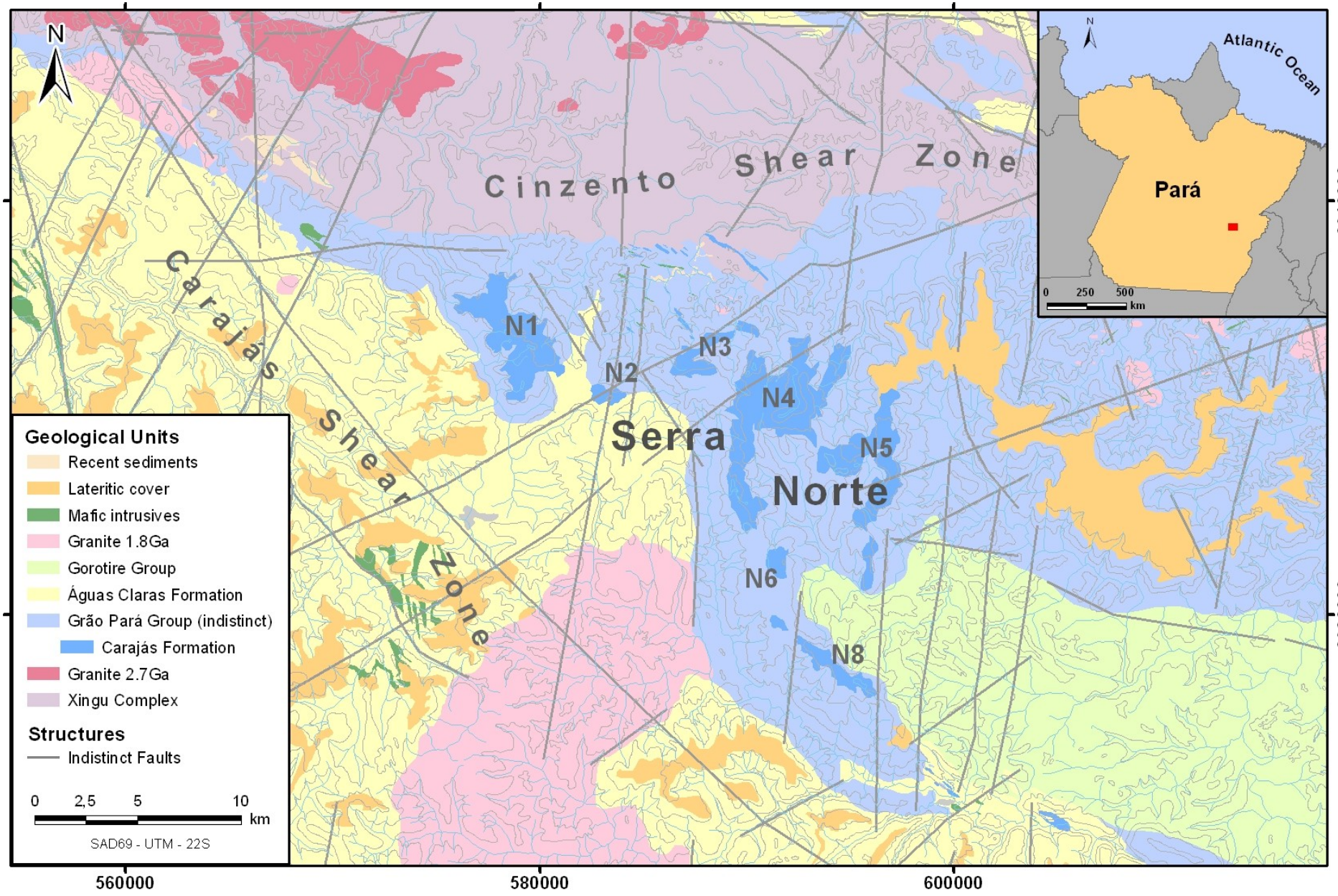
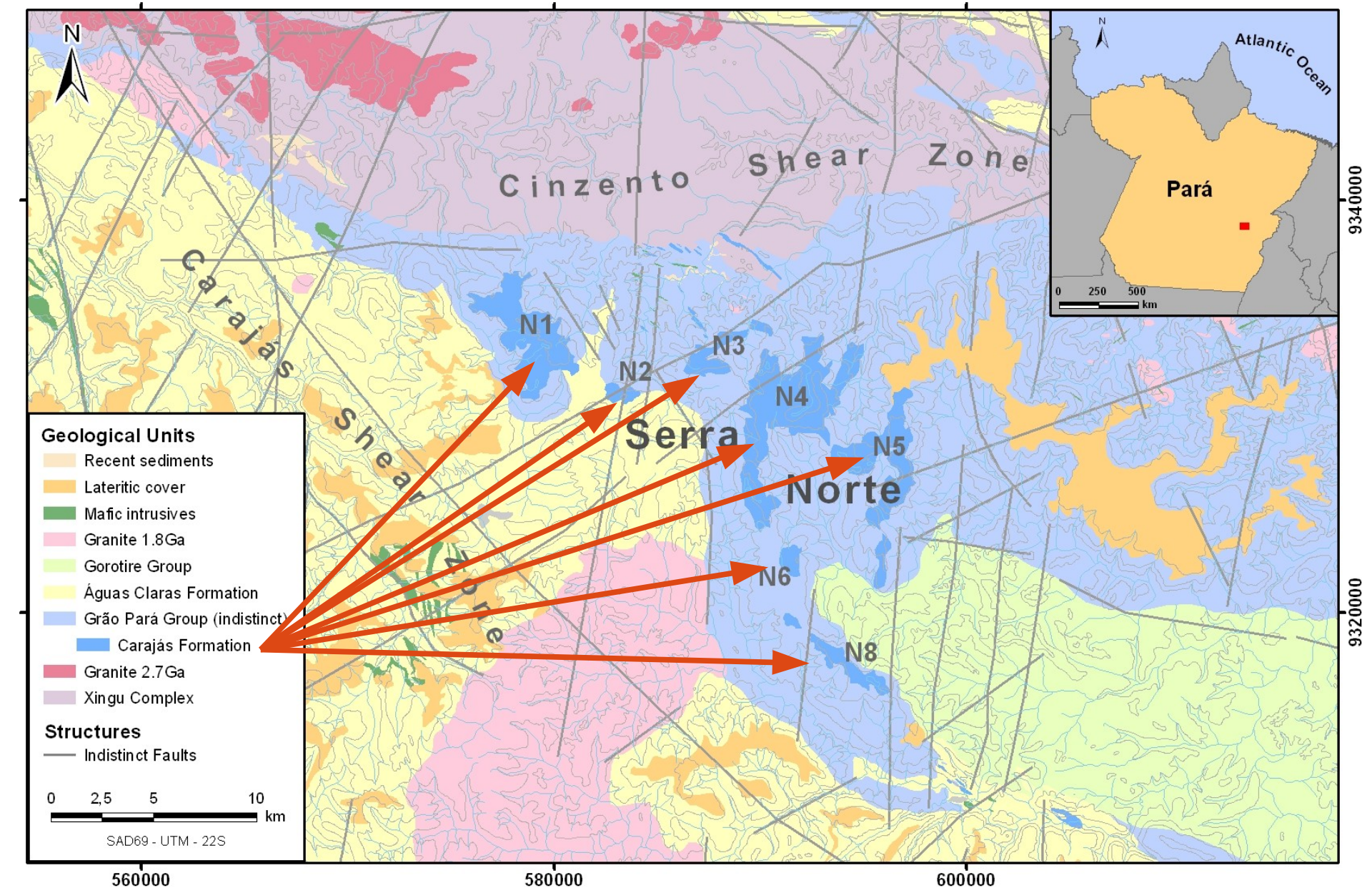
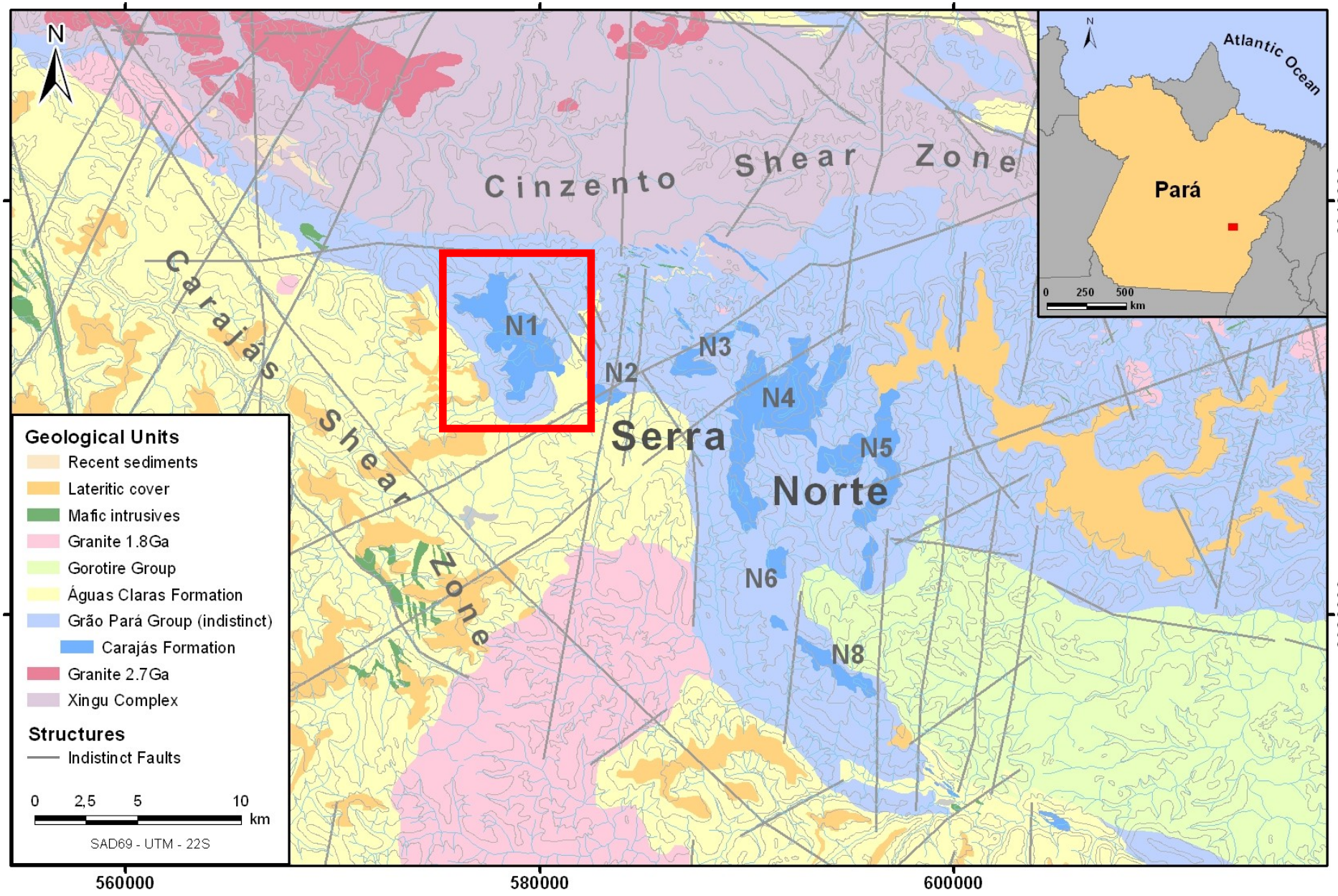
Iron ore interpretation using gravity-gradient inversions in the Carajás, Brazil

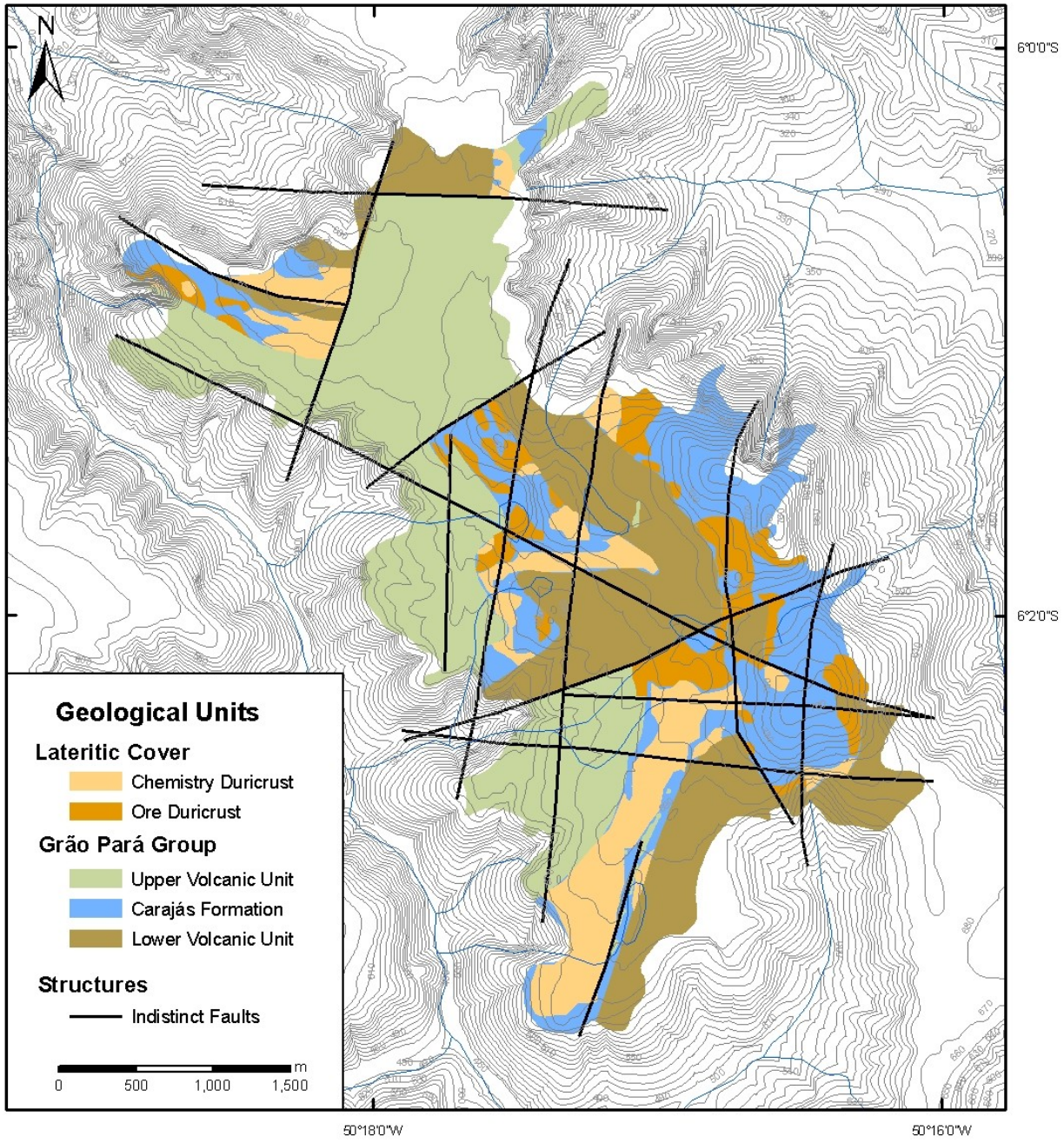
Dionisio Uendro Carlos
Leonardo Uieda*
Yaoguo Li
Valéria Cristina Ferreira Barbosa
Marco Antonio Braga
Glauco Angeli
Guilherme Gravina Peres

Carajás survey area

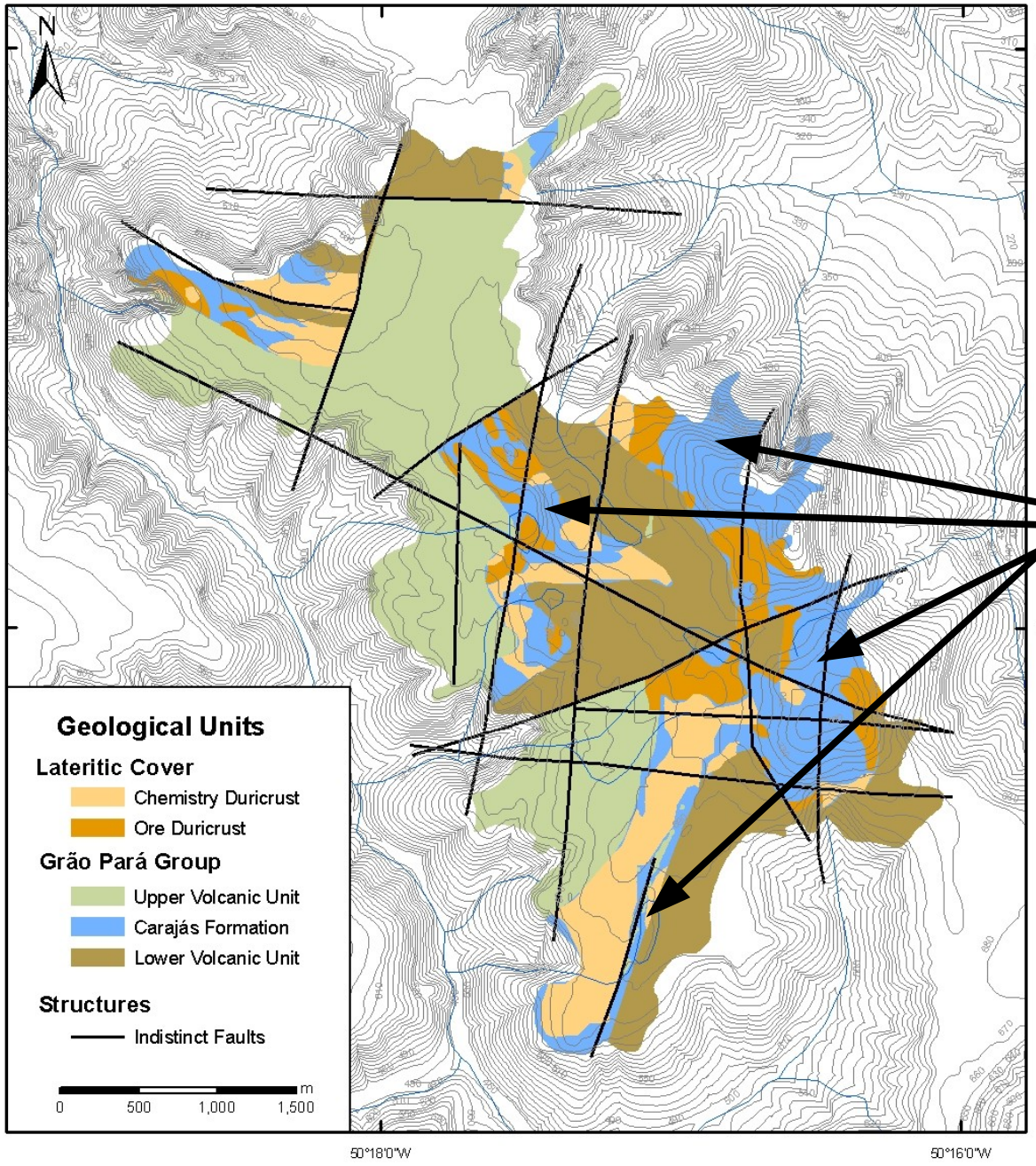

N
Cinzento Shear Zone
Carajás Shear Zone
N1
N2
N3
N4
N5
N6
N8
Serra Norte
Atlantic Ocean
Pará
0 250 500
km
Geological Units
Recent sediments
Lateritic cover
Mafic intrusives
Granite 1.8Ga
Gorotire Group
Águas Claras Formation
Grão Pará Group (indistinct)
Carajás Formation
Granite 2.7Ga
Xingu Complex
Structures
Indistinct Faults
0 2,5 5 10
km
SAD69 - UTM - 22S
560000
580000
600000
9340000
9320000


