Eötvös Centenary Event
Budapest, 15th May 2019

EARTH SCIENCE INSTITUTE
SLOVAK ACADEMY OF SCIENCES

STUDY OF THE LITHOSPHERE IN THE CARPATHIAN-PANNONIAN REGION: BASED ON INTEGRATED INTERPRETATION OF GRAVITY FIELD

Bielik M., Zeyen H., Alasonati Tašárová Z., Goetze H.J., Lillie J.R., Starostenko V., Makarenko I., Legosteva O., Horváth F., Pašteka R., Dérerová J., Pánisová J., Grinč M., Šimonová B., Balász A., Zalai Z., Harangi S. and others

Contents

- *Why were the Eötvös gravity measurements made in Egbell (now Gbely in Slovakia)?*
- *Bouguer gravity anomalies compiled during the project CELEBRATION 2000*
- *2D and 3D integrated interpretation of gravity field*

Ján Mendel

Ján Medlen (born: on January 9th, 1870, Egbell; died: June 6th, 1944, Gbely)

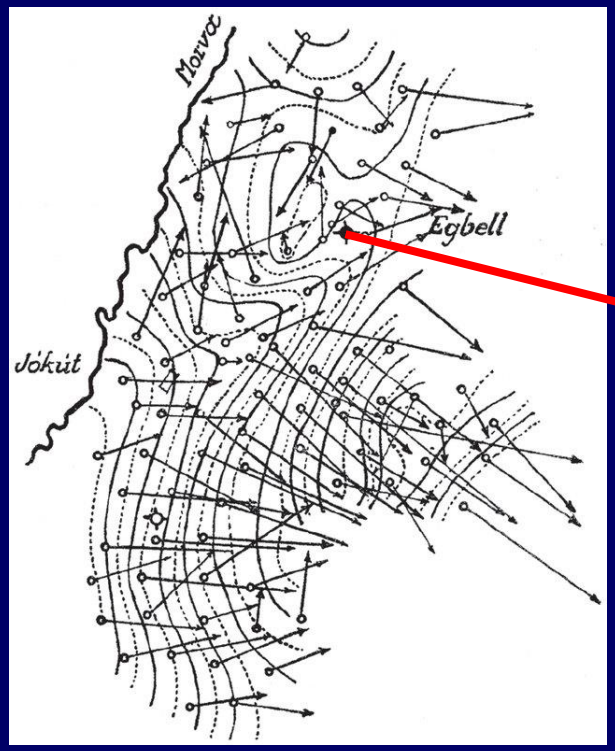
- He was a slovak farmer who discovered, in 1912, the first natural gas deposits near his house in Gbely
- He brought the gas through the corridor to his house and he started to use it for cooking and heating. Until - his house exploded after burn the gas, because the concentration of gas was very high. The story happened in 1913.

- The Ministry of Finance of the Kingdom of Hungary sent the geologists: Böckh and Papp to make a geological survey of this area.
- In 1914, they proposed to make a borehole near Gbely, that found out at a depth of 163 meters the oil.
- On January 13, 1914, Austria-Hungarian monarchy began, for the first time, to exploit oil.

His a nice bust in Gbely

Eötvös gravity measurements in Egbell (Gbely)

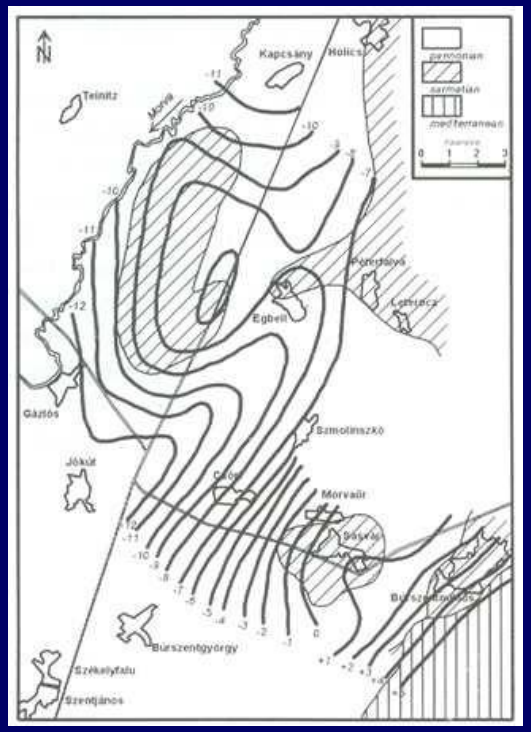
Eötvös torsion-balance map of the Egbell (Gbely) oil field (now in Slovakia)



boreholel sited by Böckh in 1913

made by Eötvös' assistants Pekár and Fekete in 1915-16

Gravity anomaly map of the Egbell (Gbely) oil field



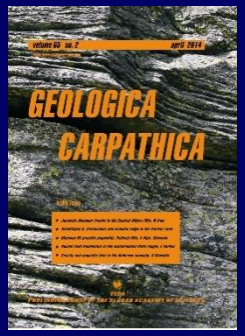
re-draft after Renner (1953). Values of isolines are in 10^{-5} ms^{-2}

- **Length arrows, showing magnitude and directions of the horizontal gradient of gravity. The contours (isogams) are in Eötvös units (10^{-6} mGal cm^{-1}).**

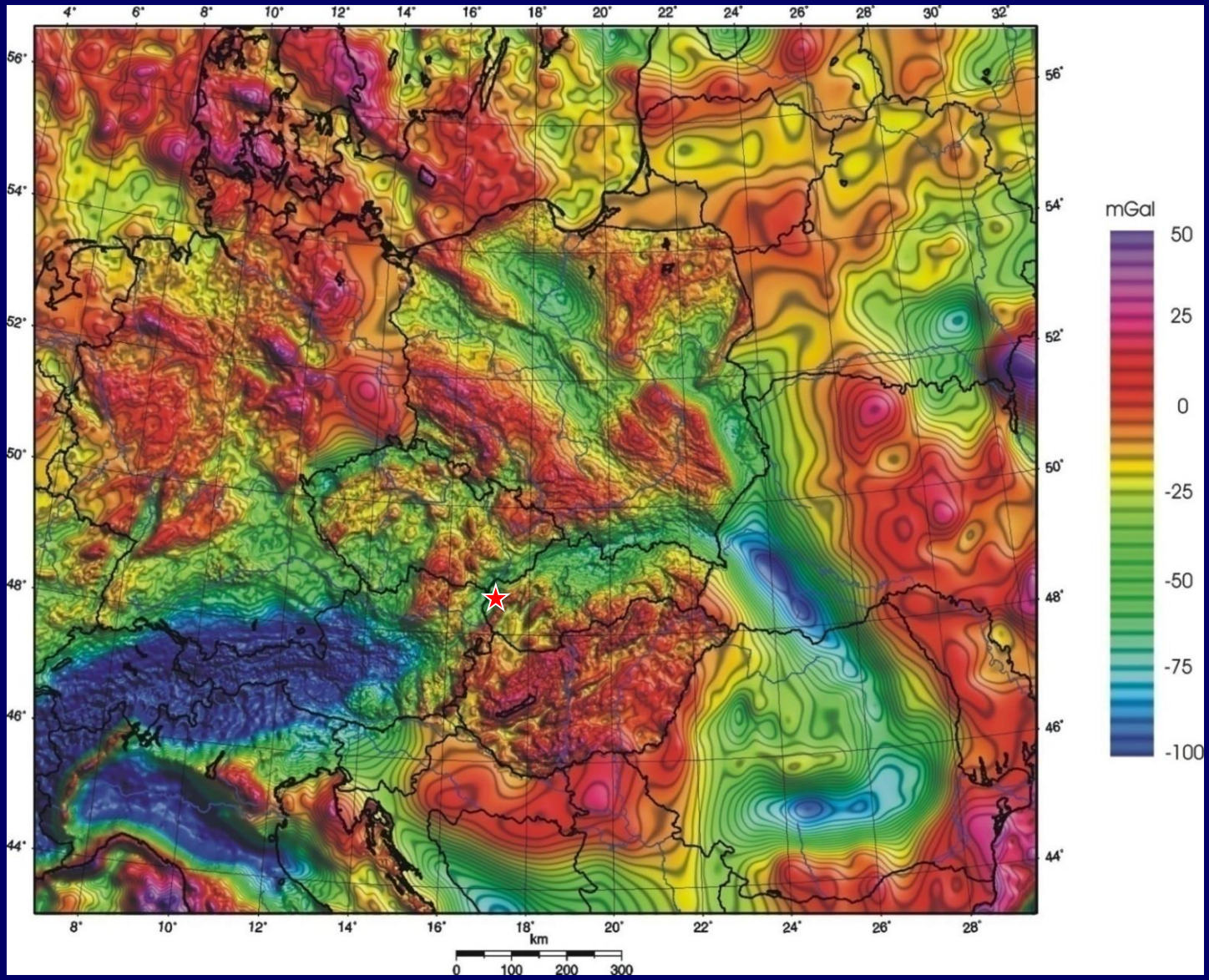
Eötvös gravimetric measurements

meant a huge success
not only for
oil industry but also for the **gravimetry in Europe and the world**

Bouguer gravity anomaly map

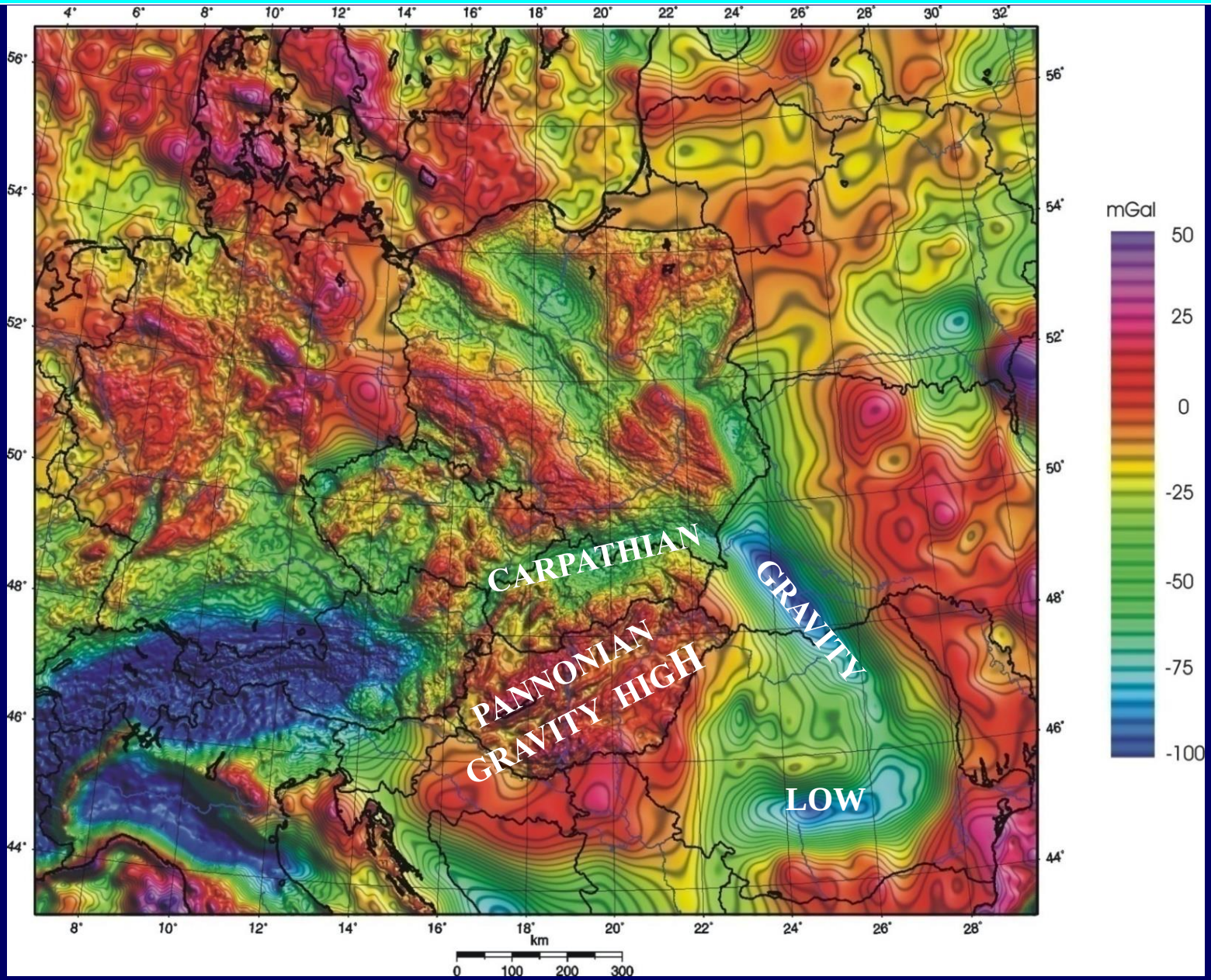


Bielik, M., Kloska, K., Meurers, B., Švancara, J., Wybraniec, S., Fancsik, T., Grad, M., Grand, T., Guterch, A., Katona, M., Krolikowski, C., Mikuška, J., Pašteka, R., Petecki, Z., Polechonska, O., Ruess, D., Szalaiova, V., Šefara, J., Vozár, J., 2006. Gravity anomaly map of the CELEBRATION, 2000 region. Geologica Carpathica, 57, 3, 145–156.

