Using gravity to identify and characterize the Permo-Carboniferious grabens at the top of the crystalline basement of Switzerland.

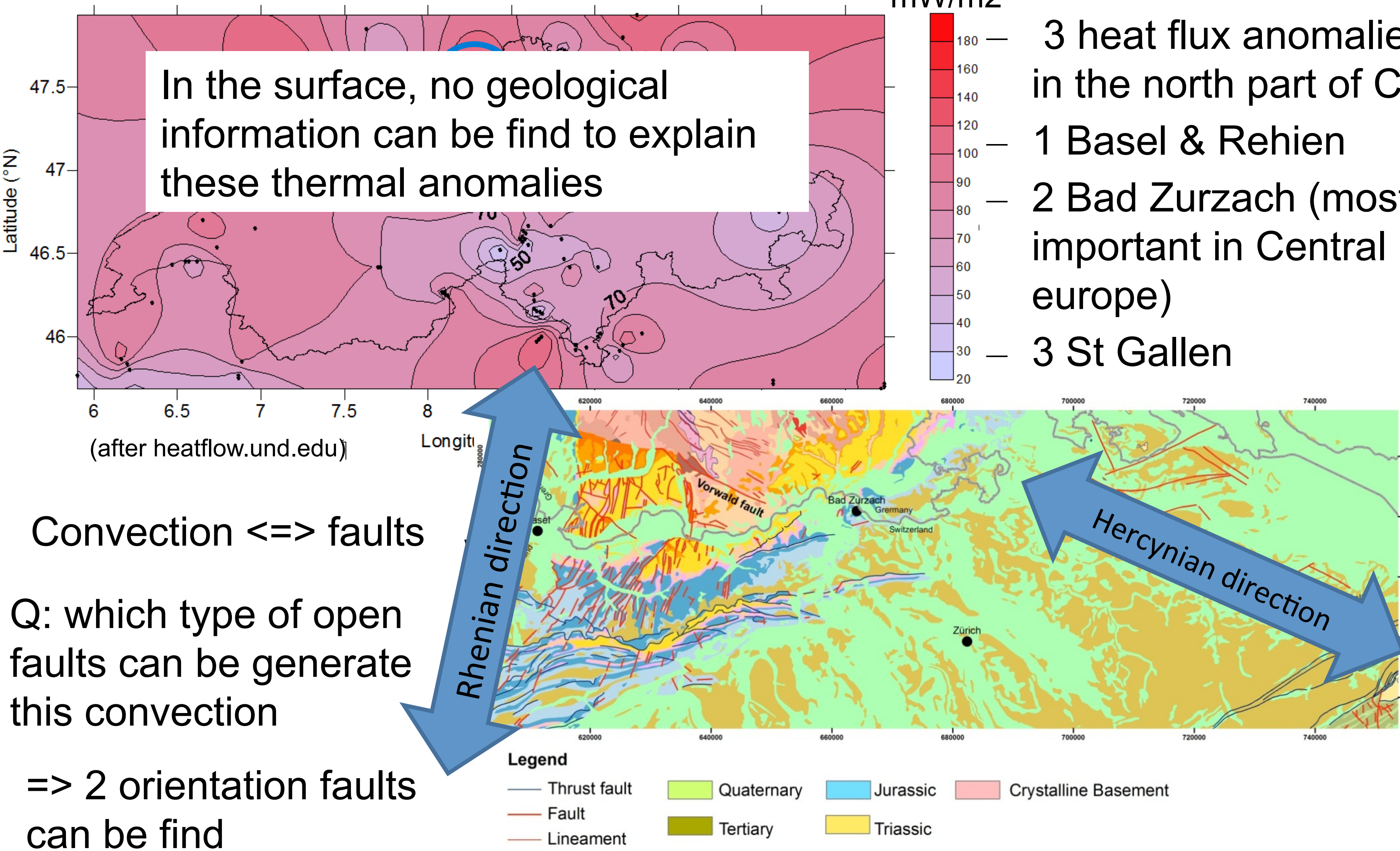
Yassine Abdelfettah

1 - Institut de Physique du Globe de Strasbourg, CNRS UMR7516, Université de Strasbourg, France
2 - Karlsruhe Institute for Technology (KIT), Institute for Nuclear Waste Disposal (INE), Karlsruhe, Germany