N
Cinzento Shear Zone
Carajás Shear Zone
Serra Norte
N1
N2
N3
N4
N5
N6
N8
Atlantic Ocean
Pará
0 250 500
km
Geological Units
Recent sediments
Lateritic cover
Mafic intrusives
Granite 1.8Ga
Gorotire Group
Águas Claras Formation
Grão Pará Group (indistinct)
Carajás Formation
Granite 2.7Ga
Xingu Complex
Structures
Indistinct Faults
0 2,5 5 10
km
SAD69 - UTM - 22S
560000
580000
600000
9340000
9320000


N
Cinzento Shear Zone
Carajás Shear Zone
N1
N2
N3
N4
N5
N6
N8
Serra Norte
Atlantic Ocean
Pará
0 250 500
km
Geological Units
Recent sediments
Lateritic cover
Mafic intrusives
Granite 1.8Ga
Gorotire Group
Águas Claras Formation
Grão Pará Group (indistinct)
Carajás Formation
Granite 2.7Ga
Xingu Complex
Structures
Indistinct Faults
0 2,5 5 10
km
SAD69 - UTM - 22S
560000
580000
600000
9340000
9320000


N
6°0'0"S
6°2'0"S
50°18'0"W
50°16'0"W
Geological Units
Lateritic Cover
Chemistry Duricrust
Ore Duricrust
Grão Pará Group
Upper Volcanic Unit
Carajás Formation
Lower Volcanic Unit
Structures
Indistinct Faults
m
0
500
1,000
1,500

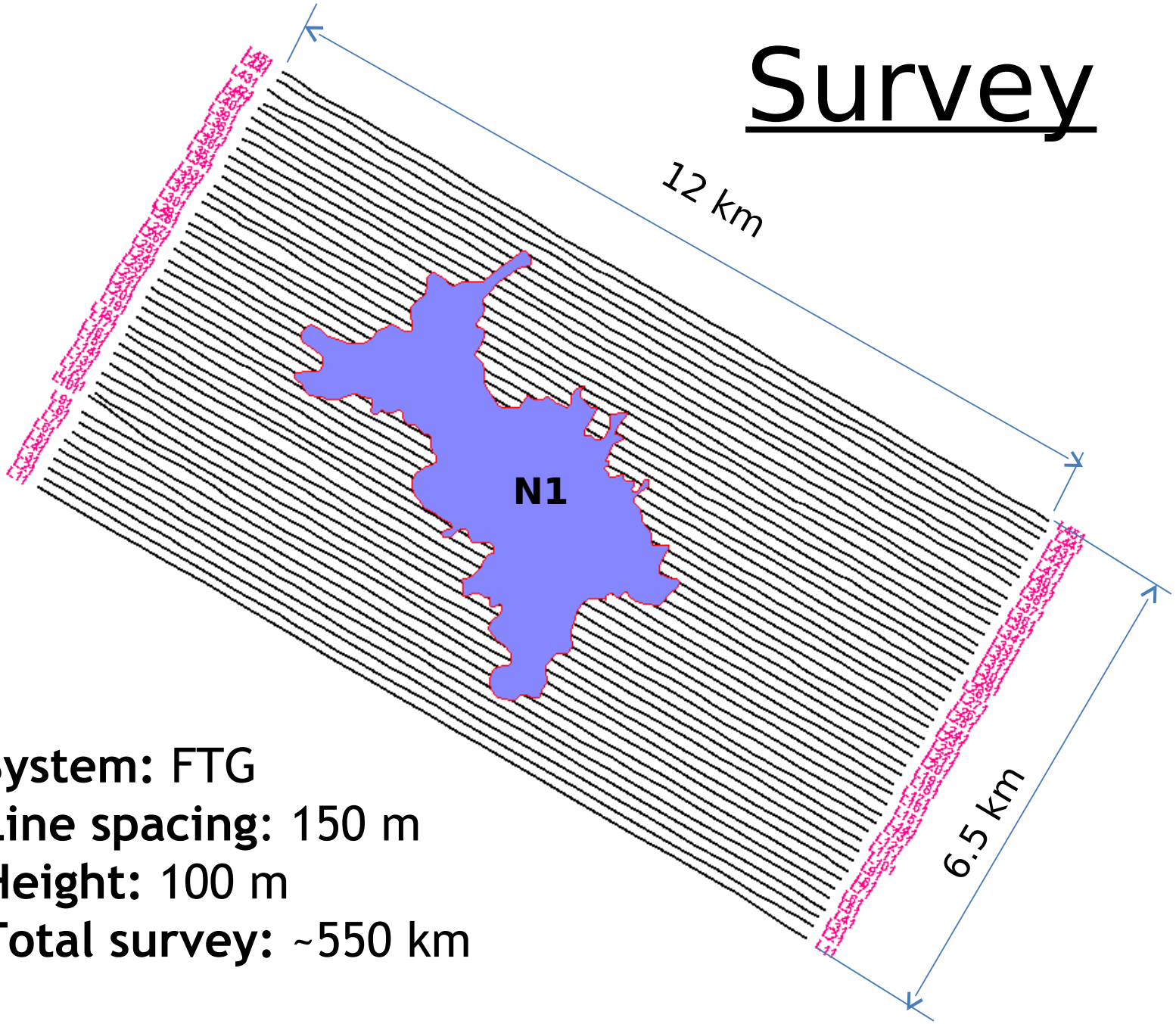
N1 plateau



N1 plateau

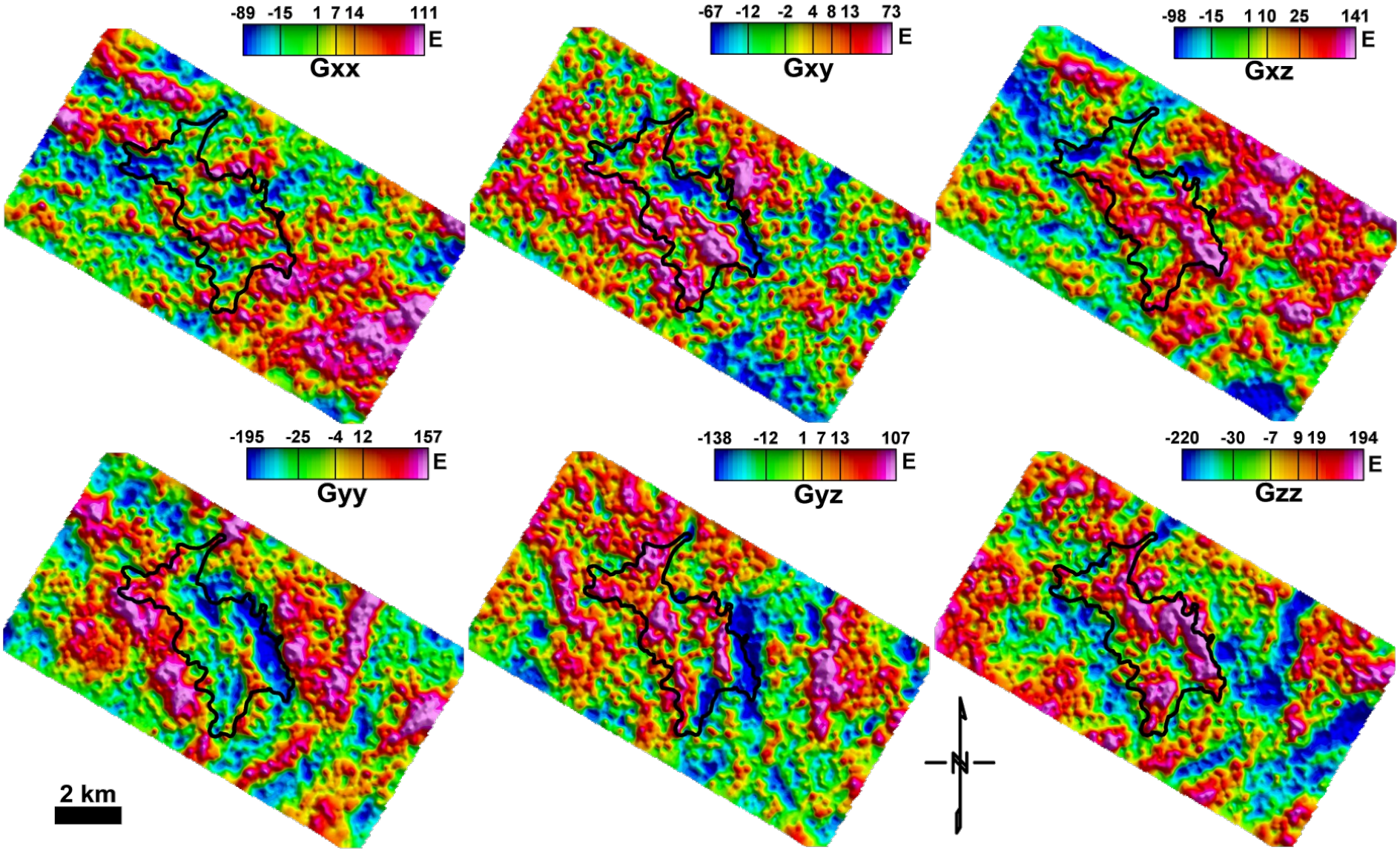
Target: hematite
hard (3.6 g/cm^3)
soft (3.4 g/cm^3)

Survey

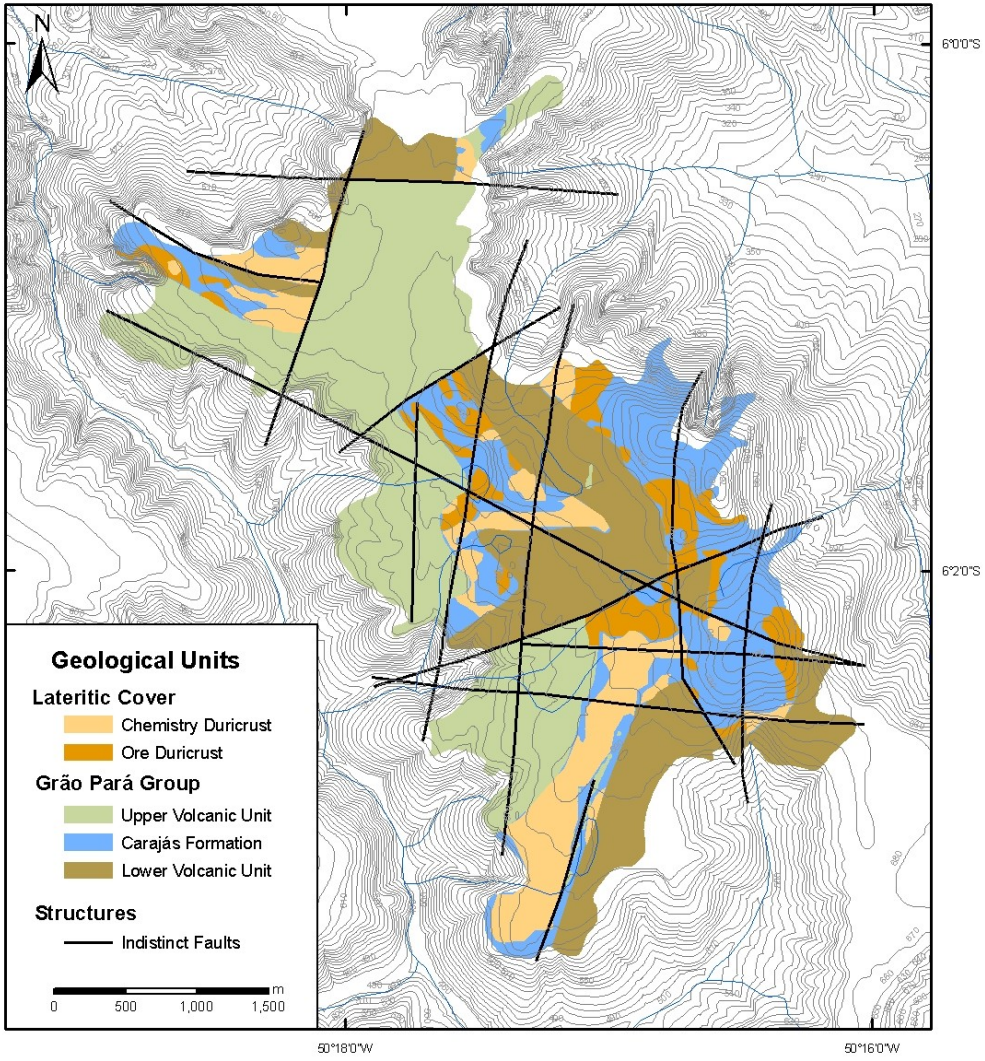


System: FTG
Line spacing: 150 m
Height: 100 m
Total survey: ~550 km

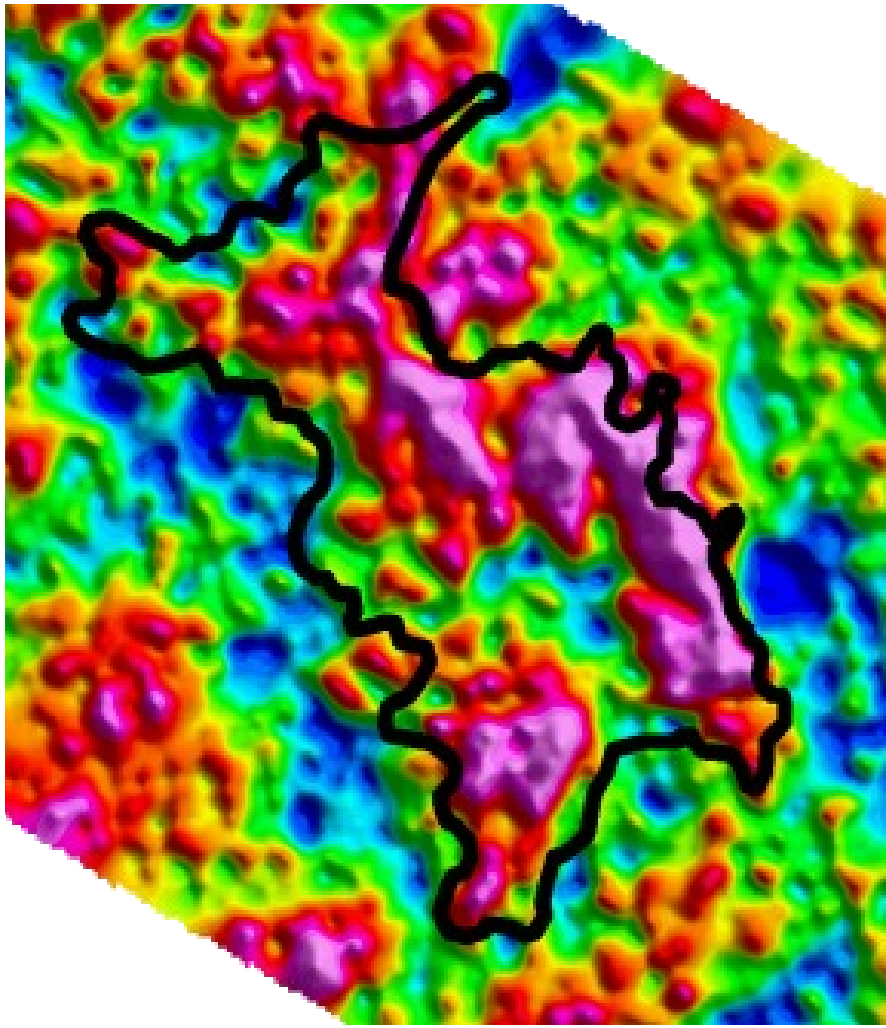
The data


-89 -15 1 7 14 111
E
Gxx
-67 -12 -2 4 8 13 73
E
Gxy
-98 -15 1 10 25 141
E
Gxz
-195 -25 -4 12 157
E
Gyy
-138 -12 1 7 13 107
E
Gyz
-220 -30 -7 9 19 194
E
Gzz
2 km
N

