pb zircon data that confirm the wide formation of Variscan magmatites in the Rhodopes. U-Pb zircon investigations of porphyroclastic metagranites (S-type) in Kessebir reka region determine an age of about 320 Ma for the granite formation. In the Madan-Davidkovo Dome, located to the west of Kessebir Dome, whole-rock granidoid samples were analyzed, using Rb-Sr method. The corresponding points determine an errorchrone, which slope allow us to calculate an age T 340±42 Ma, $(^{87}Sr/^{86}Sr)_0=0.7072\pm0.0007$ and MSWD=193. The big scatter of the points is interpreted as a result of the high-grade Alpine metamorphism, that overprinted the granites - amphibolite facies with migmatization in some parts (Arnaudov et al., 1990).

On the Rb-Sr isotope diagram the samples from the three domes: Byala reka, Kessebir and Madan-Davidkovo, are not only parallel, but also show a close initial strontium ratio. This fact suggests granite formation from an uniform or quite similar magma source.

The data about the Variscan granites put some questions for discussions:

- the correlation of the metamorphic rocks in Sredna Gora (Ograzhden complex), intruded by Hercynian granitoids, from one side, with the metagranites in Eastern and Central Rhodopes, from the other side (made by the authors of the Bulgarian geological map), is impossible. As shown above the protholites of the Rhodopean metagranites are themselfs with C-P age;
- this leads to a new view about the margins of the Balkan terrane and makes actual the idea for a Drama continent (Burg et al., 1996, Ricou et al., 1998), as a piece of Gondwana, drafted to the North in post-Pz time. The last idea needs further improvements, including isotopic.

Further isotope-geochemical comparisons of the Bulgarian C-P granitoids will be useful for genetic interpretations and the understanding of the South European Variscan suture.

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LATERITIC PALEOWEATHERING CRUSTS FROM DOBROGEA – PALEOCLIMATIC, PALEOGEOGRAPHIC AND PALEOTECTONIC IMPLICATIONS

TP16

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Lateritic weathering crusts develop in times when well known conditions occur: warm and humid, intertropical climate, tectonic quiescence, favourable to peneplane development, a bedrock with suitable petrography (preferably feldspar rich) and a very high water/rock ratio, due to an intense rainfall and a well drainage of the leaching solutions.

In Central Dobrogea, relics of a pre-Upper Bathonian lateritic crust are preserved beneath the Jurassic (Bathonian-Kimmeridgian) carbonate platform sediments of the Casimcea syncline. The lateritic crust, developed on the Late Proterozoic basement rocks of the Histria Formation includes three main units: saprolitic, fanglomerate and resedimented.

The mineralogy of the clay fraction reveals the evolution of the clay mineral associations in the sequence of crusts: from an initial illite-chlorite clay fraction of the bedrock to a kaolinite-illite-smectite assemblage. The saprolitic unit is characterized by diminishing or dissapearence of chlorite, dominantion of illite, and the appearence of kaolinite (10-15%) and smectite (5%) as first indicators of the lateritic weathering. Within the argillic zone and in the matrix of the "fanglomerate" unit, chlorite is absent, illite diminishes (30%) and the kaolinite and smectite contents increase to 50-60% and 10-15% respectively.

In North Dobrogea, relics of a pre-Cenomanian crust are preserved beneath the Cenomanian; while caolinite-rich, Aptian continental deposits occuring in South Dobrogea derived from reworking of the mentioned ancient weathering crusts from North and Central Dobrogea.

Relics of a pre-Cenomanian weathering crust are scattered all over the western, Măcin zone of North Dobrogea, where the Precambrian metamorphic rocks and the Paleozoic formations preserve in places signs of a deep weathering. The most obvious relics are recorded in Mircea Vodă, the crust being formed on gneisses and amphibolites of the Megina Group and preserved beneath the fossiliferous Cenomanian calcareous sandstones. This crust consists of a saprolitic unit still preserving the features of the primary rocks, covered in places by a resedimented unit consisting of thin sandstones, sands and red clays. The mineralogical distribution suggest the classical zonality of residual deposits: in the saprolitic zone, the clay fraction mineralogy is dominated by well crystallized smectite (46-100%); the kaolinite becomes dominant (70-100%) in the upper levels of the lateritic section and in the resedimented sands and clays; illite is subordinate (0-47%), while chlorite is accidental (0-5%).

The weathering crust relics identified in Dobrogea were produced in two of the main kaolinization periods of the Central Europe (Stör et al., 1977): Late Triassic – Early Jurassic and Cretaceous-Miocene. The pre-Late Bathonian crust resulted during the Late Triassic – Early Jurassic. The pre-Cenomanian crust, belonging to the last kaolinization period identified in Central Europe, has formed in close connection with the development of the Early Cretaceous peneplane in Europe.

Climatic conditions favorable to intense chemical and biochemical weathering have been recorded during the Aalenian, Toarcian, Hettangian and Late Triassic. Geological evidence indicate that the weathering crust from Central Dobrogea was eroded before the Bathonian. It is a well known fact that kaolinite-rich siderolitic deposits derived from removal of lateritic crusts include quartitic sands or sandstones, as well as coal beds. Accordingly, the Aalenian-Bajocian subcontinental sequences of quartzose sandstones, sands, clays and coal, pierced by boreholes in the eastern part of the Moesian Platform, might represent the products of the lateritic facies existing at least on the area of present Central Dobrogea. Accumulation of the Aalenian-Bajocian deposits suggests that an active source-area, represented by an uplifted land mass, appeared in the eastern part of the Moesian Platform during the Donetz phase (Toarcian/Aalenian) of the Alpine orogeny. The presence of the pre-Bathonian crust might be recorded by the clay fraction of the Bajocian-Bathonian Dunavățu Formation from North Dobrogea, and consequently the age of the weathering crust from Central Dobrogea might be as old as the Toarcian. An older, Hettangian lateritic crust, even if existed, might have had less chances to be preserved in such a long time-span, but it might have left traces in the clay ineral association of the Sinemurian-Pliensbachian deposits of North Dobrogea (Nalbant, Denis Tepe and Poşta Formations).

In the larger framework, the presence of an Early Cretaceous and Aptian continental formation in the adjacent areas suggests an Early Cretaceous age for the pre-Cenomanian crust from North Dobrogea, to cover the time-span necessary for transport and resedimentation of these deposits. A subtropical, warm and humid climate characterized was typical throughout the Cretaceous, favourable to lateritization, and the deposition of the pre-Aptian carbonate sequence in South Dobrogea suggests the absence of intense erosion in the neighbouring emergent areas, typical for times of tectonic quiescence and favourable to accumulation of a significant lateritic cover.

MARINE GRAVITY AND MAGNETIC DATA OVER THE BLACK SEA ROMANIAN SHELF

TP17

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In view of improving the knowledge on the geological structure of the Romanian Black Sea shelf, including the continuation of on-shore tectonic units into the marine domain, gravity and magnetic measurements have been carried out in addition to the seismic ones.

The offshore gravity measurements started in 1980, initially being used underwater meters (GDK) and subsequently onboard ones (GMN-K), both of Russian production.

The magnetic measurements started with land magnetometers, by means of an original methodology; later, marine proton magnetometers produced in Romania have been used to map the Romanian shelf.

Computer programs for processing the marine gravity and magnetic data, as well as 2D and 3D modeling software have been drawn up.

In 1985, the first results of the marine gravity and magnetic surveys have been presented at scale 1:500,000, later on, the territory being systematically mapped at scale 1:200,000. The geophysical maps have been constructed using a 2.5 mGal interval for gravity, and 50 nT interval for magnetics.

In 1990, detailed gravity and magnetic surveys have been started, mainly in the area of shoreline, aiming at producing geophysical maps at 1:50,000 scale and revealing relations between the on-shore and offshore geological structures. The precision of the geophysical maps has been much improved, the contouring intervals being 1,0 mGal for gravity and 10 nT for magnetics.

The integrated interpretation of the gravity and magnetic data led to a regional view of the relations between the on-shore and off-shore geological structures, or revealed particular aspects related to local anomalies associated with salt or magnetic bodies.

HERCYNIAN DEFORMATION AND VERY LOW GRADE METAMORPHISM OF THE PALEOZOIC FORMATIONS IN NORTH DOBROGEA

TP18

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Hercynian deformation in very low grade metamorphic conditions of Paleozoic sediments from North Dobrogea resulted in two slate belts. The northern belt, exposed in the cores of two Jurassic anticlines in the eastern, Tulcea zone, includes the Ordovician-Devonian remnants of an accretionary wedge. The western belt crops out in the western, Măcin zone, where shallow marine Silurian-Early Devonian and Late Paleozoic continental successions form the infill of two NW-SE Early Alpine synclines.

Northward vergent recumbent folds, refolded by normal folds with nearly E-W trends characterize the structural style of the northern belt, while tight to open normal folds with a constant ENE-WSW structural trend are typical for the western belt. Deformation of the Paleozoic formations is highly variable, as usuall in multilayered sequences with highly unpredictable lithological and thickness variations. A penetrative, steeply dipping slaty cleavage typically develops in all Paleozoic lithologies, with spacing, morphology and microstructure controlled by the thickness and composition of interbedded sequences. Cleavage planes show a constant eastward or north-eastward dip, their formation being related to emplacement of basement thrusts and southward migration of the deformation front. The formation of slaty cleavages clearly predates the emplacement of Hercynian postcollisional intrusions, which thermally overprint and obliterate them in areas of contact metamorphism. A clear metamorphic gap exists between the slate belts and the overthrusting metamorphic basement rocks.