Outlook

* Motivation
* PC identification problem
* Gravity as a complementary Solution
* Sensitivity analysis
* Switzerland application
* Conclusions

Introduction



(after heatflow.und.edu)

- 3 heat flux anomalies in the north part of CH
- 1 Basel & Rehien
- 2 Bad Zurzach (most important in Central europe)
- 3 St Gallen

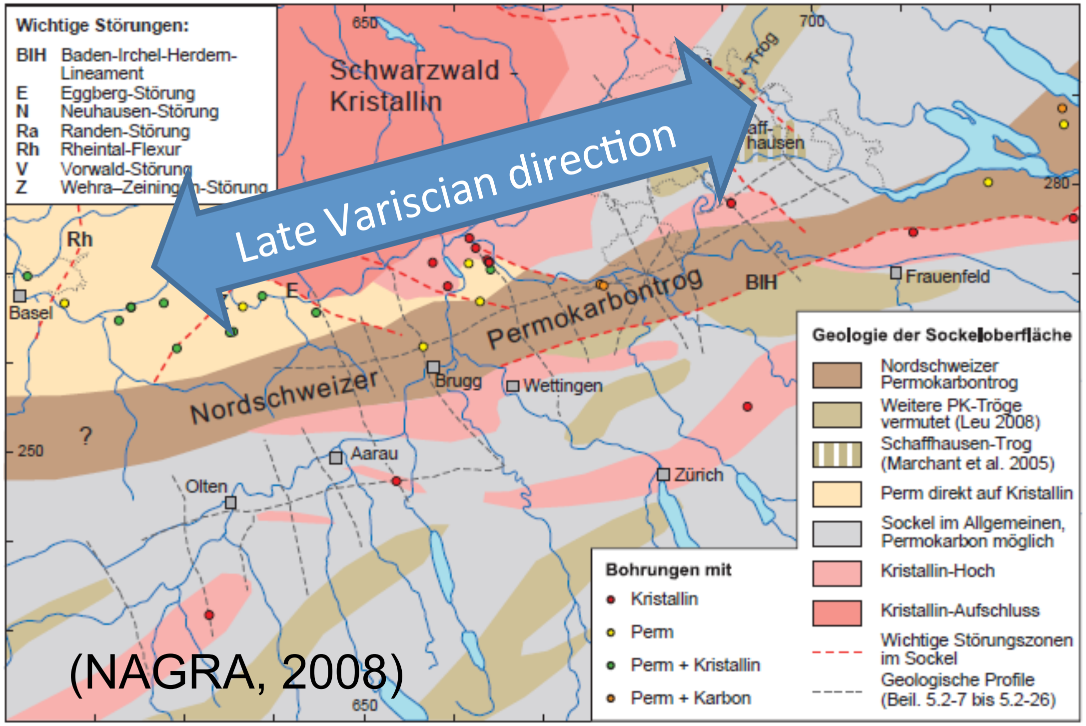
Convection <=> faults

Q: which type of open faults can be generate this convection

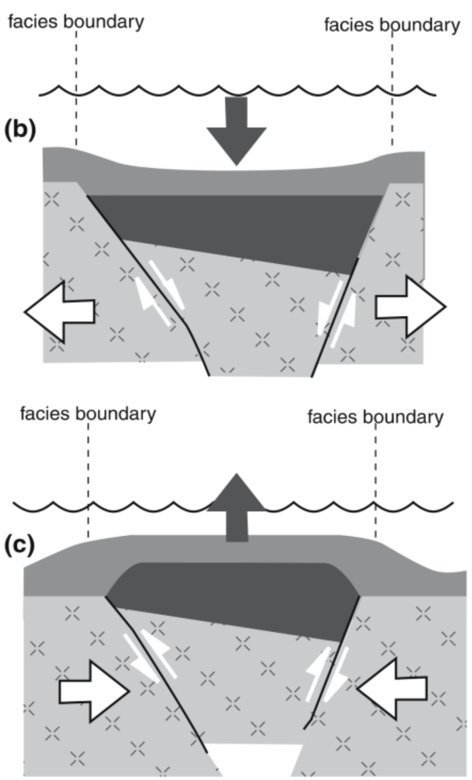
=> 2 orientation faults can be find

Local geology in the crystalline basement

Bordering faults of PC graben (high K and ϕ) may be the origin of the convection phenomenae