N1 geology

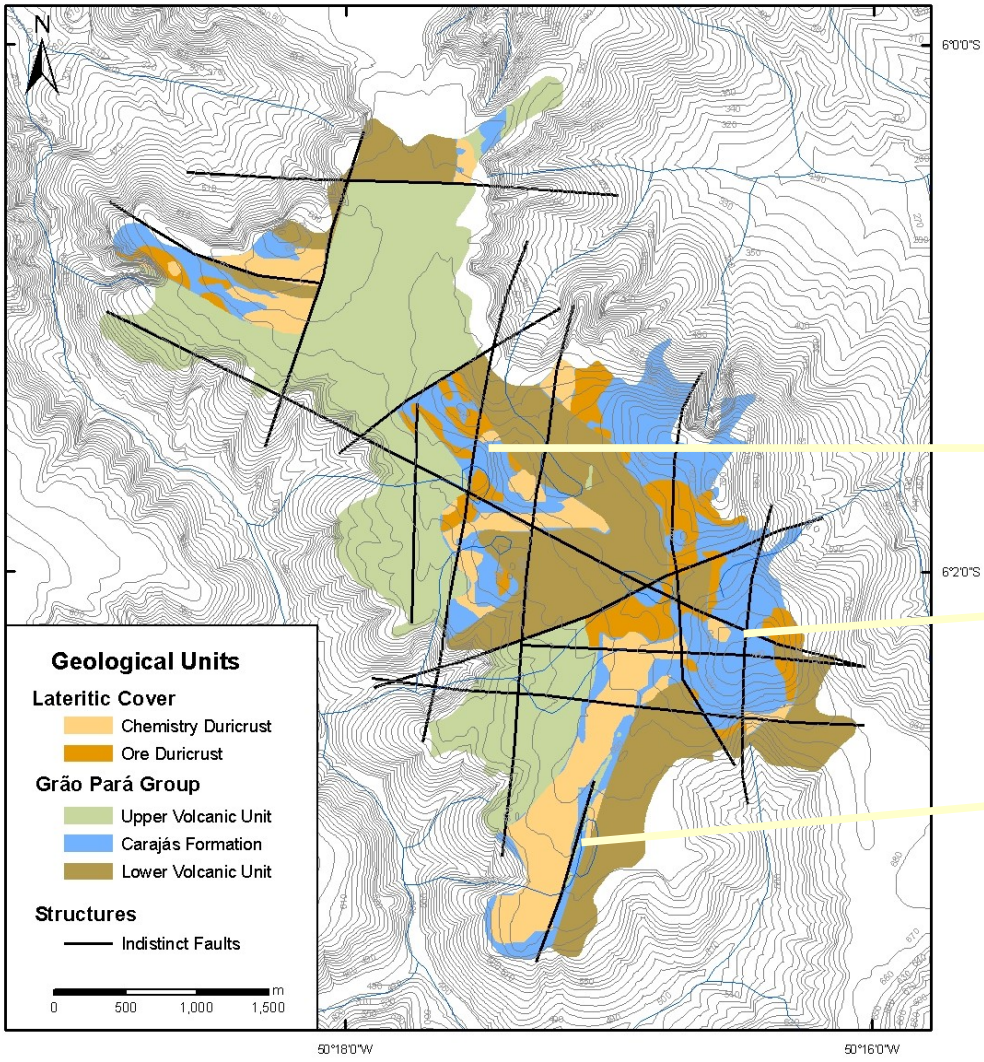


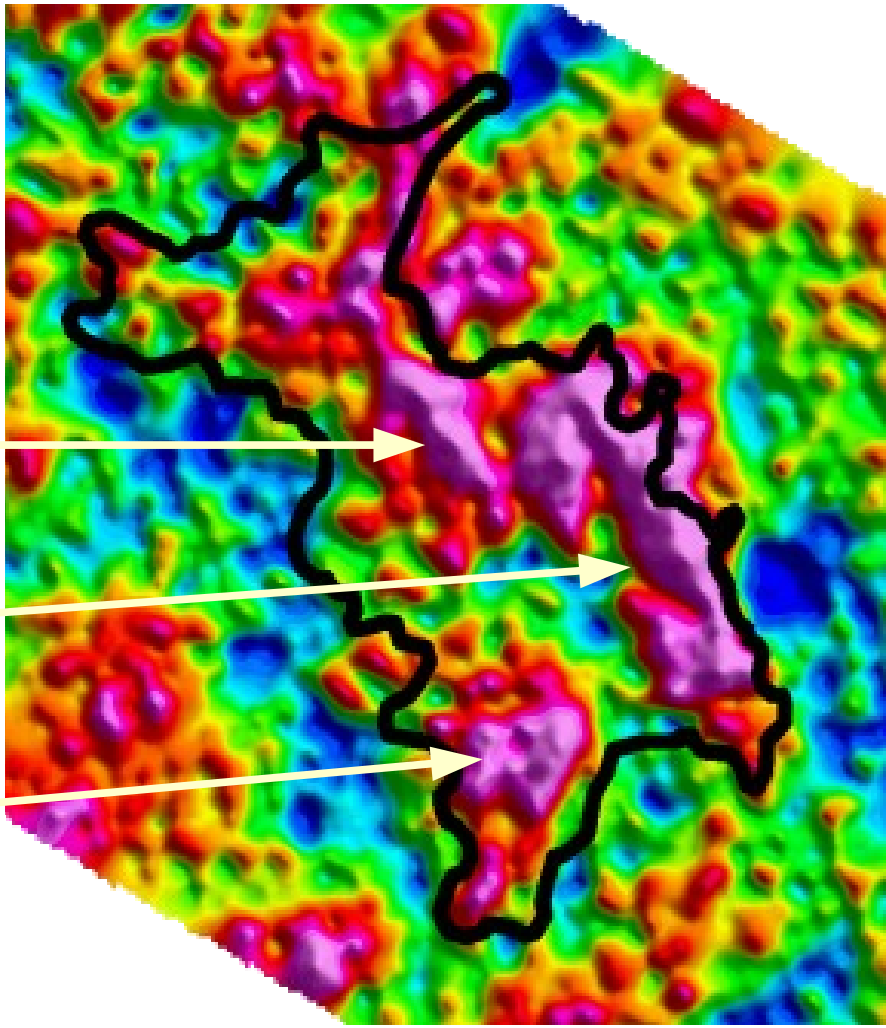
Gzz



N1 geology

Gzz





3D inversion

2 methods

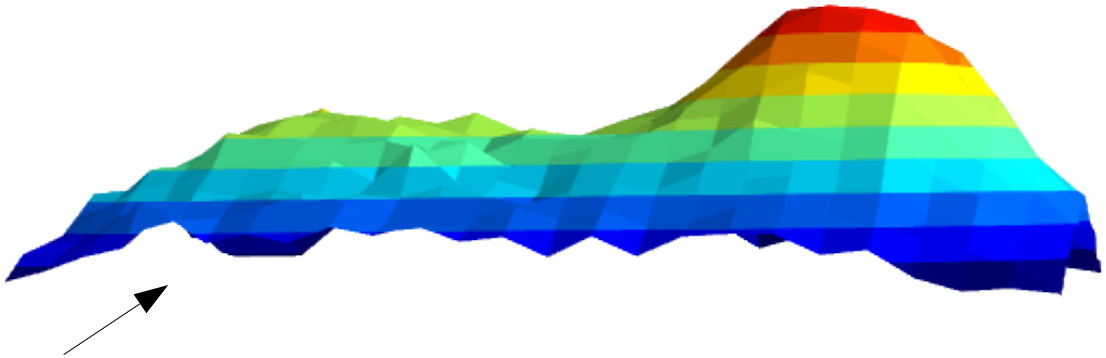
(1) Planting anomalous densities

Uieda, L., and V. C. F. Barbosa (2012), Robust 3D gravity gradient inversion by planting anomalous densities, *Geophysics*, 77(4), G55–G66, doi:10.1190/geo2011-0388.1

(2) Smooth inversion

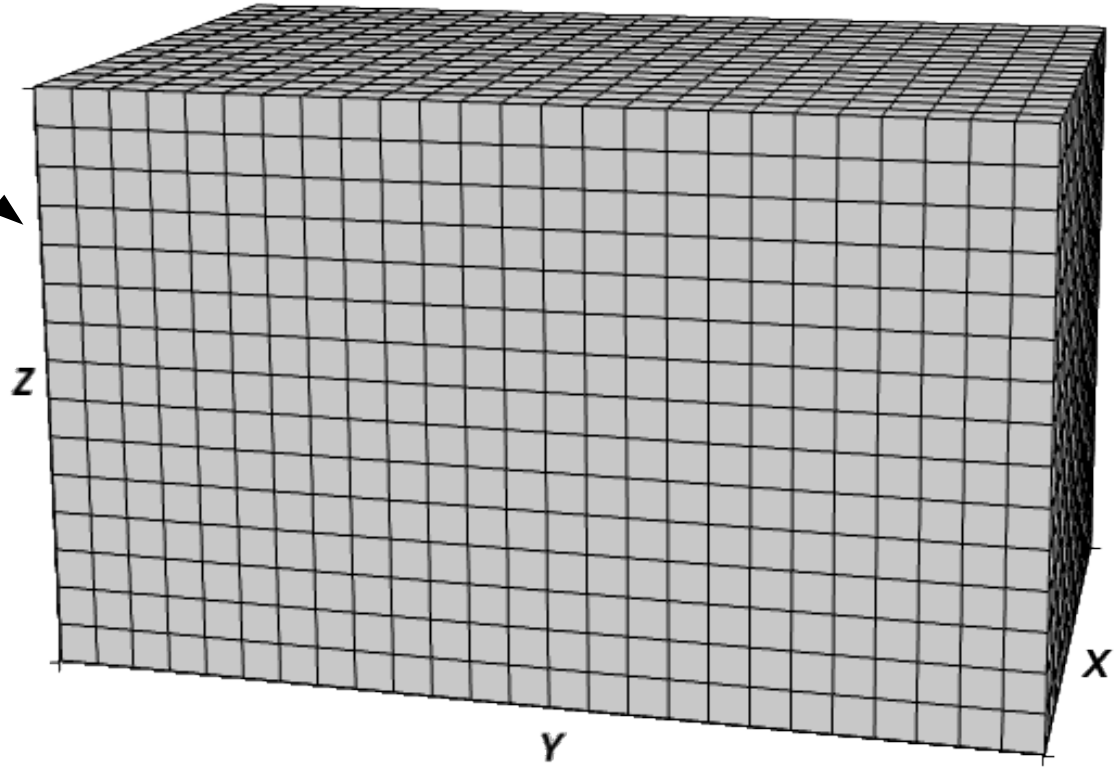
Li, Y. (2001), 3-D inversion of gravity gradiometer data, *SEG Expanded Abstracts*, 20, 1470–1473, doi:10.1190/1.1816383