Investigations by petrographic and mineralogical studies using XRD of pelitic rock samples from the Silurian-Lower Devonian the Late Paleozoic slates from the western belt were carried out in order to establish the metamorphic grade based on the illite crystallinity index. The calibration of the diffractometer used established the limit anchizone/epizone as 0.32 $\Delta^0 2\theta$ and anchizone/diagenesis as 0.53 $\Delta^0 2\theta$.

The mineralogy of the Paleozoic sequences is typical for very-low grade metamorphic rocks: illite, chlorite, quartz and albite.

The Silurian slates, pervasively deformed by a closely spaced slaty cleavage, show the lowest values for IC (0.25 – 0.32), which means the higher degree of metamorphism and recrystallization in the analyzed rocks (lower epizone). Early Devonian samples show larger IC values (0.36 – 0.47), indicating smaller degrees of recrystallization (middle anchizone). The Late Paleozoic slates show similar IC values as the Early Devonian samples.

There is a quite good correlation between the spacing and morphology of the slaty cleavages in the Silurian and Lower Devonian samples, in good agreement with the IC, which indicates an eastward increase in metamorphic grade from Lower Devonian to Silurian.

LATE PROTEROZOIC-EARLY CAMBRIAN TURBIDITES FROM CENTRAL DOBROGEA – PROVENANCE AND SIGNIFICANCE

TP19

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The source areas for the Late Proterozoic - Early Cambrian turbidites (Histria Formation) from the basement of the Moesian Platform exposed in Central Dobrogea were investigated using coarse member mineralogy and geochemical data on pelitic members.

Mineralogy of coarse members consists of volcanic and vein quartz, feldspar (plagioclase and K feldspar), detrital phyllosilicates (chlorite and biotite), epidote and lithics (rhyolite, basalt, dolerite, chert, quartzite, micaschist, gneiss, granite). Petrographic studies indicates that sandstones are highly immature lithic arkoses and volcanic arenites rich in unstable components and metastable minerals in the heavy mineral fraction. Textural and mineralogic imaturity indicate rapid transport and burial of sandstones and conglomerates, in conditions of active tectonics of the sedimentary basin, suggested by sedimentary structures (convolute lamination, flame structures). Coexistence of volcanic clasts (basalts and rhyolites), as well as the presence of pyroxenes and amphiboles in the heavy mineral fraction indicates that a main active volcanic source contributed together with a major terigeneous source, which delivered metamorphic and granite debris. Paleoflow directions indicate that both source areas were situated to the south.

The mineralogy of pelitic fraction consists of quartz, illite, albite and chlorite. Chemical composition indicates that pelitic rocks derived from fresh or slightly altered sediments, rich in feldspars, micas, chlorite and with subordinate contents of initial montmorillonite and kaolinite. The field of the Histria Formation overlaps the fields of clays from the Pacific, Indian and Atlantic oceans, as well as the field of the Late Proterozoic - Eocambrian turbidites from Norway. The high FeO/Fe_2O_3 ratio indicates either an initial reducing depositional environment, or the subsequent reduction of iron and its inclusion in the lattices of silicates during the post-sedimentary history of rocks. The abundance of syn-diagenetic pyrite crystals in sandstones suggests sediment accumulation in an initial reducing environment, as well as a cold climate of the depositional area.

REE BASED PROVENANCE STUDY OF SILURIAN SEDIMENTS IN THE BALTIC BASIN

TP20

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The Baltic basin is a part of the Dniepr-Baltic system of marginal basins established in Vendian - Early Palaeozoic time due to rifting along the Baltica margin. In Silurian time the subsidence of the basin drastically increased, that is related to the docking of Eastern Avalonia to the western margin of Baltica. A combined effect of supra- and sub-crustal loads evoked the flexuring of the plate which climaxed in the late Silurian. This was associated with gradual increase in the terrigenous supply to the basin. The former part of Silurian is described in terms of starved basin which evolved into the overfilled foreland basin by the end of Silurian – Earliest Devonian. Deep water graptolitic shales dominate the western and central parts of the Baltic basin. In the east they grade into the shallow-water carbonates. Close to the North German-Polish Caledonides (NGRC) siltstones were deposited since Wenlock.

The increase in the terrigenous influx to the Baltic basin is accounted to the gradual advancing and increasing topography of the adjacent NGRC. The previous lithofacies studies suggest the domination of the eastern (platform) provenance in the beginning of Silurian, while western (orogenic) source supplied the major part of terrigens in the Middle and Late Silurian. Seeking to map the spatial distribution of the different sourced shales and to reveal the temporal trends in the provenance, rare-earth and trace elements were studied from the shales and marlstones sampled in three representative wells located in the eastern, central and western Lithuania, thus examining the three major lithofacies belts recognised in the central and eastern parts of the Baltic basin. Because REE are not easily fractionated during sedimentation, sedimentary REE patterns provide an index to average composition of provenance.

The total contents of REE significantly varies from 32 ppm in the eastern samples to 190 ppm in the west, that is related to carbonate dilution effect. By contrast to the pronounced variations in the total contents, the chondrite- and NASC-shale normalised REE patterns show strong similarity for the all samples thus pointing to the domination of one source. An exception are just Late Silurian marlstones from the eastern well which shows the absence or even positive Eu anomaly suggesting the possible Archean crust sourced deposition in the east during Late Silurian. The rest samples have pronounced negative Eu anomaly. They show steep LREE slope and low differentiation of HREE. The ratios and contents of indicator elements persuade the domination of felsic lithologies in the provenance. Just some miserable trends might be considered as indication of very slight increase in the mafic portion in Late Silurian.

Assuming the western source has been the main one, a clear domination of felsic component in the studied shales enable to classify the western provenance as the recycled orogen. Sedimentary wedges provided the main bulk of terrigens during Silurian with just a minor (if any) maffic source admixture in the Late Silurian. The eastern Precambrian platform source was of importance for easternmost Late Silurian lithofacies only.

LATE CRETACEOUS INVERSION TECTONICS IN THE BALTIC REGION: CONSTRAINTS ON FAR-FIELD STRESS TRANSMISSION REGIME

TP21

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After the long-term break in sedimentation, a wide invasion of marine basin from the west into the Baltic region occurred in Late Albian and it lasted until Maastrichtian. This transgression is explained in terms of global see level rising and basin subsidence. Glauconitic sands and silts of 40-80 m thickness were deposited during Late Albian - Cenomanian times. They are overlain by Turonian – Maastrichtian chalk succession of 80-160 m thickness.

The total thickness of Cretaceous sediments in Lithuania and Kaliningrad District shows just slight variations across the territory. By contrast, the thicknesses of separate stages are highly differentiated with distinct stratigraphic breaks documented within the local structures. A compilation of the set of isopach maps of Cretaceous stages and sub-stages enabled to trace the structuring history of the region in detail. The long-wavelength folding dominated the tectonic architecture of the basin. During Albian – Cenomanian the NE and NNE oriented structures predominated in the western part of the Baltic Basin, while W-E direction was prominent in the east. In a course of time the latters gradually ceased, and NE oriented structures became distinct in the latter part of Late Cretaceous. The wavelength of these regularly oriented structures ranges in order of 40-60 km, amplitudes are of 20-80 m. The most intense growth of structures is stated for Campanian and Maastrichtian times, amplitudes reaching 120-160 m.

The inversion of the folds was a characteristic feature of the tectonic evolution of the Baltic basin, when antiform folds recurrently experienced downwarping associating with relative upwarping of adjacent sinforms. This is related to fluctuation of the horizontal stress generated in remote Alpine and North Atlantic areas and transmitted to the Baltic region. The maximum compression led to maximum differentiation of structures, essentially of the antiform folds that often show hiatus on the crestal parts. Their inversion is accounted to sharp decrease in the stress that was not enough to maintain the previous buckling amount, thus leading to inversion of structures approaching the more stable position. This inversion mechanism points to the elastic behaviour of the (upper) crust.

Based on the structural evolution of the fold structures, the evolutionary trend of the geodynamic regime has been reconstructed for the Baltic basin. (1) Late Albian compression; (2) Cenomanian drop in compression leading to slight inversion of structures; (3) Turonian-Lower Coniacian compression; (4) latest Lower Coniacian sharp increase in compression associated with maximum structural differentiation; (5) Late Coniacian stress drop leading to structural release and inversion; (6) Santonian compression; (7) earliest Campanian high intensity compression leading to the uplift of structures to 100-160 m; (8) Campanian-Maastrichtian decrease of compression leading to collapse of prior uplifted structures to 100-160 m (with possible stress increase between Campanian and Maastrichtian). This succession of events reflects tectonic processes in remote stress generating tectonically active regions.