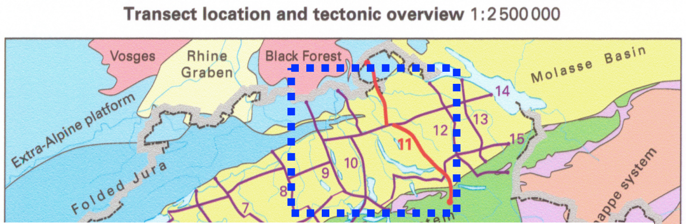
(NAGRA, 2008)



Representation of the PC graben

Allenbach et Wetzel, 2006

Problem in the dealination of the PC using 2D seismic



Geological stratigraphy in the Swiss Molasse Basin

Cenozoic

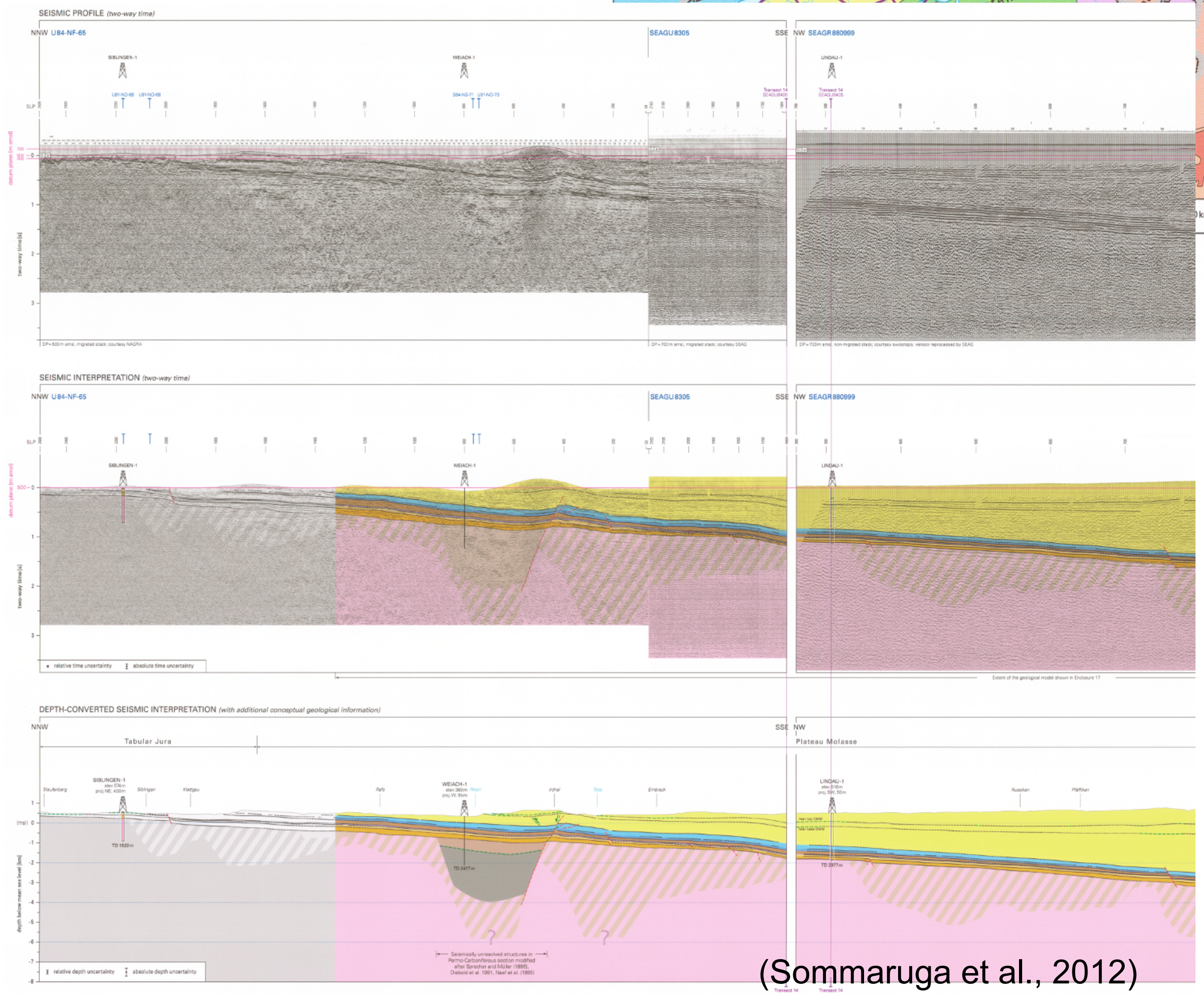
*** Tertiary&Quaternary (Molasse)**

Mezosoic:

*** Malm, Dogger, Liassic, Triasic**

Paleozoic & Precambrian

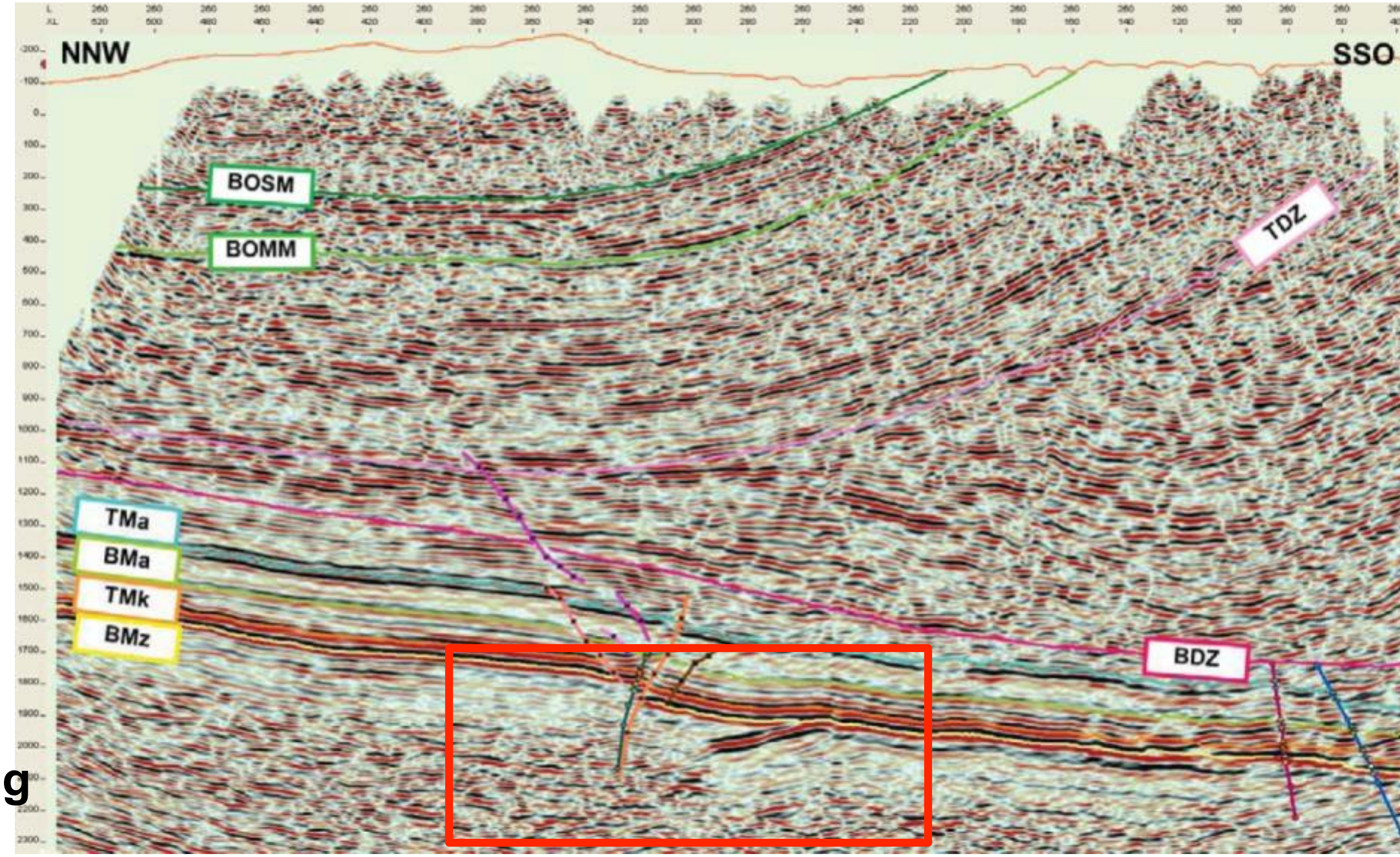
*** Permian, PC, Cristalline basement**



(Sommaruga et al., 2012)

Problem in the dealination of the PC using 3D seismic

Ambiguities in the 2D & 3D seismic interpretation about the accurate loclization of the Paleozoic PC graben



Courtesy of Stadtwerke St. Gallen

2 tools are so developped

1) 3D FwD modeling using a finite element method

⇒ to simulate the Bouguer response for ANY 3D geological model

And

2) Butterworth filter

Mathematical formulations for FwD modeling

1) The intensity of the gravity field can be computed by

$$\mathbf{E}(\mathbf{r}) = \kappa\rho \int_D d\tau' \, \nabla_{\mathbf{r}} \frac{1}{|\mathbf{r}' - \mathbf{r}|} = -\kappa\rho \int_D d\tau' \, \nabla_{\mathbf{r}'} \frac{1}{|\mathbf{r}' - \mathbf{r}|}.$$

D Volume

2) 1st reduction : Gauss Theoreme (D => S)

$$\mathbf{E}(\mathbf{r}) = -\kappa\rho \int_S d\boldsymbol{\sigma}' \frac{1}{|\mathbf{s}' - \mathbf{r}|}, \qquad \mathbf{E}(\mathbf{r}) = -\kappa\rho \sum_{k=1}^{K} \mathbf{n}_k \int_{S_k} d\sigma' \frac{1}{|\mathbf{s}' - \mathbf{r}|},$$

