3D inversion of gravity data by separation of sources and the method of local corrections: Kolárovo case study

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the inversion method :
method of local corrections

inversion of potential field data

in terms of

isolated compact (star-convex) source bodies

or

density/magnetic contrast contact surfaces (interfaces)

or

the combination of the two

the method :

1) Separation of signal of sources from a pre-selected depth interval :
   upward-downward-upward harmonic continuation
2) Lateral signal of sources separation :
   3D line segment approximation
3) Method of local corrections
   geometry of star-convex source homogenous bodies
   geometry of contrast interfaces (contact surfaces)
   combination of the two above

Elimination of signal of sources down to depth *d*

(making the field harmonic down to depth *d*)

1) **Upward harmonic continuation to height = *d* (above surface)**
   Poisson integral (planar approximation)
   removal of model regional field
   numerical integration inside data area only
2) **Downward harmonic continuation over 2*d* (to depth *d*)**
   Poisson integral – integral equation
   continuation through sources
   linear ill-posed inverse problem -- regularization
3) **Upward harmonic continuation over *d* (back to surface)**
   Poisson integral (planar approximation)
   numerical integration

REMOVAL OF MODEL REGIONAL FIELD

Model regional field -- 3D surface *f* (x,y)

- harmonic in 2D sense
- on the boundary of the data area same values as data

$$\begin{cases} \frac{\partial^2 f}{\partial^2 x} + \frac{\partial^2 f}{\partial^2 y} = 0 & \text{within area } S \\ f = \Delta g & \text{on its boundary } \partial S \end{cases}$$

- ☐ has no extrema (maxima or minima) inside data area
- ☐ creates no false signal in terms of causative bodies

UPWARD HARMONIC CONTINUATION – DIRECT

$$\frac{1}{2\pi} \iint \frac{h}{\left((x-x')^2 + (y-y')^2 + h^2\right)^{3/2}} U(x,y,0)\, dxdy = U(x',y',h)$$

h = d

DOWNWARD HARMONIC CONTINUATION – INVERSE PROBLEM

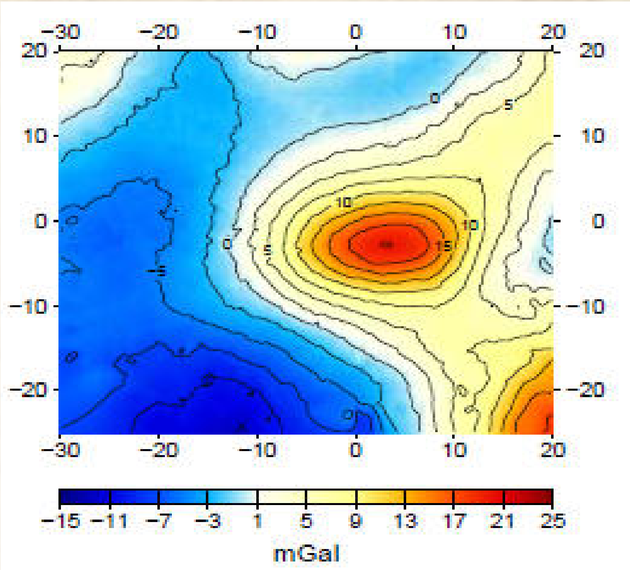
$$\frac{1}{2\pi} \iint \frac{h_1}{\left((x-x')^2 + (y-y')^2 + h_1^2\right)^{3/2}} U(x,y,-h)\, dxdy = U(x',y',h),$$