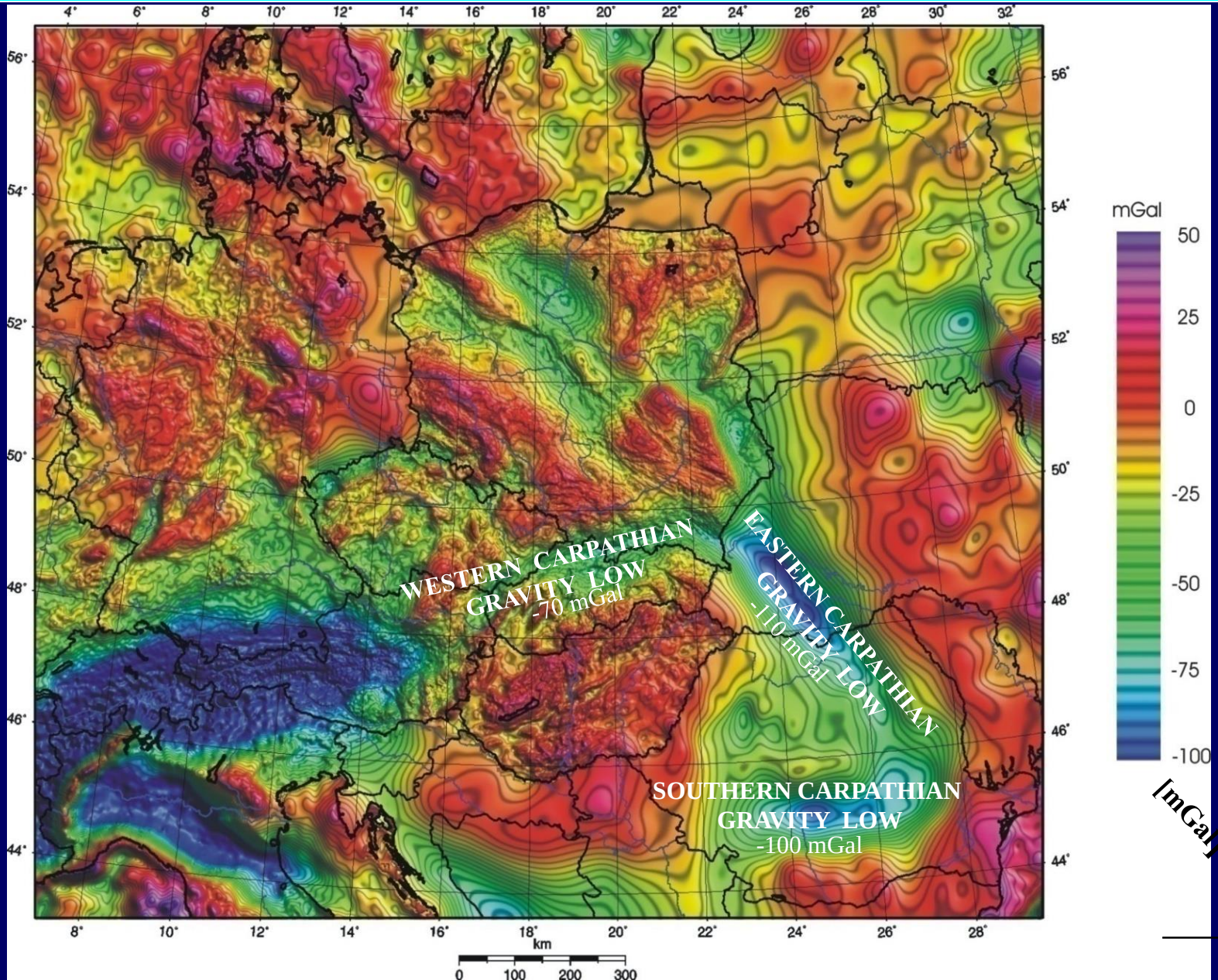


compilated in frame of International project CELEBRATION 2000

Bouguer gravity anomaly map



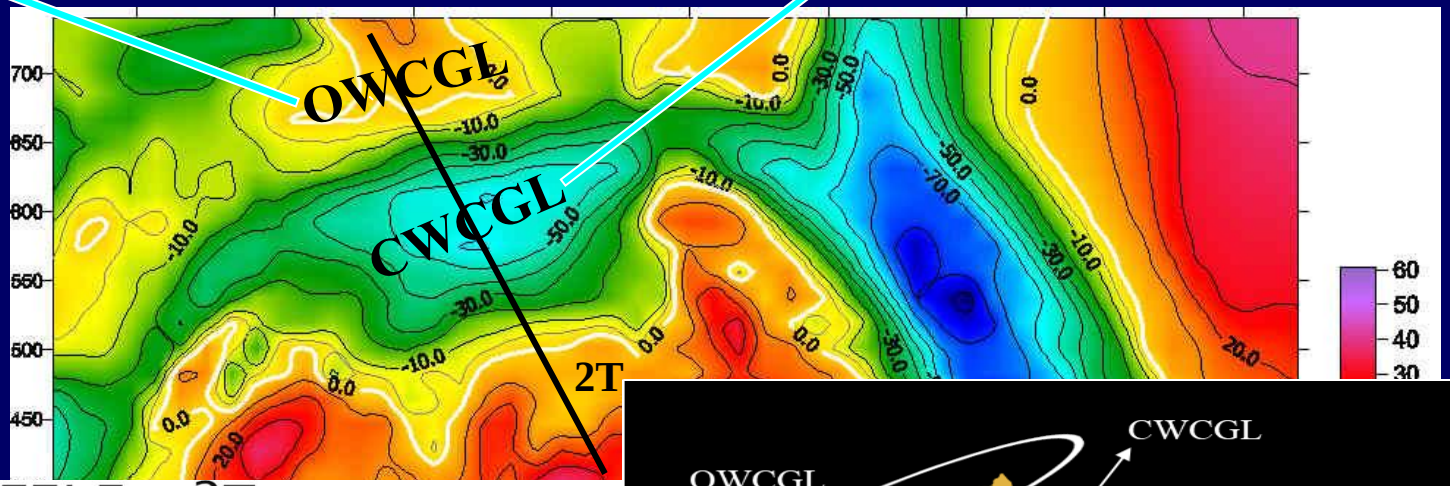
Bouguer gravity anomaly map

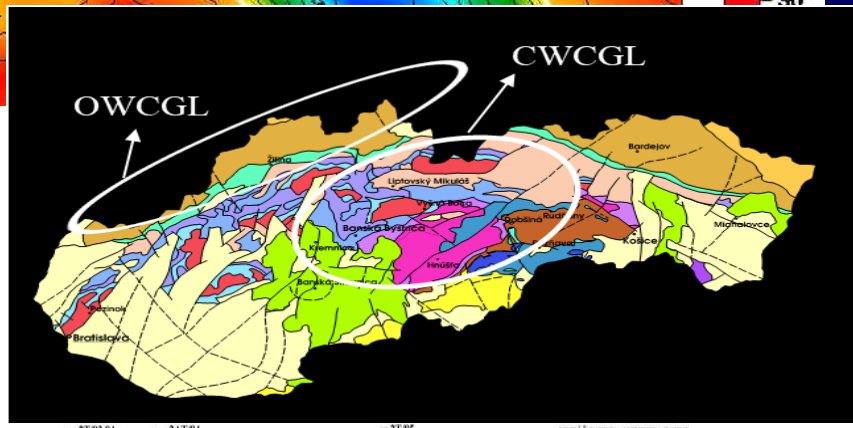


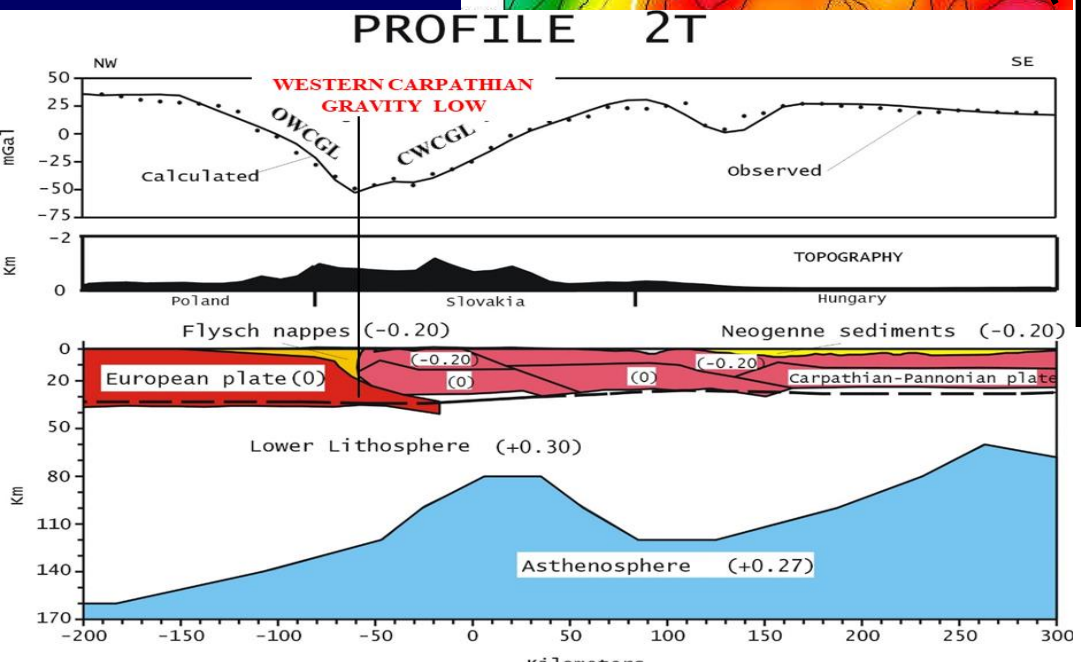
Bouguer gravity anomaly map

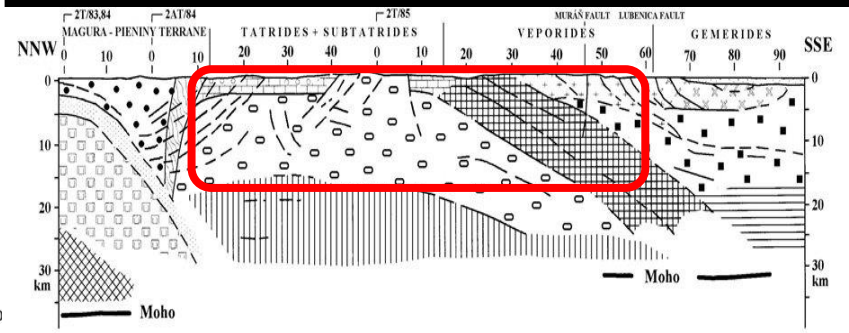
Source 1: Low density Sediments

Source 2: Low density Upper Crust

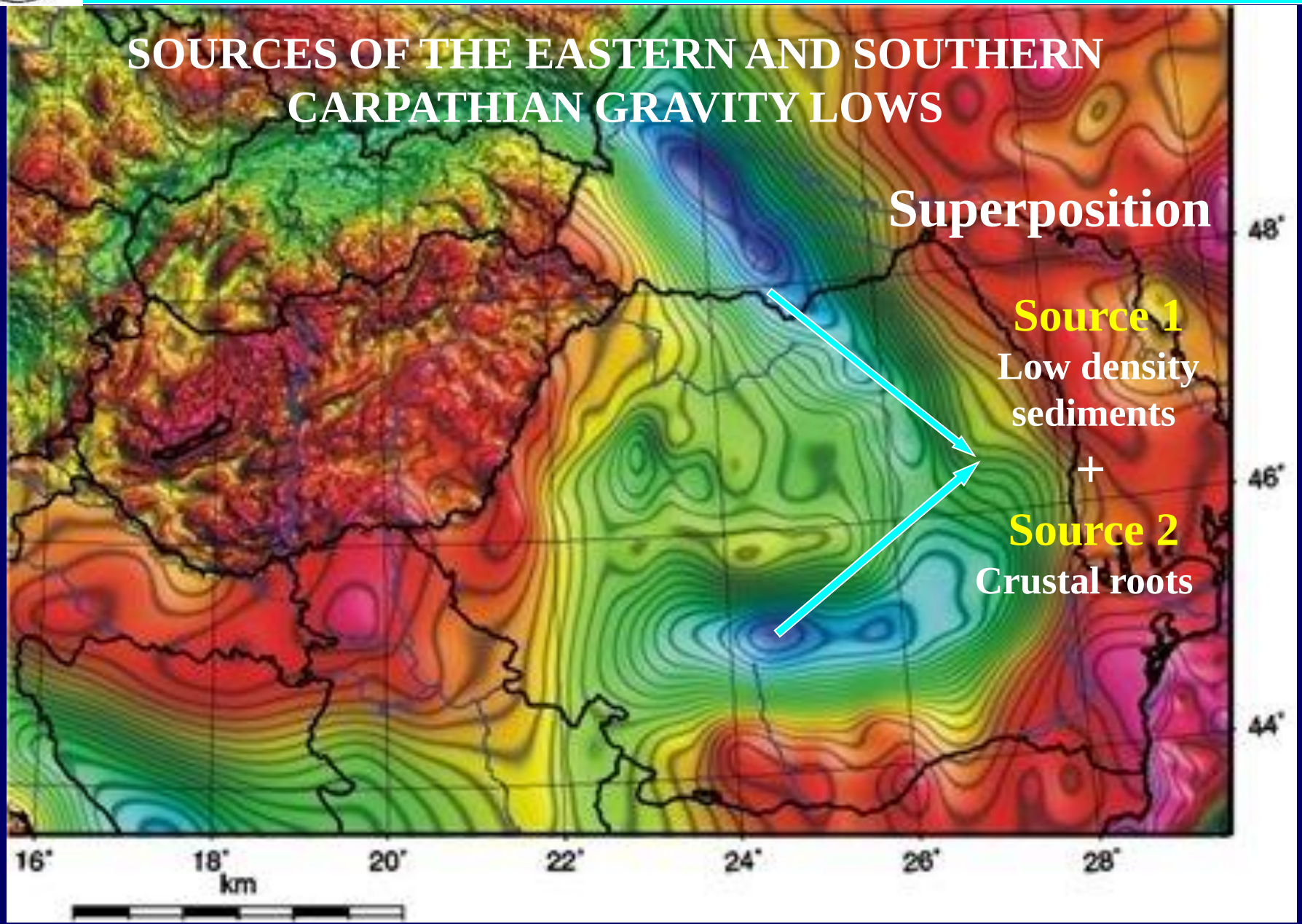




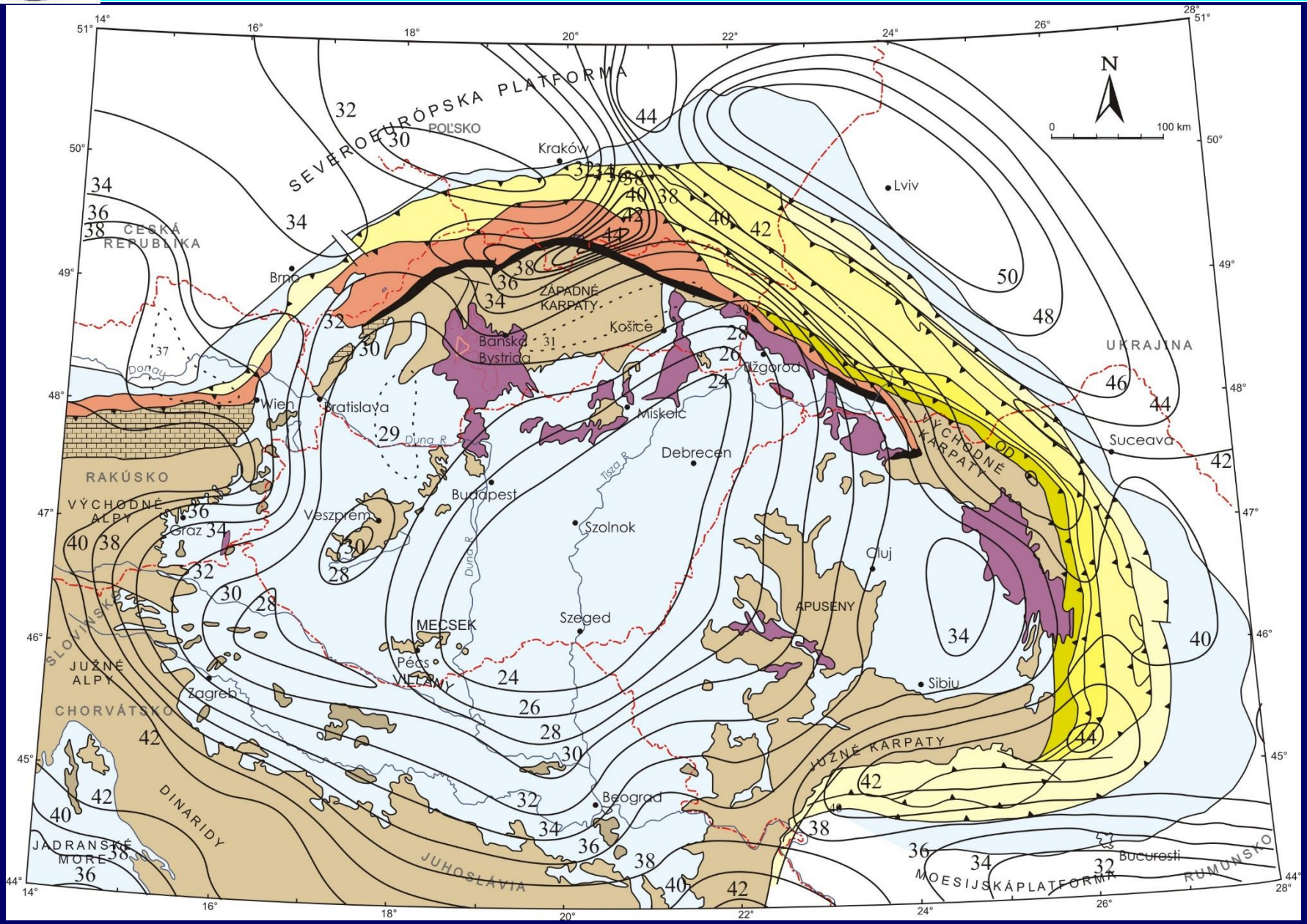




Bouguer gravity anomaly map



Moho depth


SEVEROEURÓPSKA PLATFORMA
POĽSKO
ČESKÁ REPUBLIKA
RAKÚSKO
VÝCHODNÉ ALPY
SLOVINSKO
JUŽNÉ ALPY
CHORVÁTSKO
DINARIDY
JADRANSKÉ MORE
JUHOSLÁVIA
ZÁPADNÉ KARPATY
VÝCHODNÉ KARPATY
JUŽNÉ KARPATY
APUSENY
MOESIJSKÁ PLATFORMA
RUMUNSKO
UKRAJINA
Kraków
Lviv
Brno
Wien
Bratislava
Banská Bystrica
Košice
Užgorod
Miskolc
Debrecen
Suceava
Budapest
Veszprém
Graz
Szolnok
Cluj
Szeged
MECSEK
Pécs
VELEBIT
Zagreb
Sibiu
Beograd
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Duna R.
Tisza R.
Donau
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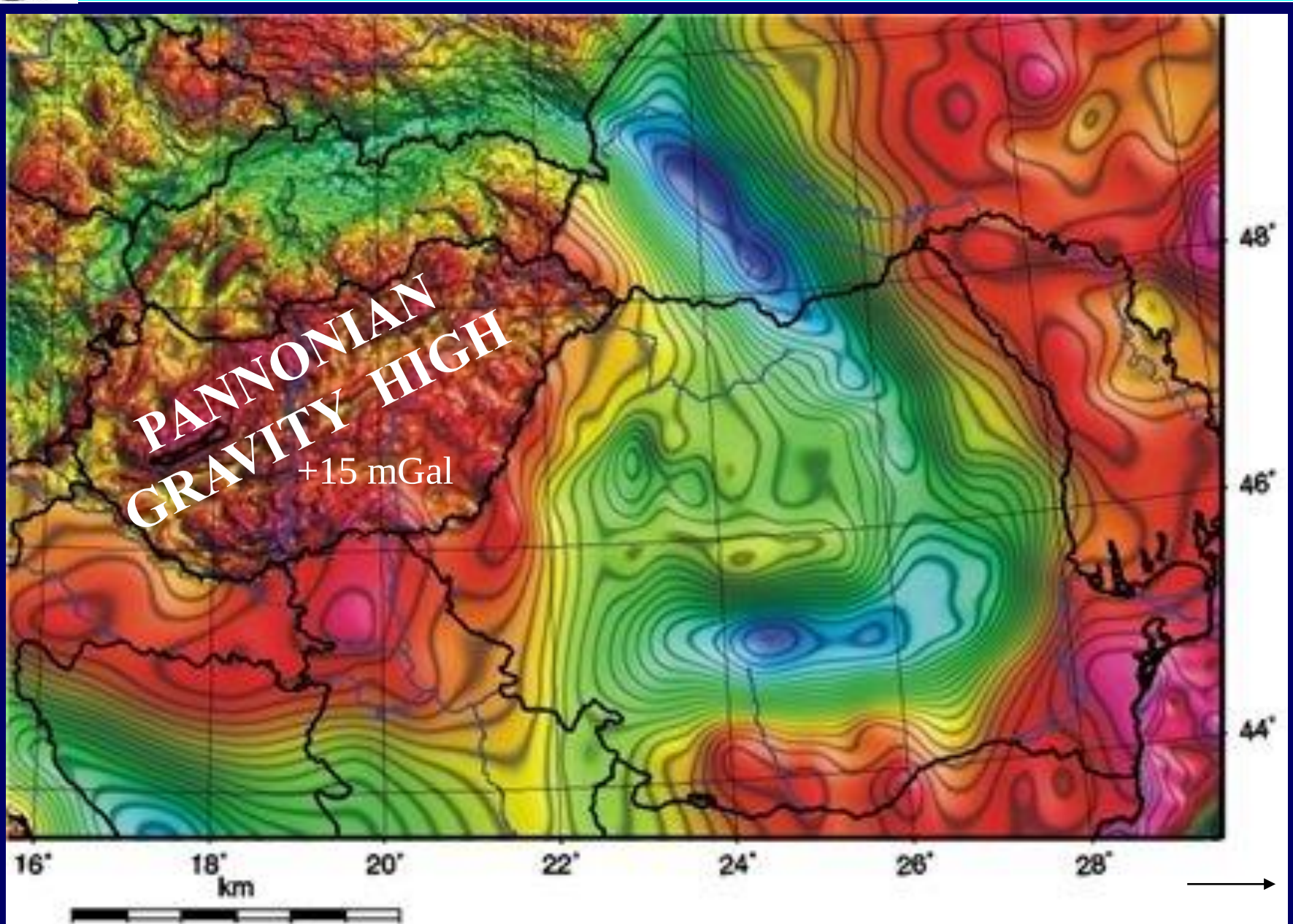