PALAEOMAGNETISM AND PALEOGEOGRAPHY OF PALAEOZOIC TERRANES IN THE VARISCAN AND ALPINE FOLD BELTS

TP22

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The Variscan fold belt of Europe resulted from the collision of Gondwana, Baltica, Laurentia and the intervening microplates (Avalonia and the Armorican Terrane Assemblage) in Early Palaeozoic times. Convergence and intracontinental deformation lasted for some 150My with the closure of at least four oceanic basins - the Iapetus, Tornquist, Rheic and Galicia-Massif Central

Basins - with associated deformation corresponding to the Caledonian, Variscan and to some extent the Alpine orogenies. Although the Palaeozoic drift history for Gondwana remains a matter of controversy, the palaeogeography of Baltica, Avalonia and Laurentia in the Lower Palaeozoic are now fairly clear (MacNiocall and Smethurst, 1994, Torsvik et al., 1992, 1993). The nature of the Gondwana derived Armorican terrane Assemblage (ATA) is more enigmatic (Tait et al, 1997). Geological and new palaeomagnetic data, however, suggest it formed an assemblage of terranes or microblocks which nevertheless underwent similar drift histories from Ordovician through to Devonian times. It is proposed that the ATA drifted away from the northern margin of Gondwana in the mid Ordovician times, and collided with the southern margin of Baltica/Avalonia, thus closing the Rheic Ocean, in Late Silurian or Early Devonian times. The situation for the southern margin of the Armorican Terrane Assemblage is also complicated, and the palaeogeography of the various terranes now situated within the Alpine fold belt remains unclear due to strong Alpine overprinting and deformation. Nevertheless, faunal and facies studies of the Proto-Alpine terranes (e.g. Northern Greywacke Zone, Carnic Alps and Karawanken) indicate that these elements have many features in common. Importantly, many of the mid Palaeozoic faunas appear to be distinct from both Gondwana and Bohemian assemblages (Schönlaub 1992) suggesting that these terranes formed independent microblocks. New palaeomagnetic data support this model, in which the Proto-Alpine terranes formed a tectonically discrete microplate. It rifted from the Gondwana margin, probably in mid Ordovician times and drifted northwards, behind the ATA. Final collision and amalgamation of the Proto-alpine terranes onto the southern margin of the ATA probably occurred in Carboniferous times.

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PALYNOLOGICAL EVIDENCE FOR THE PALEOZOIC IN THE BASEMENT OF NORTH DOBROGEA

TP23

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Cores from boreholes which intercepted the low and very low grade Boclugea group sequences from the basement of North Dobrogea have yielded palynological associations which indicate Cambrian to Silurian ages of the initial sediments.

The microfloristic association from Boclugea Group, identified in muscovite schists from borehole 5 - Iulia, borehole 59.547 and well 4 - Iulia, consists of phytoplankton of the Acritacha group; the association includes microfloral elements with evolution starting in the Precambrian and ending in the Cambrian, forms which appear only in the Cambrian and others with evolution restricted to the Lower Cambrian. The lower Cambrian age of the muscovite schists is ascribed based on the following association: *Micrhystridium* sp., *M. lanatum*, *Leiomarginata simplex*, *Granomarginata prima*, *Uniporata nidius*, *Tasmanites* sp. This suggests that the low grade metamorphism is probably related to a Caledonian deformation event.

Borehole 61.488 - Movila Săpata, drilled in a 600 m thick sequence of Lower Paleozoic sediments, yielded associations dominated by Chitinozoans (*Lagenochitina deunffi*, *Cyathochitina campanulaeformis*, *Angochitina longicolla*), with scarce Acritarcha (*Multiplicisphaeridium radicosum*). These associations indicate a Middle-Upper Ordovician age for the lower member (bedded chert and siliceous shales) and a Lower Silurian age for the overlying black slates. The siliceous pelagic rocks are rich in silicified, undeterminable radiolarians.

Borehole 69.508 - Marca pierced only the black slates from the upper part of the Rediu Formation and yielded Silurian palynological associations (*Conochitina elegans*, *Cyathochitina fusiformis*, *Cyathochitina novempopulanica*, ?*Angochitina sp.*), in good agreement with the conodont dominated microfauna previously described in outcrops.

Palinological data provided additional evidence, that the Ordovician – Silurian sequences from the northern part of the North Dobrogea represent remnants of an accretionary wedge.

The protolith ages of the pre-Silurian metamorphic rocks in North Dobrogea is still uncertain in the absence of reliable geochronological evidence. Paleozoic formations intercepted by boreholes contain only undeterminable microfauna (radiolarians).

TOR STATUS FALL 1999. TOR - A SEISMIC STUDY OF THE LITHOSPHERE AND ASTHENOSPHERE OF NORTHERN EUROPE.

TP24

Voss, P., Gregersen, S., and the TOR Working Group

See TO10

NEW VIEWS OF SELECTED EUROPEAN GEOPHYSICAL FIELDS

TP25

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The geophysical fields are believed to contain information about the plate units that were active in tectonic collisions during the geological history. The plate units, former continents and terranes, often have different physical properties distribution characteristics, depending on the processes that were active during their formation. Similarly, the boundaries between the plate units may have their characteristic imprints. Mathematical transformations and image processing are useful processes for extraction of the information that may identify the various units and features.

Gravity and magnetic fields.

A working group within the TESZ project of EUROPROBE has compiled a database consisting of gravity and magnetic data from most parts of Europe. So far, the database has primarily been presented in the form of colour shaded relief maps, from which many geological-tectonic features have been identified. In this poster, we will extend the presentation to include new transformations of the data. Here, we present maps of the gravity and magnetic fields together with the two sets of fields transformed by the so-called "fractional-vertical-integral" technique. This technique enhances the low-frequency content of the vector fields, such that the main geological-tectonic units appear more clearly. The transformed gravity field reveals some major units that are not obvious in the map of Bouguer anomalies. The magnetic signatures of Precambrian and Phanerozoic Europe are completely different in central Europe, separated by a distinct lineament. This well-known difference is strongly enhanced in the processed map. The Tornquist line was originally defined from this magnetic lineament.

Geomagnetic induction field.

Ad hoc group compiled the geomagnetic induction vector data from Europe. Usually these data are presented as a map of vector arrows which is difficult to analyze when the data are abundant. We propose a new method of presentation of these data. They have been transformed using Hilbert transform to the form which can be easily presented and analyzed. The well known geomagnetic anomalies such as German-Polish, Carpathian and Scandinavian are clearly visible.

Geothermal field.

World heat flow data have been compiled and can be downloaded from the Internet. These data from Europe together with new Polish data are presented as a colour shaded relief image.

Hypsography data.

Important information about geology are included in hypsography data (terrain relief). We show here hypsography image of Europe based on several datasets including those available in the Internet and also un-published Polish data.

GEORIFT SESSION
ORAL PRESENTATIONS

PALEOZOIC CIRCUM-BALTICA PLATE-TECTONICS

GO1

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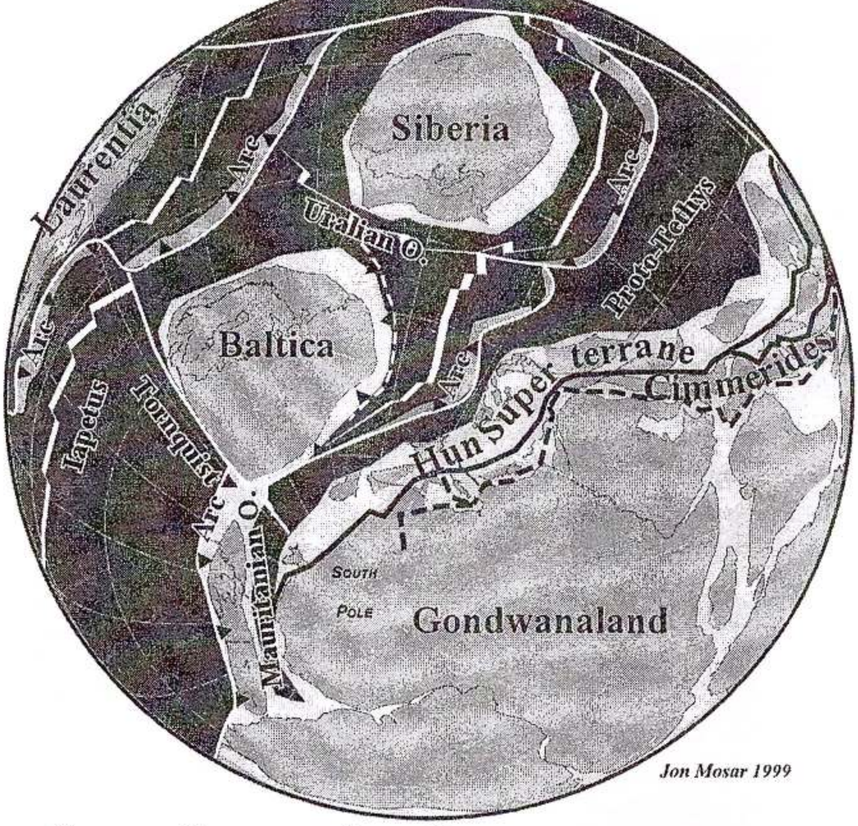

TENTATIVE/SPECULATIVE EARLY ORDOVICIAN RECONSTRUCTION

The drift of the Baltic shield (including the Fennoscandian Shield and the East European Craton) during the Paleozoic is analyzed. The relations with the displacement of the Gondwanaland, the Siberian, the Kazakhstan, and the Laurentia plate determines the evolution of the oceans involved. Similarly the subduction zones leading to the development of different circum-Baltic orogens and back-arc rifting determine the evolution of the Baltica margins and possibly the intracontinental deformation (Dniepr-Donetz, Peri-Caspian basins f.ex.).

To the South, Baltica's history is related to the evolution of the Tornquist transform zone and the amalgamation of Gondwanaland-derived microcontinents into the Hercynian orogen. To the NW the evolution of the Baltica margin is related to the opening and demise of the Iapetus and its associated back-arcs. The subsequent collision with Laurentia, led to the development of the Caledonian orogen. To the East, Baltica is bordered by the Urals orogen which resulted from the convergence of Siberia and Kazakhstan with Baltica. They resulted from the obduction of the Sakmarian back-arc system and the westward subduction of the Uralian ocean.

A general feature associated with the circum-Baltica oceans is the development of repeated back-arc openings in a supra-subduction setting and the subsequent obduction of ophiolites and final closure of the main oceans involved.

After forming the Laurasian plate, with Baltica in its center, the collision with Gondwanaland leads to the formation of Pangea.