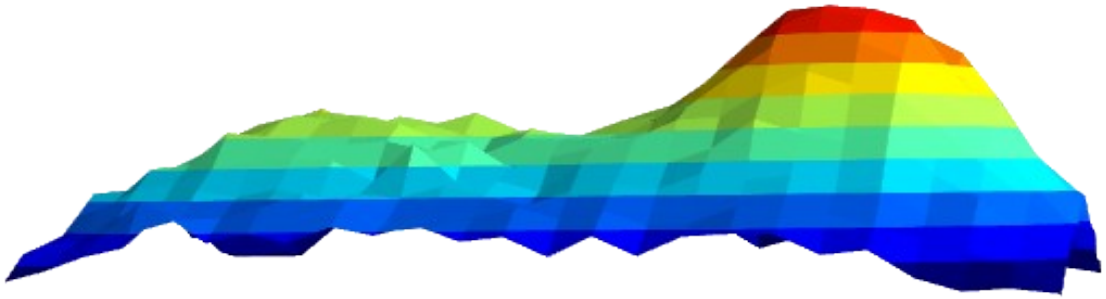
Planting anomalous densities

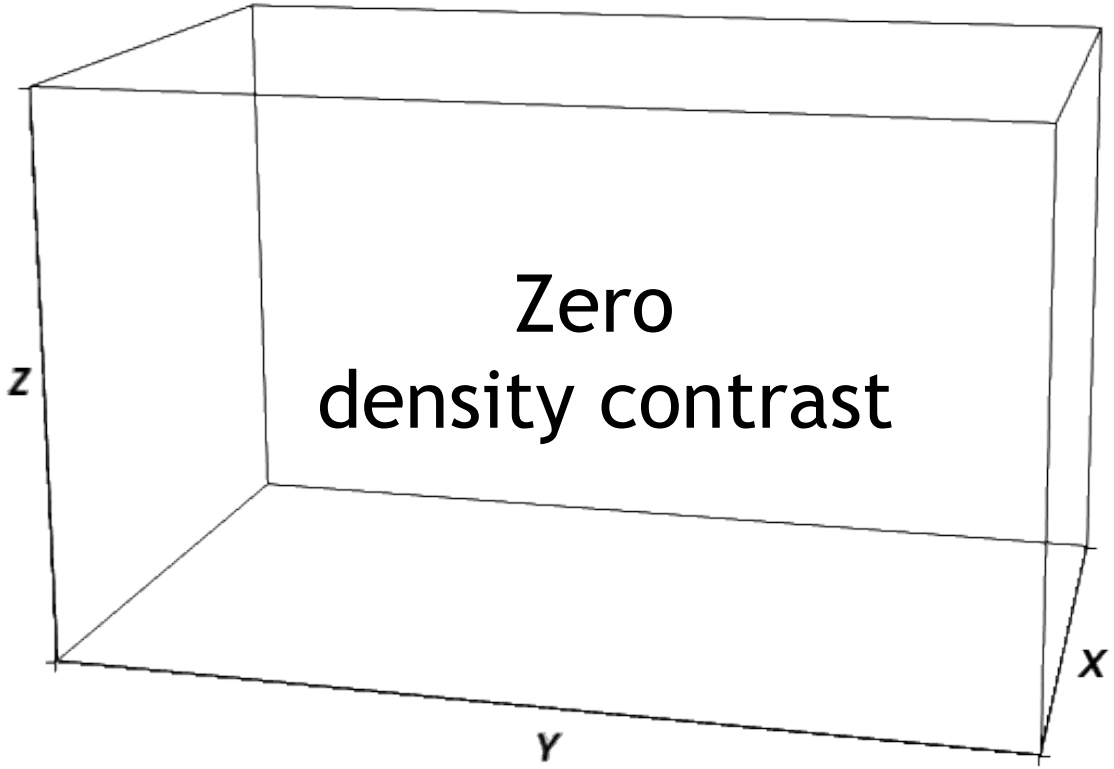


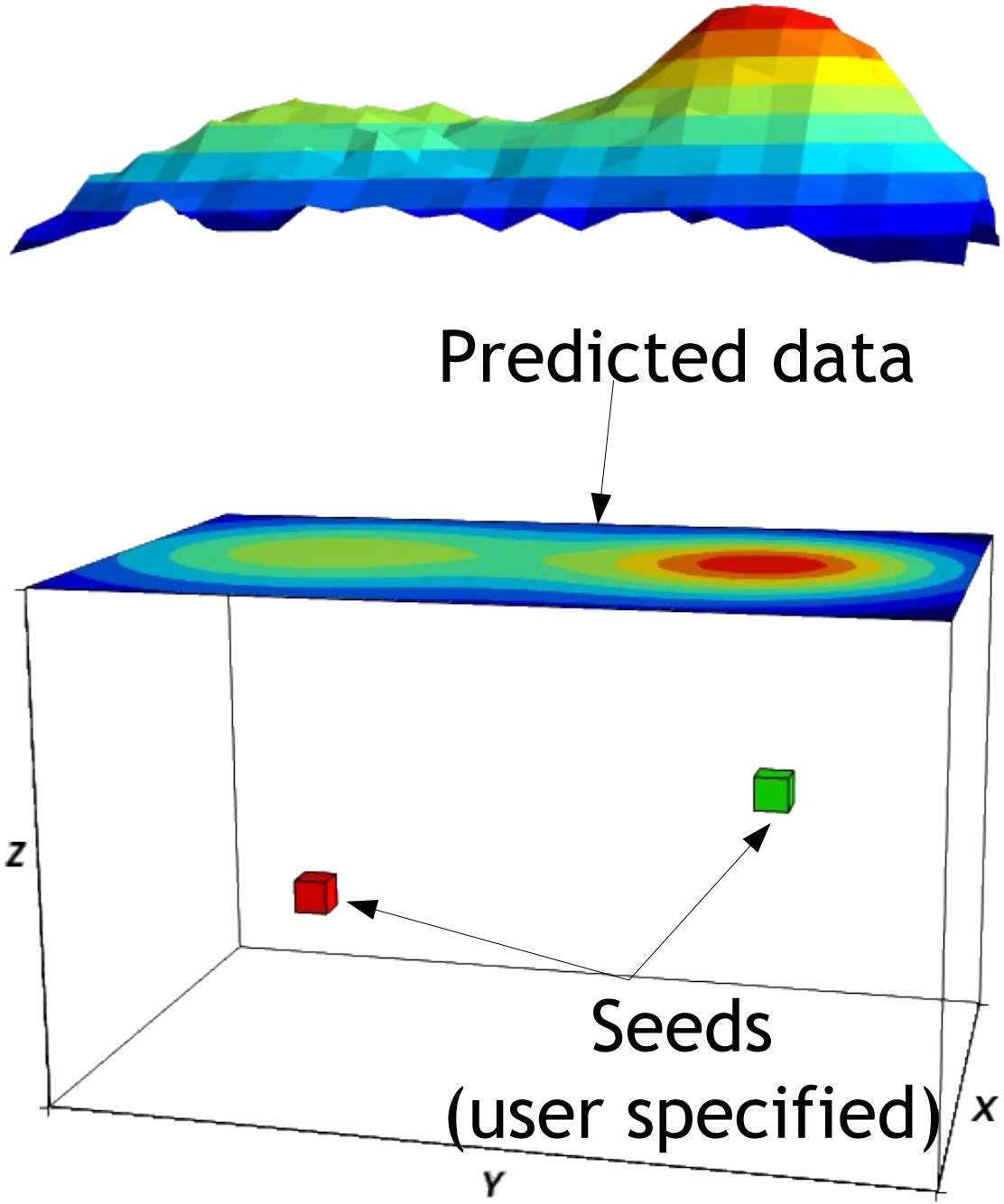
Observed data

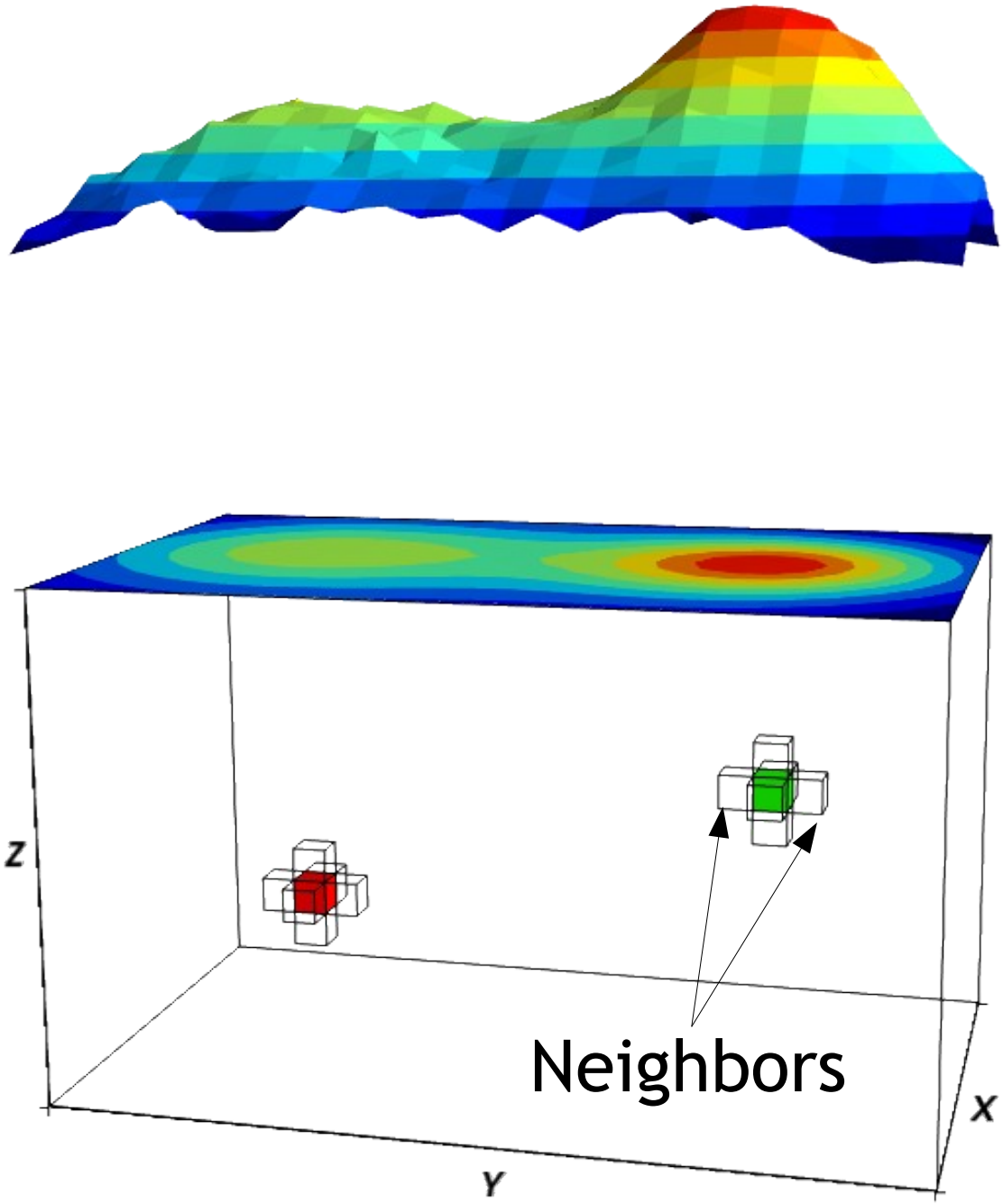
Mesh

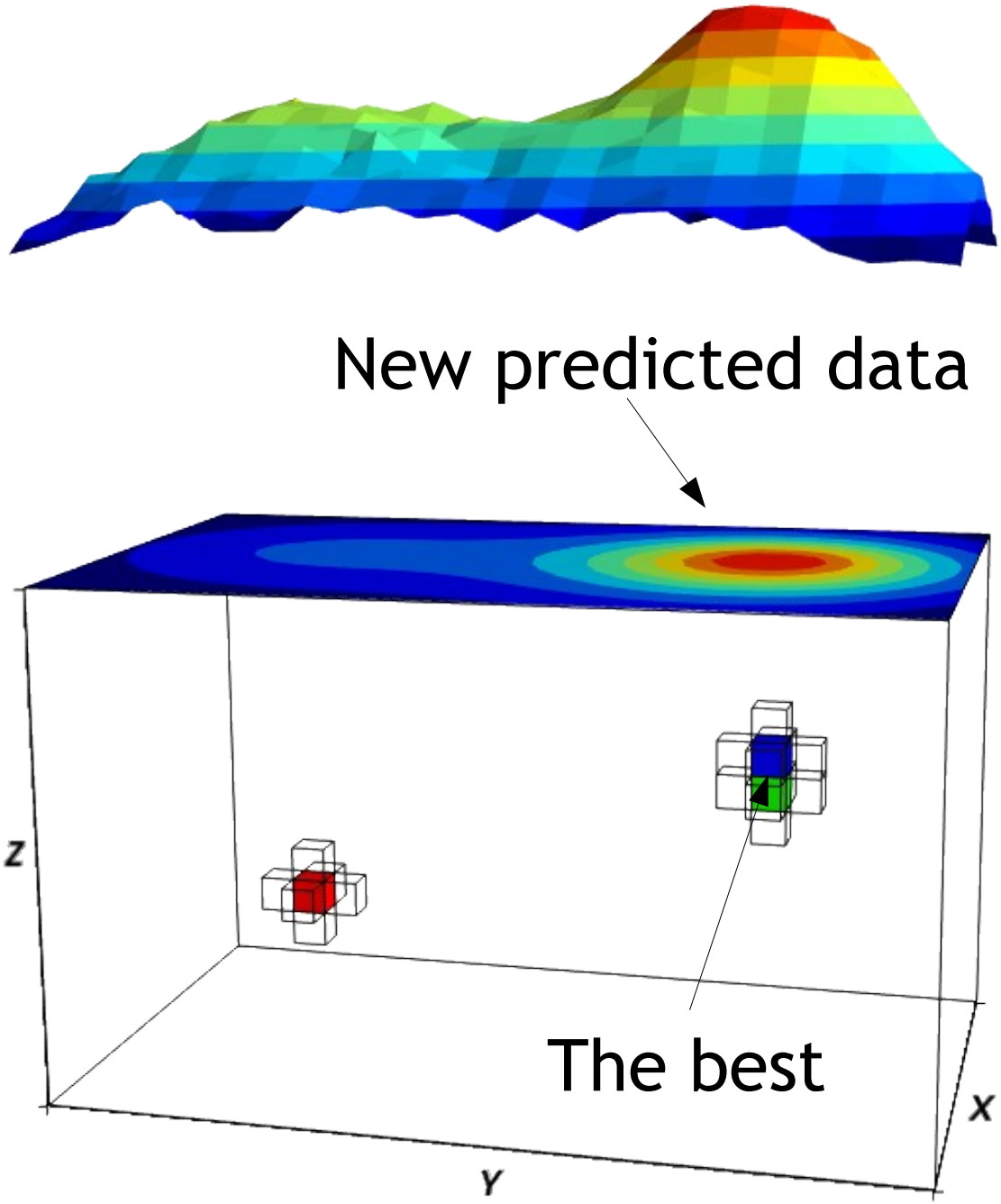


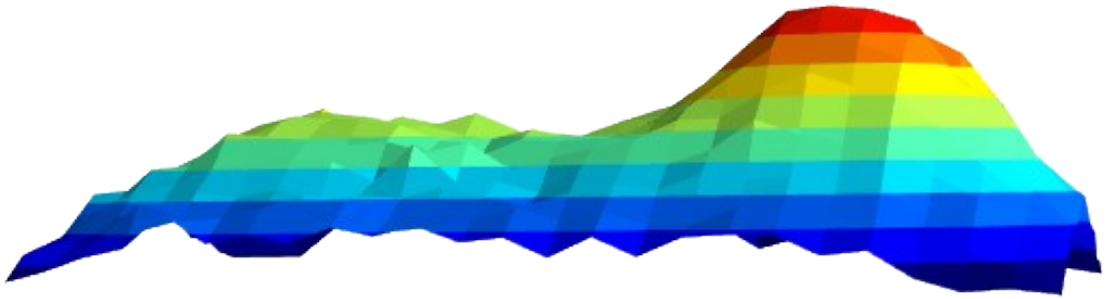



Zero
density contrast
z
Y
X


Predicted data
Z
Seeds
(user specified)
X
Y


Z
Y
X
Neighbors


New predicted data
Z
Y
X
The best



New predicted data

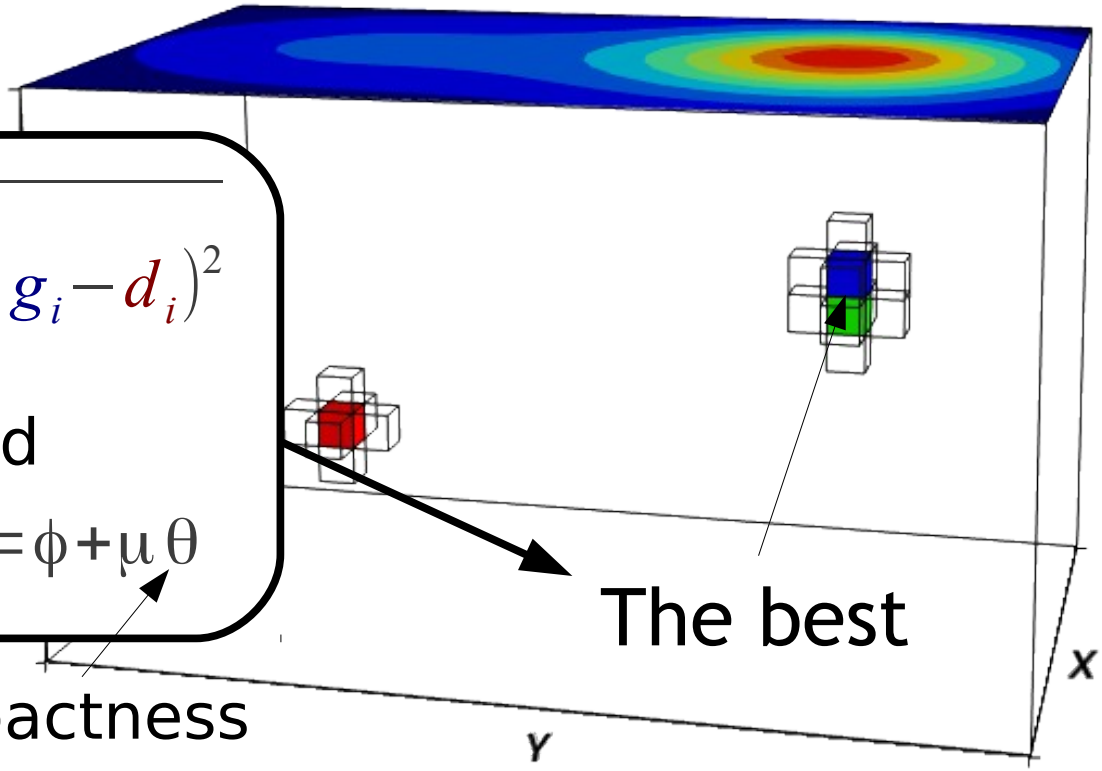
$$\phi = \sqrt{\sum_{i=1}^{N} (g_i - d_i)^2}$$