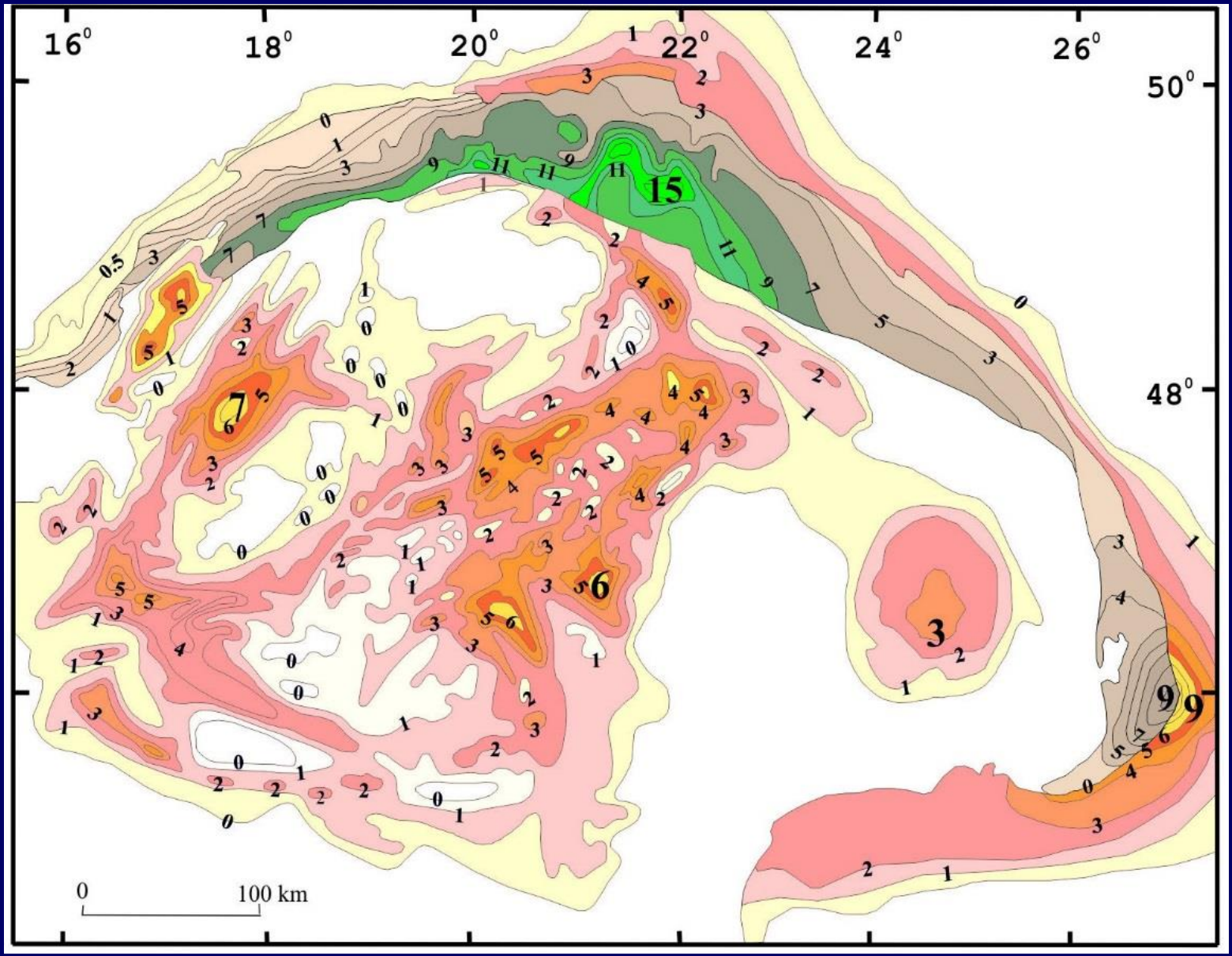
100 km

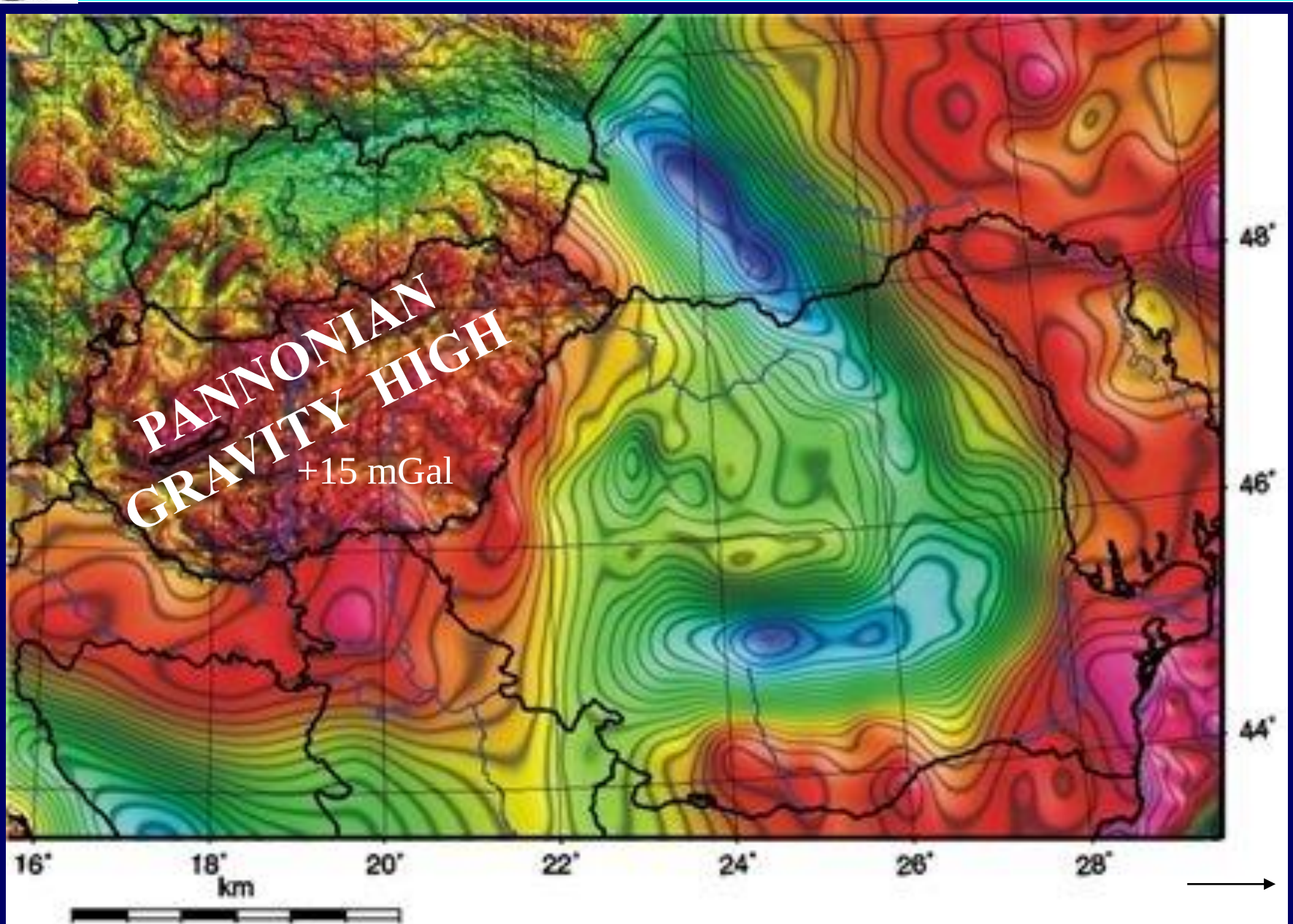
Bouguer gravity anomaly map



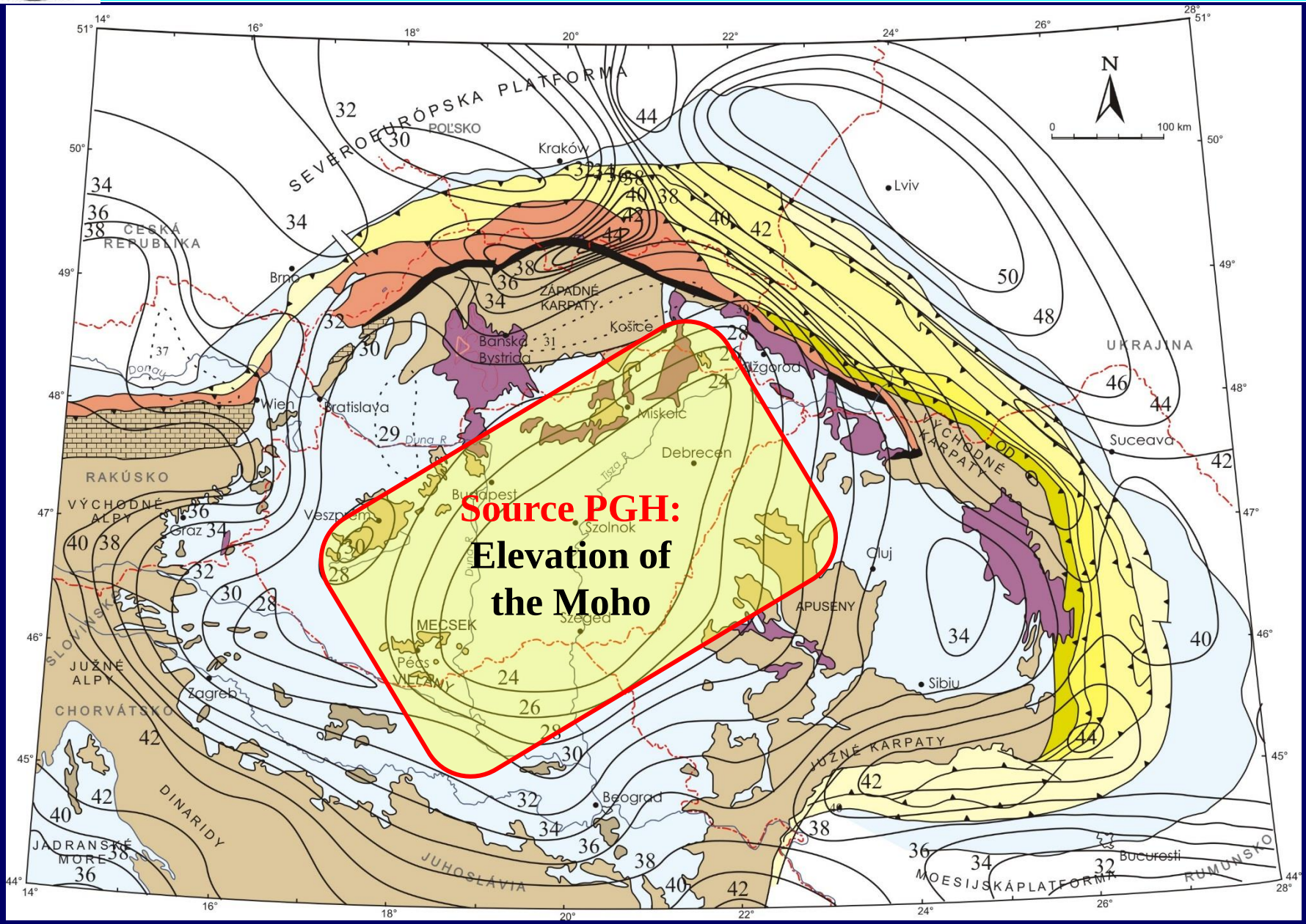
Sedimentary thickness model



Bouguer gravity anomaly map



Moho depth


Source PGH:
Elevation of the Moho
SEVEROEURÓPSKA PLATFORMA
POĽSKO
ČESKÁ REPUBLIKA
RAKÚSKO
VÝCHODNÉ ALPY
JUŽNÉ ALPY
SLOVINSKO
CHORVÁTSKO
DINARIDY
JADRANSKÉ MORE
JUHOSLÁVIA
ZÁPADNÉ KARPATY
VÝCHODNÉ KARPATY
JUŽNÉ KARPATY
UKRAJINA
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VELEBIT
Kraków
Lviv
Brno
Wien
Bratislava
Banská Bystrica
Košice
Užgorod
Miskolc
Debrecen
Budapest
Szolnok
Szeged
Veszprém
Graz
Zagreb
Pécs
Cluj
Sibiu
Suceava
Beograd
București
Dunaj R.
Tisza R.
N
0
100 km

2D INTEGRATED GEOPHYSICAL MODELLING

GOAL

DERMINATION
THERMAL LITHOSPHERIC STRUCTURE AND THICKNESS

CAGES software

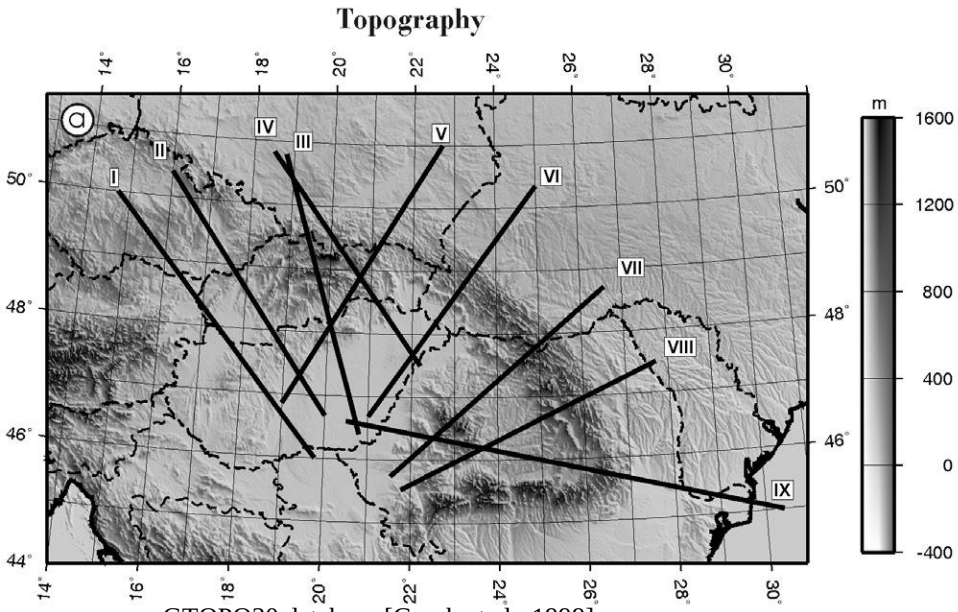
(Zeyen and Fernandez, 1994)

- Surface heat flow
- Gravity field
- Geoid
- Topography

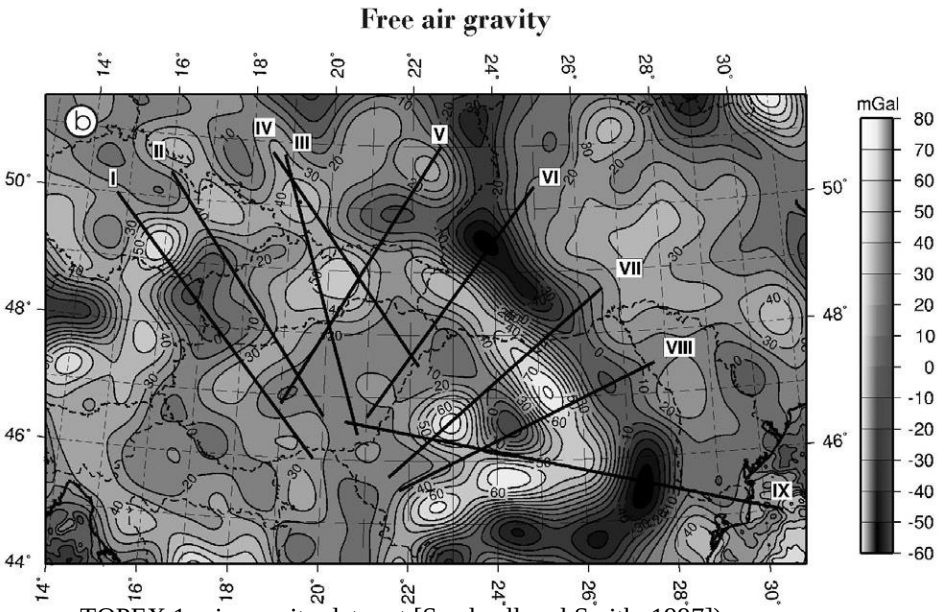
Anomalous bodies are defined:

- Heat conductivity [$W.m^{-1}K^{-1}$]
- Heat production [$W.m^{-3}$]
- Density [$kg.m^{-3}$]
- Geometry [m]