MESOZOIC AND CENOZOIC EVOLUTION OF THE SCYTHIAN PLATFORM-BLACK SEA-CAUCASUS DOMAIN

GO2

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The Scythian Orogen fringes the southern margin of the East-European Craton and was consolidated at the end of the Late Carboniferous-Early Permian. This orogenic belt includes the Scythian, Great Caucasus, Moesian and Pontides domains and forms the eastern prolongation of the Variscan Orogen of Western and Central Europe.

Following Late Permian degradation of the Scythian Orogen, the area of the Scythian and Moesian platforms and the Pontides were affected by an Early to Middle Triassic cycle of back-arc rifting during which the oceanic Svanetia-South Crimean-Küre Basin opened. During the late Carnian to Hettangian Early Cimmerian Orogeny, the continental Elburz terrane was accreted to the Scythian Platform. This was accompanied by a cycle of back-arc compression, causing inversion of Triassic rifts on the Scythian Platform. From Jurassic to Paleocene times, the evolution of the Scythian-Pontides-Great Caucasus domain was governed by a sequence of back-arc extensional and compressional cycles that were controlled by activity along the north-dipping Vardar subduction zone. During successive phases of back-arc extension new rift systems developed whereas others, such as the Great Caucasus Trough, were repeatedly reactivated. In time, a southward shift of rifting activity is observed, particularly during the Late Cretaceous opening of the West Black Sea Basin and during the Eocene development of rifted basins on top of the eastern Pontides-Transcaucasus magmatic arc. Main phases of back-arc extension occurred during the Early and Late Jurassic and during the Aptian(?)-Albian to early Santonian. These were interrupted by the Bajocian-Bathonian

Mid-Cimmerian and the end Jurassic-earliest Cretaceous Late Cimmerian phases of back-arc compression. The both Western and Eastern Black Sea basins had been opened nearly simultaneously during Cenomanian to Coniacian times. The Late Eocene-Oligocene Caucasus orogeny was controlled by the collisional interaction of Arabia with the East-European Craton.

GO3

CENTRAL-BALKAN NEOTECTONIC REGION NORTH OF THE AEGEAN: TECTONIC EXHUMATION ALONG LOW-ANGLE DETACHMENTS OR RIFTING AND NORMAL EROSIONAL DENUDATION AND UNROOFING?

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Formation of the Aegean Sea in Late Miocene time is usually explained by opening through large-scale crustal extension (s. Mercier, 1979). The extrapolation of the process northwards, within the Central-Balkan neotectonic region, led to implementation of modern ideas about exhumation of Late Alpine metamorphic core complexes through rapid large-scale movements along low-angle detachment surfaces (references in Dinter, 1998). However, the conclusions already published do not correspond to the geological evidence.

The Central-Balkan neotectonic region is built mostly of the Ograzhdenian (Prerhodopian) and the Rhodopian amphibolite-facies metamorphic complexes of Precambrian age. Palaeogene (Palaeocene to Oligocene) sedimentary formations are non-metamorphic, cover the weathering crust of the metamorphic complexes with depositional unconformable contacts, and contain numerous pebbles from them. Pebbles from metamorphics rocks of Rhodope provenance are present also in Permian, Triassic and younger non-metamorphic formations in the circum-Rhodope basins. No Alpine metamorphic events younger than Mid Cretaceous have been proven.

The Late Alpine tectonic history of the region is characterized by stratigraphically proven major compression episodes (Figure) in Mid Cretaceous, Late Cretaceous, late Middle Eocene, and early Early Miocene times. Extensional collapse-related igneous activity took place in Late Cretaceous (crust-derived granitoids), and Bartonian - Late Oligocene (volcanics and granitoids) times. Extensional graben basins have been formed in Palaeocene - Middle Eocene, Late Eocene - Early Oligocene, Late Oligocene - earliest Miocene, and Middle (or Late) Miocene to Pliocene times. Pebble provenance from adjacent horsts excludes large horizontal tectonic displacements.

Neogene tectonics (Figure) was dominated by alternating isostatic uplift of the core built up of thickened continental crust, and extensional collapse with rifting. Rifting occurred mostly along the Maritsa and Strouma fault belts (Zagorchev, 1992), and was related to vertical and horizontal displacements in the northern Aegean margin, along the Northern Anatolian fault and its splay faults. Vertical displacements reached 3 – 4 km, and locally, up to 7 km. Correlation of planation surfaces (peneplains, pediments) in the horsts with the coeval sedimentary formations in the grabens enables dating with a good precision of the principal events. As an effect of Aegean extension, horizontal movements along the low-velocity level in the Rhodope massif at depths of 6 to 8 km may have also taken place. Unroofing of Palaeogene granitoids resulted from increased erosion in the most uplifted neotectonic blocks during prolonged isostatic uplift combined with rifting since late Oligocene to Maeotian time included. The unroofing of the plutons occurred in Pontian time when coarse sedimentary formations in the grabens were the first to contain Palaeogene granitoid pebbles. The erosion rate (roughly identical with the uplift rate) varied between 0.4 - 0.6 mm per year, being only 15 to 40% of the modern uplift rate.

On the basis of the geological evidence, large-scale detachment faulting and exhumation of Alpine metamorphic core complexes should be excluded. Besides the rifting, possible graben-forming mechanisms include pull-apart, normal faulting due to post-thrusting relaxation, and vertical isostasy-related movements.

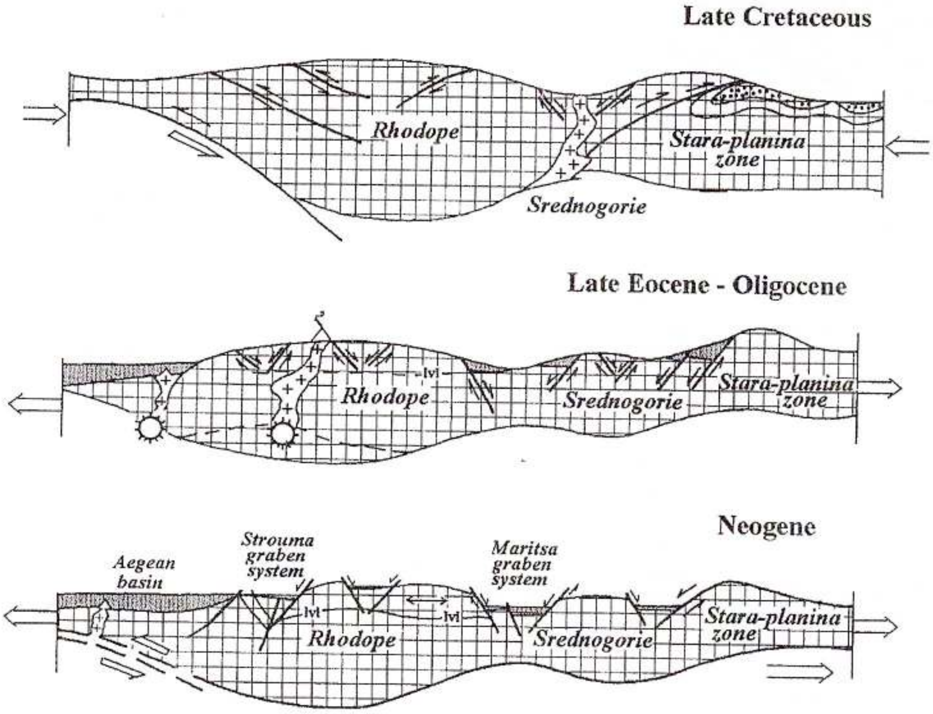

Figure 1. Cartoons for the Late Alpine and Neogene tectonics on sections across the Peri-Aegean region. lvl – low-velocity level.

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GO4

DRIVING FORCES, STRAIN AND TEMPERATURE NECESSARY FOR INTRACRATONIC RIFTING AND INVERSIONS FROM THE VIEWPOINT OF RHEOLOGICAL MODELS OF LITHOSPHERE

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Intracratonic rifting and inversion events are quite common in geological history. Early calculations based on the laboratory-derived rock rheology (e.g. Kusznir and Park, 1984) showed that, for "normal" cratonic lithosphere, the forces necessary to induce whole lithospheric failure (WLF) are much higher than "typical" plate tectonic forces. The critical force required for failure is drastically reduced by an increase of lithospheric temperatures. These results led to the conclusion that intracratonic rifting could not be initiated by plate driving forces only but that some "heating" was also necessary. In such a case, however, all intracratonic rifts should be related somehow to "mantle plumes". For intracratonic inversion, the situation is more problematic. The required critical force in a compressional environment is even higher than in the extensional one but the lithosphere underlying basins being inverted is typically relatively cold. Therefore, whole lithospheric failure cannot occur even under the action of extremely high plate tectonic forces in the framework of this model. Nevertheless, inversion structures are quite common and the simultaneity of their occurrence over large intracontinental regions testifies to in-plane forces as their cause. Therefore, we have re-examined the earlier conclusions incorporating more recent developments in lithosphere rheological models. In particular, we consider the strain necessary to account for the observed inversions and rifting, the necessity of WLF during rifting and inversion events, and the influence of semi-brittle deformation on the critical level of in-plane force.

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GO5

THE BLACK SEA BASIN: TECTONIC HISTORY AND MODELLING

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The Black Sea is situated in an area between Ukraine, Russia, Georgia, Turkey, Bulgaria and Romania. The Black Sea Basin is surrounded mainly by late Cenozoic mountain areas with thickened continental crust (the Caucasus, the Pontides, Southern Crimea, the Balkanides). There are two deep basins in the crustal structure of the Black Sea Basin: the Western Black Sea Basin with oceanic to suboceanic crust and sedimentary thickness up to 19 km, and the Eastern Black Sea Basin with thinned (by up to 10 km) continental crust and sedimentary thickness up to 12 km. Five main seismic sedimentary complexes of the Black Sea Basin are recognised: upper Cretaceous(?), Paleocene-Eocene, Oligocene-Early Miocene, Late Miocene and Pliocene - Quaternary.