h = d

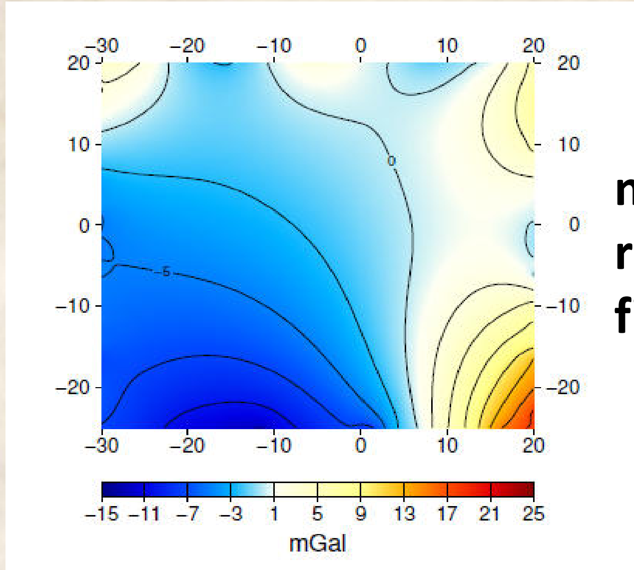
h_1 = 2d

KOLÁROVO GRAVITY ANOMALY

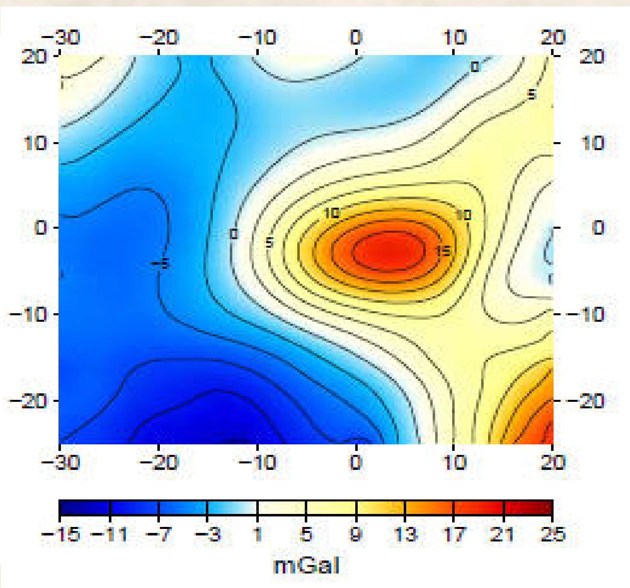
observed gravity anomaly



model regional field

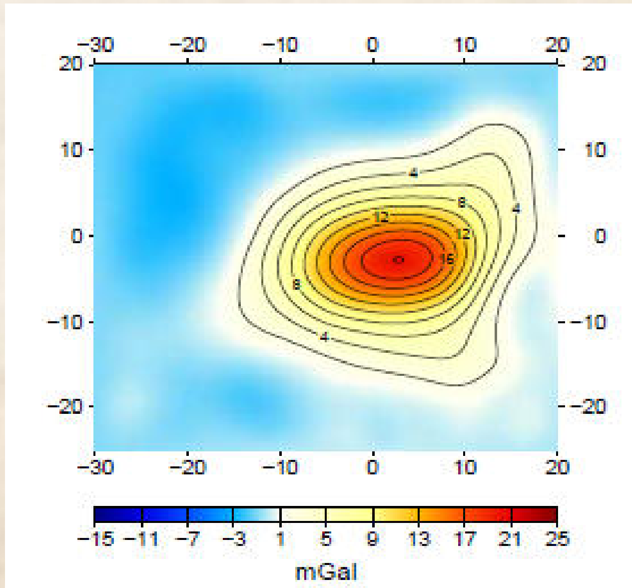


observed gravity anomaly, signal of shallow sources to 2 km removed



residual gravity anomaly

signal of sources



INVERSION BY THE METHOD OF LOCAL CORRECTIONS

Assumptions:

causative anomalous density distribution given by:

- ❑ star-convex compact homogenous body/bodies
- ❑ density contrast contact surface/surfaces (interfaces)
- ❑ combination of above

Inversion:

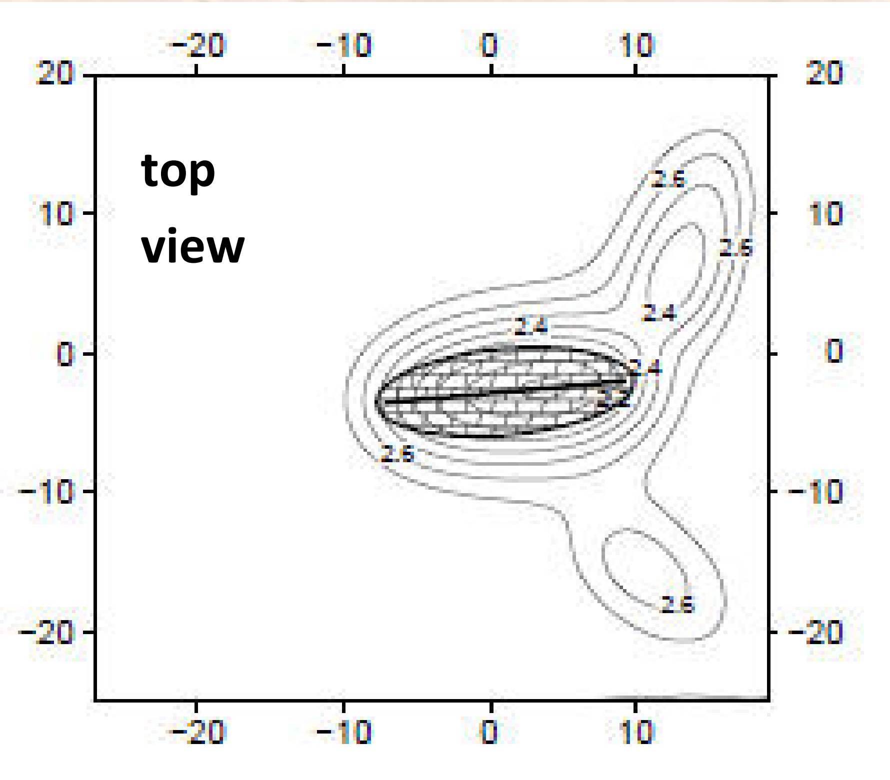
geometry is the solution (non-linear inverse problem)

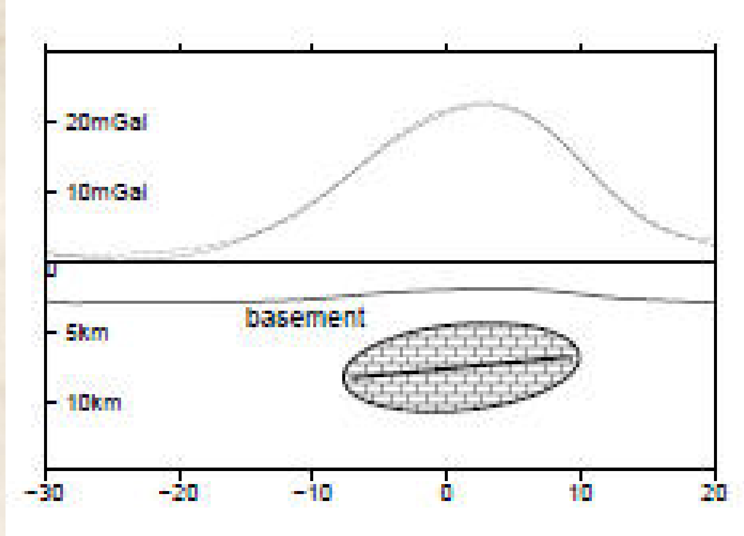
- ➢ non-linear integral equation for 3D geometry of the boundary
- ➢ discretization
- ➢ ill-posed problem – regularization
- ➢ iterations (for 3D geometry of surfaces / body shapes)
- ➢ 3D line segments assist in starting the iterations
- ➢ assymptotic plane in case of contrast interfaces

KOLÁROVO GRAVITY ANOMALY INVERSION – SOLUTION A

density contrast 300 kg/m³

2 line segments – bottom boundary of sediments (contour lines – depth to basement)
1 line segment – anomalous causative body (ellipsoid) entirely within basement





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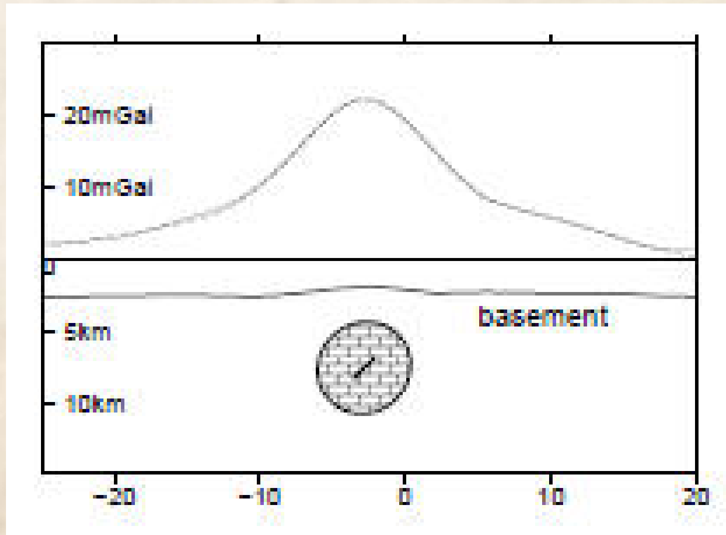