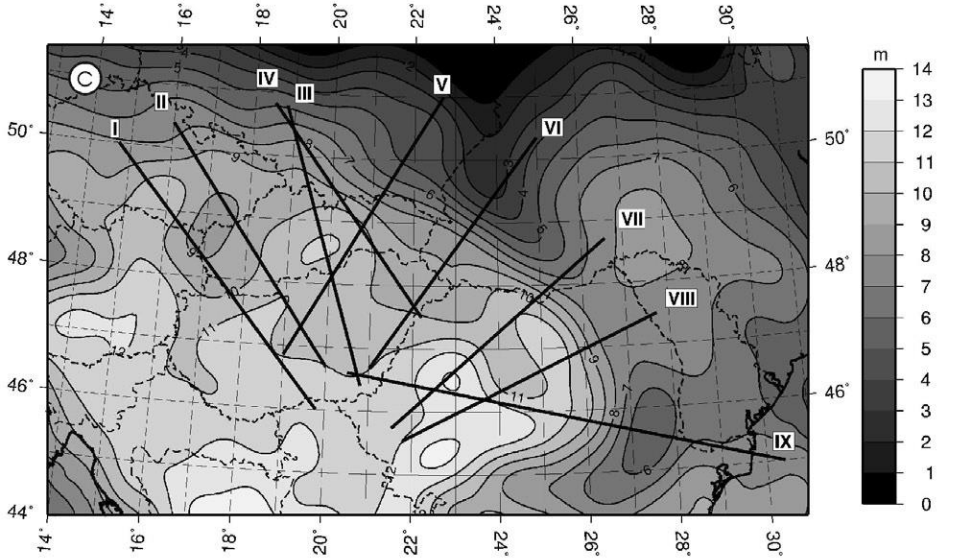
Input data



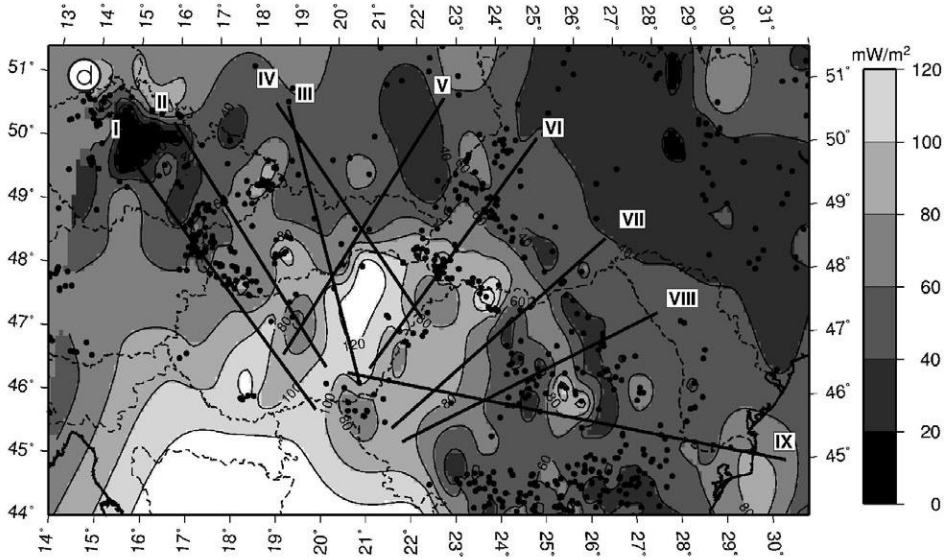
GTOPO30 database [Gesch et al., 1999]



TOPEX 1-min gravity data set [Sandwell and Smith, 1997])

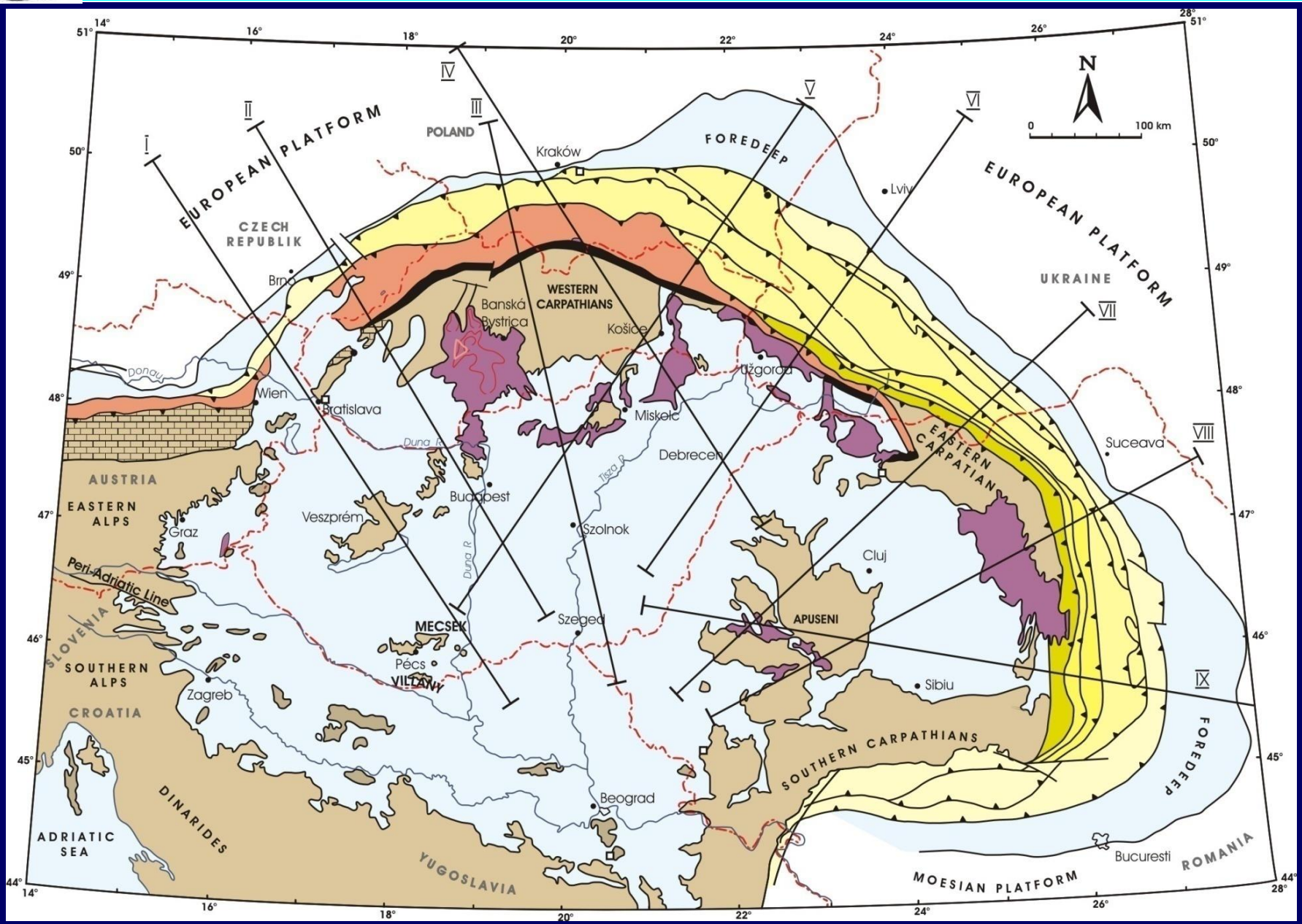


EGM96 global model **Geoid** [Lemoine et al., 1998]

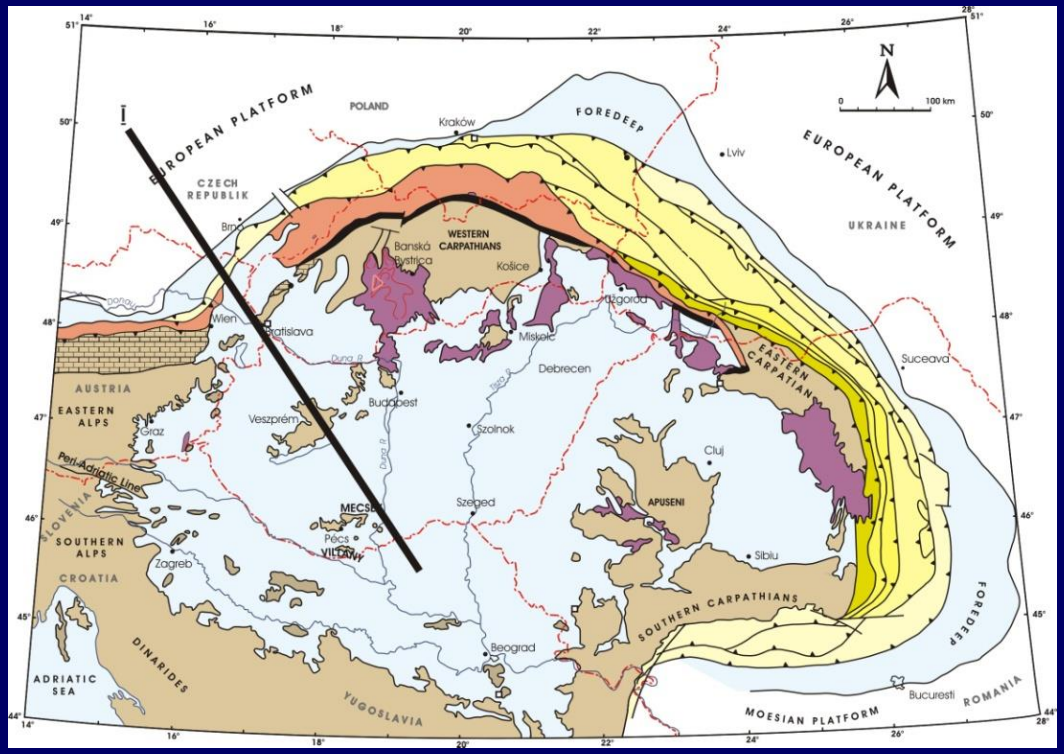


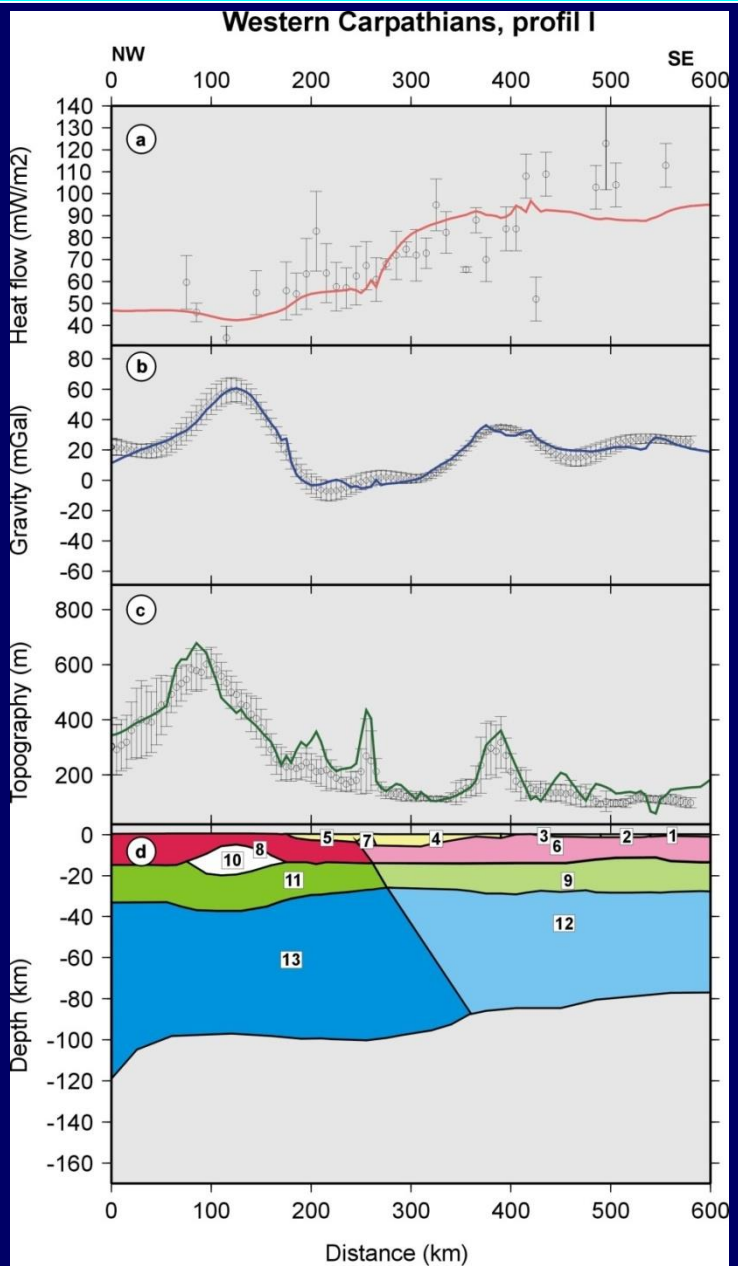
worldwide data set **Surface heat flow** Pollack et al. [1993]

Profiles location

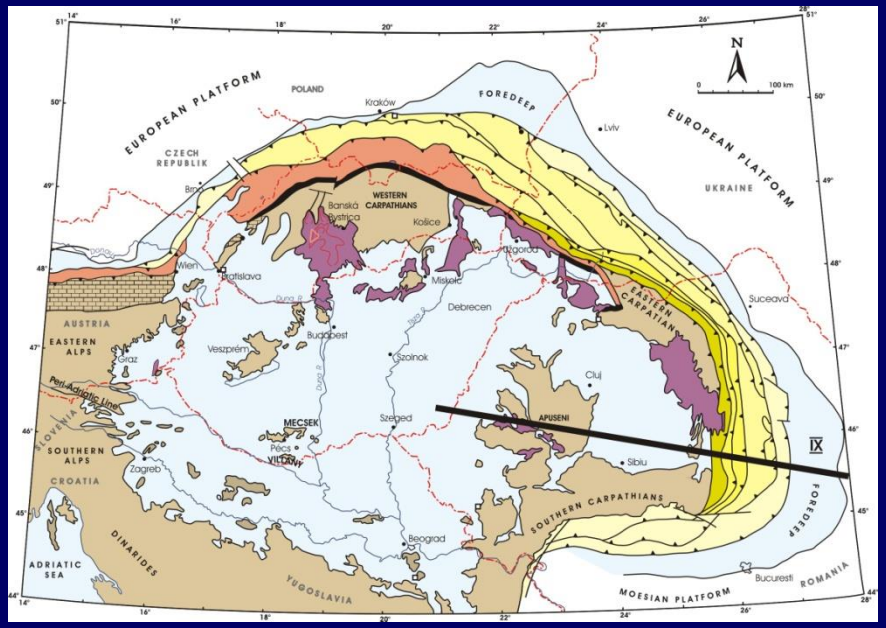


Profile I


I
EUROPEAN PLATFORM
POLAND
Kraków
FOREDEEP
Lviv
EUROPEAN PLATFORM
UKRAINE
CZECH REPUBLIK
Brno
WESTERN CARPATHIANS
Banská Bystrica
Košice
Uzgorod
Wien
Bratislava
Miskolc
Debrecen
Suceava
EASTERN CARPATIANS
AUSTRIA
EASTERN ALPS
Graz
Budapest
Veszprém
Szolnok
Cluj
Periadriatic Line
SLOVENIA
MECSEK
Pécs
VILLANY
Szeged
APUSENI
SOUTHERN ALPS
Zagreb
Sibiu
CROATIA
SOUTHERN CARPATHIANS
FOREDEEP
DINARIDES
Beograd
ADRIATIC SEA
YUGOSLAVIA
Bucuresti
ROMANIA
MOESIAN PLATFORM
N
0
100 km


Western Carpathians, profil I
NW
SE
Heat flow (mW/m2)
Gravity (mGal)
Topography (m)
Depth (km)
Distance (km)
a
b
c
d
1
2
3
4
5
6
7
8
9
10
11
12
13