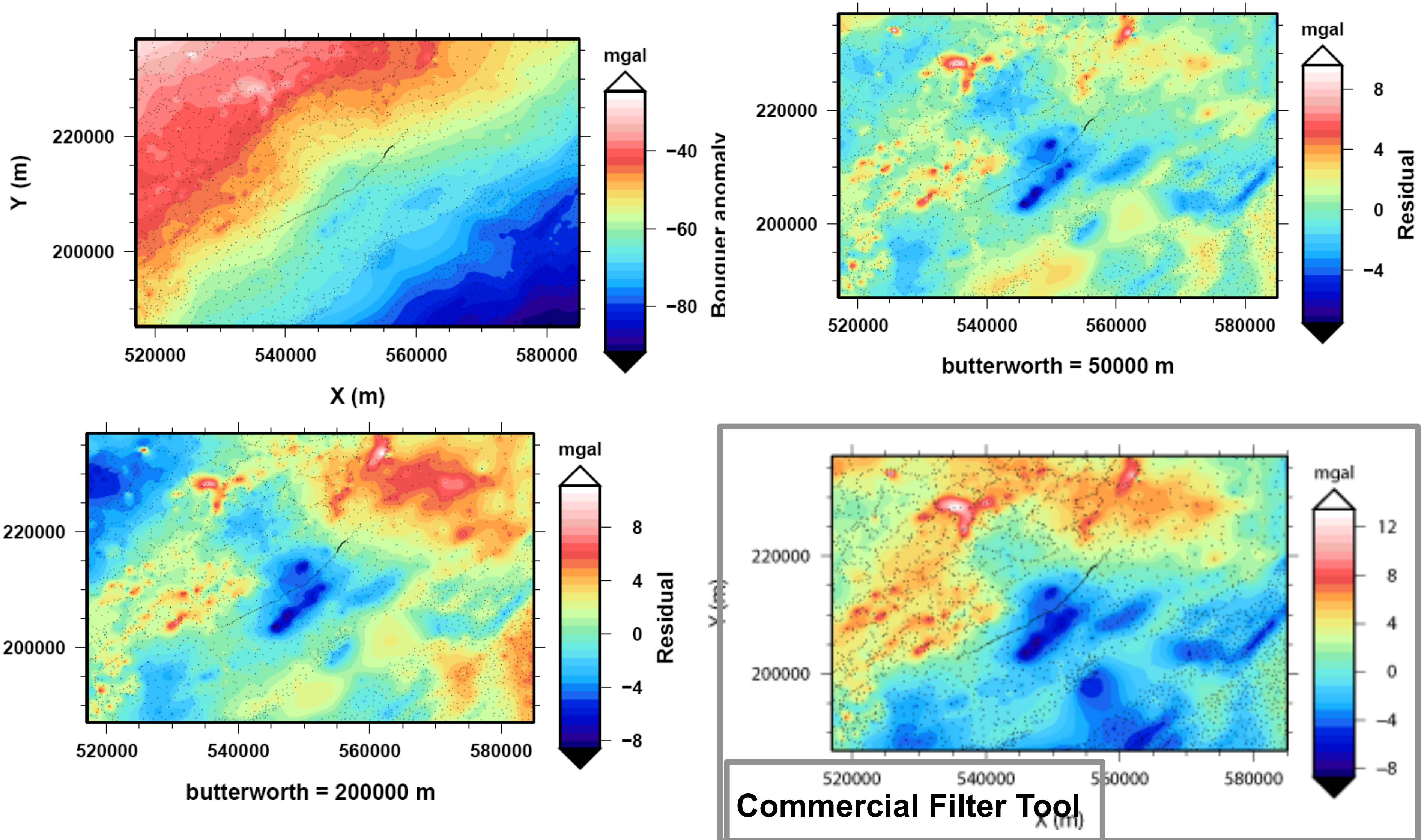
S Surface

3) 2nd reduction : 2D Gauss Theoreme (S => L)

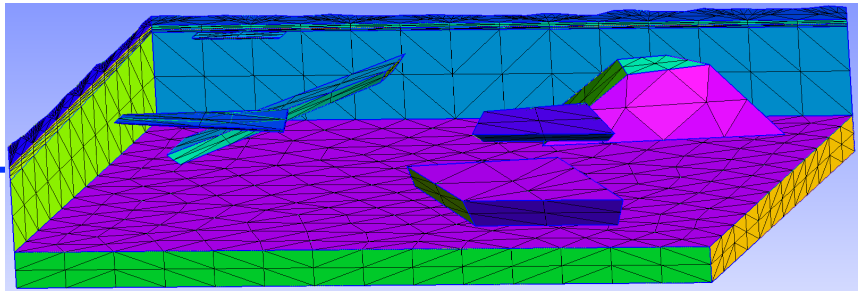
$$\int_{S_k} d\sigma' \frac{1}{|\mathbf{s}' - \mathbf{r}|} = \int_{L_k} d\boldsymbol{\xi}' \cdot \frac{\mathbf{l}' - \mathbf{r}}{|\mathbf{l}' - \mathbf{r}| + |\mathbf{n}_k \cdot (\mathbf{l}' - \mathbf{r})|},$$