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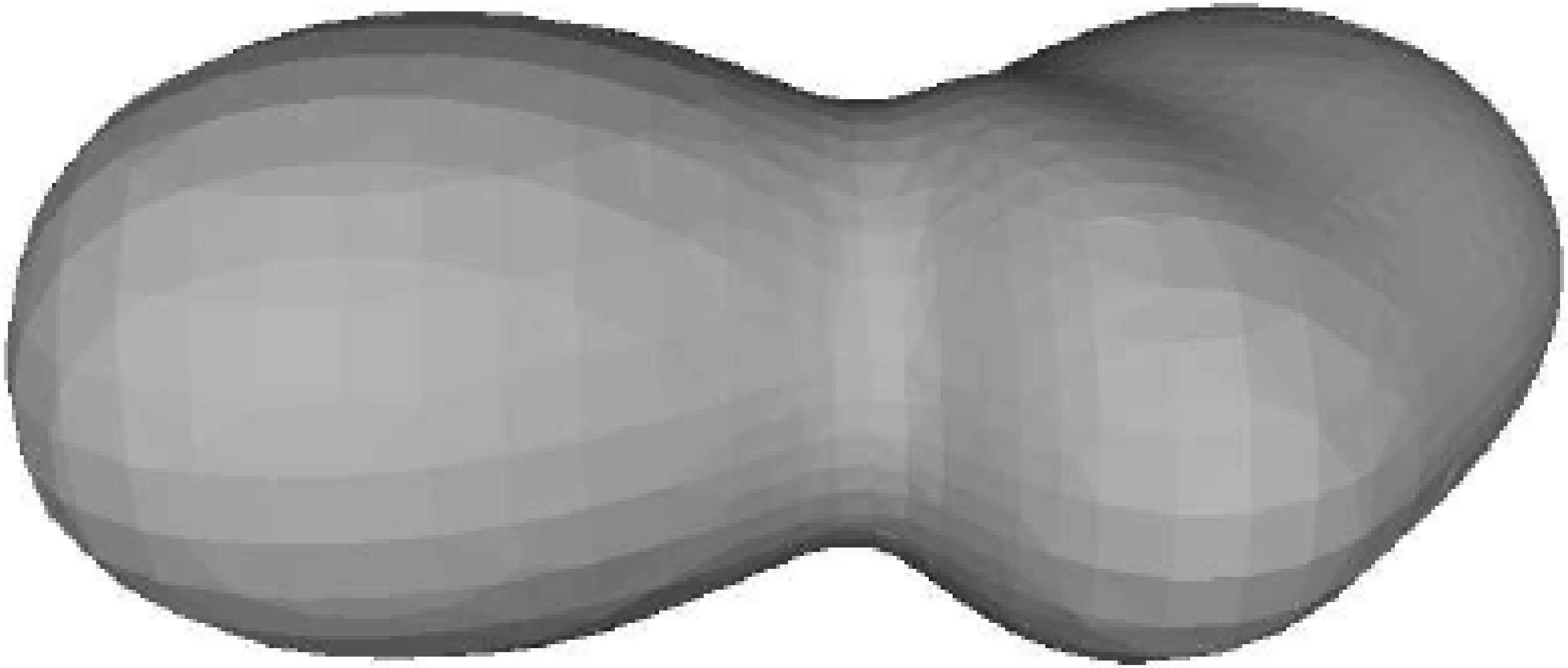
KOLÁROVO GRAVITY ANOMALY INVERSION – SOLUTION B