Profile IX


EUROPEAN PLATFORM
POLAND
Kraków
FOREDEEP
EUROPEAN PLATFORM
UKRAINE
Lviv
CZECH REPUBLIK
WESTERN CARPATHIANS
Banská Bystrica
Košice
Wien
Bratislava
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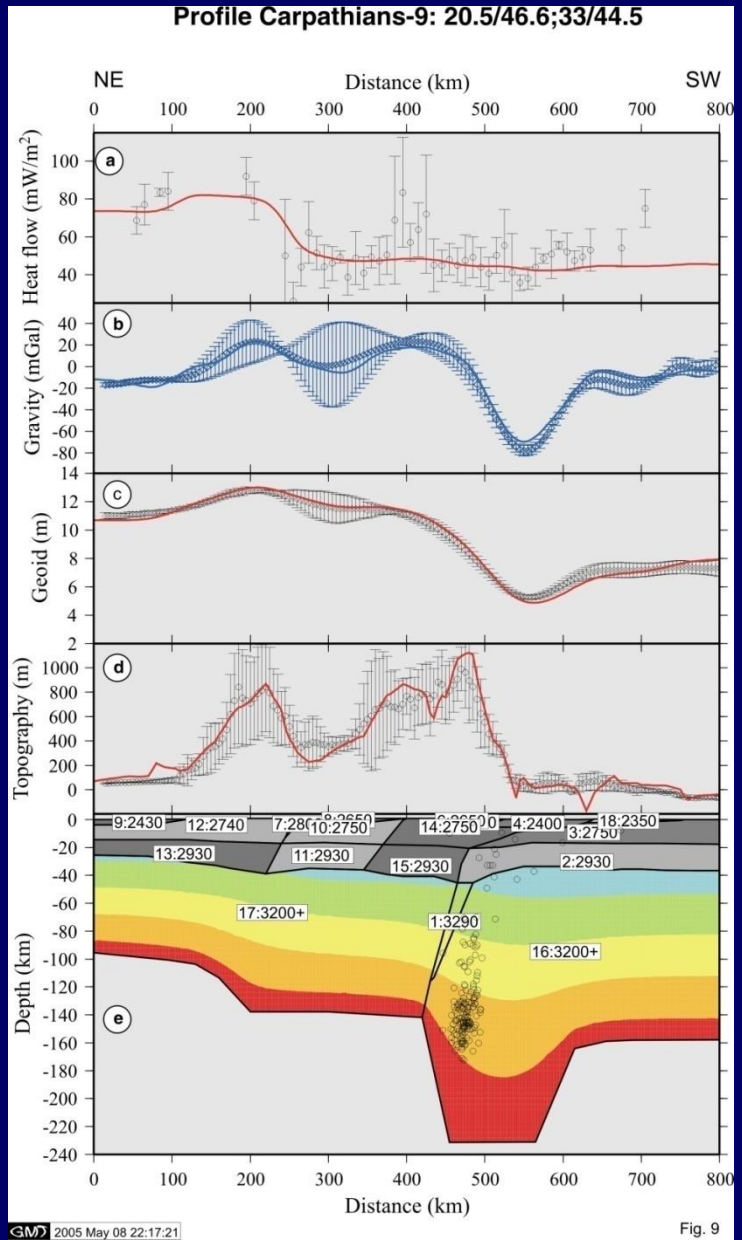
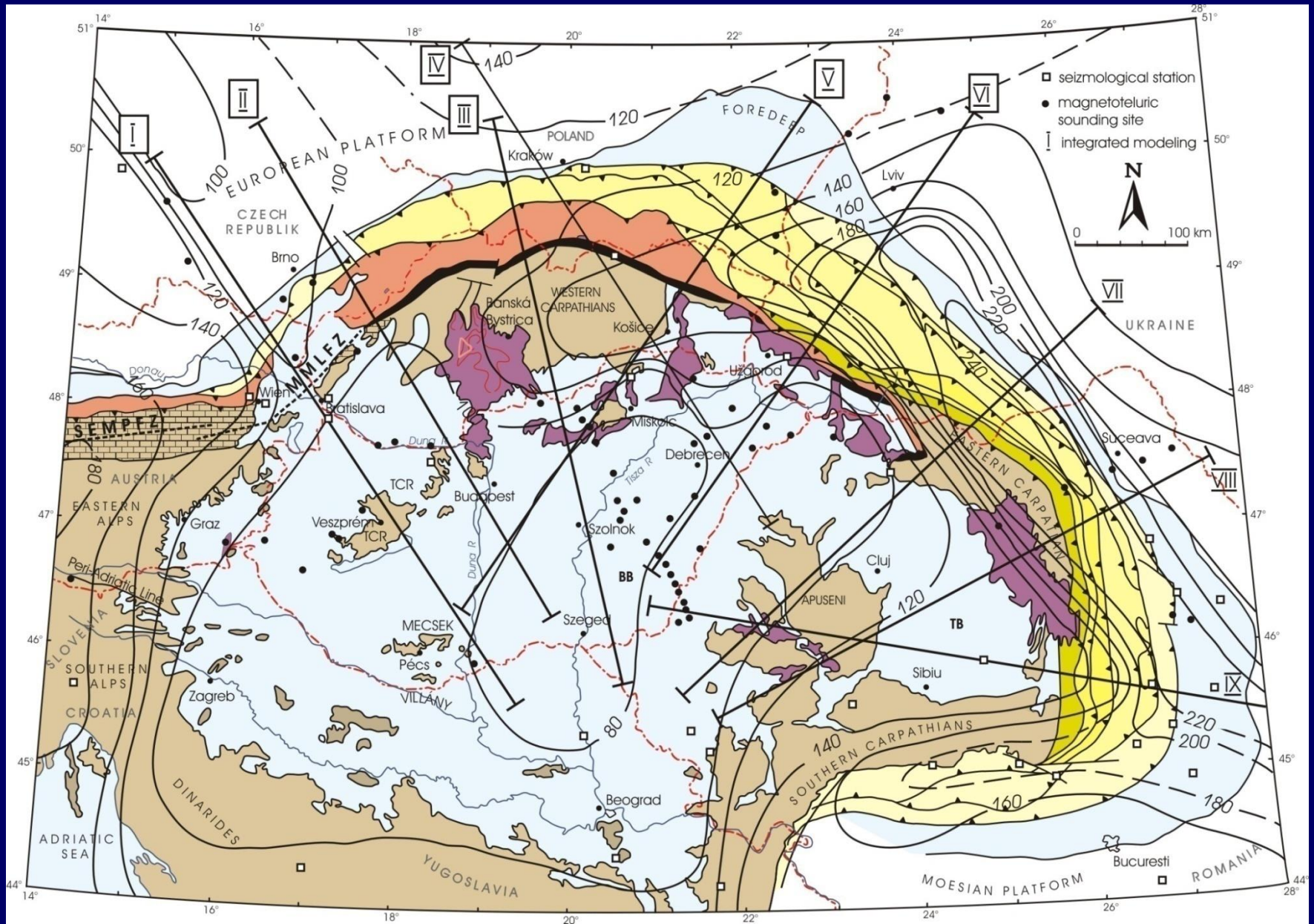
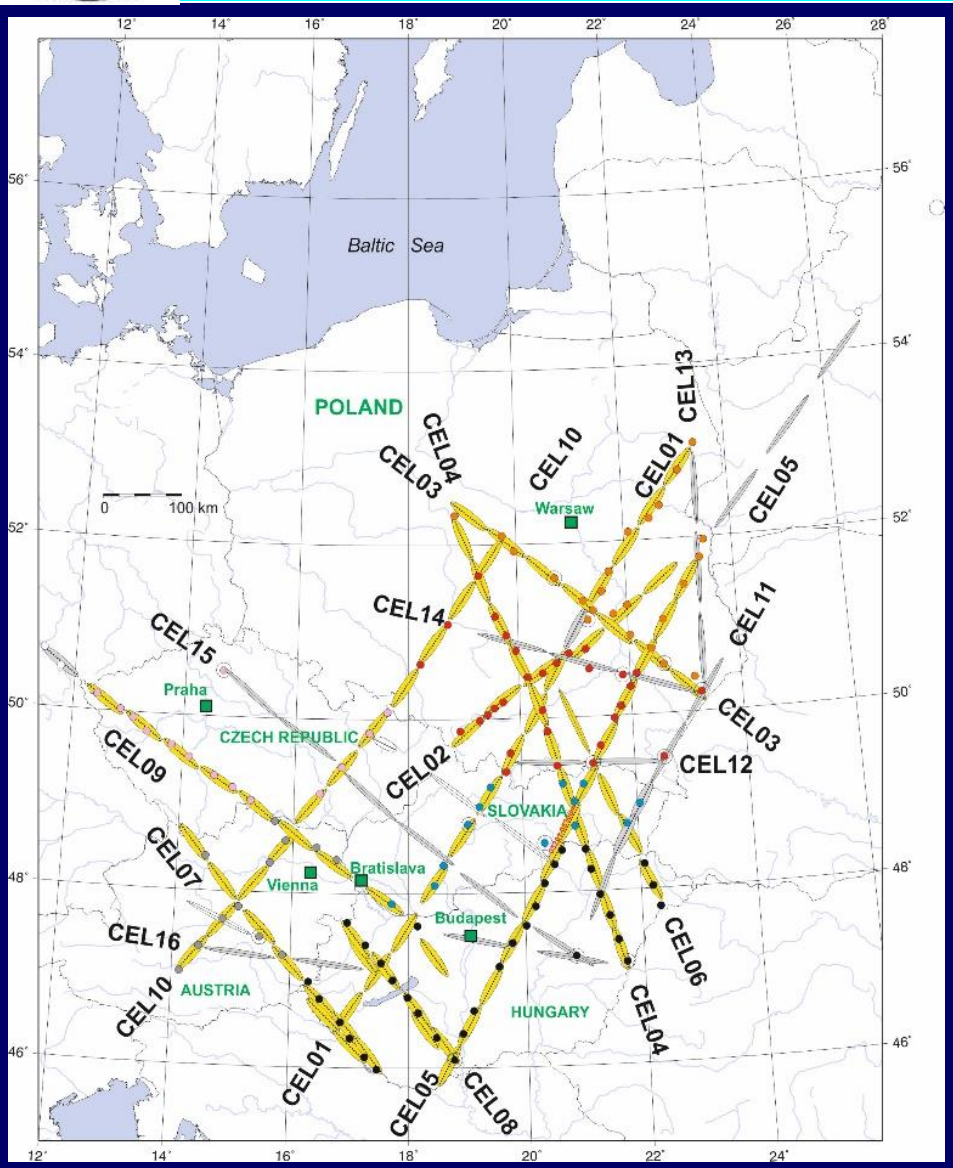
APUSENI
Pécs
VILLÁNY
IX
SOUTHERN ALPS
Zagreb
Sibiu
CROATIA
SOUTHERN CARPATHIANS
FOREDEEP
Beograd
DINARIDES
ADRIATIC SEA
YUGOSLAVIA
Bucuresti
ROMANIA
MOESIAN PLATFORM
N
0
100 km

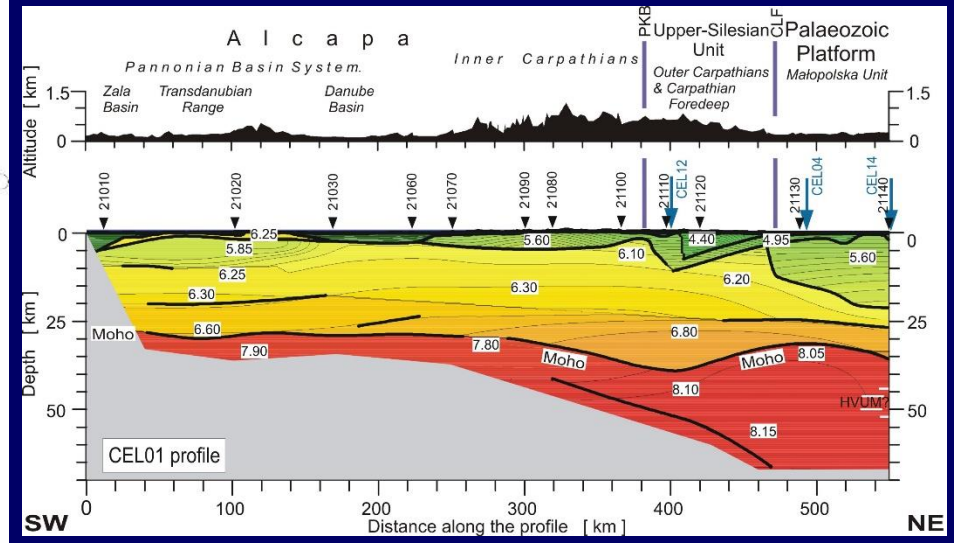

Profile Carpathians-9: 20.5/46.6;33/44.5
NE
Distance (km)
SW
Heat flow (mW/m²)
Gravity (mGal)
Geoid (m)
Topography (m)
Depth (km)
a
b
c
d
e
9:2430
12:2740
7:2860
8:2650
10:2750
14:2750
20:2650
4:2400
18:2350
3:2750
13:2930
11:2930
15:2930
2:2930
17:3200+
1:3290
16:3200+
Distance (km)
GMT 2005 May 08 22:17:21
Fig. 9

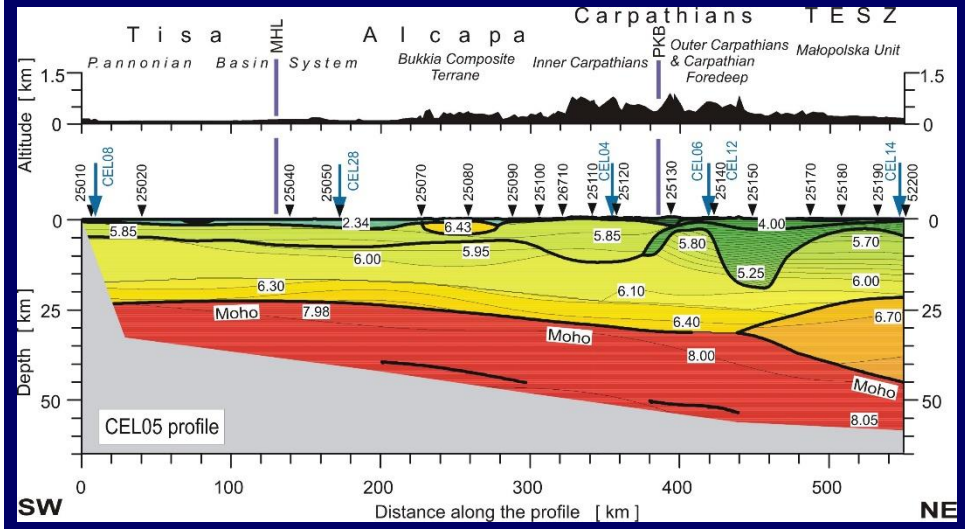
Map of lithosphere thickness



CELEBRATION 2000 seismic experiment

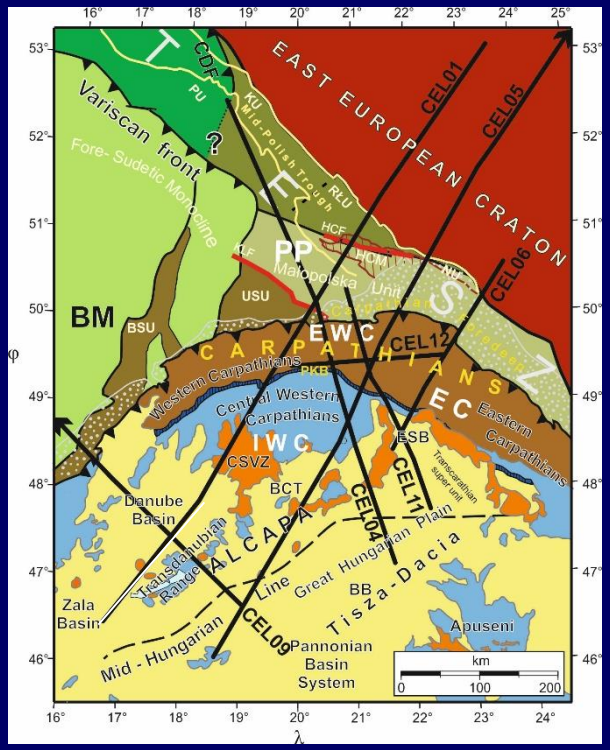




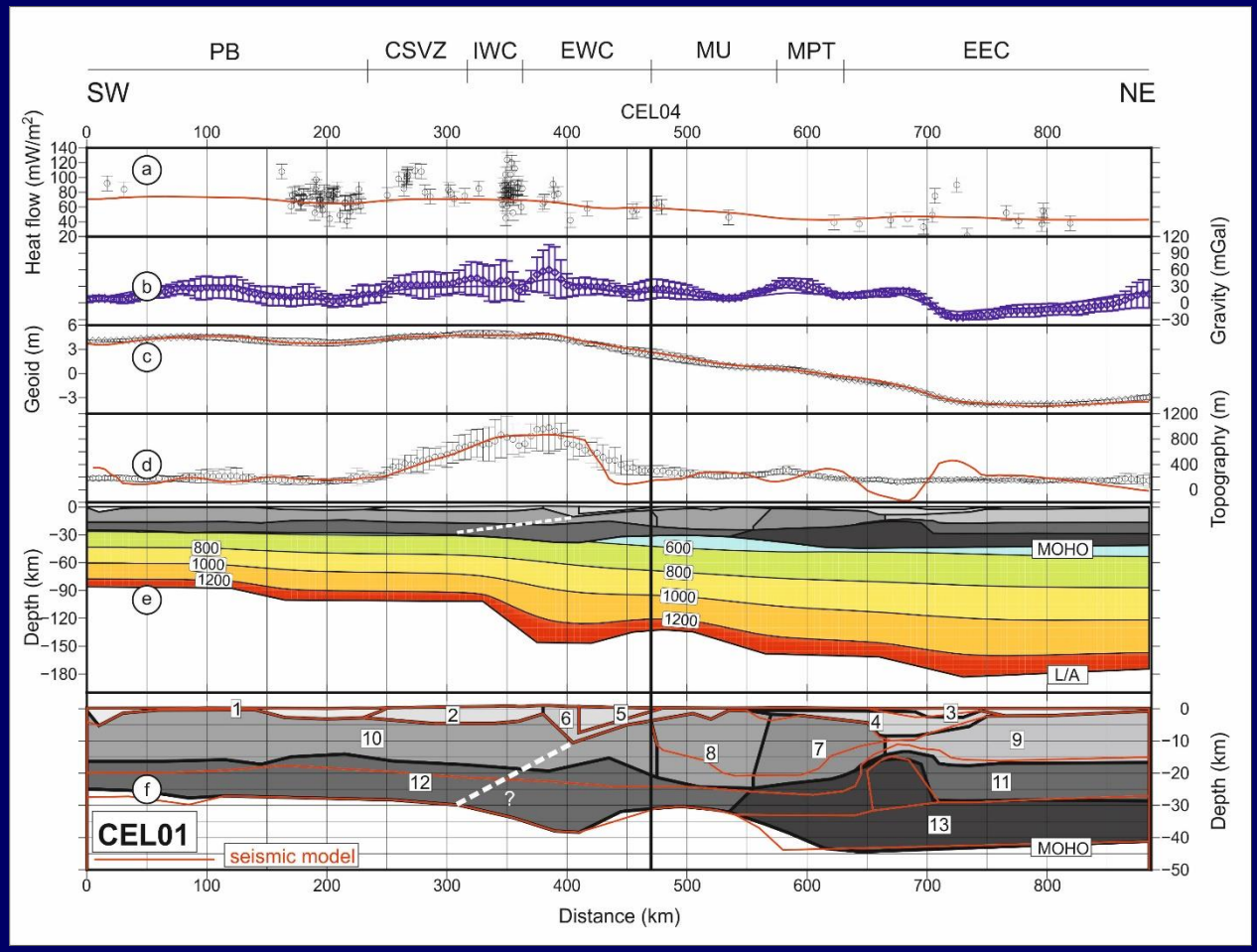


Location of the profiles of the CELEBRATION 2000 experiment (modified after Guterch et al. 2003)