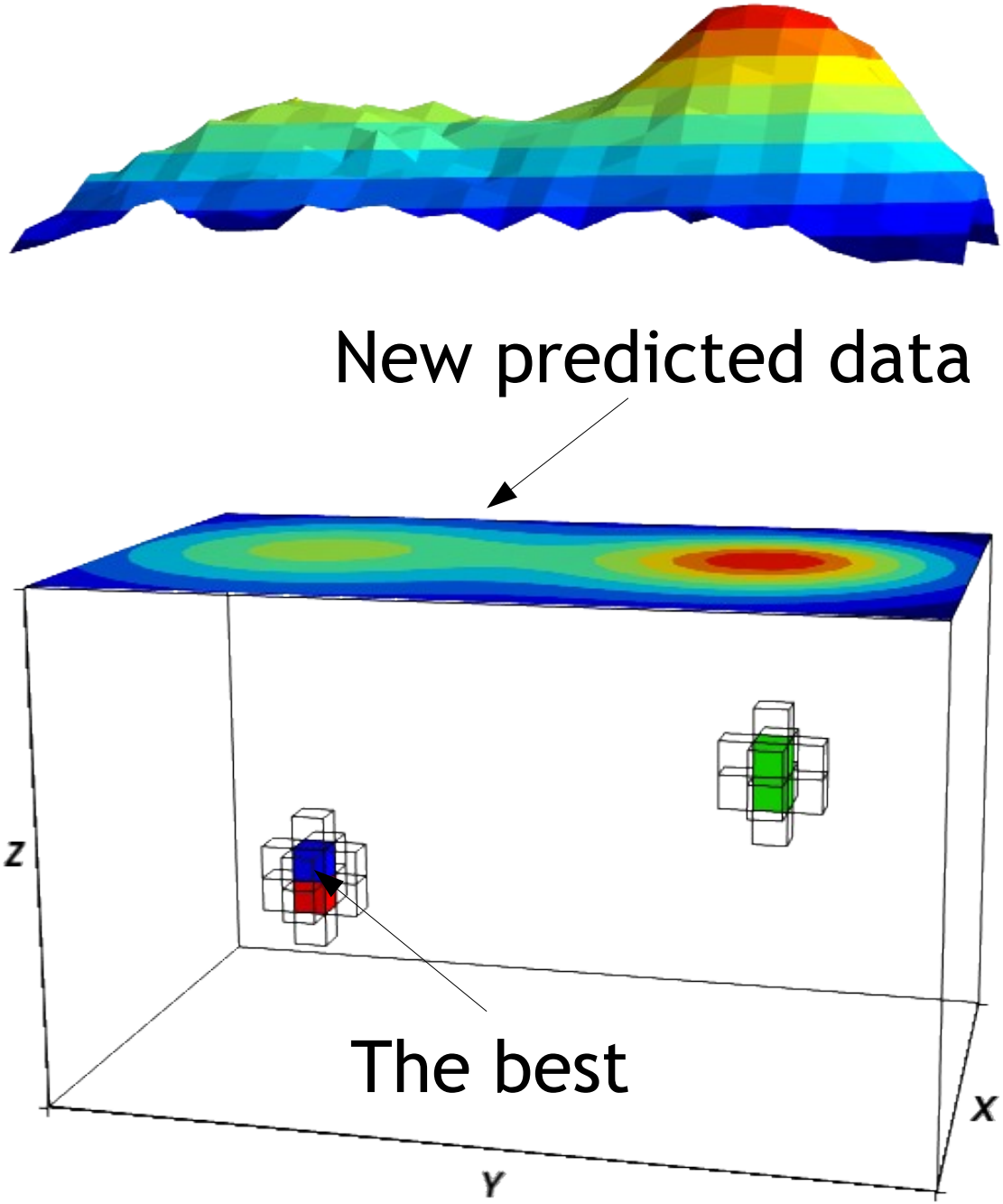
and

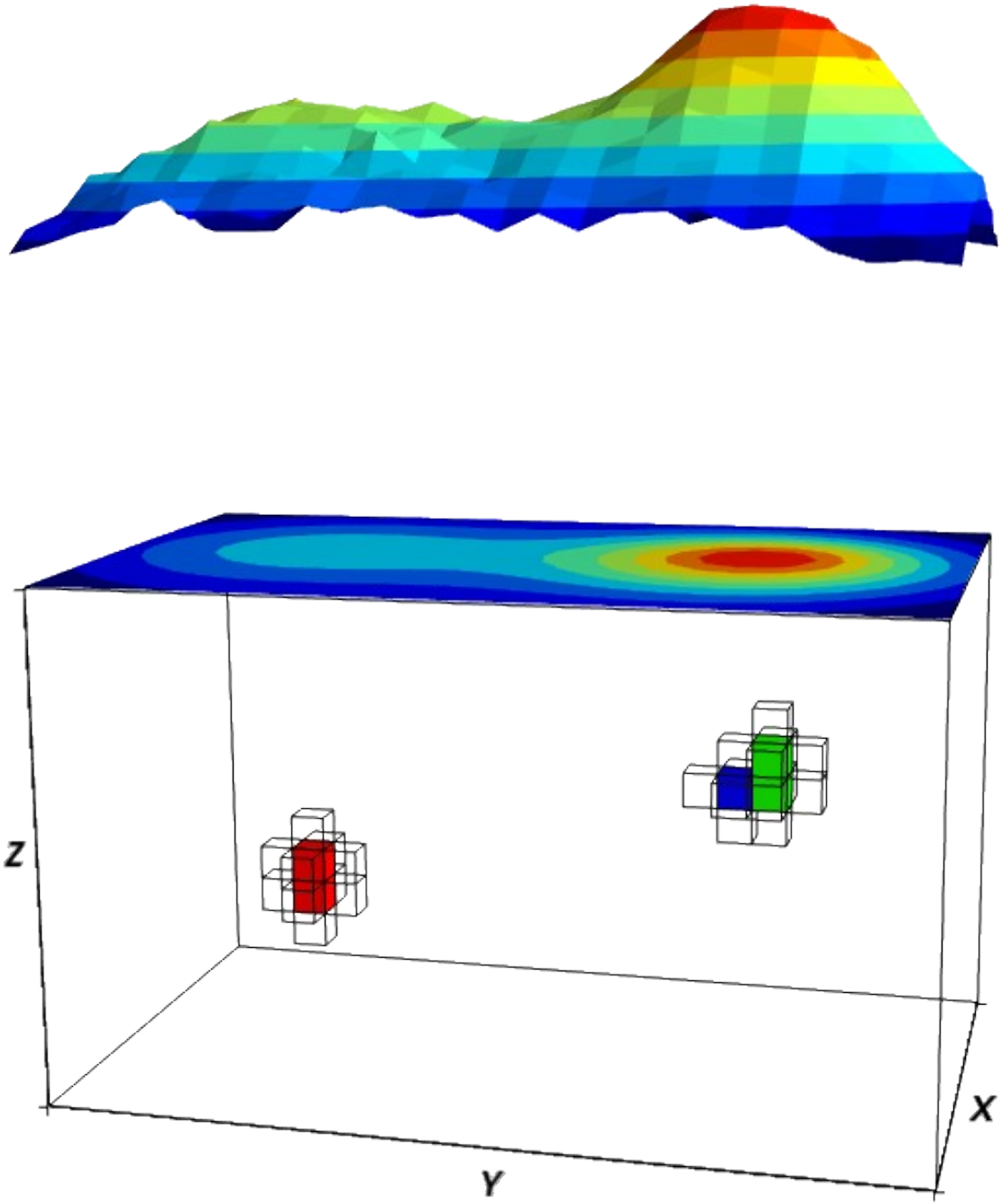
$$min\ of\ \Gamma = \phi + \mu\theta$$

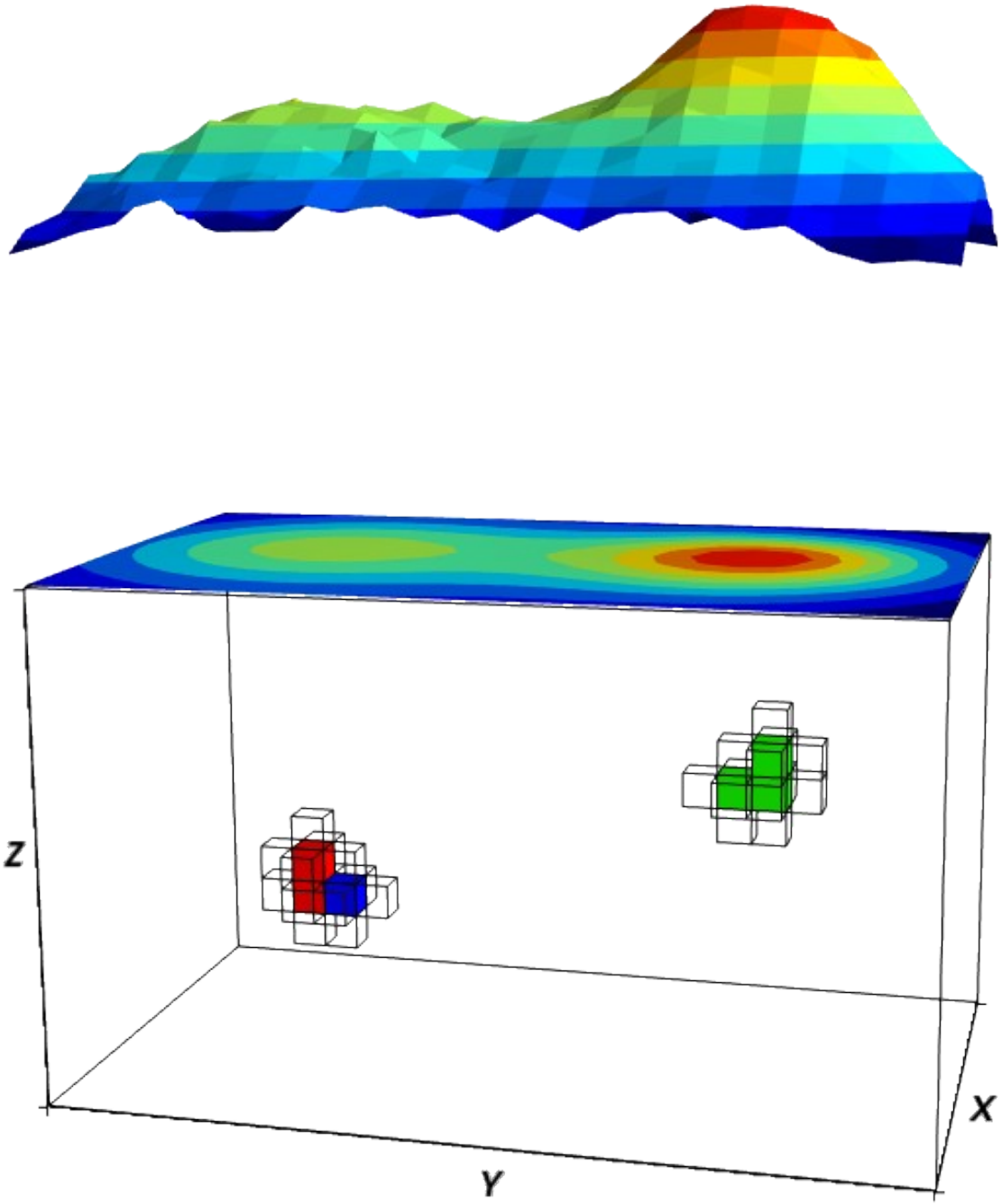
compactness

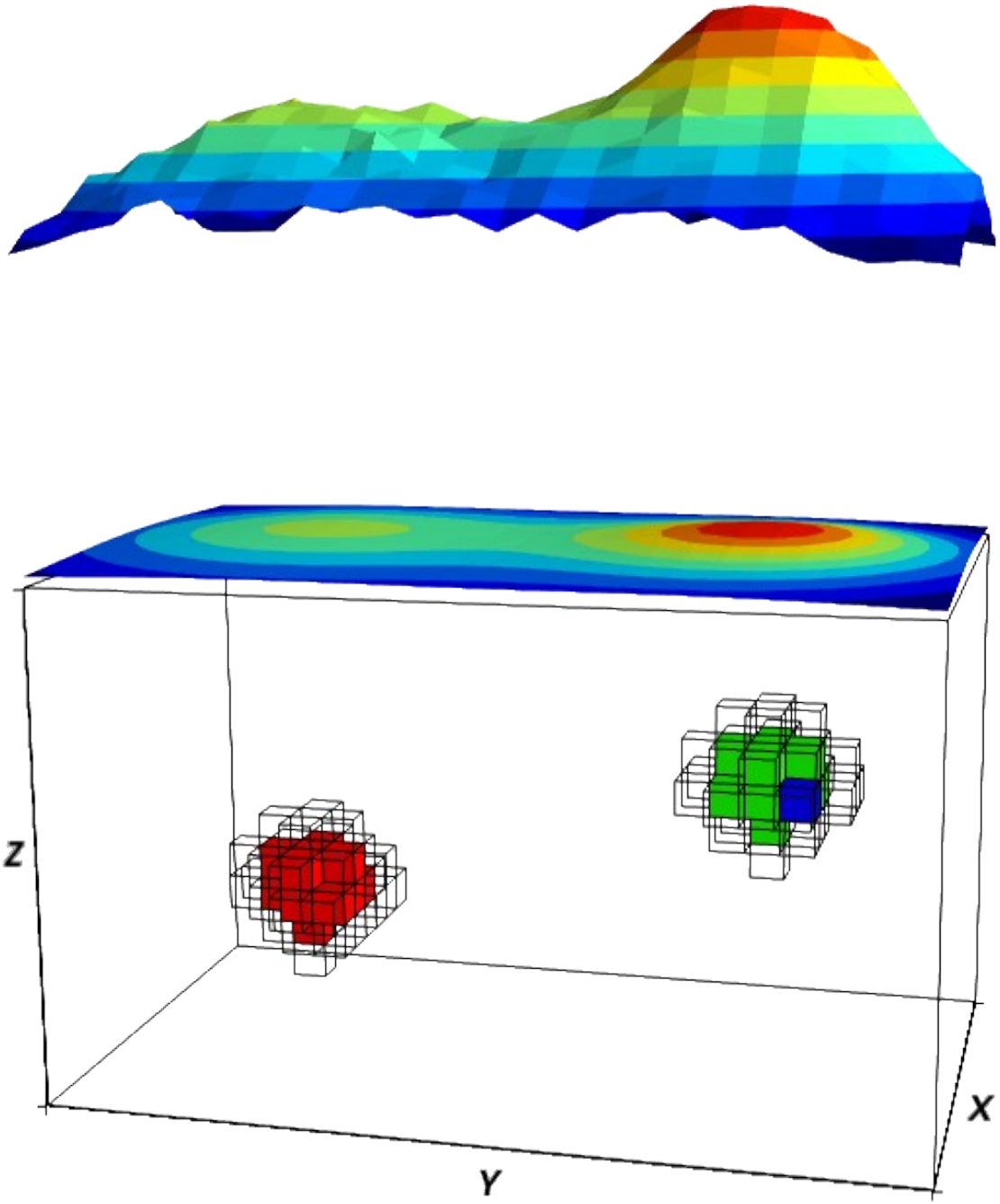
The best

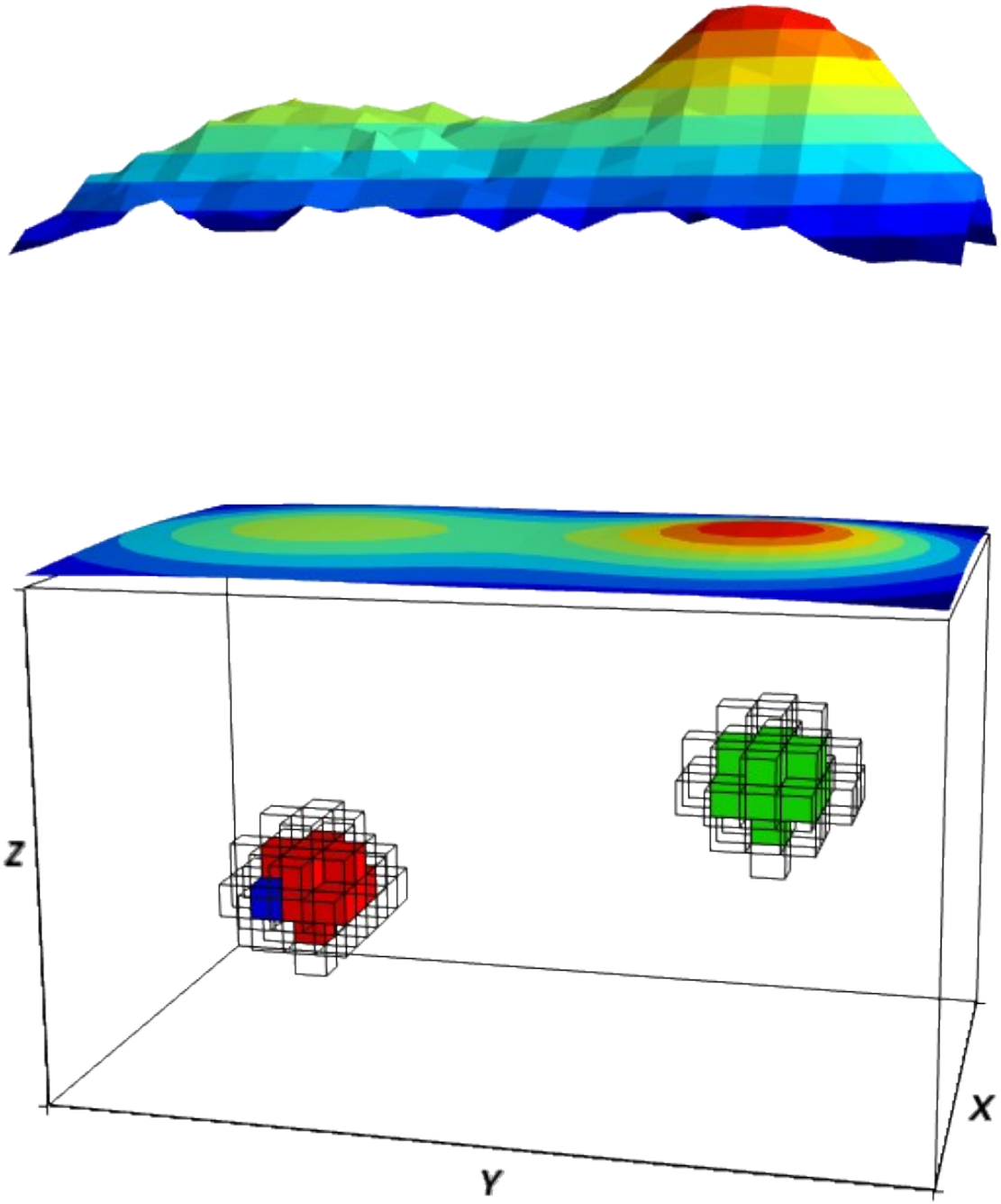


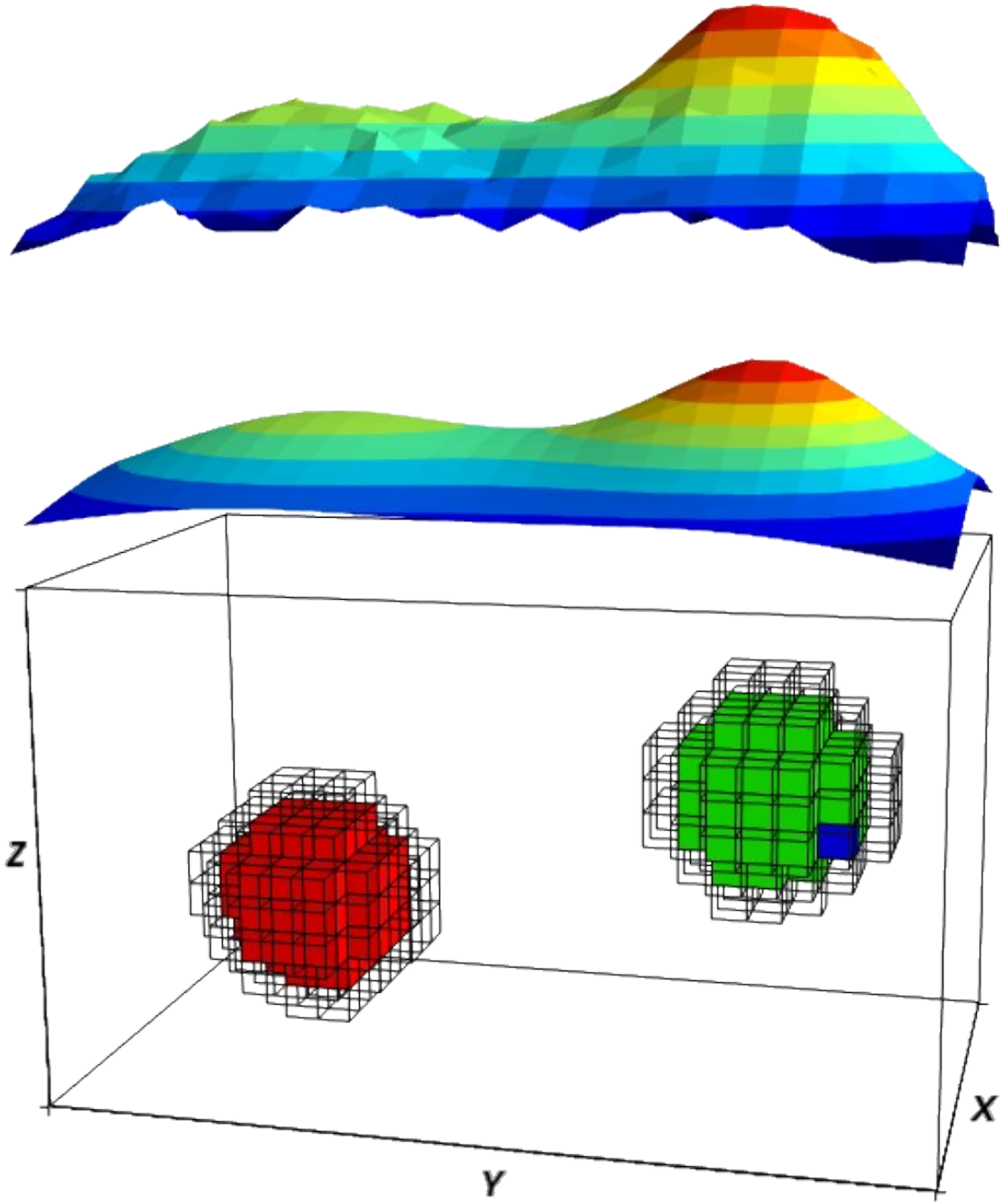

New predicted data
The best
Z
Y
X

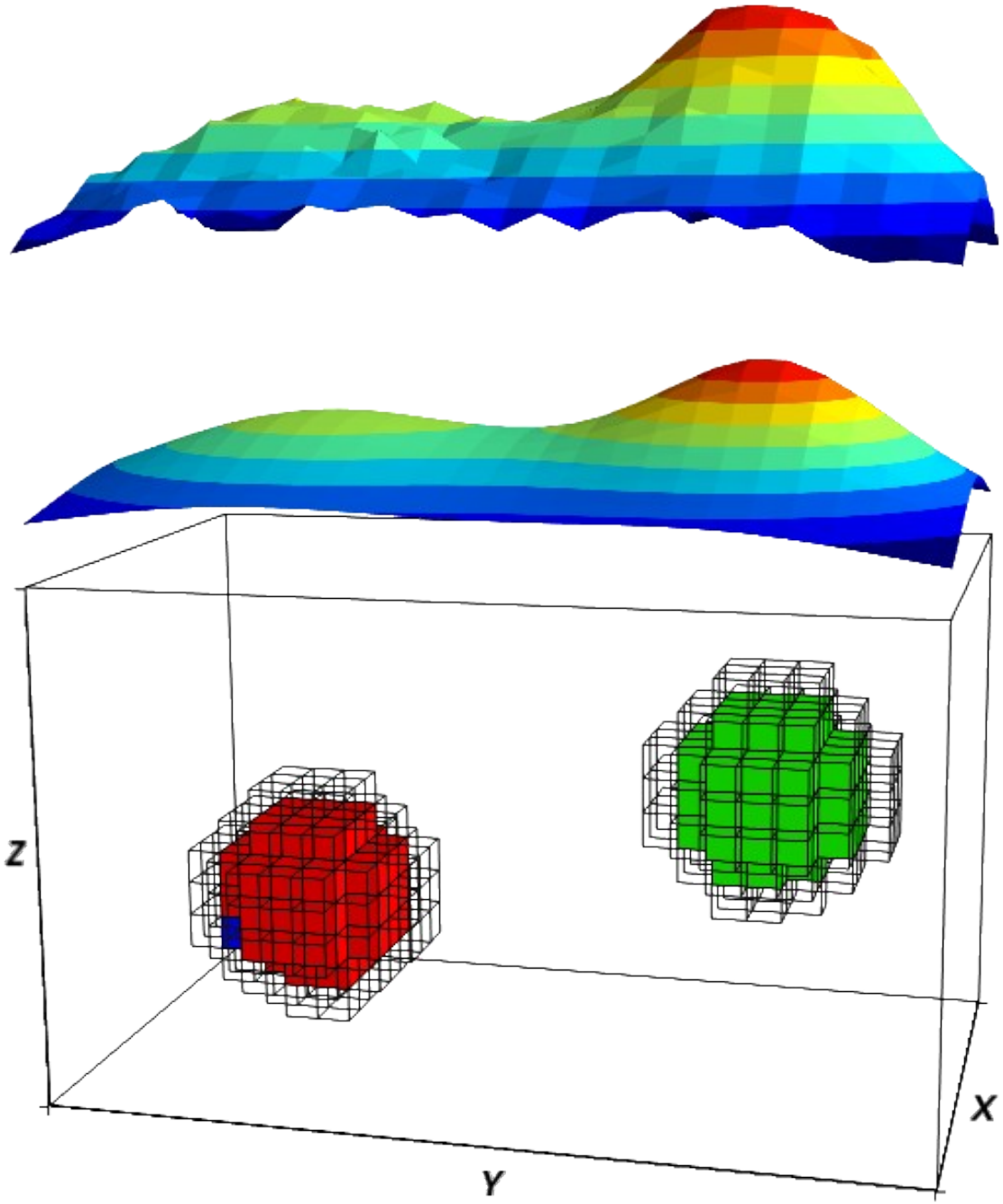

Z
Y
X

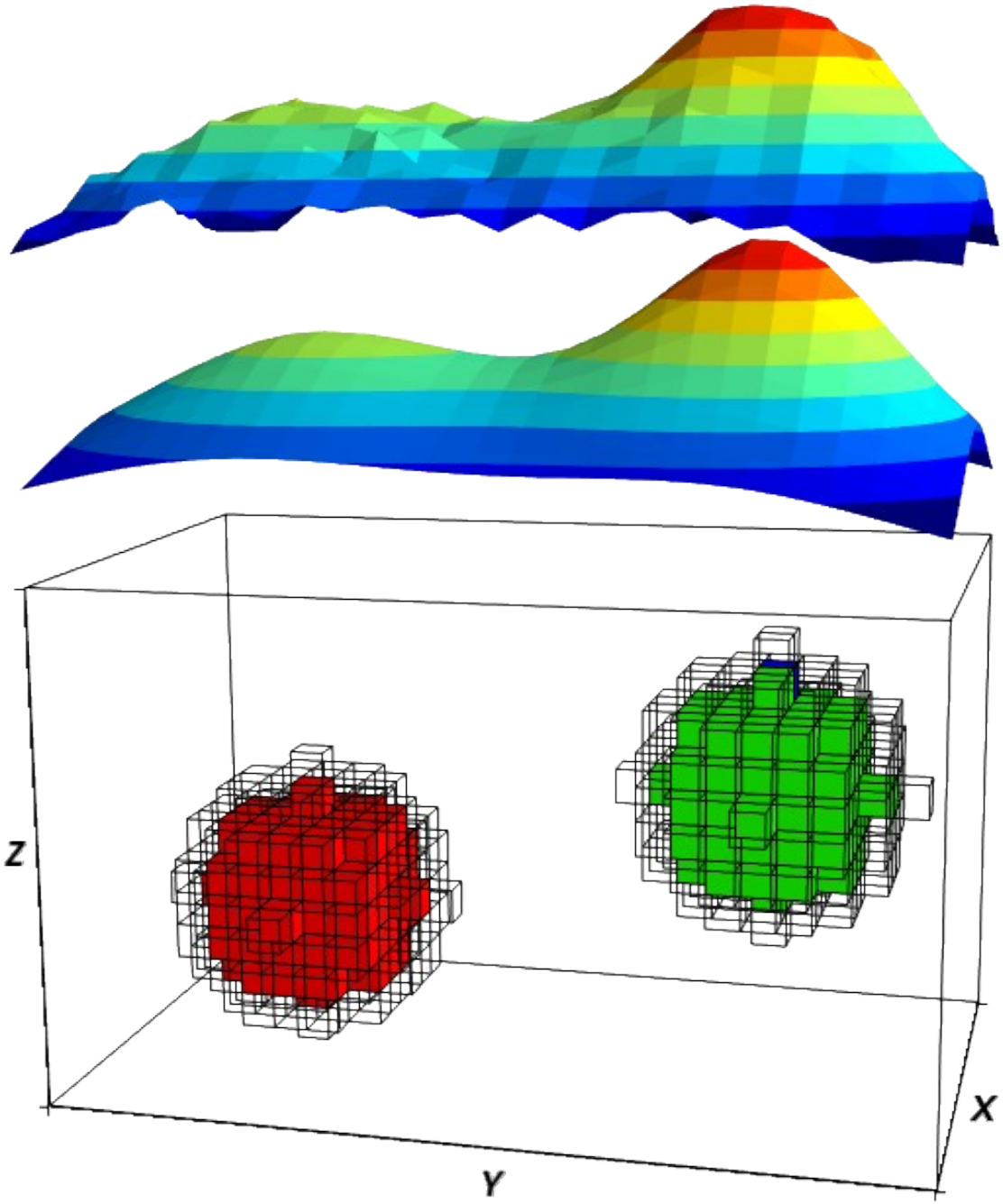

Z
Y
X

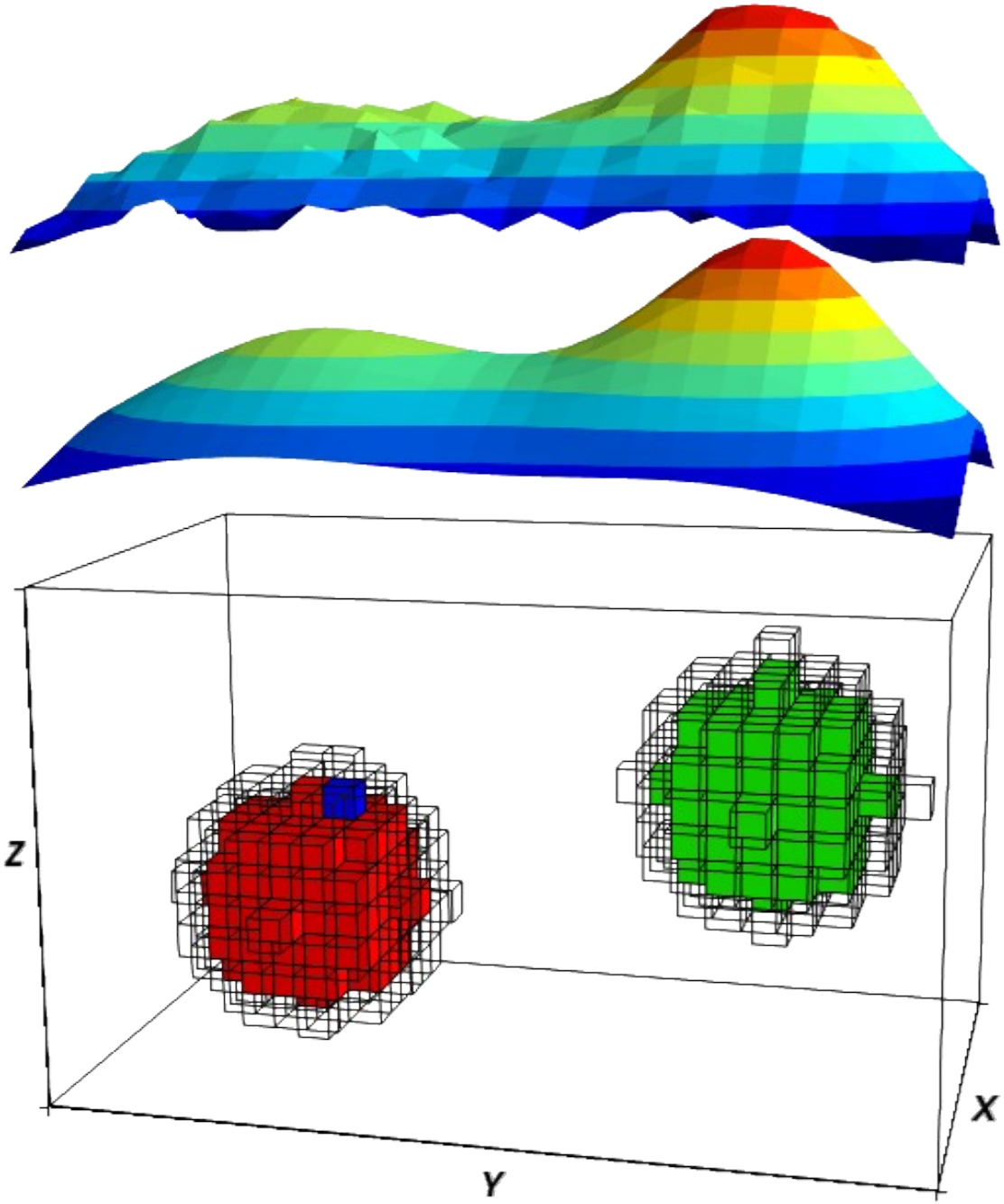

Z
Y
X