Anomalous body

3 line segments – anomalous causative body

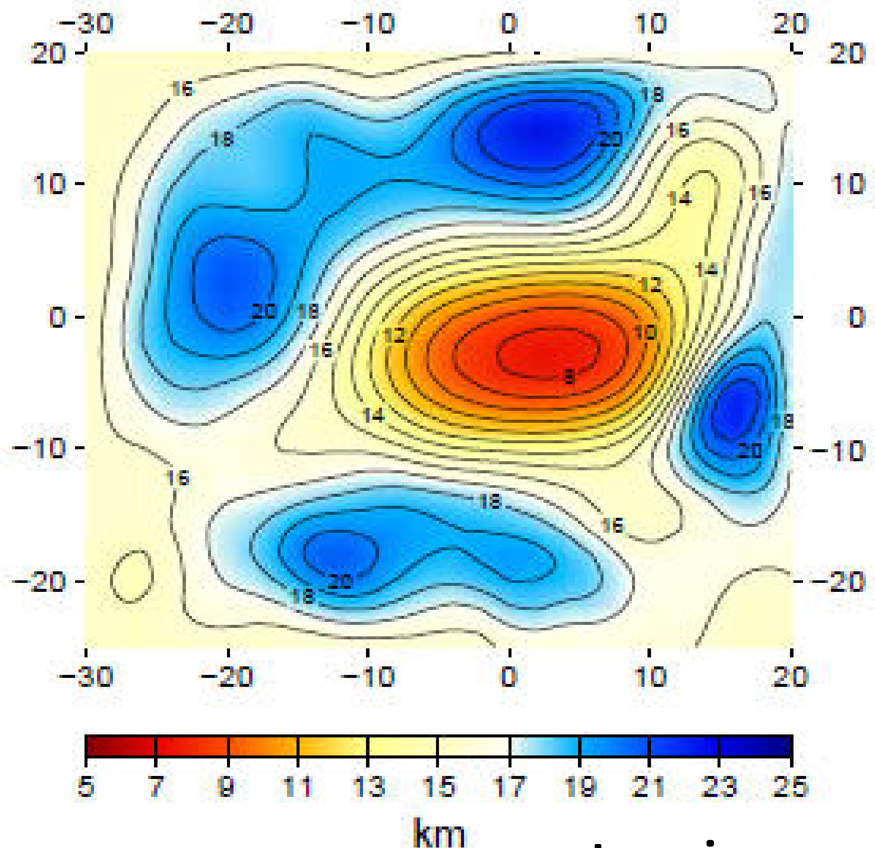


intrusion of basic lower crustal material into upper crust

density contrast 300 kg/m^3

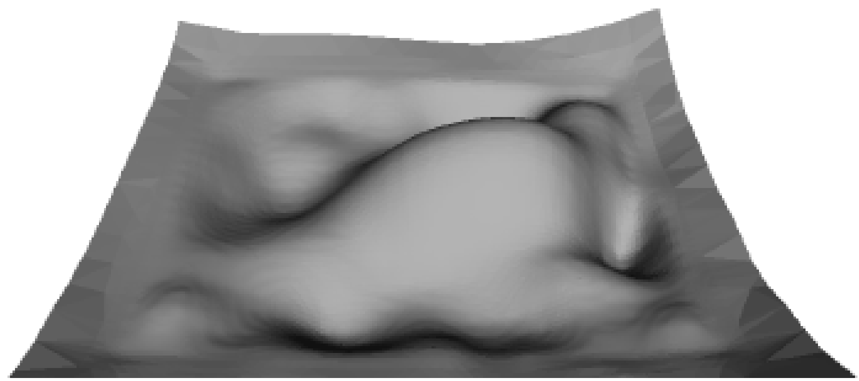
KOLÁROVO GRAVITY ANOMALY INVERSION – SOLUTION C

Contact surface of a density contrast (interface)