L line

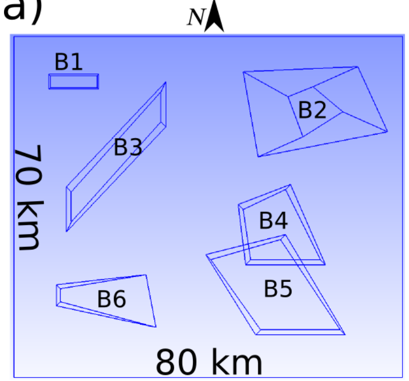
Butterworth filter vs. others

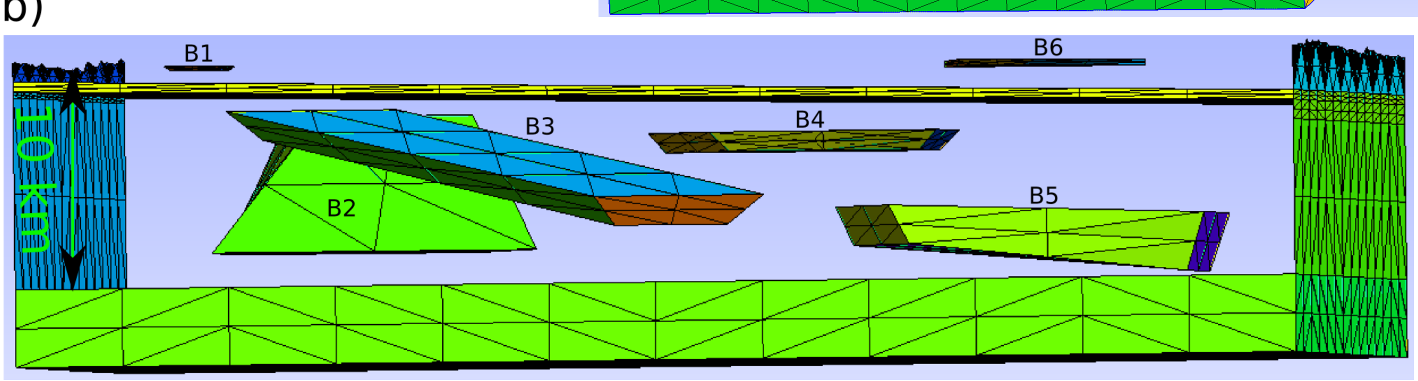