Lithospheric model for profile CEL01

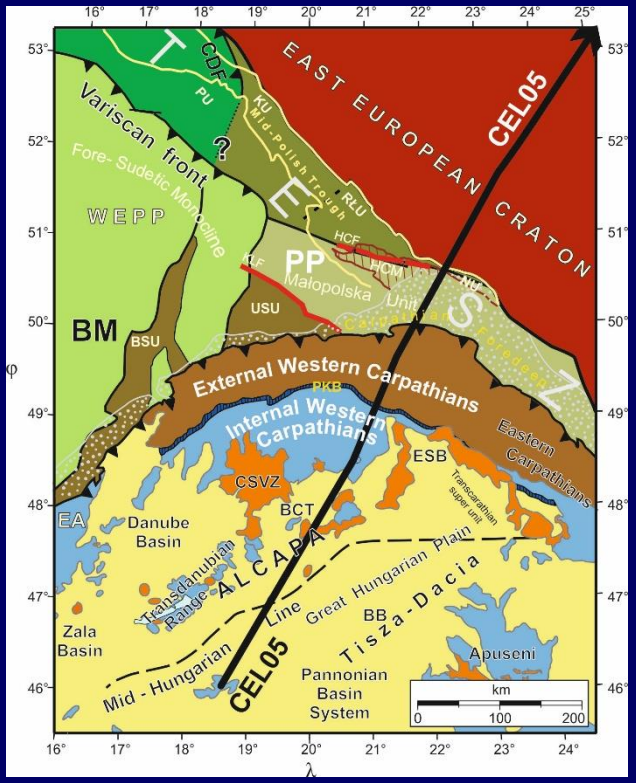


Location of the CELEBRATION 2000 seismic profile CEL01 on the background of geological map of Central Europe

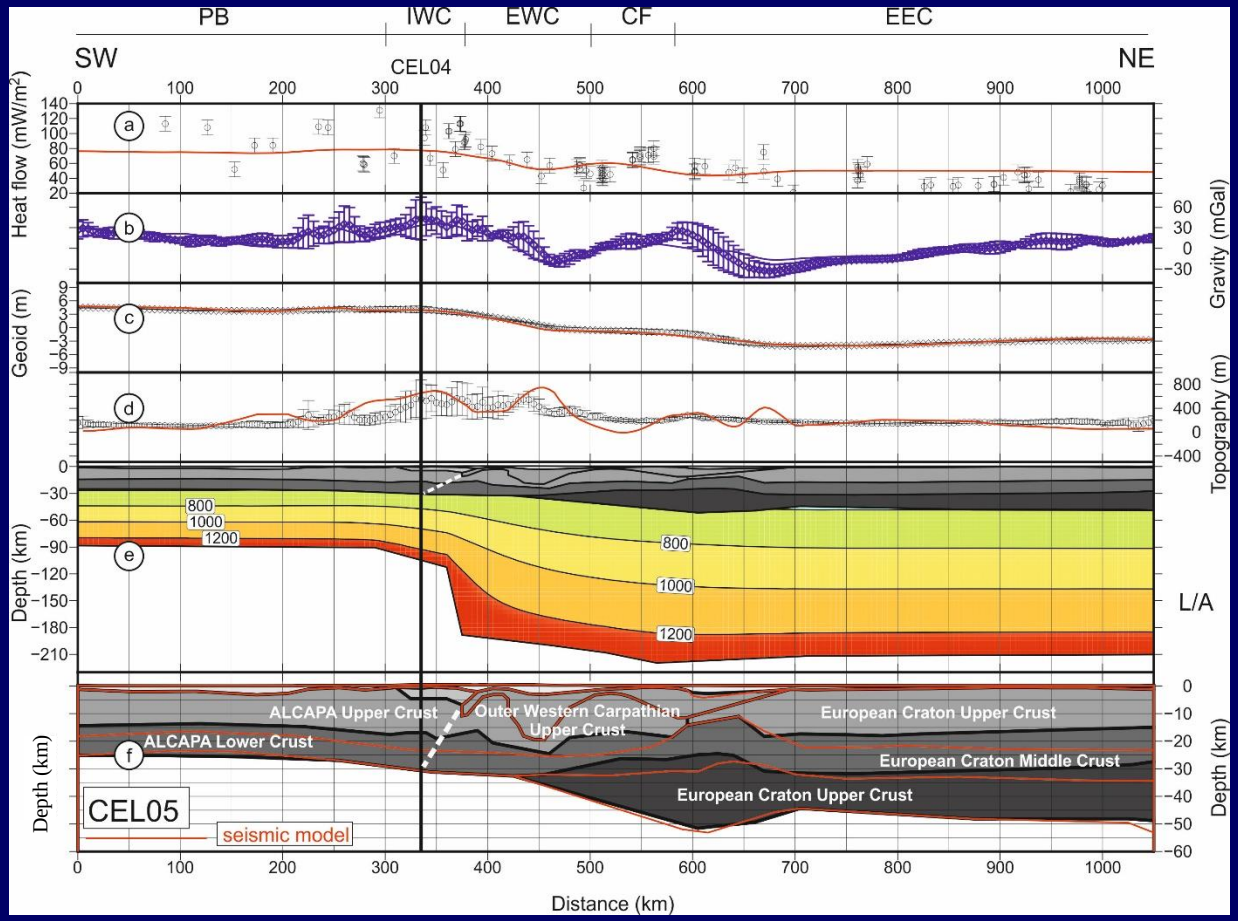


(a) Surface heat flow density, (b) free-air gravity anomaly, (c) geoid, (d) topography with dots corresponding to measured data with uncertainty bars and solid lines for calculated values; (e) lithospheric structure, in the lithospheric mantle, isotherms are indicated every 200 °C; (f) crustal structure. The white dashed line indicates the expected boundary between microplate ALCAPA and European platform.

Lithospheric model for profile CEL05



Location of the CELEBRATION 2000 seismic profile CEL05 on the background of geological map of Central Europe



(a) Surface heat flow density, (b) free-air gravity anomaly, (c) geoid, (d) topography with dots corresponding to measured data with uncertainty bars and solid lines for calculated values; (e) lithospheric structure, in the lithospheric mantle, isotherms are indicated every 200 °C; (f) crustal structure. The white dashed line indicates the expected boundary between microplate ALCAPA and European platform.

3D INTEGRATED GEOPHYSICAL MODELLING

Lit Mod software

Finite difference method

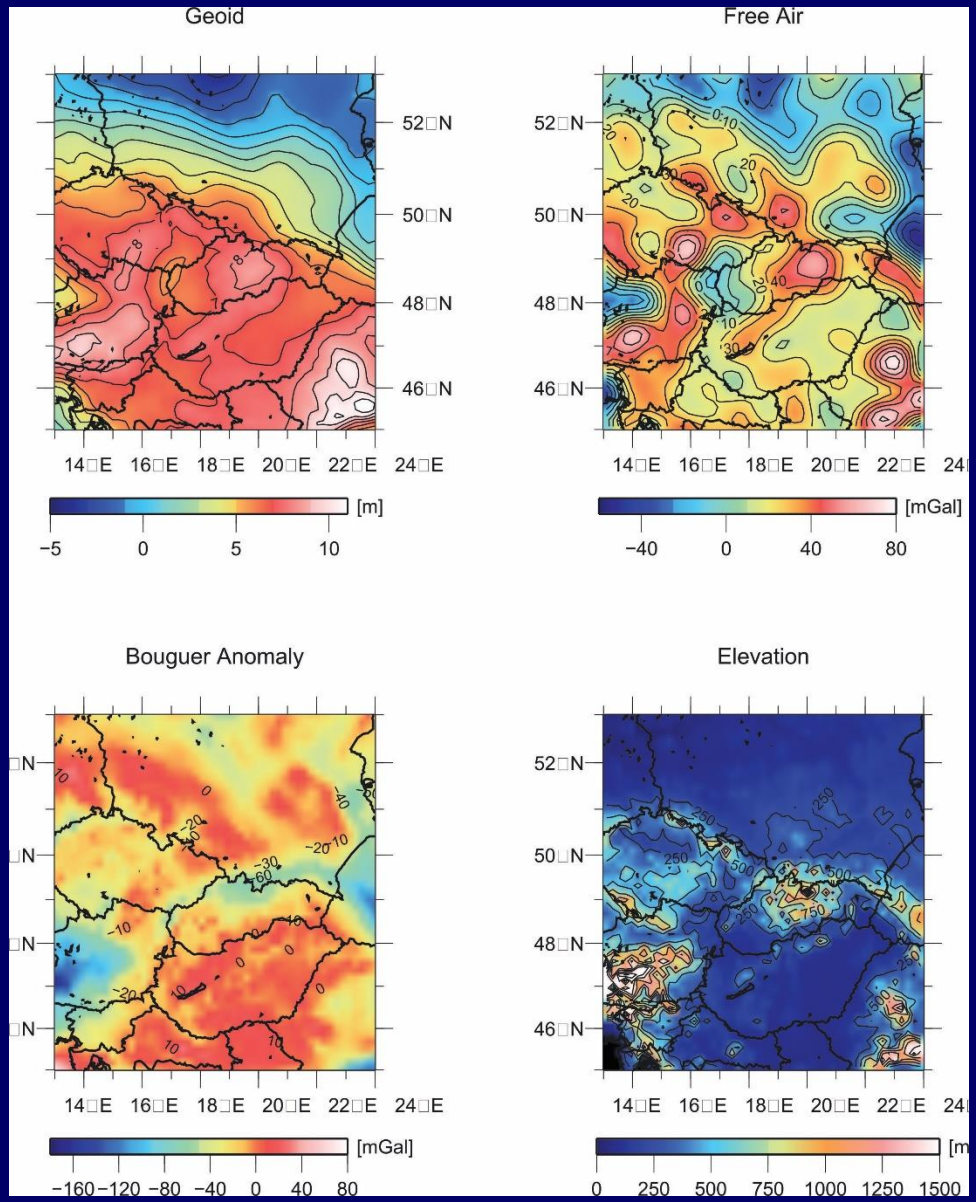
Numerical implementations are given by
AFONSO ET AL. 2008 and FULLEA ET AL. 2009

combining a geophysical, geological and upper mantle petrological data is capable to study both

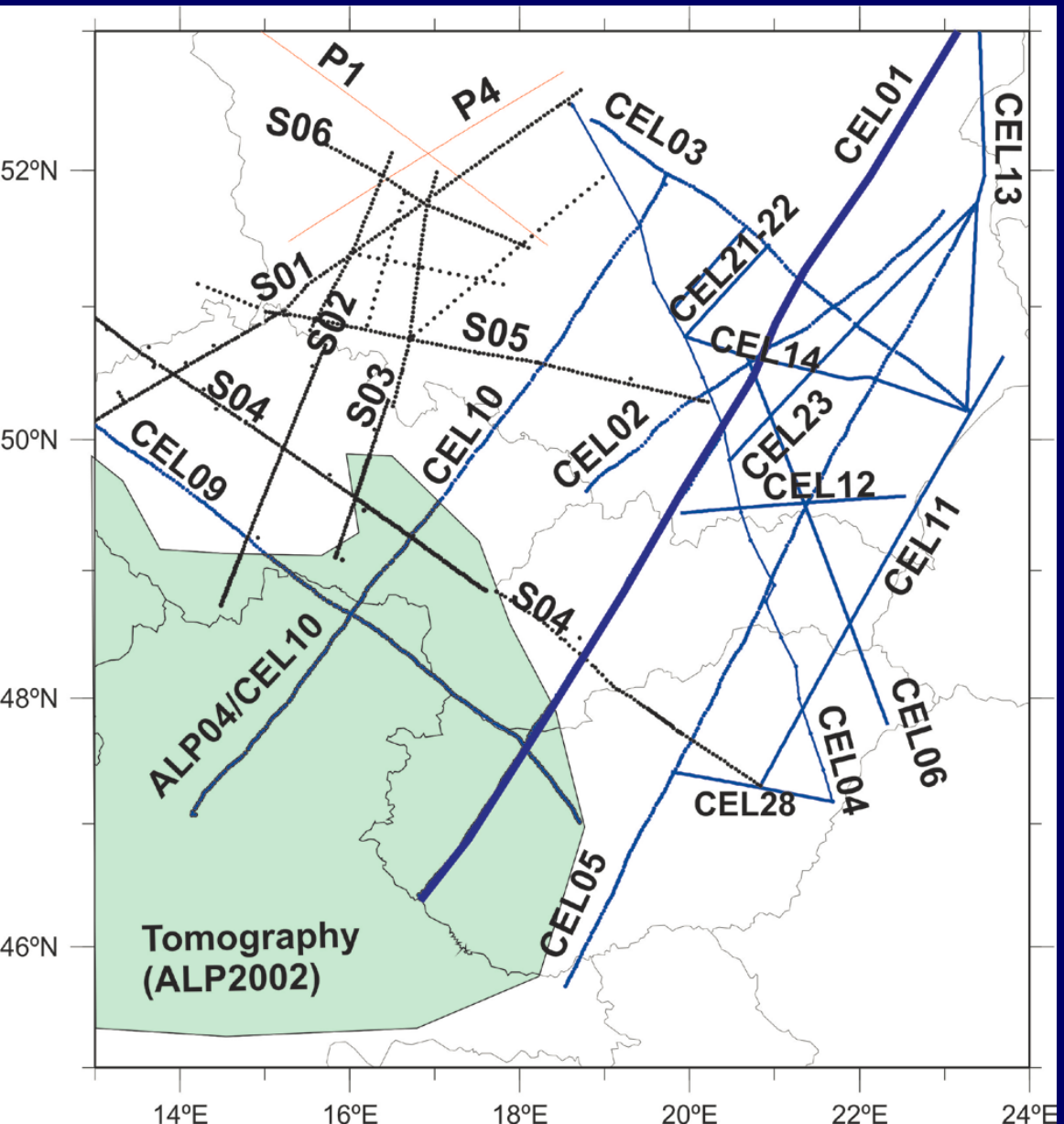
the crust and the lower lithophere

3D integrated geophysical modelling

Input data



3D integrated geophysical modelling

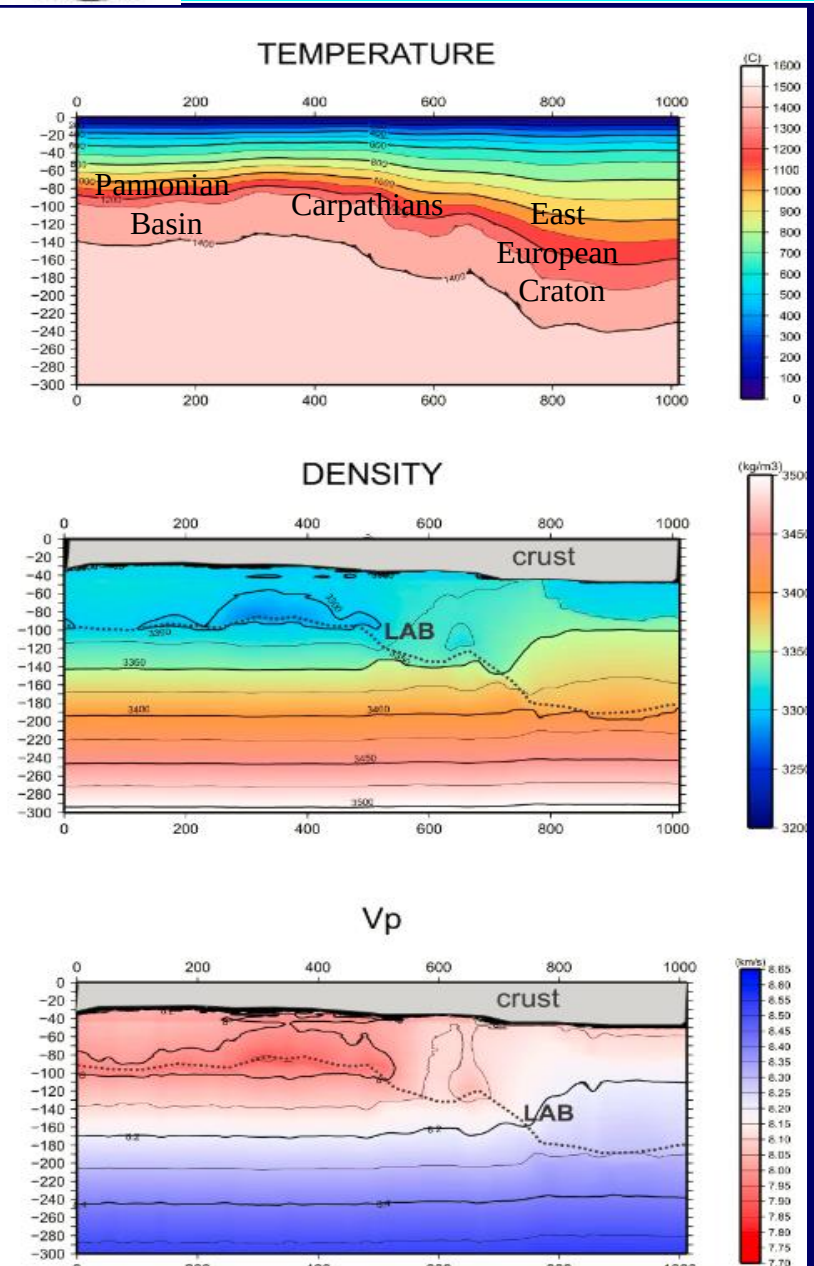


Robust model is based on the results of the seismic projects

- POLONAISE 97
- CELEBRATION 2000
- ALPS 2002
- SUDETES 2003

Seismic study includes 18 000 profile km in total

3D integrated geophysical modelling



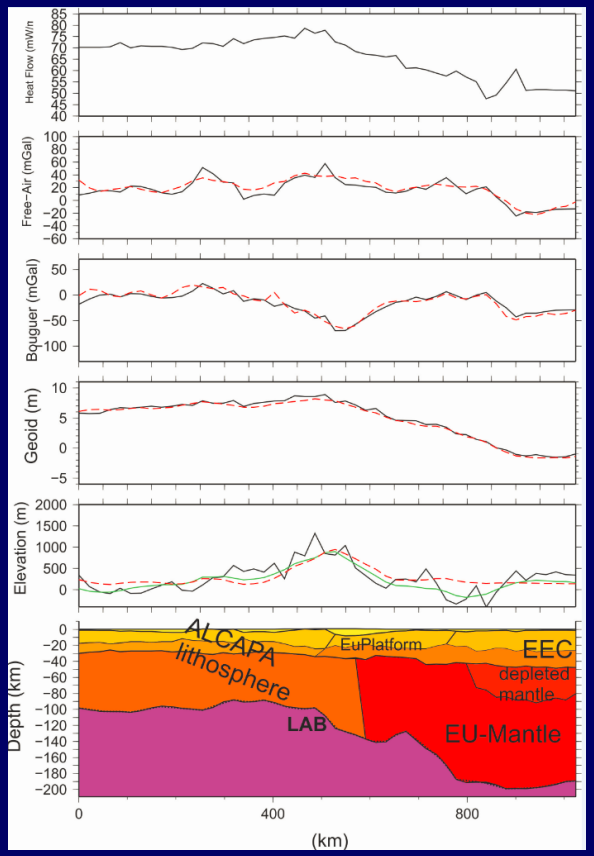
Profile CEL01

Distribution of:

- **Temperature**
- **Density**
- **Seismic velocity**

in Lower Lithosphere and Asthenosphere

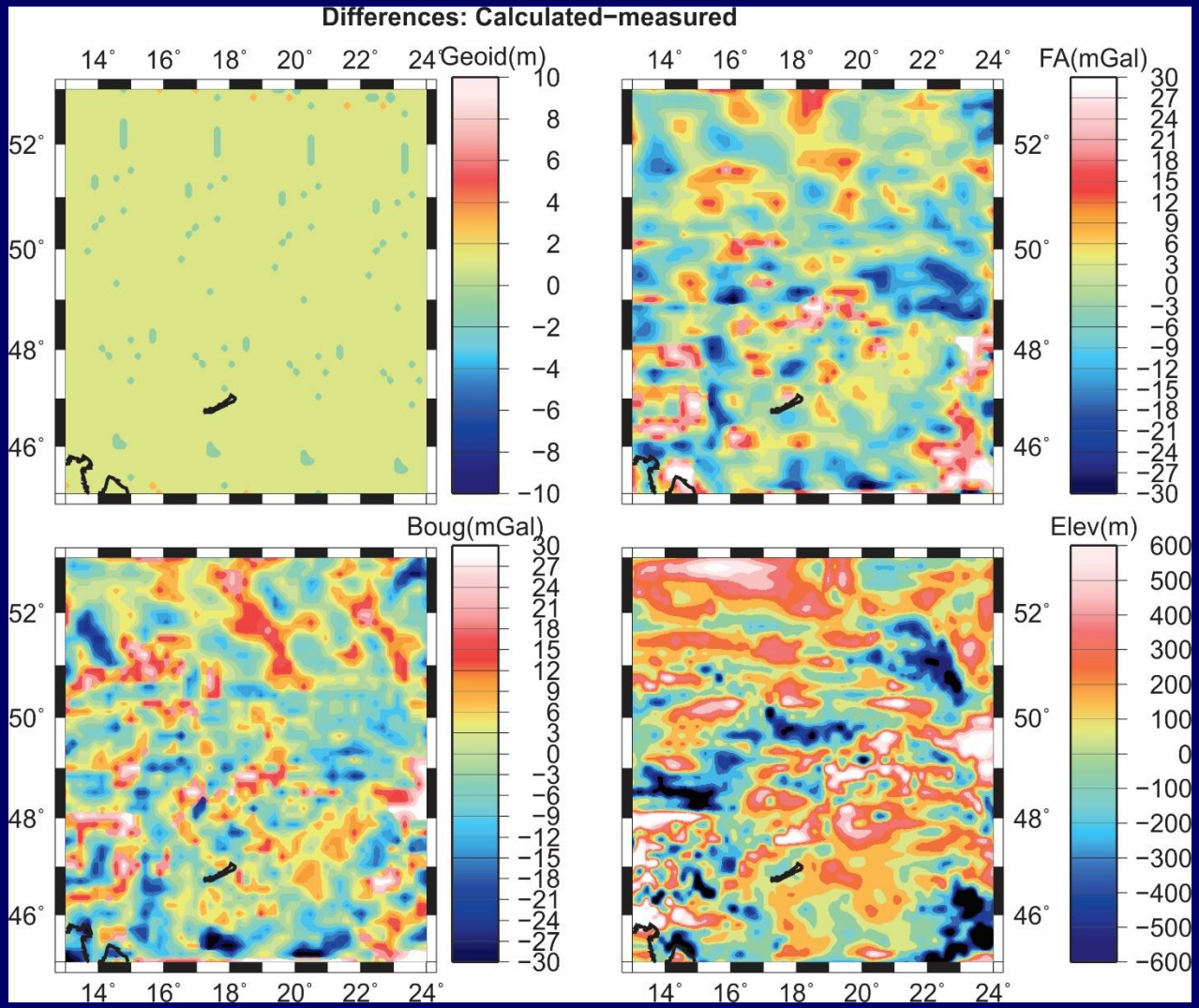
3D INTEGRATED GEOPHYSICAL MODELLING



Profile CEL01
Geophysical model of the lithosphere

- **Fit to the observed and modeled data**

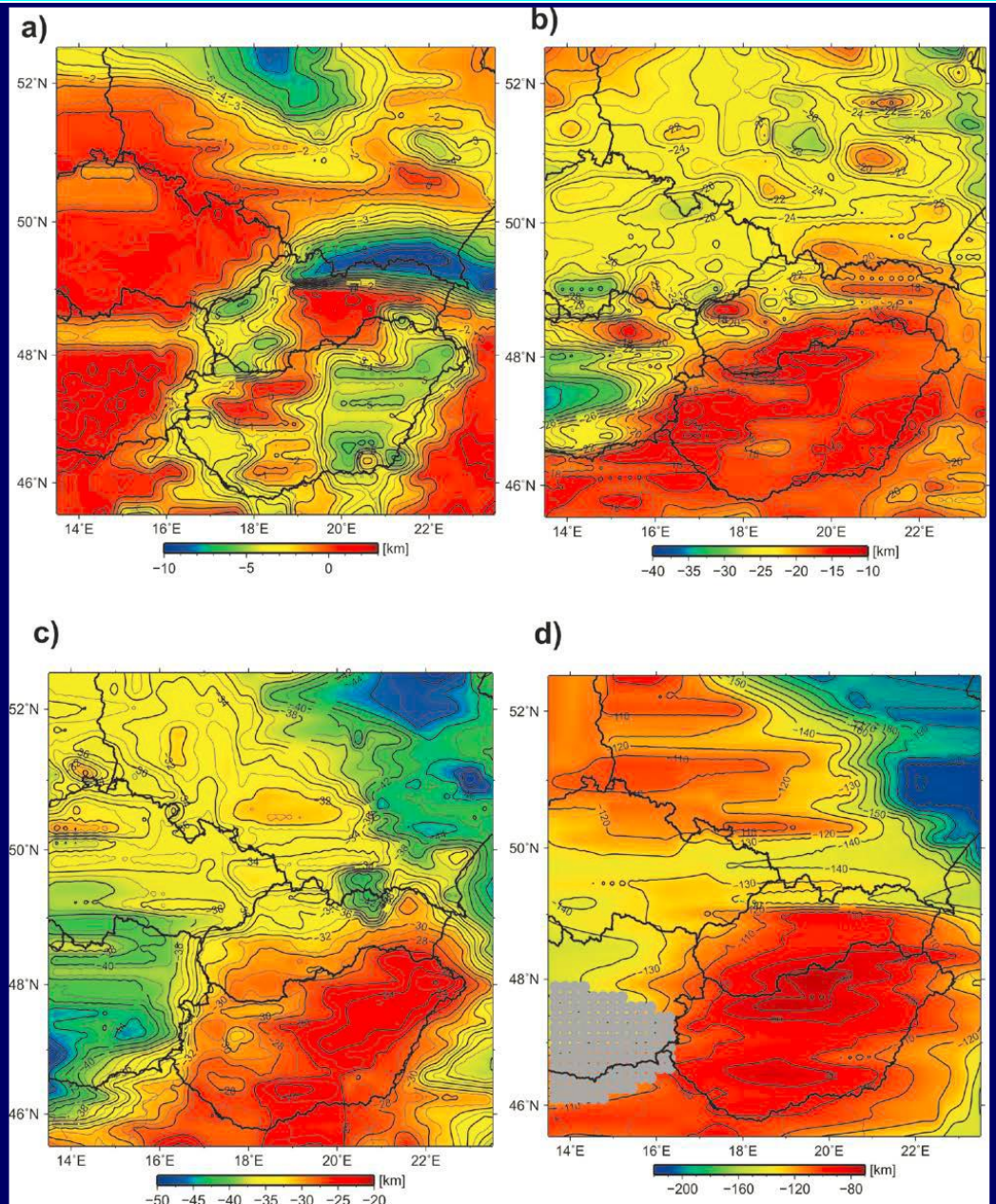
Fit to the observed and modeled data for the studied area



3D integrated geophysical modelling

Sediment thickness

Depth of the boundary between upper and lower crust



Moho depth

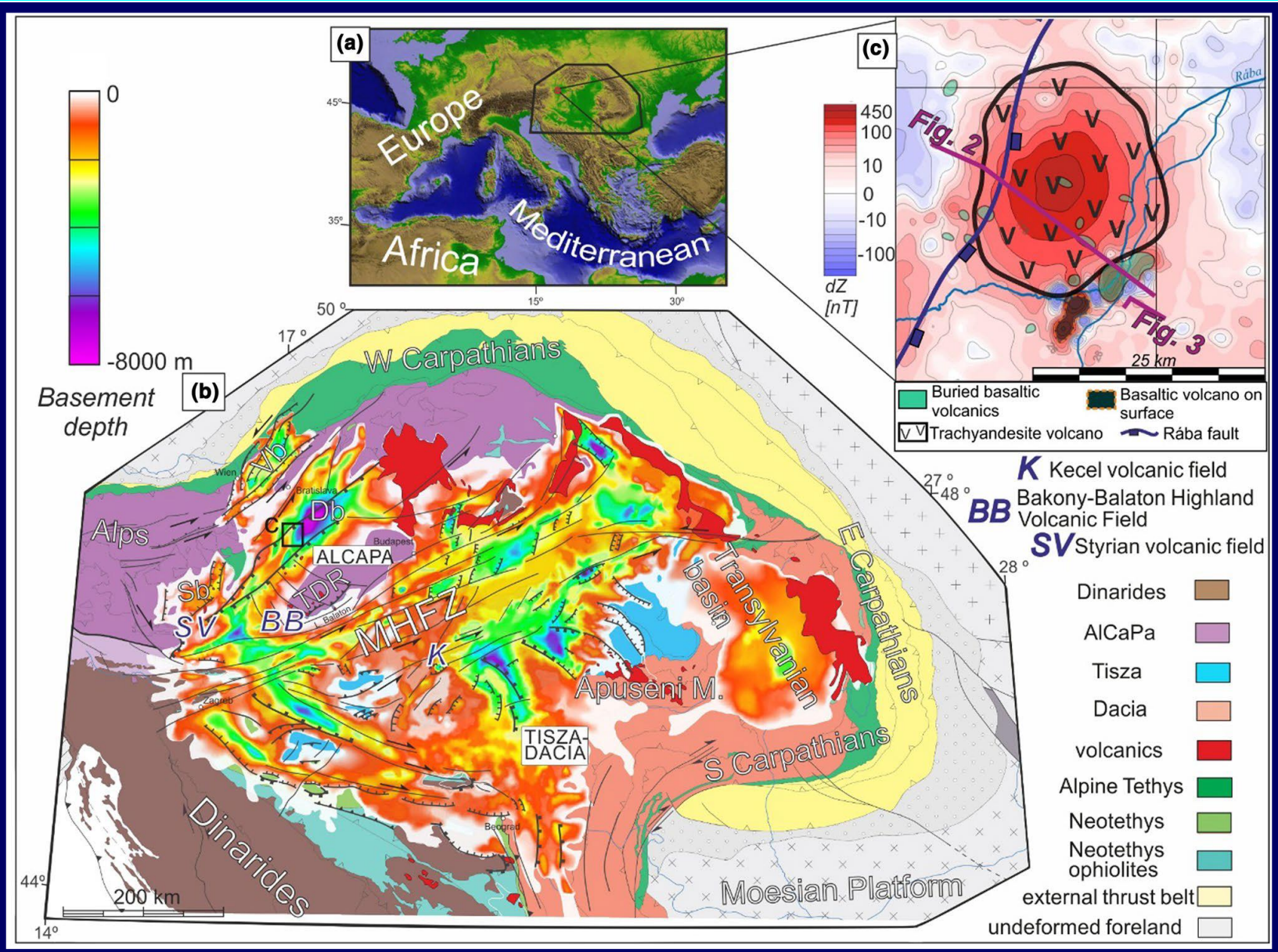
LAB depth

IGMAS+

3D interdisciplinary modelling approach

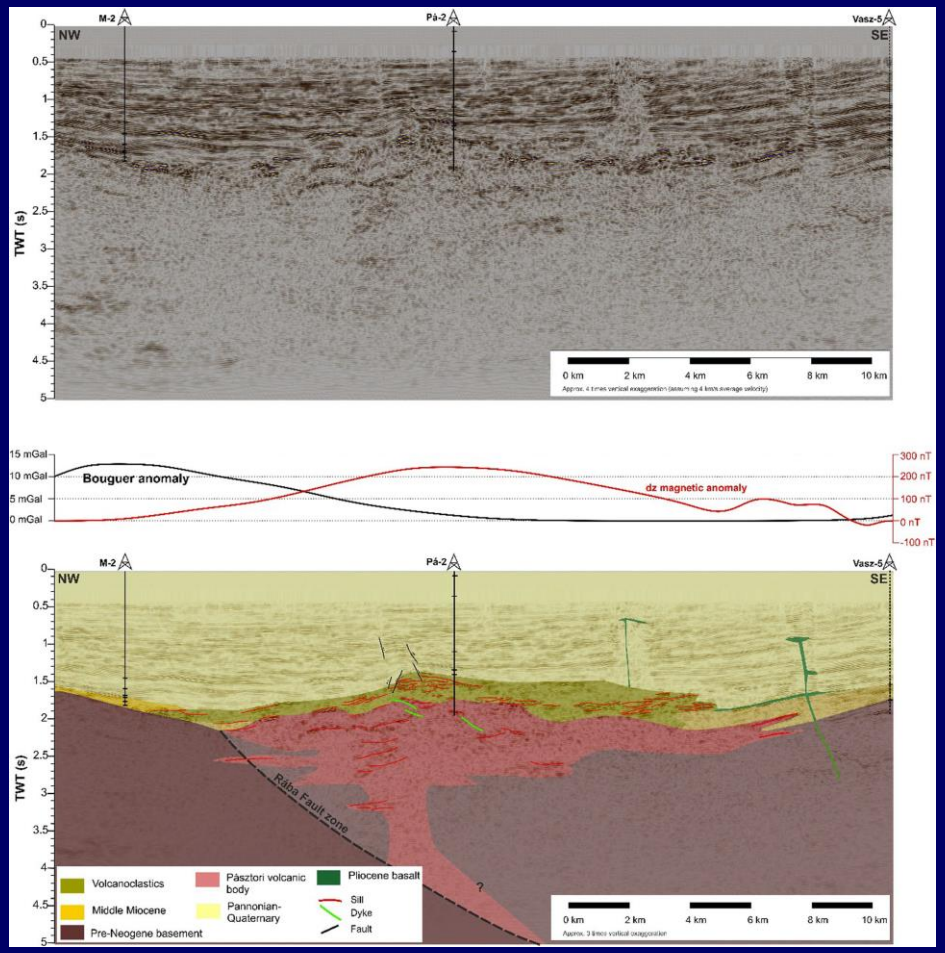
given by
Schmidt et al. (2015) and Götze (2014)

3D integrated geophysical modelling of the Pásztori volcano in the Danube Basin



3D integrated geophysical modelling

Reflection seismic transect calibrated by well data from the southern part of the Danube Basin



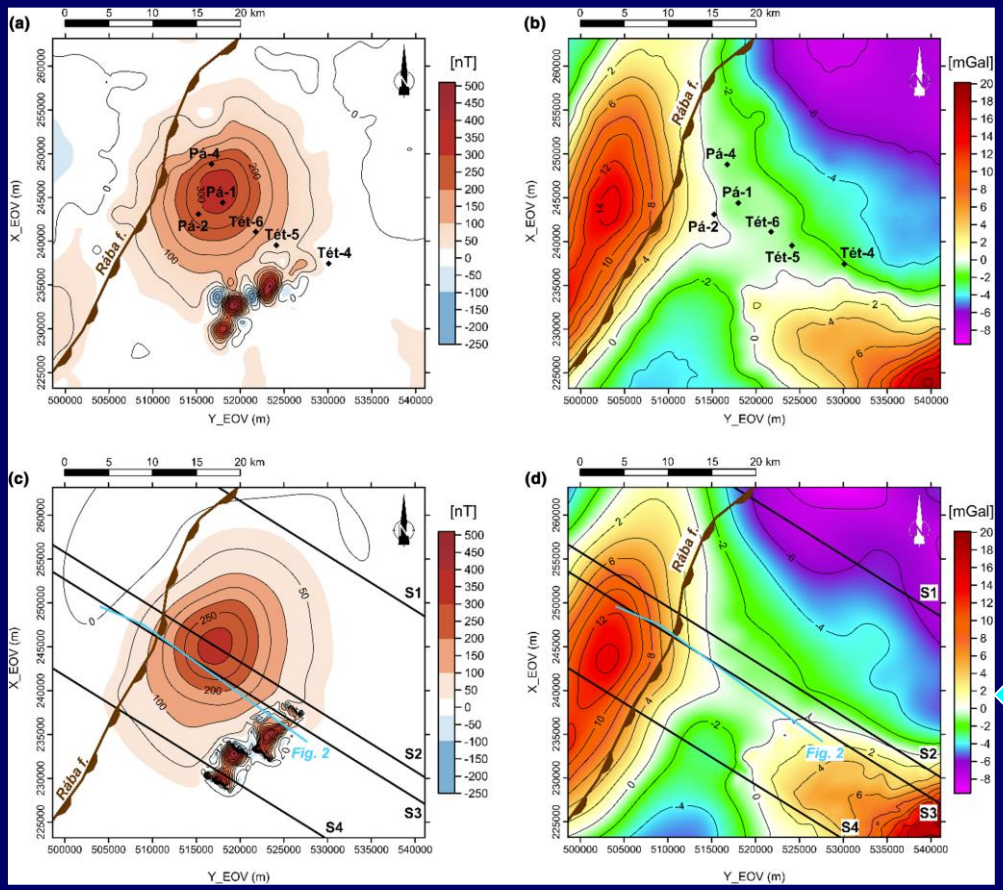
Low Bouguer gravity but high magnetic anomalies above the Pásztori volcano