The Black Sea Basin originated as a back-arc basin during Cretaceous times. Continental rifting took place during from Aptian to Albian. Large-scale crustal thinning and separation mainly along the former Albian volcanic arc has occurred since the Cenomanian. Both the Western and Eastern Black Sea basins opened nearly simultaneously during Cenomanian to Coniacian times. From the Santonian until the Paleocene the Black Sea region was affected by compressional deformations. An extensional event affected the eastern part of the region in the Eocene. Since the latest Eocene the basin region has been affected by compressional deformations. Rapid Pliocene to Quaternary basin subsidence took place in connection with regional compression.

1-D and 2-D burial history modelling has been carried out for the Black Sea. We can recognise several stages of subsidence: Late Cretaceous-Eocene, with tectonic subsidence up to 4.3 km in Western Black Sea Basin and 3.8 km in the Eastern Black Sea Basin; Oligocene-Miocene with tectonic subsidence of 0.6 km in the Western Black Sea Basin and 0.4 km in the Eastern Black Sea Basin; and Pliocene-Quaternary with tectonic subsidence of 0.45-0.5 km in both basins.

Here we propose a model of syn-compressional downward bending of the Black Sea Basin lithosphere as an explanation of the rapid Pliocene-Quaternary subsidence. Rheological modeling of the Black Sea lithosphere shows that EET in the central part of the basin is 60-70 km and EET in the margin of the basin is 30 km. EMS is downflexured with an amplitude of about 15-25 km. Under compression, with a force of $5*10^{12}$ N/m, the central part of the modelled profile subsides 0.4 km. This compares favourably to the tectonic subsidence inferred from modelling the burial history. Kinematic and dynamic modelling of the subsidence of the Black Sea Basin shows that compression-induced downward bending of the basin lithosphere could be the reason of this rapid additional non-thermal subsidence.

GO6

GEOLOGIC ENVIRONMENTS AND GEODYNAMICS OF THE SOUTHERN MARGIN OF EAST EUROPEAN CRATON

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The sedimentary columns of boreholes, geologic cross sections and geologic maps for the southern portion of East European craton and Northern Caucasus, the maps of depth to the basement and to the Moho boundary for the area of study, the Bouguer gravity anomalies and magnetic field map were compiled to define the geologic environments and geodynamics for the southern margin of East European craton.

The East European craton comes in contact through the Teisseir-Tornquist suture zone with West European geologic units and has too difference from that way at its southern boundary. The Peri-Caspian and Black Sea basins that have oceanic-type floor beneath the up to 20-22 km thick sedimentary cover, the Karpinsky Swell coming from Dnieper-Donets Rift through Donbass area and stretched from NW to SE between Peri-Caspian basin and Scythian plate, and Scythian plate located just south from Karpinsky Swell constitute the tectonic framework of the area of interest. Borehole data show that Peri-Caspian basin is filled with Middle-Paleozoic and younger sediments that traditionally are subdivided in to middle-late Devonian syn-rift complex, late Devonian early Carboniferous and middle Carboniferous-early Permian "pre-salt" sequences, early Permian salt and late Permian-Cenozoic post-salt deposits.

Deep seismic study gives evidences that up to 5-7 km thick sediments underlie the Middle Paleozoic strata. We assume this deposit to be from Riphean to Early Paleozoic in age, and to originate in terms of initial rifting followed by post-rift subsidence.

The Karpinsky Swell consists predominantly of Middle Paleozoic terrigenous sediments metamorphosed in low-grade facies, and dislocated in to folds and thrusts. Seismic data show that the Karpinsky Swell metamorphic complex has a thickness up to 15 km. The crystalline crust, which is about 30-32 km thick, underlies the metamorphic complex of the swell. Boreholes and reflection seismic data recognize the thrusting of the Karpinsky Swell onto lower Permian strata of the Peri-Caspian basin. Deep seismic refraction/wide-angle reflection data display that collision between the Scythian plate and southern margin of the East European craton gave rise to that thrust tectonics.

The Scythian plate has crystalline crust which thickness varies from 20-25 to 40-42 km. Predominantly Middle Paleozoic terrigenous sediments metamorphosed in low-grade facies rest on the crystalline crust. The rocks mentioned above are very similar to that in Karpinsky Swell. We assume that both these complexes were originated in marginal basin.

The several pre-Mesozoic major stages of geodynamics of the discussed area can be suggested. (1) - in Riphean, there was a rifting in the peri-Caspian basin area and within the margin of East European craton. (2) - in Middle Paleozoic, the active extension in the Karpinsky Swell-Scythian plate area just south from the East European craton took place, and accompanied by Middle-Late Devonian extension (resulted in sea formation) within the Peri-Caspian basin and by rifting, in Frasnian-Famennian time, in Dniper-Donets rift. In that time, the Donbass area is suggested to be transition between Dniper-Donets rift and sea basin. (3) - in early Permian, there was contraction of the marginal basin and collision between Scythian plate and East European craton resulted in Karpinsky Swell forming.

INNER STRUCTURE AND EVOLUTION OF SALT MASSIFS IN THE PRIPYAT PALEORIFT

GO7

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More than 300 local uplifts have been revealed in the sedimentary cover of the Pripyat Trough. These uplifts differ in size and morphology as are of different genesis and evolution history. Rifting and halokinesis were the main structure-formation factors in the Pripyat Trough, that is why local uplifts are there of overblock or salt types. Within the Pripyat Trough the halokinesis processes were most evidently shown in the Lebedian lower halite substrata of the Middle Famennian saliferous strata, to a lesser extent - in the Upper Frasnian (Yevlan-Liven) saliferous strata. Most of local uplifts are salt ones and are of very complicated inner structure, therefore, these have been the main objects of studies and classification.

The authors suggest the unique classification of salt structures of the aulacogen as a whole which was developed on the basis of all the studies performed for the present and all the data available on the composition of salt structures of the Pripyat Trough.

The classification of salt uplifts was based on the criteria:

- halokinesis evidences and occurrence of salt stocks in one or two saliferous strata;
- shape of uplifts in plan;
- relationship between salt uplifts and enclosing structures, firstly, those of the subsalt bed;
- relationship between salt stocks and overlying deposits;
- extent to which salt stocks broke supersalt deposits;
- uplift features inherited by supersalt deposits;
- shape of salt stocks in section;
- inner structure of salt massifs.

A system of the coordination features revealed permits the differentiation of groups, subgroups, types, subtypes, classes, subclasses, kinds, sorts and varieties of positive salt structures. All uplifts may be of single salt and double salt types. Single salt uplifts are subdivided into two subtypes: anticlines and domes, among which two classes - inherited and superimposed uplifts, and three subclasses - diapiroids, cryptodiapirs and diapirs are differentiated. Cryptodiapirs may be of several kinds: Pre-Mid-Famennian, Pre-Upper-Famennian, Pre-Carboniferous, Pre-Upper-Visean, Pre-Upper-Serpukhovian, Pre-Moskovian, Pre-Triassic, Pre-Olenekian, Pre-Jurassic, Pre-Tertiary ones. All salt uplifts are subdivided into the inherited buried and degradation ones. In shape of salt stocks two varieties of cryptodiapirs and diapirs are distinguished: pillar and mushroom-like ones. Negative structures may be subdivided into three types: interdome, compensating and sag ones.

Inner structure of salt uplifts had been more intensively formed during rifting in Upper Devonian time in the Pripyat Trough. The post-rift stage can be divided into three periods of salt massif growing. The Polessian-Permian, Triassic and Jurassic-Cenozoic stages are distinguished.

During the Polessian-Permian stage (Early Visean, Early Bashkirian, Moskovian and Upper Permian time) the upper part of salt cryptodiapirs were exposed as a result vertical salt movements while the sedimentation processes did not work in the Pripyat Trough. Caprocks and subsidence troughs formed during breaks in sedimentation. Almost a half of the whole volume of salt massifs was eroded and partly accumalated in interdome zones.

During Triassic time the roofs of salt domes have been continuously uprised as a result of salt movement from limbs to arcs of the domes and subsidence of synclinal zones surrounding the salt massifs. Troughs were formed above salt massifs in the periferal parts of the Pripyat Trough. The rate of salt movements ranged from 3 to 8 m/mln yrs. During the Jurassic-Cenozoic stage the structural pattern of the salt massif changed very little. Fault and salt movements were very small at that time and the rate of salt movements was not greater than 1-3 m/mln yrs.

THE INVERSION OF THE HYSTRIA BASIN - ROMANIAN BLACK SEA SHELF

GO8

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The Hystria basin has a long and complicated history, involving extension, inversion and subsidence, that began at the end of Triassic and continued into Middle Tertiary. Inversion in this area, is situated on the northern margin of the basin and it was accomodated by reactivation of basement normal listric faults. The most important factors controlling the inversion appear to be pre – inversion structural framework of the basin margins.

Hystria Basin was developed in a subsident extensional regime during the Triassic – Early Cretaceous. Its bassement and sedimentary fill constitues two megasequence which contain four sequences. The form of the basin, as result from seismic lines interpretation, is a NW – SE sinclinorium. The basin boundaries are defined by an unconformity at the top of preoligocene formations. The basin is interpreted as an extensional one. The extensional displacement on the normal listric faults, produced a syncline basin progressively widened with time. Post Eocene – Lower Oligocene compression inverted the basin.

Seismic lines show that inversion is selective with only some of normal listric faults. Inversional structures, associated with the compressional reactivation of normal listric faults, form important structural traps for hydrocarbons. Migration into these traps must occur post - inversion.