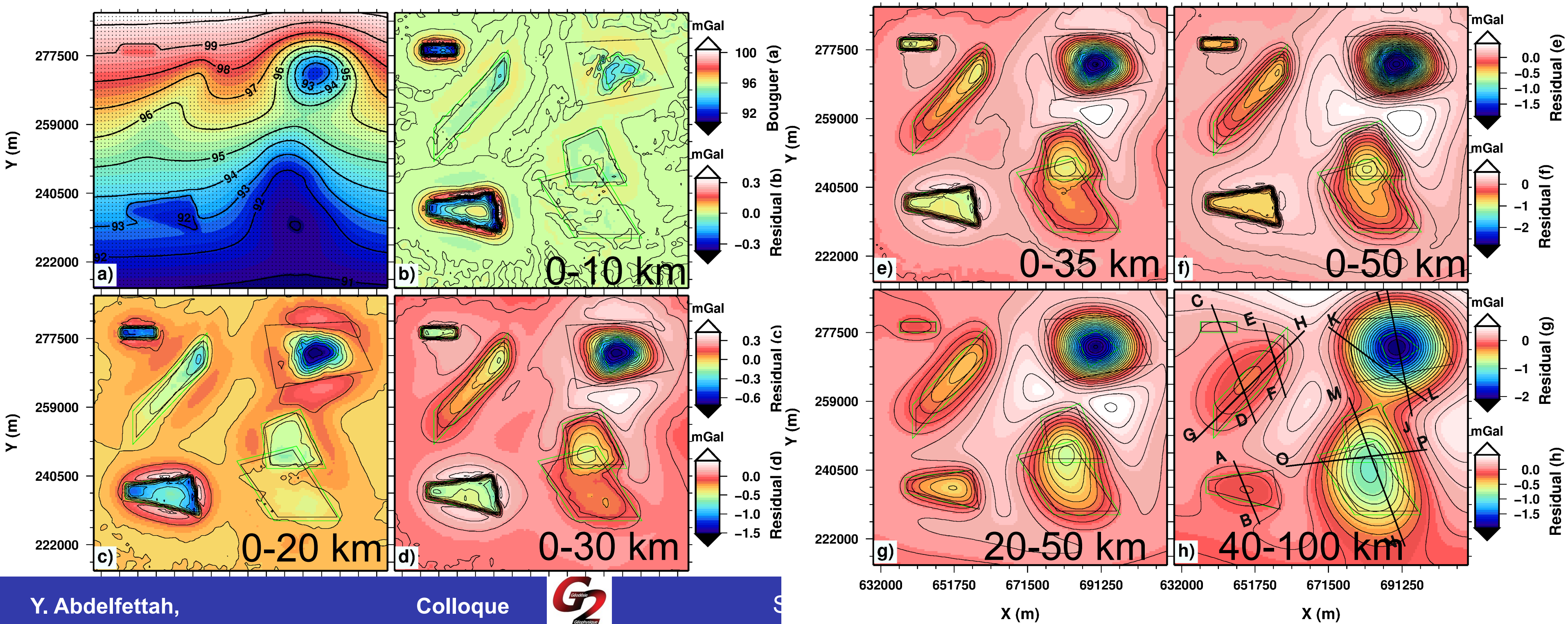
Sensitivity study for Butterworth filter