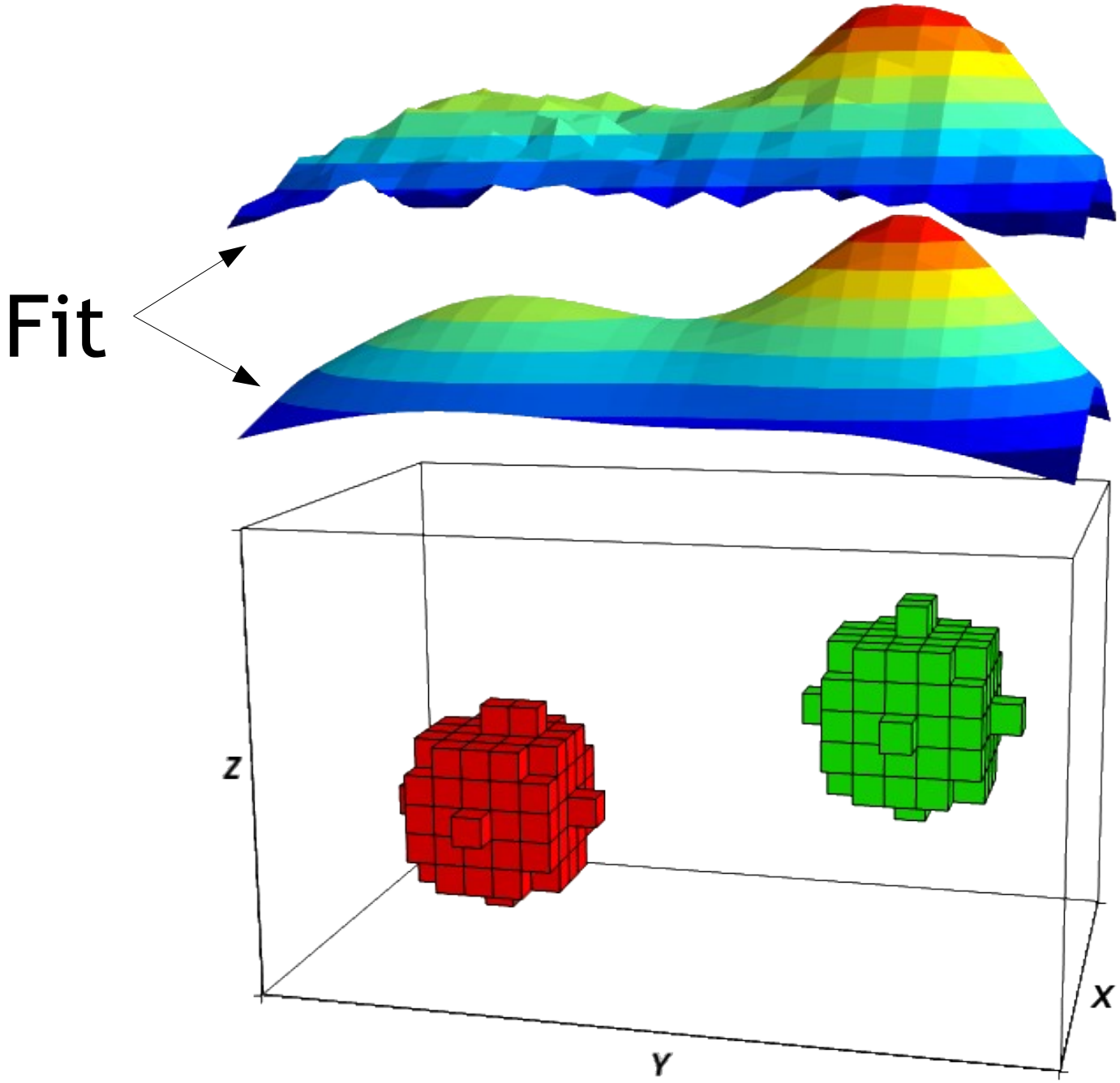

Z
Y
X


Z
Y
X

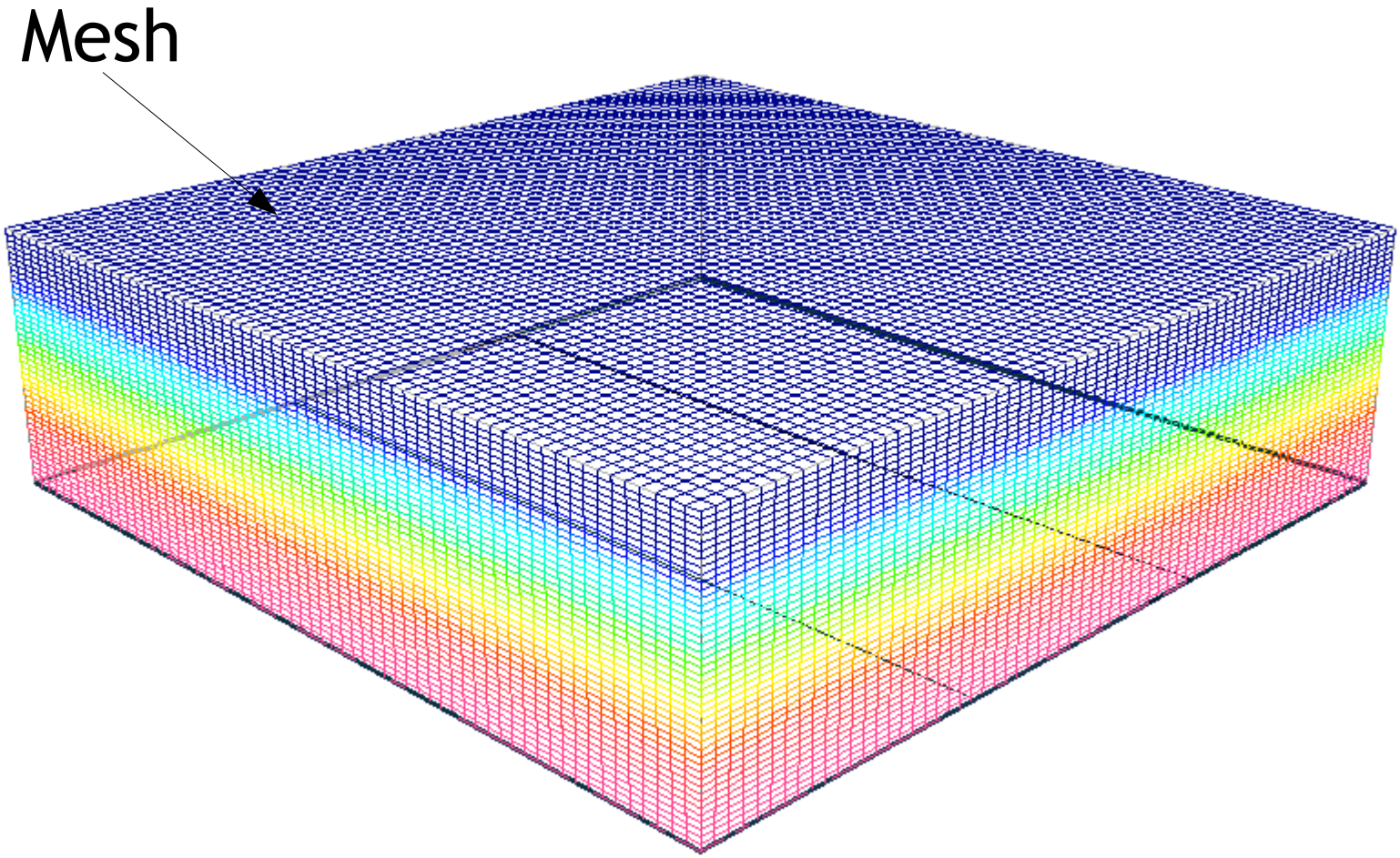

Z
Y
X


Z
Y
X


Z
Y
X


Fit
Z
Y
X

Smooth inversion


Mesh

$$min\ \phi(p) = \phi_d + \mu\,\phi_p$$

Densities

$$min\ \phi(p) = \phi_d + \mu\,\phi_p$$

Densities

Data misfit

$$min\ \phi(p) = \phi_d + \mu\,\phi_p$$

Densities

Data misfit

$$min\ \phi(p) = \phi_d + \mu\,\phi_p$$

Smoothness + depth weights

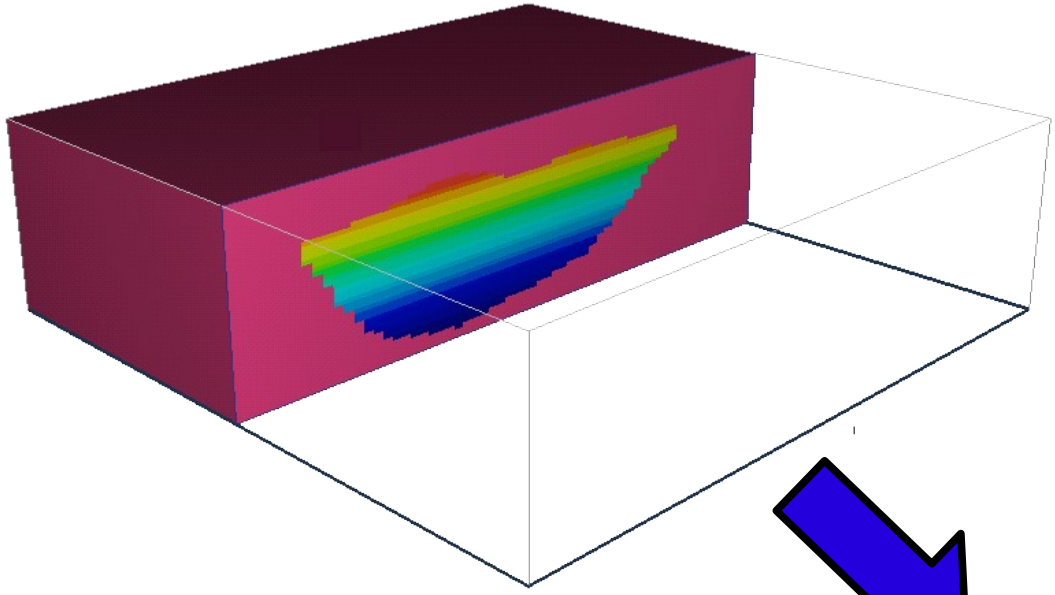
Densities

Data misfit

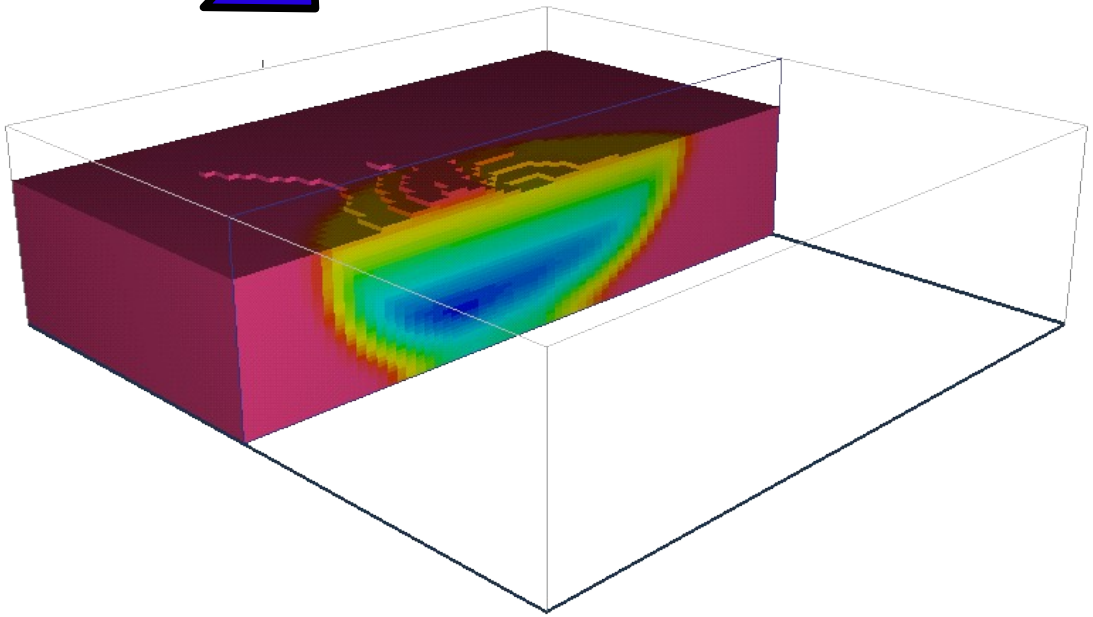