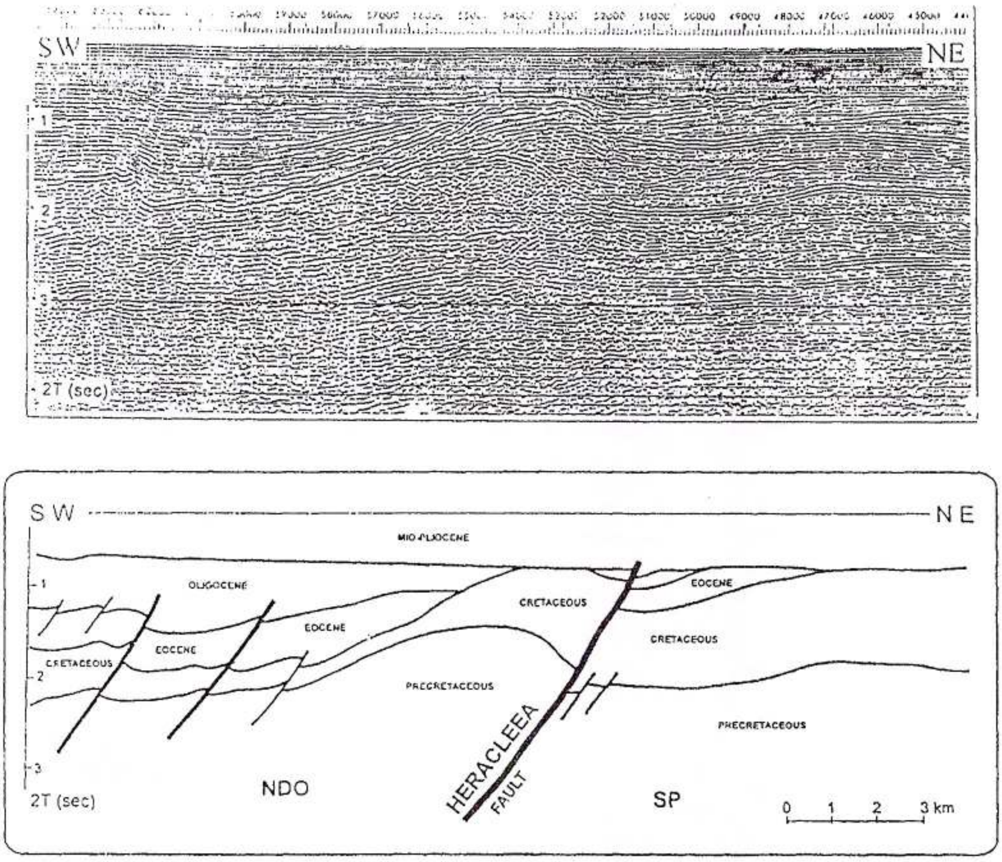

Figure 1 – Uninterpreted and interpreted seismic line showing the compressional tectonics in the northern margin of the Hystria basin

SOME KINEMATIC INDICATORS FOR THE TECTONIC EVOLUTION OF THE DONBAS FOLD-AND-THRUST BELT (UKRAINIAN PART)

GO9

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Our first fieldtrip was carried out in the Ukrainian part of the WNW-ESE trending Donbas fold-and-thrust belt (DF). We collected fault slip data sets as kinematics indicators in order to elucidate the tectonic evolution of the region. Data were collected in Proterozoic crystalline rocks, Devonian and Carboniferous sedimentary series, and in Cretaceous deposits. According to the classical division of the DF, most of visited sites were located in the southern zone and on the southern margin. Fault slip data set inversion allows the determination of the paleostress fields that have affected the DF area. Classical criteria (as crosscutting striae, pre- or post-folding stress tensors, stratigraphic control, etc.) were used to establish the relative chronology of different tectonic events. Nevertheless, the preliminary results should be taken with caution: more fieldwork is necessary to improve our results by collecting more data. But we can already bring some constraints on the chronology and on the mechanisms of major events involved in the extension(s) and the inversion of the basin.

The first event which seems to have strongly affected the Proterozoic and Paleozoic rocks took place in a strike-slip regime with σ_1 trending NE-SW. Following this event, a nearly N-S extensional regime is recorded in these old rocks. These tectonic regimes could correspond to the first steps of the late Palaeozoic evolution of the area, with strike-slip tectonics occurring prior the genuine N-S directed rifting of the basin. In Cretaceous rocks, as well as in older rocks, an E-W extension was determined with syn-sedimentary normal faulting in Cenomanian terranes. A NE-SW directed compressional event affected Palaeozoic rocks but also Upper Cretaceous rocks in both the southern and northern zones of the DF. This corresponds to the last deformation that we could determine, occurring during "Alpine" time and recorded in Maastrichtian rocks. Further investigations are needed to constrain better the intensity of this tectonic phase and the timing of this post-Maastrichtian event (by studies, for example, in Tertiary series).

MECHANISMS OF SALT DIAPIR FORMATIONS: SOME MODERN IDEAS AND THEIR COMPARISON WITH OBSERVATIONS

GO10

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The mechanisms that generate salt diapirs have long been a matter of debate but they are not completely understood. Nevertheless, an understanding of these mechanisms is of great importance for oil/gas exploration and the comprehension of basin tectonic evolution. Results of sandbox modelling, along with the interpretation of some observations in the field and on seismic lines, led many workers to ideas about the mechanisms of salt diapirism in sedimentary basins that relied strictly on the precepts of brittle deformation in salt overburden. Recent numerical and physical modelling studies of salt tectonics have considered in more detail viscous as well as brittle deformation of the overburden, i.e. a more realistic view of the behaviour of sedimentary rocks.

The Dniepr-Donets Basin (DDB) is the deepest basin of Europe an and excellent natural laboratory on salt tectonics although it has been incorrectly reported in the literature as an enigmatic Ukrainian salt basin having negligible salt structures. In fact, salt pillows, anticlines, and diapirs of different shapes are located in the basin. Diapirs are up to 10-15 km thick. Periods of diapirism coincided with regional tectonic phases. At first sight, salt tectonics of the DDB confirms the ideas that gravity forces exerted a small influence on the formation of diapirs. However, it can be demonstrated that patterns of salt tectonics and various peculiarities of overburden deformation in the DDB contradict those that are compatible with "brittle" models of salt diapirism.

Observations to be documented and discussed in terms of diapiric mechanisms include: (1) concordance of salt pillows and anticlines formed during phases of regional extension with the sedimentary overburden; (2) the degree and regularity of overburden faulting in comparison with the thickness of the underlying salt complex; (3) the development of faults and fractures as a result of salt movements rather than *vice versa*; (4) the temporal development of salt pillows and anticlines in the presence or absence of reactive piercement of salt diapirs; (5) the style of deformation in sediments older than halokinesis; (6) the lack of development of grabens in the overburden over salt walls compared to grabens that have developed due to overburden bending over salt pillows and anticlines and to salt dissolution; (7) the relationship of salt structures with basement faults; (8) the formation of salt structures, in periods of both tectonic extension and compression, which are concordant as well as discordant with overburden; and (9) the role of erosion of the overburden relief caused by flowing of salt into salt structures as one of the most effective mechanisms in promoting salt piercement.

TRIASSIC VOLCANIC ACTIVITY IN THE EASTERN FORE-CAUCASUS (SCYTHIAN PLATFORM): NEW DATA ON THE PROBLEM OF NORTH-TETHYS VOLCANIC BELT

GO11

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Volcanic rocks of Triassic age were discovered in the eastern Fore-Caucasus in the 1960s after drilling for oil and gas. Recently, these rocks are proven to be present in an area of about 30000 km^2; their thickness varies from 100-200 m to more than 1.5-2.5 km. There is considerable volume of data collected on the petrography and composition of these rocks but publications concerned with their interpretation are almost absent. According to these data the evolution of volcanic activity in this region may be as follows.

The presence of non-rounded acid ash in Early Triassic (Indian-Olenekian) carbonate sediments is evidence of explosive eruptions of rhyolites-dacites typical for "mature" island arcs and active continental margins. An increase of ash content to the south-west indicates a source location near the boundary of recent Stavropol high and Terek-Caspian depression. In Olenekian-Ladinian times, a volcano-sedimentary succession with total thickness more than 2.1 km was formed in a narrow (2-4 km) zone along the boundary between the Karpinsky Swell and the East Manych Trough. The sequence is represented by fine-grained clastic sedimentary rocks (40%) together with lavas and related intrusive bodies of basalts (35%), and rhyolites and rhyodacites (25%). Main oxides composition in the volcanic rocks is similar with that in rocks of bimodal series of island arcs, back-arc basins, and of some Phanerozoic mobile belts of island-arc stage. The complex of petrological and geological data shows the origin of this rocks to be concerned with rifting process.

In the Late Triassic volcanic activity sharply increased, resulting in the formation of covers of rhyolitic and dacitic tuffs and ignimbrites with minor lavas of calc-alkaline andesites, mostly above sea level. (The association is typical for "mature" island arcs and especially for Andean type active continental margins.) The greatest total thickness of these rocks exceeds 1.5 km. The area of Late Triassic volcanic rocks is at present 50 km wide and has a NNE strike. To the east tuffs are gradually replaced by contemporaneous volcano-sedimentary rocks. Across this NNW zone no systematic variations of rock chemistry have been discovered, but there is a tendency for increasing K_2O+Na_2O and Fe/Mg in rocks with equal SiO_2 content in this direction. One possible explanation would be the previous existence of a broader Late Triassic volcanic belt of WNW strike (i.e. parallel to the trend of the main Caucasus structures) that has been significantly eroded. Nevertheless, there is little in the way of re-deposited volcanic material in younger sedimentary rocks of the Fore-Caucasus, and this may result from the discontinuity of this belt.