3D integrated geophysical modelling

Observed magnetic field above the Pásztori volcano

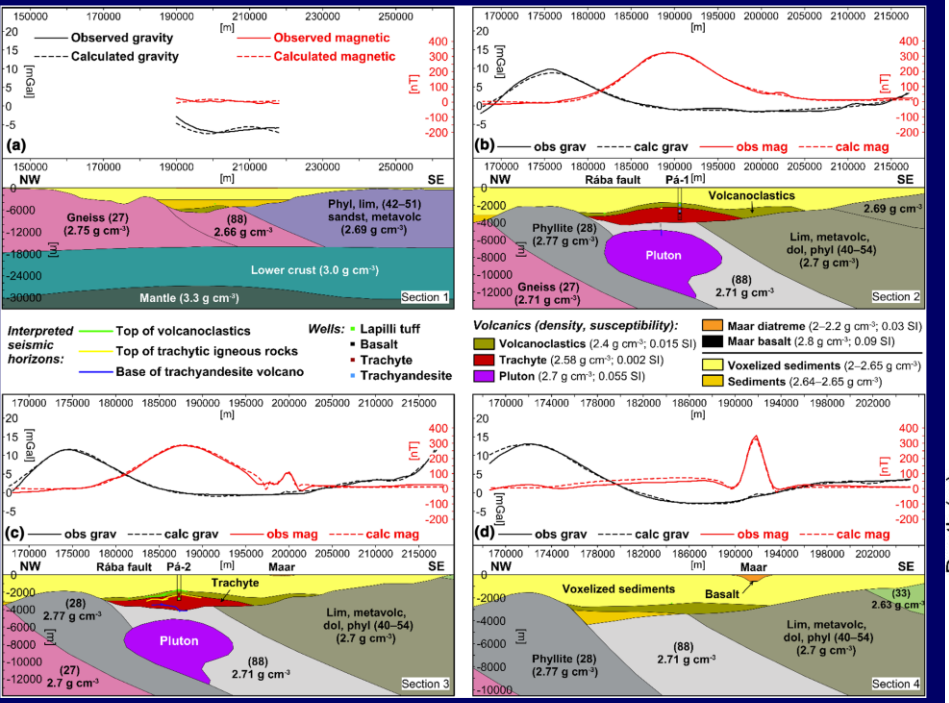
Observed gravity field above the Pásztori volcano

Calculated magnetic field above the Pásztori volcano

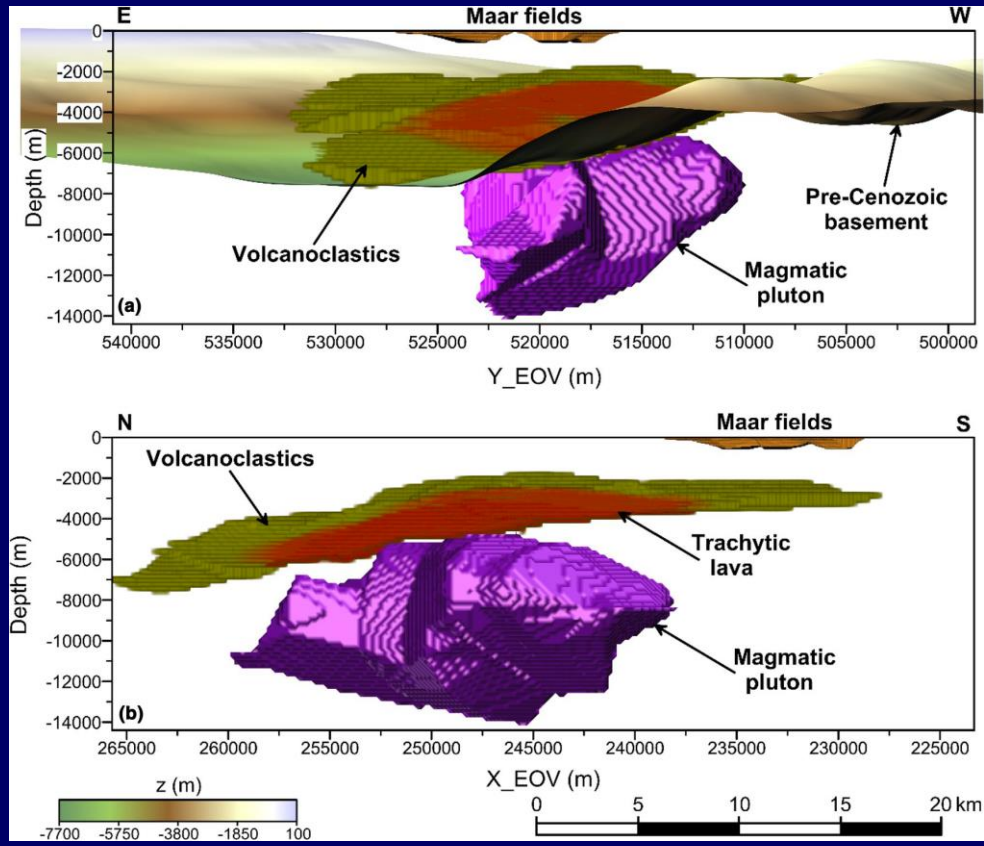


Calculated gravity field above the Pásztori volcano

3D integrated geophysical modelling

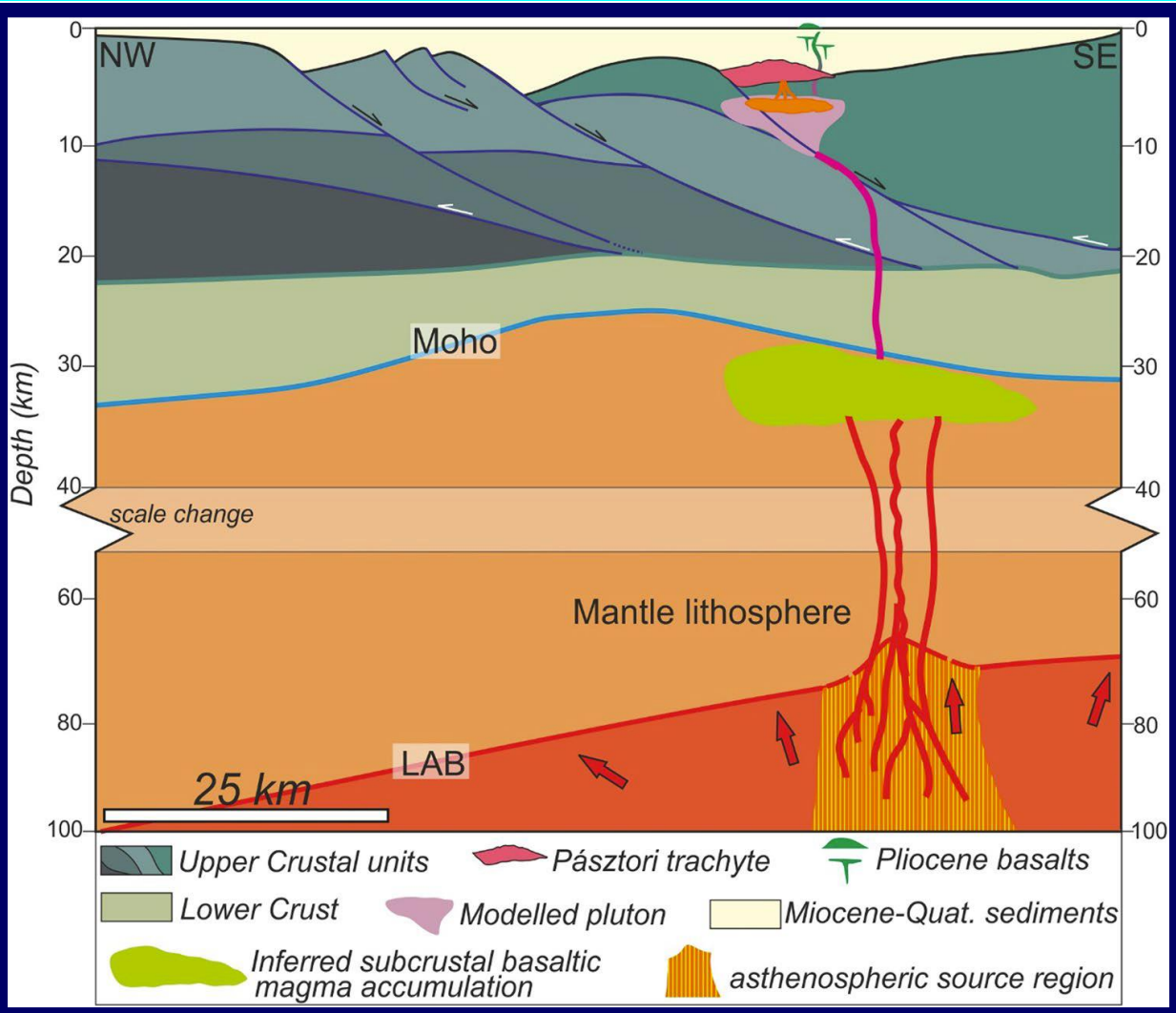


Four selected cross sections of the final Pásztori model

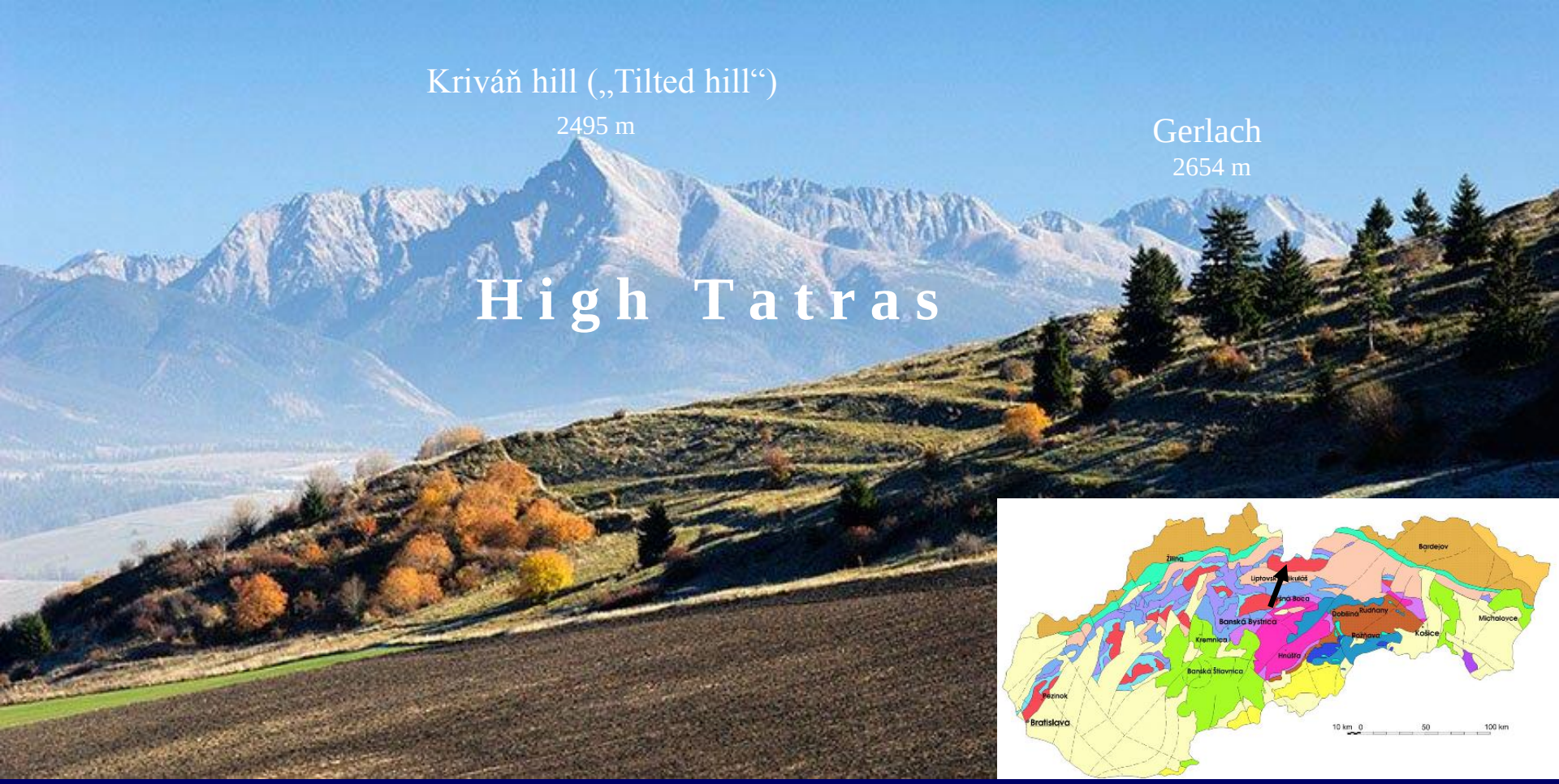


3D geophysical model of the Pásztori volcano: north view (a) and west view (b)

3D integrated geophysical modelling



Simplified sketch showing the asthenospheric sourced volcanism in the Little Hungarian Plain Volcanic Field



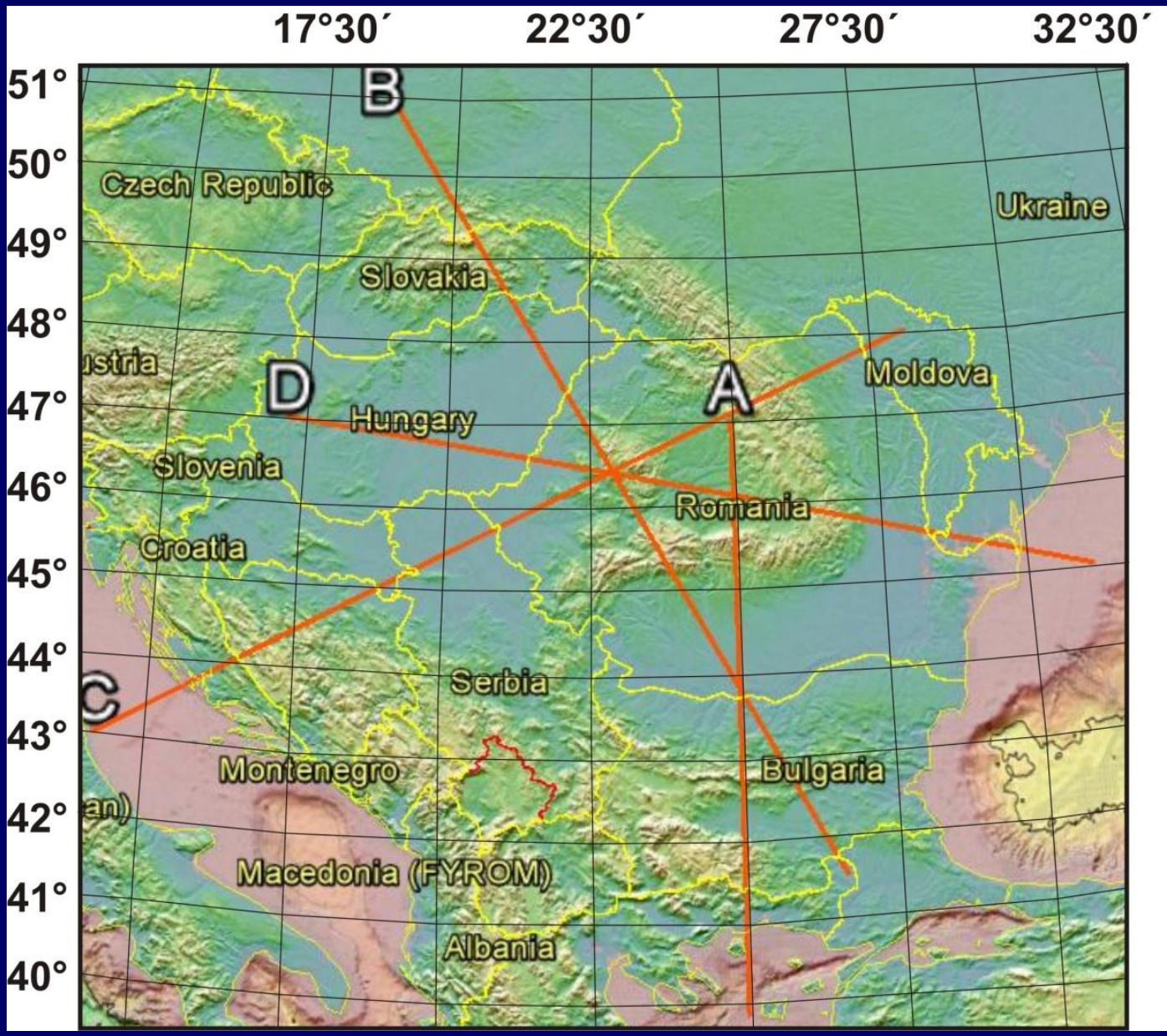
Thank you for your attention

and special thanks to

Baron Roland von Eötvös

Central european lithospheric transects

Location of 2-D transects



Lithospheric model for transect C