$$min\ \phi(p) = \phi_d + \mu\,\phi_p$$

Smoothness + depth weights

$$subject\ \ a \leqslant p \leqslant b$$



True model



Recovered

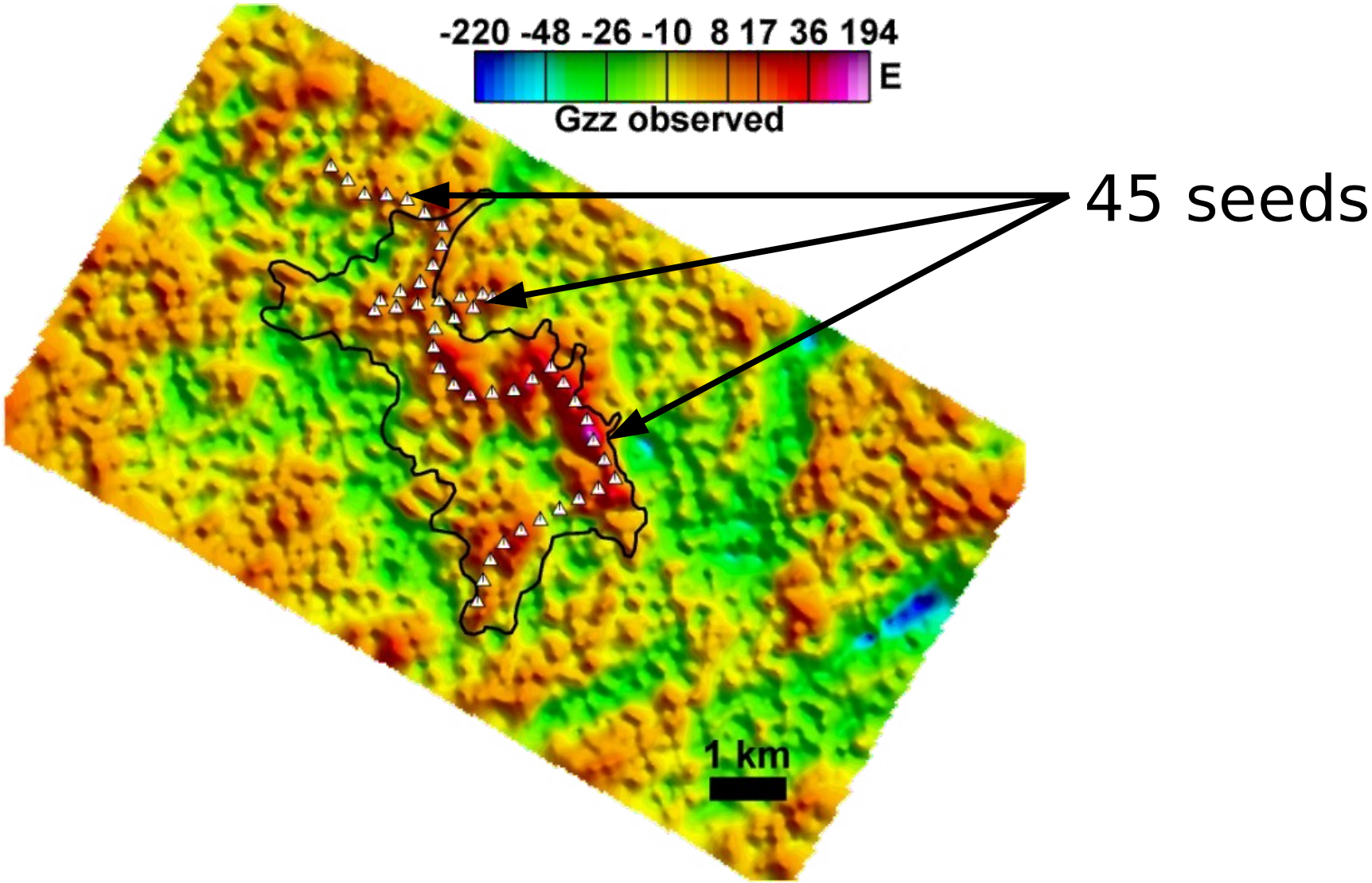
Different methods

- Different approaches
- Different constraints
- Common data
- Common target

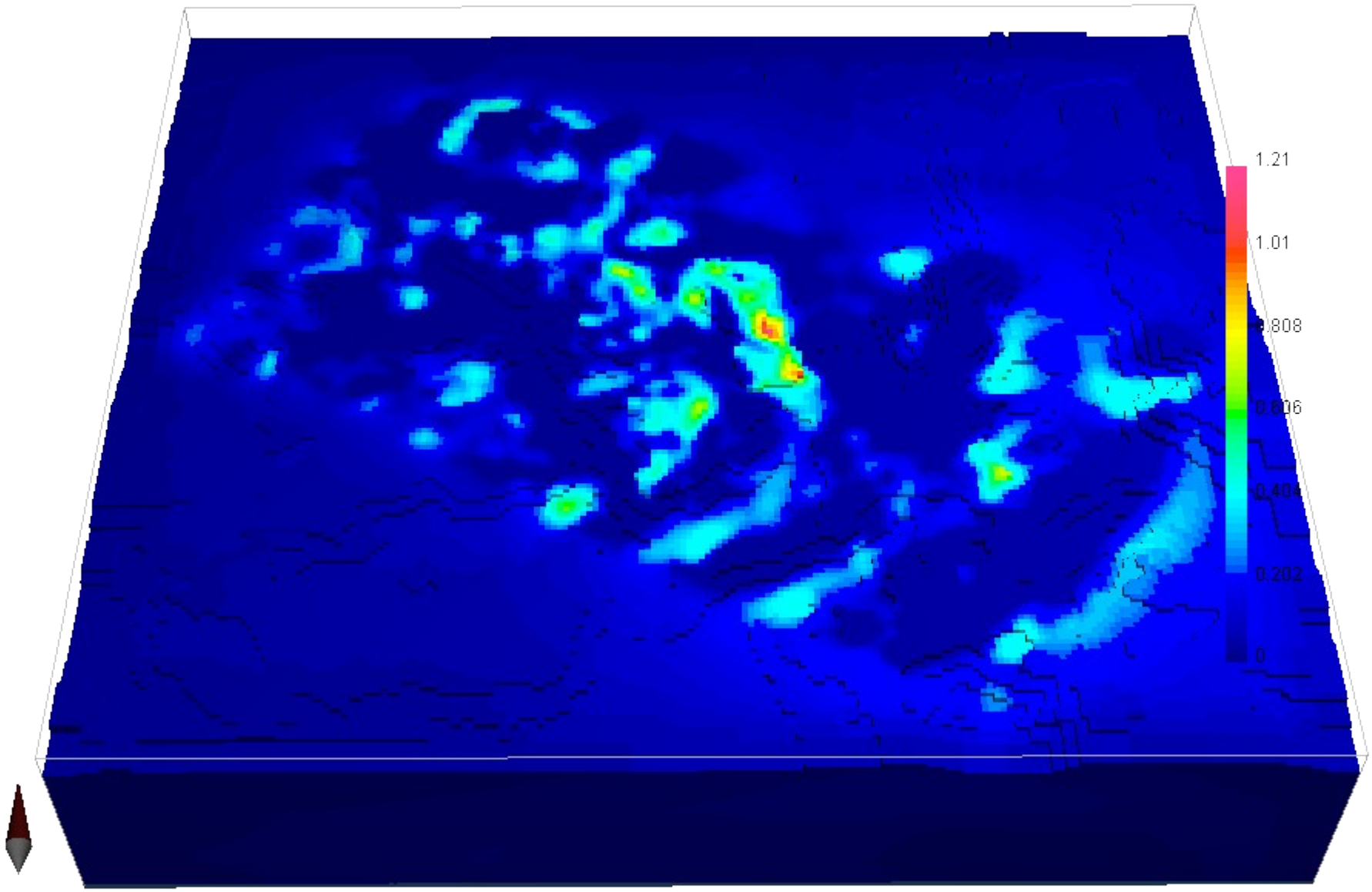
Inversion parameters

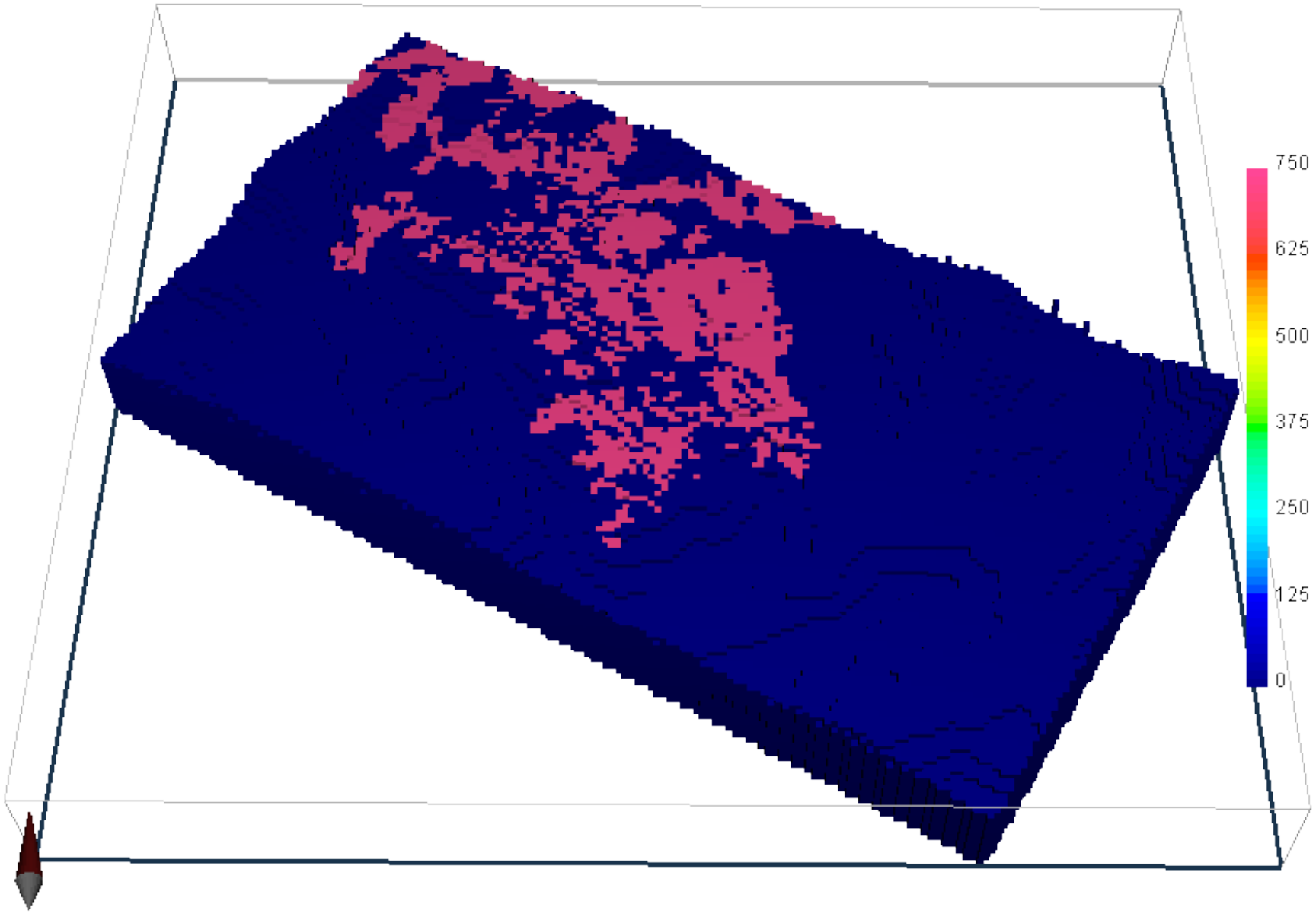
- Gzz component = 9,053 obs
- Cell size = 75 m
  - Planting = 581,440 cells
  - Smooth = 1,520,960 cells (larger mesh)