EARLY PERMIAN REGIONAL UPLIFT OF THE SOUTH-EASTERN PART OF THE DNIEPR-DONETS BASIN

GO12

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Stratigraphic records indicate that there were two main uplift phases during the post-rift evolution in the Dniepr-Donets Basin (DDB). They were in the Early Permian and between the Mezosoic and Cainozoic. Tectonic reactivation during the Early Permian was most pronounced in the south-eastern, deepest part of the DDB, while it was least obvious in the north-western part. Early Permian erosion was extensive and widespread in the direction of the Ukrainian Shield. It is supposed that more than 2 km of the Middle and Upper Carboniferous succession were eroded. The character of the erosional unconformity as seen on seismic data suggests that the Early Permian paleo-coastline was located in the area near the present erosional boundary.

A 1-D numerical technique was developed to estimate the magnitude of uplift during tectonic sedimentary basin inversion events. It is based on the well-known backstripping procedure, on forward modelling, and on a newly developed approach.

In the DDB, Early Permian uplift, calculated for fifty-six stratigraphic sections located on the basin's the south-eastern flank, varies in the range 400-3000 m (cf. Figure). The character of uplift is similar to a wave, with two crests, which are located at a distance of about 110 km from each other. One peak is to the south-east of Poltava, where the uplift reached a greatest magnitude of 3000 m, and the other one, with an amplitude of 2500 m, is within the Sarmatsko-Vovchansky high located near the Donbas Foldbelt.

It is concluded that the Early Permian uplift can be explained by (1) changes in far-field, horizontal stress fields due to late Palaoeozoic orogenesis; (2) deep mantle processes; and (3) the response of the lithosphere to mantle flow coupled to contemporaneous tectonic events on the south and east margins of the East European Craton.

DEEP STRUCTURE OF THE LITHOSPHERE BELOW THE DNIEPR-DONETS BASIN AND DONBAS FOLDBELT ACCORDING TO GRAVITY AND SEISMIC DATA

GO13

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The Dniepr-Donets Basin (DDB) is a linear, NW-SE trending, Late Palaeozoic and younger sedimentary basin on the East European Platform separating the Ukrainian Shield from the Voronezh Massif. Its north-western (Dniepr) segment has the characteristics of a typical rift basin. To the south-east, through a transition zone of approximately 200 km length, the DDB is progressively uplifted and compressionally deformed into Donbas Foldbelt (DF). Along the axis of the Dniepr graben a series of gravity highs has been previously explained by dense crystalline crust underlying the basin, corresponding to zones of increased P-wave velocity and caused by intrusion of mafic and ultramafic mantle rocks.

To investigate the crustal and upper mantle structure in the region of DDB-DF transition zone and DF the 3-D gravity analysis, using a gravity backstripping technique, has been carried out. Two general models of the sedimentary cover, assuming: (1) constant average density in the layers and (2) an exponential density increase in the upper (up to 6 km) sedimentary layer, were considered. A residual gravity field I, obtained by substracting the gravity influence of the sedimentary succession of the DDB, reveals a distinct positive anomaly along the axis of the rift basin increasing in amplitude (up to 120 mGal) according to increasing sedimentary thickness. Two respective models of the crystalline crust structure below the basin considering the alternative Moho models, based on different interpretations of the published crust and upper mantle seismic velocity models, were calculated. The first of these (model A) assumes crustal thickening beneath the transition zone and DF (to a Moho depth up to 50 km) whereas the second (model B) assumes a Moho shallowing (to depth in the range 35-37 km) along the whole basin axis. For each model, the best-fitting 3-D distribution of average density in the crystalline crust has been computed. Both models indicate the existence of a high density body in the crystalline crust along the DDB axis, increasing in density from the Dniepr graben to the DF. Higher average crustal density is required in the case of Moho model A compared to B (3.17×10^{-3} kgm^{-3} versus 3.06×10^{-3} kgm^{-3}). This may be interpreted as dense crystalline crust below the DDB-DF transition zone and DF caused by intrusion of mafic and ultramafic rocks during Late Palaeozoic rifting processes.

CDP SEISMICAL AND OTHER GEOLOGICAL DATA RECEIVED IN THE CRIMEA - BLACK SEA REGION: INTERPRETATION AND USING FOR ESTABLISHING THE FORMING HISTORY

GO14

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Studying the periodicity of the tectonic phases (T-phases) in Mesozoic-Cainozoic period and also the distribution of the regional spreading of the seismological interfaces in sedimentary basins of the Crimea - Black Sea region revealed a new regularity: in time intervals that as a whole correspond to contemporary idea of tectonic epochs (T-epochs) significance of the T-phases periodicity is retained. Since the greatest tectonical activity is inherent to the first half of T-epoch, the basic stages of rift forming period of the basin development as a rule correspond to its beginning.

Analysis of development history and plunging intensity at the Crimea-Black Sea region show: during Early Kimmerian T-epoch (Late Triassic-Middle Jurassic) the greatest deep speeds were inherent to the Neardobrudja depression; the Late Kimmerian T-epoch (Late Jurassic - Valanginian) to Black Sea deep-water depression; the Cretaceous - Eocene T-epoch to Crimea - Black Sea region; the Oligocene - Miocene T-epoch to Indolo-Kubanian depression (that is a component part of the Crimea - Black Sea region).

The rift period in development of the last one took place in the following way. In Late Kimmerian T-epoch forming of the deep-water Black Sea depression was accompanied by lifting of the conjugate southern edge of the East European platform (Scythian plate). To the epoch end the stage of initial riftogenesis was established; it was accompanied by regional extension, lying of the sublatitude rift faults, beginning of the formation the alongfault daughter depressions (South Golitsynian and North Azovian depressions along northern zone of rift fault, South Mikfailovsky and Indolo-Kubanian one along southern zone), bodily separation the mid-rift rise that separate these depression systems along line Central Mikhailovsky rise zone - Central Azowian swell.

Oga's T-phase (Hauterivian - Aptian) initiated the early downfall stage of slow deeping alongfault depressions with average velocity that not exceed a few tens meters per million years but almost without changing the initial boundaries of generated rift. During Austrian T-phase (Albian - Lower Santonian) an intensive downfall stage with average lowering velocity of a hundreds meters per million years and with tendency to broaden the rift limits took place. The last one occured because of lowering the mid-rift rise that ensured the wedging effect. Tangential stresses from southern direction (from the side of underthrusted oceanic plate) prevented expansion, facilitated formation of an asymmetrical unilateral graben characterized by reverse stepped structure and appearing of upthrow-thrusted dislocations along sublatitude rift faults.

During Subhercynian (Upper Santonian - Lower Paleocene) and Laramian (Upper Paleocene - Eocene) T-phases the region was in stage of lowering (degeneration) the basically smoothed surface with low average deep velocities and inverse swelling of some areas.

GEORIFT SESSION POSTER PRESENTATIONS

3-D ANALYSIS OF THE GRAVITY FIELD OF THE NW BLACK SEA AND THE ADJACENT LAND (DOBROGEA)

GP1

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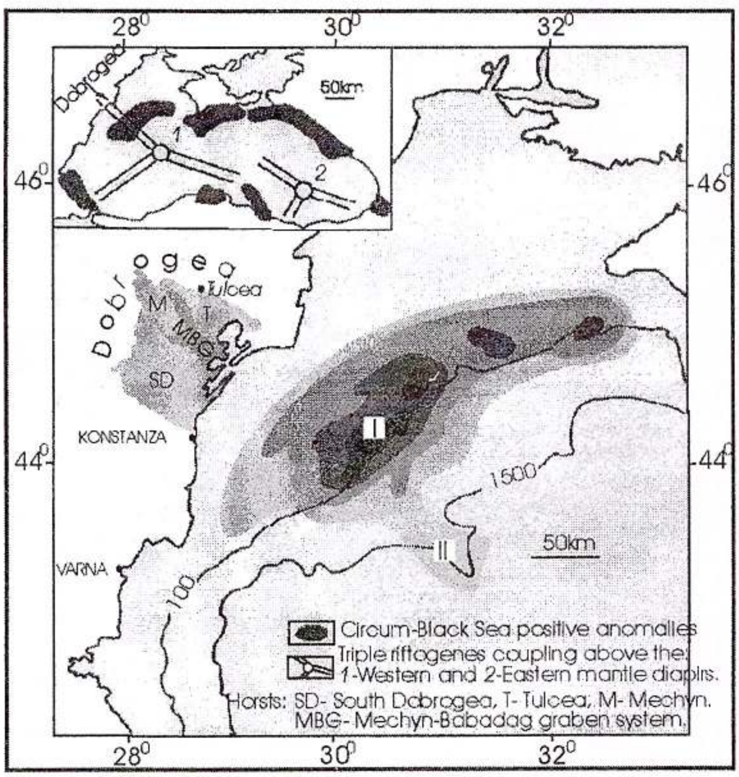
A detailed interpretation of two anomalies: Gubkinskaia (I) and Radial (II) has been made (cf. Figure). The former is situated on the boundary of the shelf with the continental slope and belongs to the anomalies of the Black Sea Basin periphery (cf. Figure inset). The latter branches from the Gubkinskaia in a SE direction coming next to the Moiseev ridge genetically belonging to the north-west rift of the western deep-water trough. The sea-floor depth is 70-200 m on the Gubkinskaia and increases to 2 km on the Radial anomaly. Correspondingly, the thickness of the Maikop-Anthropogenic sediments changes.