top view

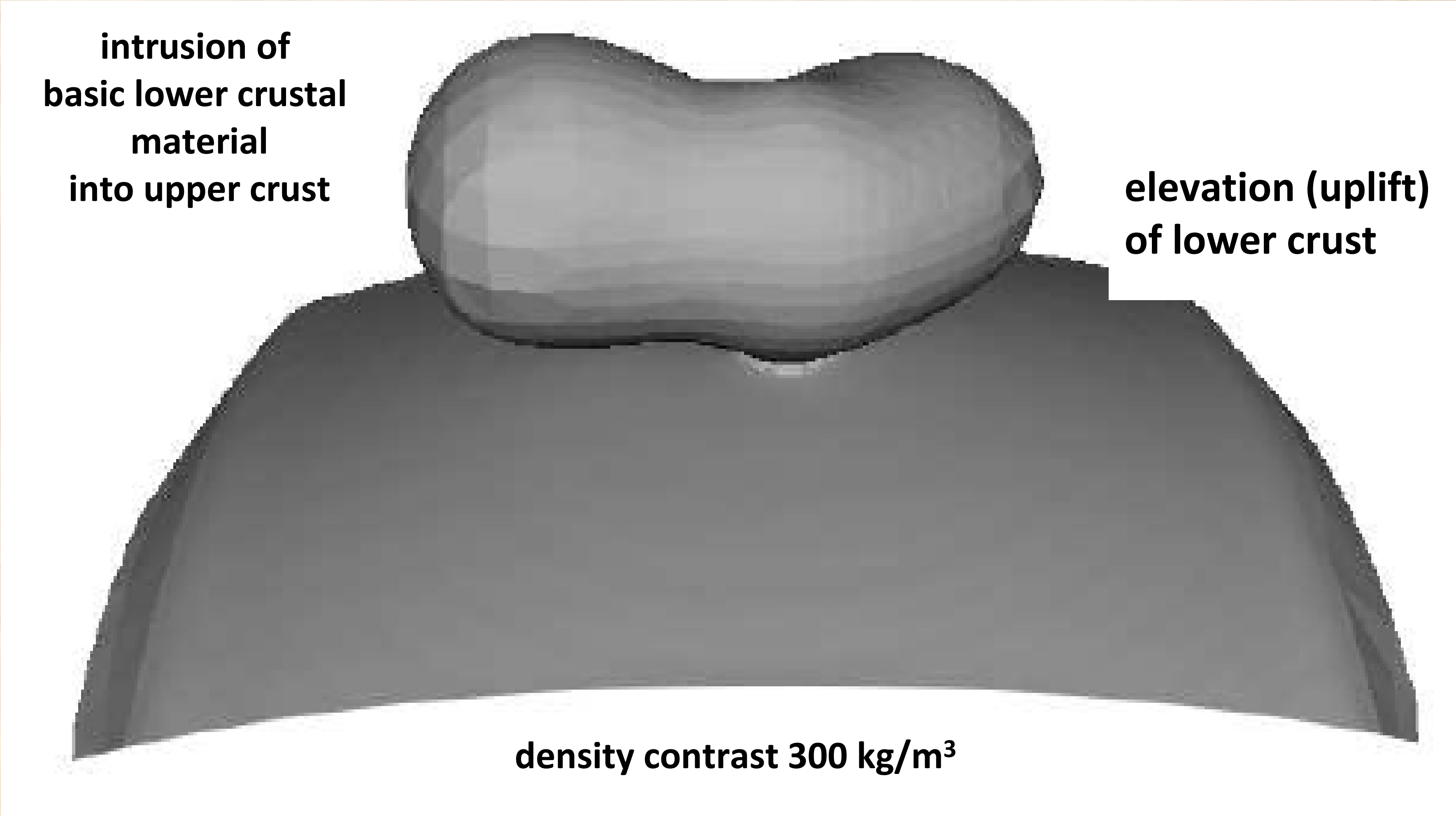
density contrast 300 kg/m³



elevation (uplift) of basic lower crustal material

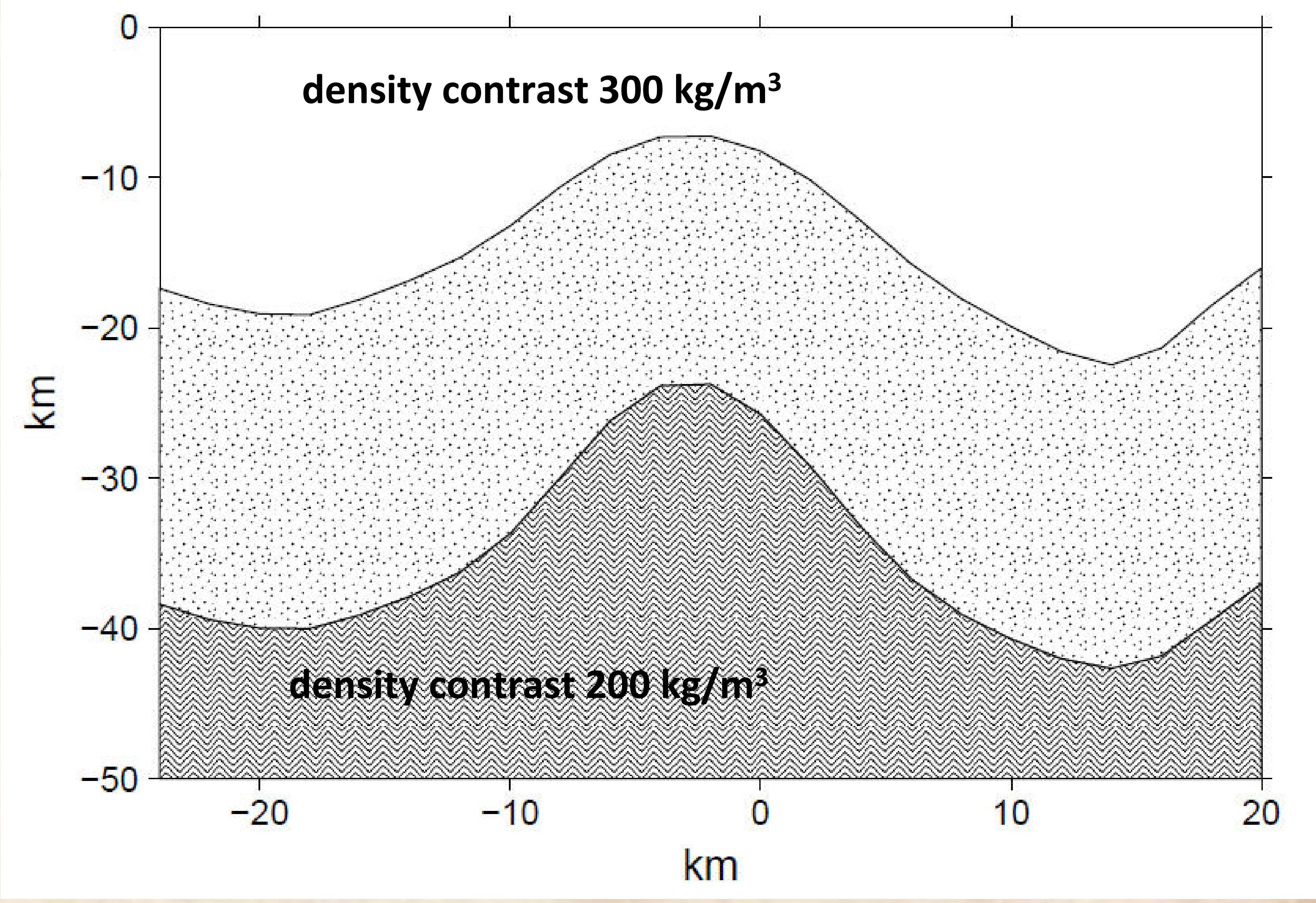
KOLÁROVO GRAVITY ANOMALY INVERSION – SOLUTION D

contact surface and anomalous body



KOLÁROVO GRAVITY ANOMALY INVERSION – SOLUTION E

2 contact surfaces (signal 50% / 50%) – NS cross-section



DISCUSSION

The solution is **unique** – in terms of geometry:

- ❑ for a source body
  of **given density contrast** and **given weight**
- ❑ for a contact surface
  of **given weight**, **density contrast** and **depth of assymptotic plane**

The solution is **non-unique** (arbitrary decisions)

- ❑ number of bodies and/or contact surfaces
- ❑ weigts of bodies / contact surfaces
- ❑ density contrasts
- ❑ depths of assymptotic planes

CONCLUSIONS

The „Prutkin“ inversion method

- offers a great tool for potential field data interpretation
- produces several sets of admissible model solutions
- the admissible solutions can be discriminated based on geological, tectonic, and additional geophysical (geoscientific) information

FUTURE WORK ON KOLÁROVO

- joint gravity/magnetic inversion
- geological / tectonic / geoscientific constraints