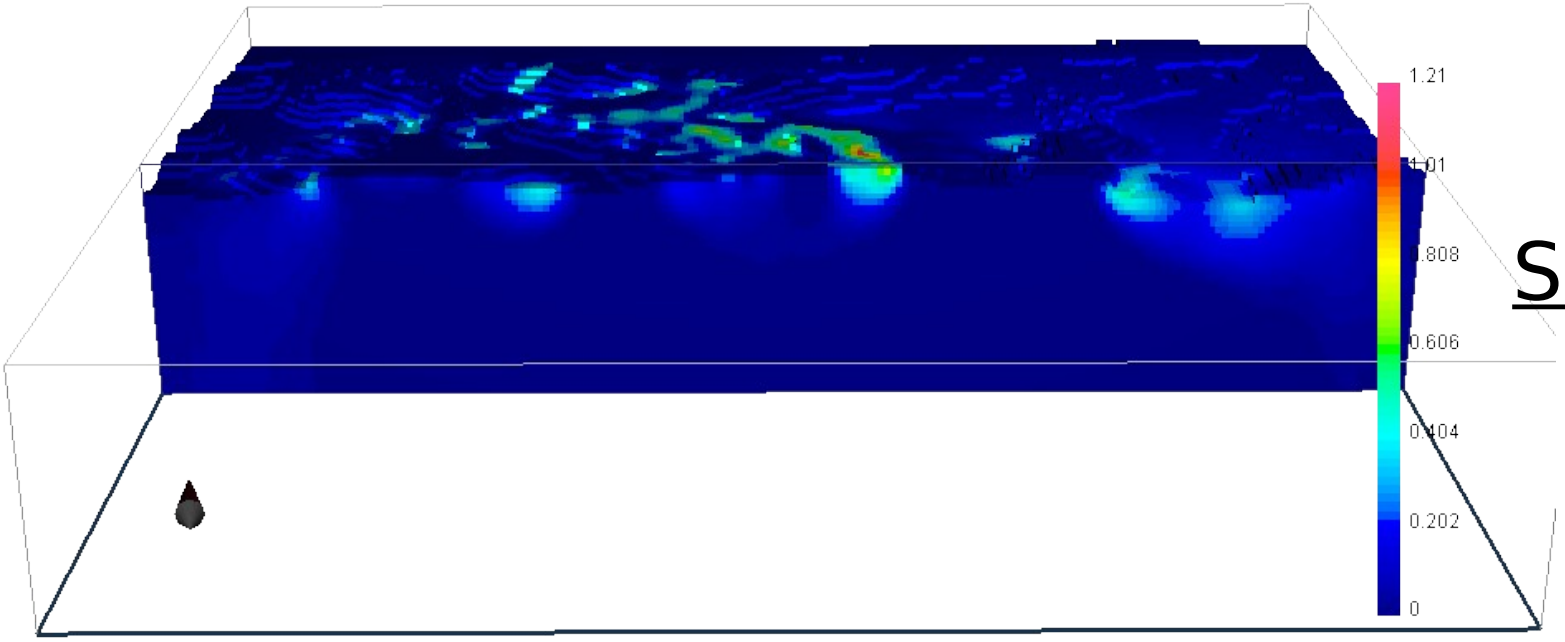
Seeds



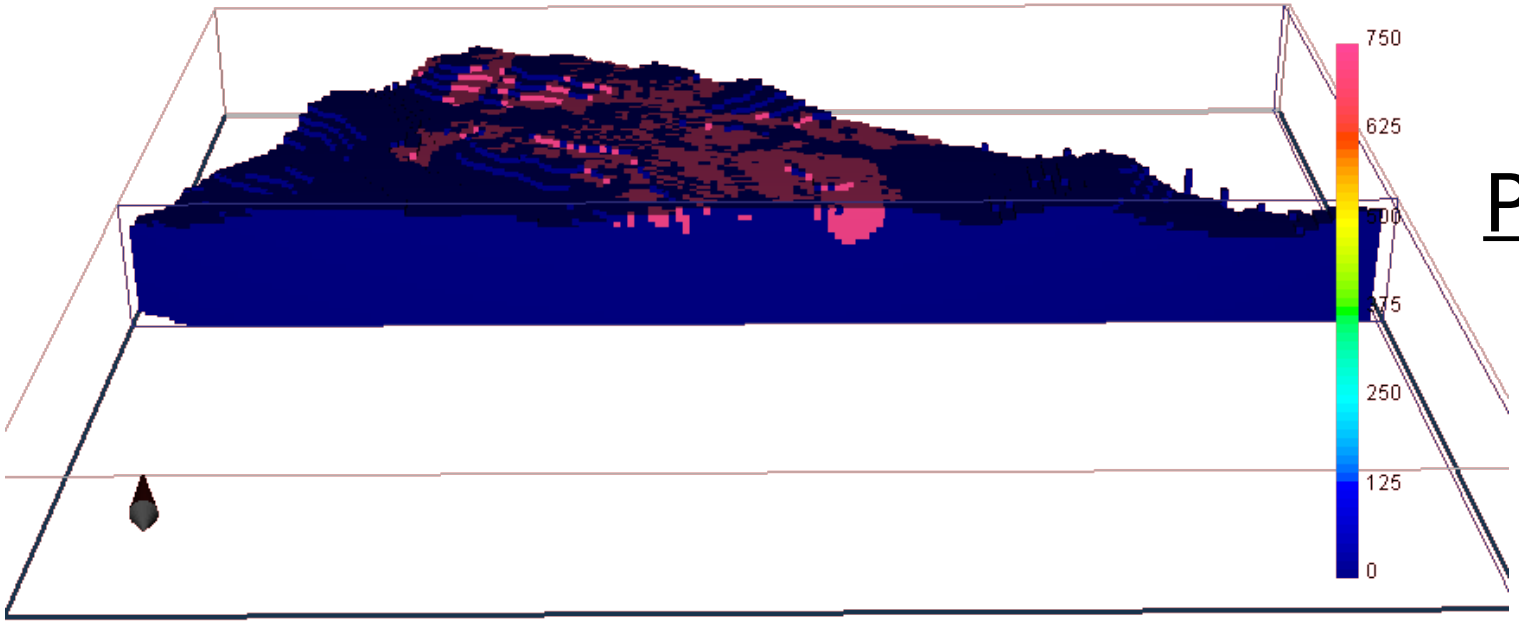
Results


1.21
1.01
0.808
0.606
0.404
0.202
0

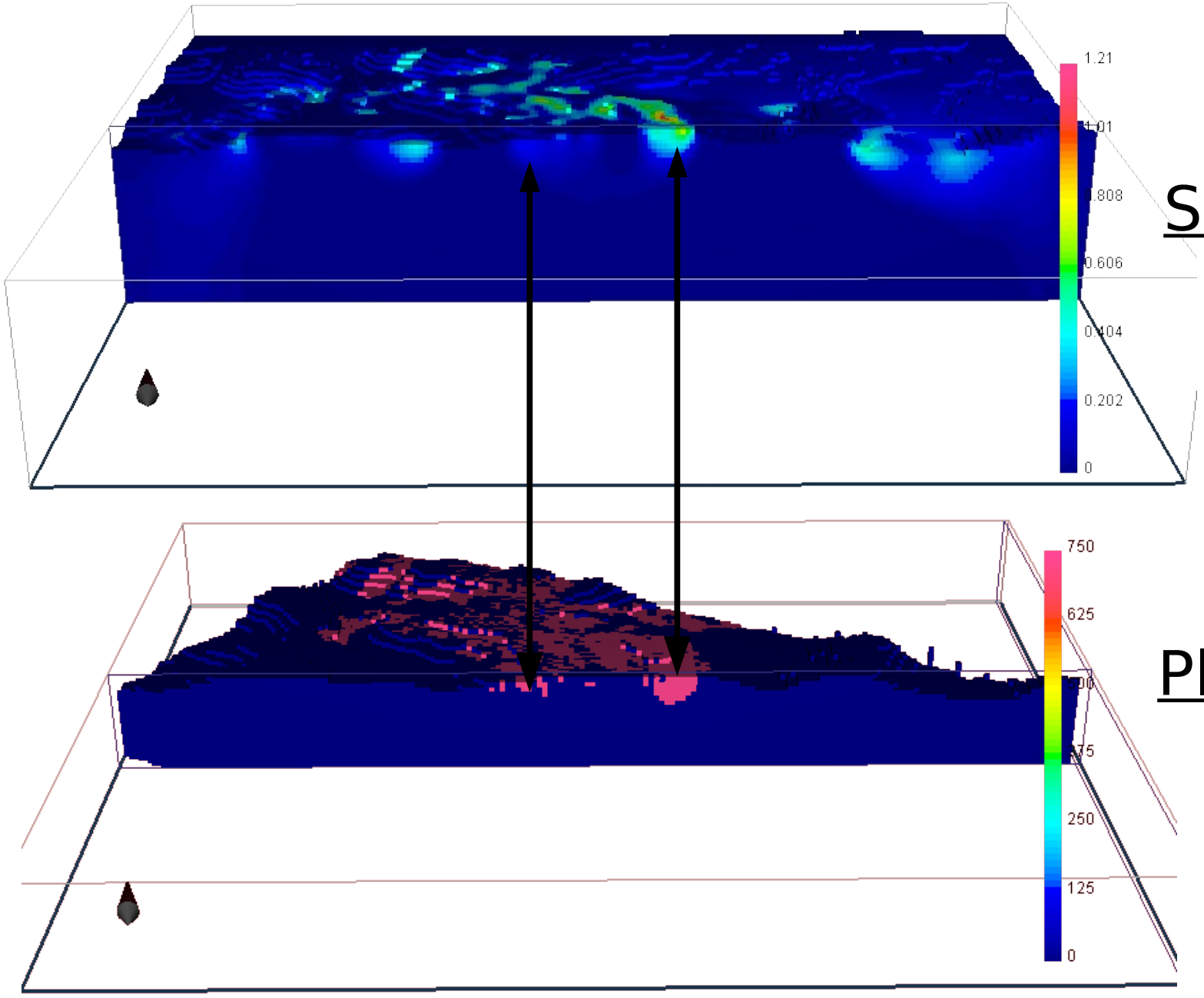

750
625
500
375
250
125
0



Smooth



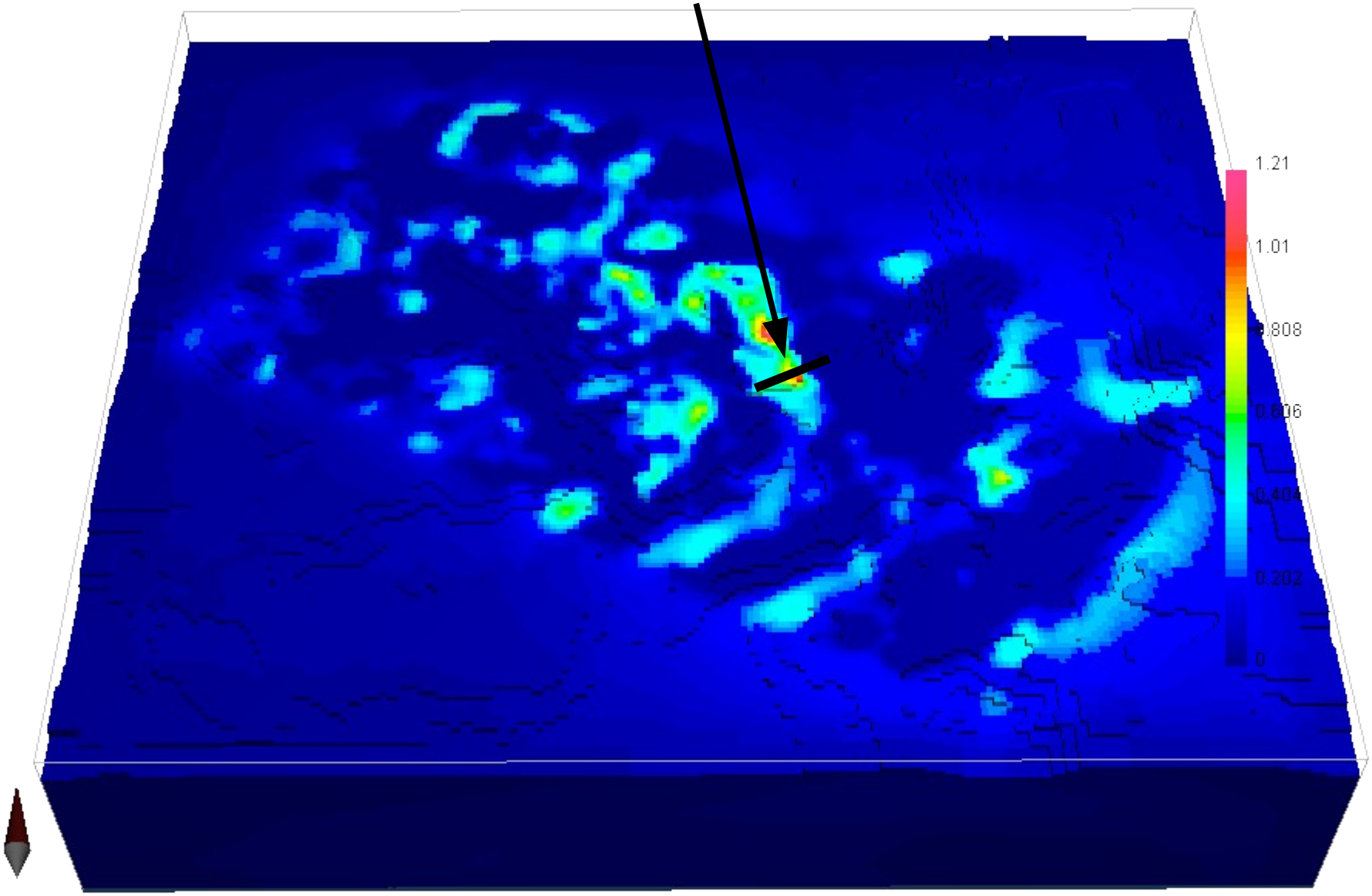
Planting



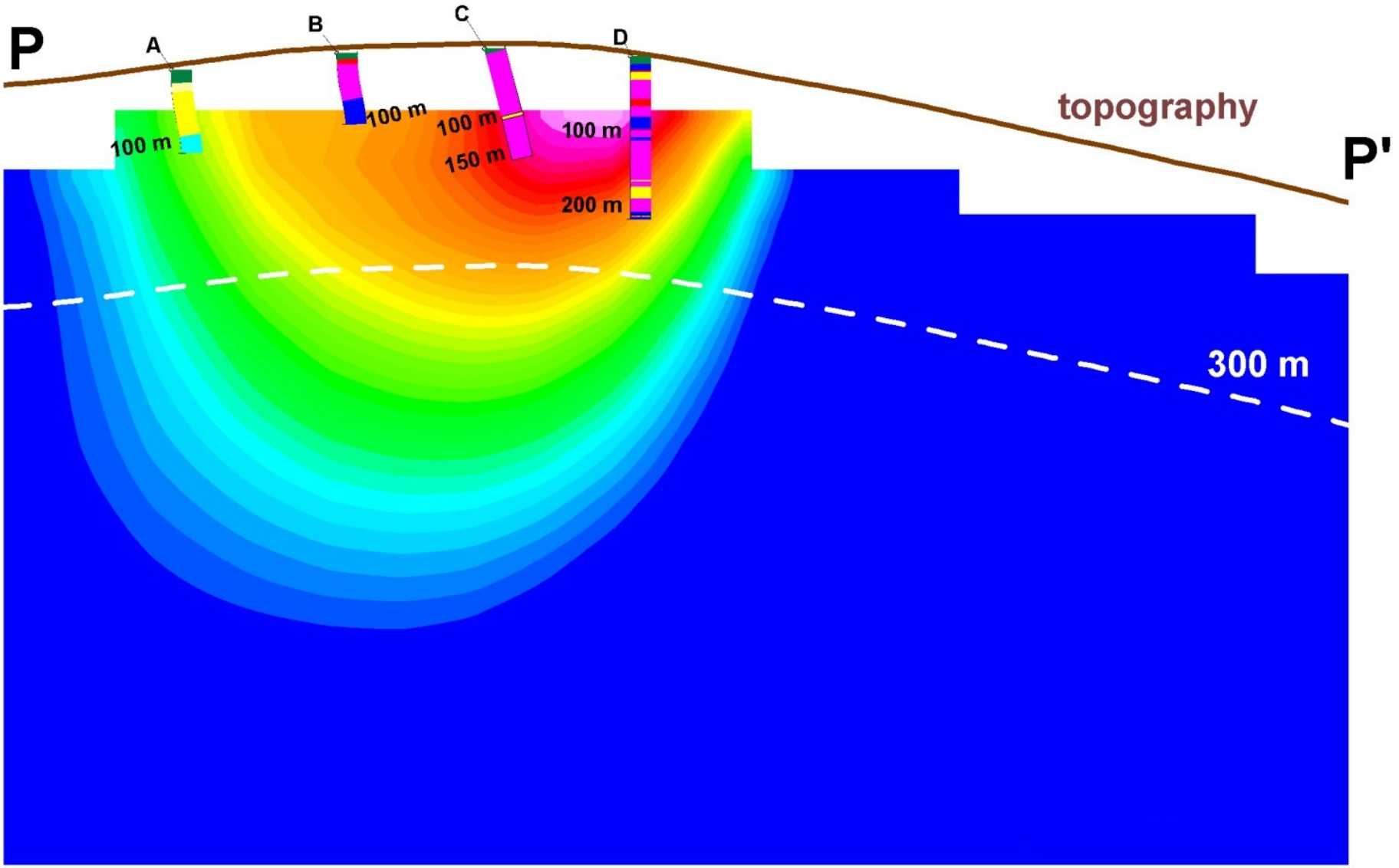
Smooth

Planting

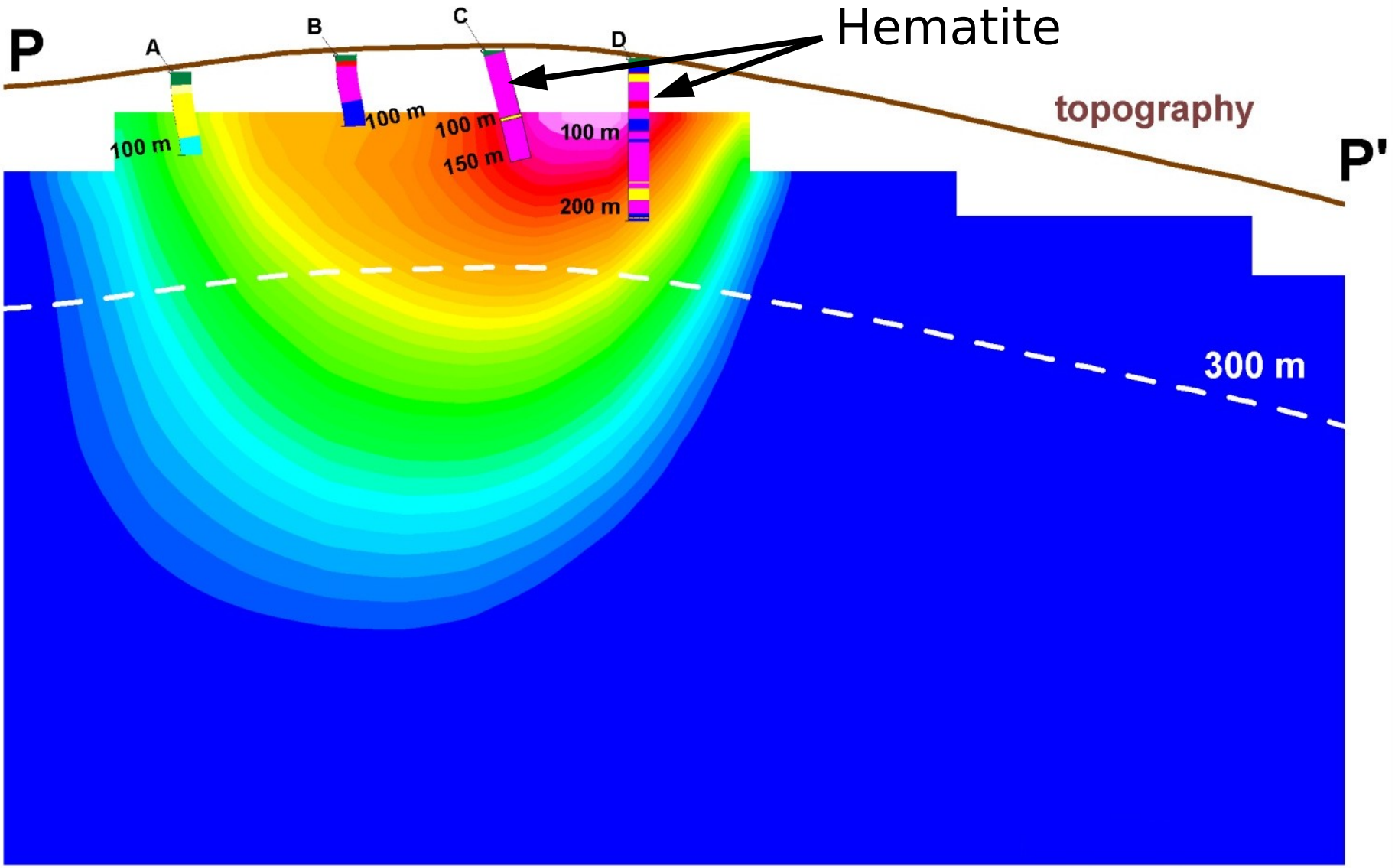
Cross-section



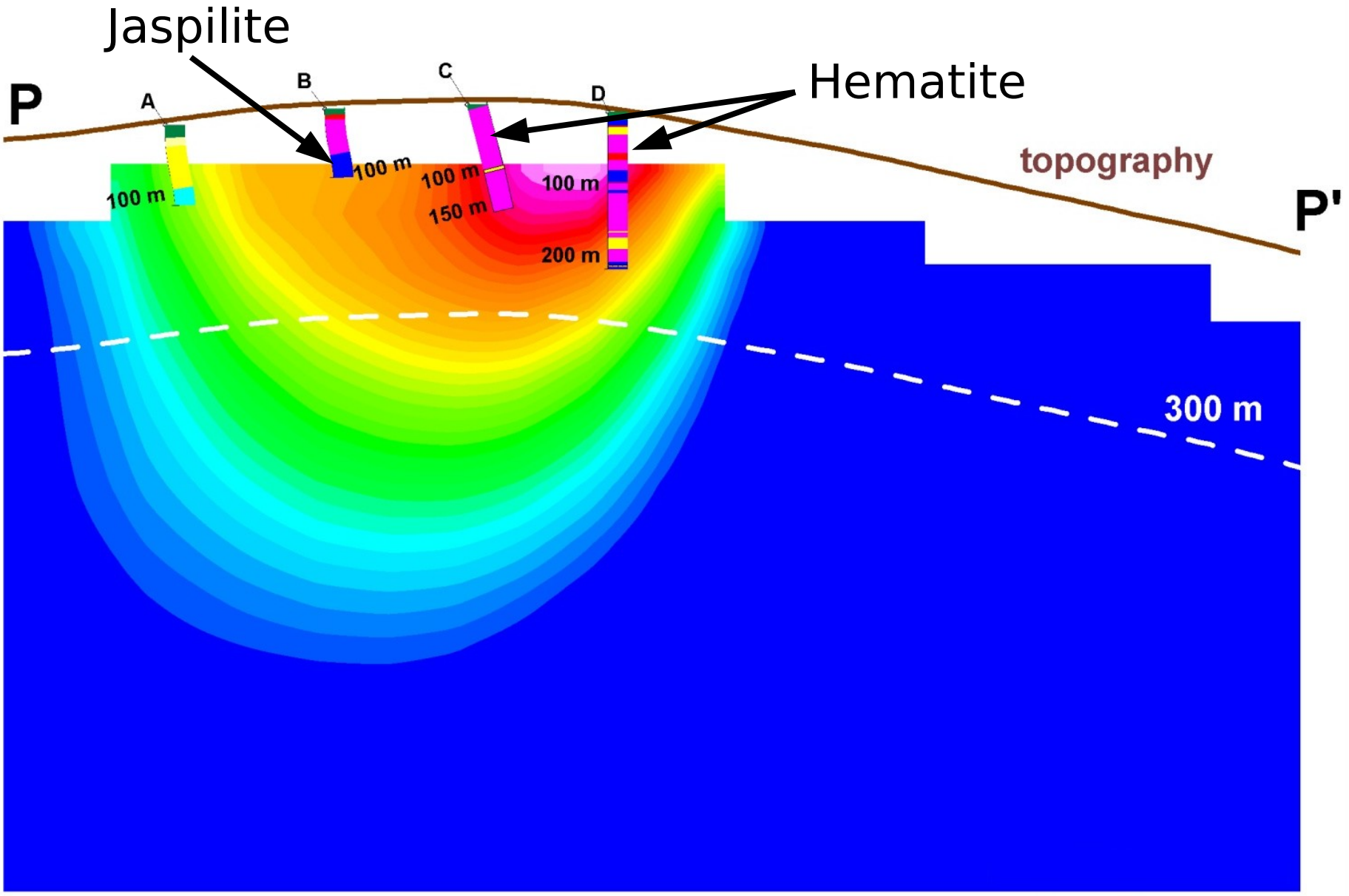
Smooth



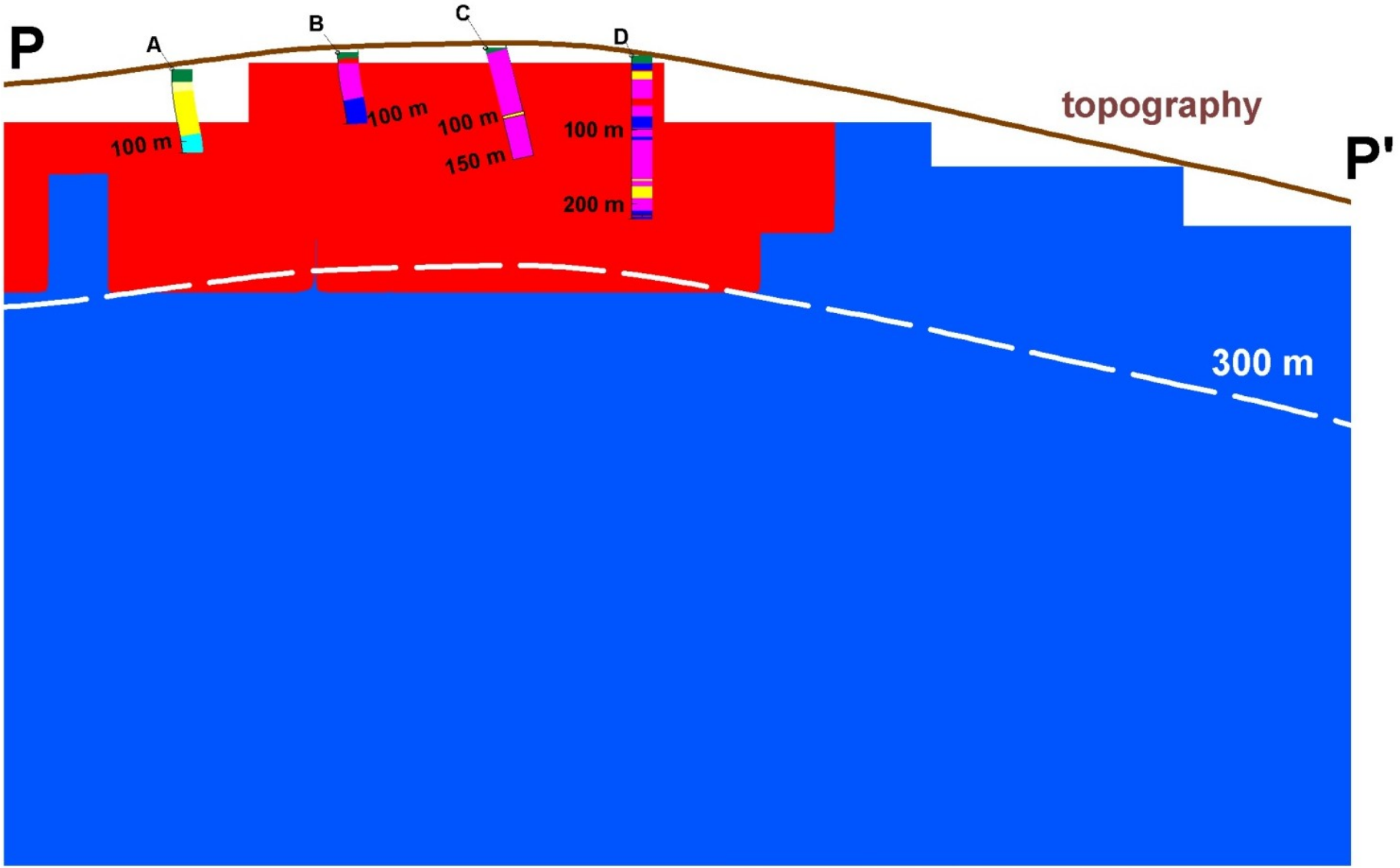
Smooth


P
A
B
C
D
Hematite
topography
P'
100 m
100 m
100 m
150 m
100 m
200 m
300 m

Smooth


Jaspilite
Hematite
P
P'
A
B
C
D
100 m
100 m
100 m
150 m
100 m
200 m
topography
300 m

Planting anomalous densities



Conclusions

- Joint interpretation
- Preliminary results
- Compatible solutions
- Agree with boreholes
- Concentrated above 300 m
- Bellow 200 m could be jaspilite
  - Same density contrast

Acknowledgements

Colorado School of Mines, USA

Observatório Nacional, Brazil

Vale S.A.