The Gubkinskaia anomaly reflects a sub-horizontal plate whose upper and lower limits are situated at 2 and 7 km, respectively. The density is 2.92 g/cm^3. Three bodies generate the Radial anomaly. The depth of their upper boundaries is 4.0, 4.5, and 4.8, therefore within the Pliocene-Quaternary succession. These are ca. 2 km below the upper boundary of the density body inducing the Gubkinskaia anomaly. Densities are 3.12, 2.92, and 3.02 g/cm^3, respectively. The geological nature of the anomalies considered is due to basic and ultrabasic intrusive bodies of different age contained in the crust of the Black Sea.

The Gubkinskaia anomaly does not exhibit any connection with the continent. The magmatic masses intruded into this zone during the Cretaceous and Paleogene over a tectonic node between the earlier north-west rift zone and the later circum-Black Sea fault (cf. Figure, inset) that forms the continental slope of the Black Sea. The Radial anomaly controls the submarine Moiseev ridge represented on land by the Dobrogea ridge. The formation of this continental-marine tectonic system is associated with the western mantle diapir intrusion into the crust from the end of Paleozoic to the beginning of Mesozoic.

The Gubkinskia and the Radial anomalies are of different age. They reflect the complicated structure of the north-west Black Sea and are associated with two major epicontinental periods of the evolution of the Black Sea region. The first (*progressive*) period is featured by the intrusion of the western mantle diapir into ancient continental crust in the Triassic. The large arched structure that forms in this process is accompanied by extension, which causes three-way rifting (cf. Figure, inset). One of these rays is the rift on the north-west slope. Along its tectonically weakened zone, basic-ultrabasic magmatites intrude that are accompanied by later ultra-acid palingenetic formations of the Dobrogea (Mechyn-Babadag graben system). As a result of these processes, the crust there is dense and from the shelf to Dobrogea the gravity field level is +40 mGal. This inflow of magmatic material into the crust was accompanied by the collapse of the western mantle diapir top, leading to the formation of the circum-Black Sea fault with simultaneous squeezing out of the remaining magmatic material through it in the Paleogene. The crossing of the north-west rift by the circum-Black Sea fault caused the formation of a respective tectonic node. Magmas intruded through its weakened zone resulting in the Gubkinskaia anomaly (the gravity level is +75 mGal). These events characterise a *regressive* period in the evolution of the Black Sea region and are marked by the formation of the Black Sea Basin itself. This process continues even now and is accompanied by the formation of local positive gravity anomalies related to the 2.92-3.12 g/cm^3 density of the anomaly-forming bodies.



THE INFLUENCE OF REMOTE EARTHQUAKES ON STABLE REGIONS (EXAMPLES FROM LITHUANIA)

GP2

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The territory of Lithuania is not very seismically active, being in a stable, intraplate tectonic setting, but historical data show that earthquakes of destructive character have occurred in the past. During the last several years, stations of the Scandinavian seismological system fixed a number of weak seismic events in the territory of Lithuania. Other studies during the last decade show that much of the Earth's crust is affected by horizontal tectonic stresses. Most deformation (about 90%) is related to tectonic faults, an abundant system of which characterises the territory of Lithuania. Seismological studies in other countries show that only 2% of seismic deformation energy is discharged by earthquakes that are less than intensity 5 (using the MSK-64 scale).

Thus, the occurrence of strong, though rare, earthquakes in the territory of Lithuania, for example, may be a natural and unavoidable phenomenon. That is, the Earth's crust in Lithuania may be considered to be in a "seismic" condition. Seismic events occur in one of two situations: 1) when accumulation of tectonic strain on a fault reaches a certain limit which exceeds the stability of the fault; 2) the ambient strain accumulation is not sufficient to induce fault movement but a seismic wave coming from outside gives a sufficient impulse for an increase of fault activity. The historical data on powerful earthquakes in the Baltic region show that all of them have been induced by seismic waves originating remotely, from seismically active regions such as Italy or Romania).

The perhaps-strongest earthquake in Lithuania occurred near Vilnius on January 8, 1909. A crack, 1 km long, opened. Earthquakes of intensity 5-7 occurred throughout the entire Baltic region at that time. It is supposed that they may have been related to an earthquake at Mesina (Italy), M=7.5, which occurred on December 28, 1908. The most powerful earthquakes in Europe, with intensities 8-10, arise in the Carpathians area. Many of these earthquakes have been perceptible in Lithuania.

NEW 3-D CRUSTAL DENSITY MODEL FOR THE EASTERN PART OF THE DNIEPR-DONETS BASIN AND DONBAS FOLDBELT: AUTOMATED METHOD AND RESULTS

GP4

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Initial data in the form of scanned isoline maps (relief of the layer tops and bottoms, density distribution, etc.) are introduced to the computer as digital models. The forward gravimetric problem is then solved by allowing arbitrary changes of density within the study area. Solutions are found in a rectangular co-ordinate system (for gravity prospecting) and in a spherical one (for consideration of the sphericity of the Earth, Moon and other planets and natural satellites in regional studding). Results are automatically represented as maps, schemes, and/or sections.

The methodology has been used to construct a new 3-D density model for the eastern part of the Dniepr-Donets Basin (DDB) and Donbas Foldbelt (DF). The study area includes the south-eastern part of the Voronezh Massif and the south-eastern and the Near-Azov parts of the Ukrainian Shield (USh) and covers an area of 360 × 255 km. The gravity effect was calculated on a 3,75 × 3,75 km grid; therefore, the model field reflects the regional and the local density inhomogeneities of the medium. The model was set up using new reinterpretations of seismic data along the I, X, and XI DSS profiles and also taking into account recent geological-geophysical data on the upper part of the sedimentary succession.

The modelling has: 1) elucidated the nature of local anomalies generated by intrabasinal structures including salt domes; 2) determined the anomalous effect of the sedimentary succession compared to areas with little or no sedimentary cover (-40 mGal in the DDB and +20 mGal in the DF with respect to the USh); 3) calculated the effect of anomalously dense rocks within the crystalline crust of the DDB (+40 mGal, which compensates the negative effect of the sediments) and the DF (+70 mGal); 4) constrained the relief of the M-discontinuity of the study region on the basis of DSS and gravity data; 5) compared the calculated gravitational effect of the crustal model with the gravity field of "normal" Precambrian platforms. The mantle component of the gravity field in the DDB appears to be the same as for the Precambrian platform elsewhere whereas in the DF, a notable mantle "decompaction" producing -80 mGal anomalies has been detected for the first time.

3-D GRAVITY MODELLING OF THE CRUSTAL STRUCTURE FOR THE EUROBRIDGE'97 PROFILE AREA (BELARUS AND UKRAINE)

GP5

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Large-scale 3-D gravity modelling has been carried out in 1:1 000 000 scale for the area, crossed in its central part by Eurobridge'97 profile. The area includes the Pripyat Trough (PT) and Chernigov swell of the Pripyat-Dniepr-Donets Basin (PDDB); the North-Western (which includes the Novograd-Volyn block and Korosten pluton), the Dnestr-Bug, and Ros-Tikich Domains of the Ukrainian Shield (USh). The most expressive features of the observed gravity field for the study area are a gravity low of –60 mGal amplitude over the PT (its southern part embraces the Korosten pluton), located between the gravity high of Osnitsk block of USh and Chernigov maximum of 50 and >80 mGal magnitude correspondingly.

To investigate crustal structure of the study area, 3-D modelling using a gravity backstripping analysis was performed. The model comprises the sedimentary cover, where thickness varies from 100 m on the USh to 6 km in the PDDB, and two heterogeneous layers within the crystalline crust, divided at a depth of 15 km. The 3-D gravity effect of a model of the sediments, considering different density approximations, was calculated. Its removal from observed field (resulting in a residual field) shows that the gravity low of the PT is mainly caused by the influence of the boundary between sediments and the crystalline basement. In the residual field the Korosten pluton is revealed by an isometric low reaching –25 mGal in its northern part. This may give an indication of the maximum thickness of Rapakivi granites in the pluton and suggests that the source for acid magma of Korosten pluton was probably located in its northern part. As such, it could have been controlled by the EW South-Pripyat fault, repeatedly activated in Proterozoic and Paleozoic times (in connection with formation of PT). In the residual field a stripe of positive anomalies, parallel to the South-Pripyat fault, joining the Osnitsk gravity high and Chernigov maximum, can be seen. Most likely this anomaly is caused by dense basic and ultrabasic rocks intruded into the crust during the Paleozoic-rifting phase. In this case the axis of intrusion was displaced to the southern flank of the rift in contrast to the Dniepr graben, where it occurred along the graben axis.

As a basis for determining a model density distribution on the top of the upper crystalline crust we used laboratory measurement data, compiled as a petro-density map for the USh. A series of calculations shows that the density contrast may be maintained to the depth of 15 km. As a result, a quite satisfactory agreement was reached between the calculated and residual field (with the exception of Chernigov high) for the final upper crustal model. Thus, the main features of the gravity field for the study region can be explained by the influence of density heterogeneities within the upper crustal stage. The efficiency of the present gravity modelling approach, integrated with DSS data, was confirmed by calculating the gravity effect of the lower crustal layer, limited at its base by the seismically determined Moho. The average Moho depth of the region is in the range of 40-45 km, but a Moho uplift up to 35-37 km and two zones of thickening crust, with Moho down to a depth of 50 km, can be seen. These give rise to negative anomalies reaching –100 mGal not seen in the observed field. By a trial and error method, a 3-D density distribution in the lower crust, maintaining the adopted Moho topography, was calculated. It shows high density domains beneath the zones of deep Moho and beneath the majority of the Osnitsa-Mikashevichi Igneous Belt. A lower crust of low density is predicted beneath the Korosten pluton and PT.

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