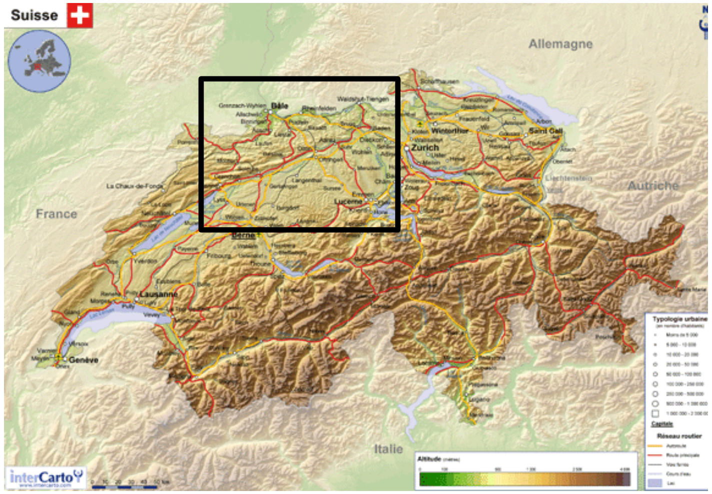
Abdelfettah & Schill, 2013



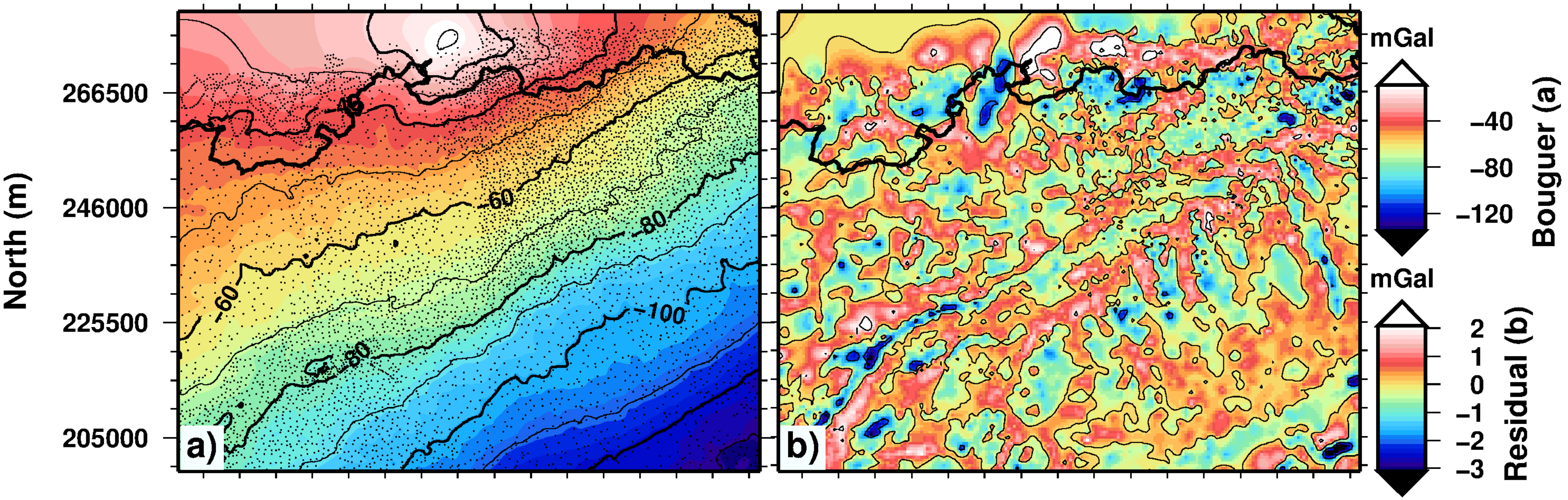




Application in NW of Switzerland



Abdelfettah et al, 2014



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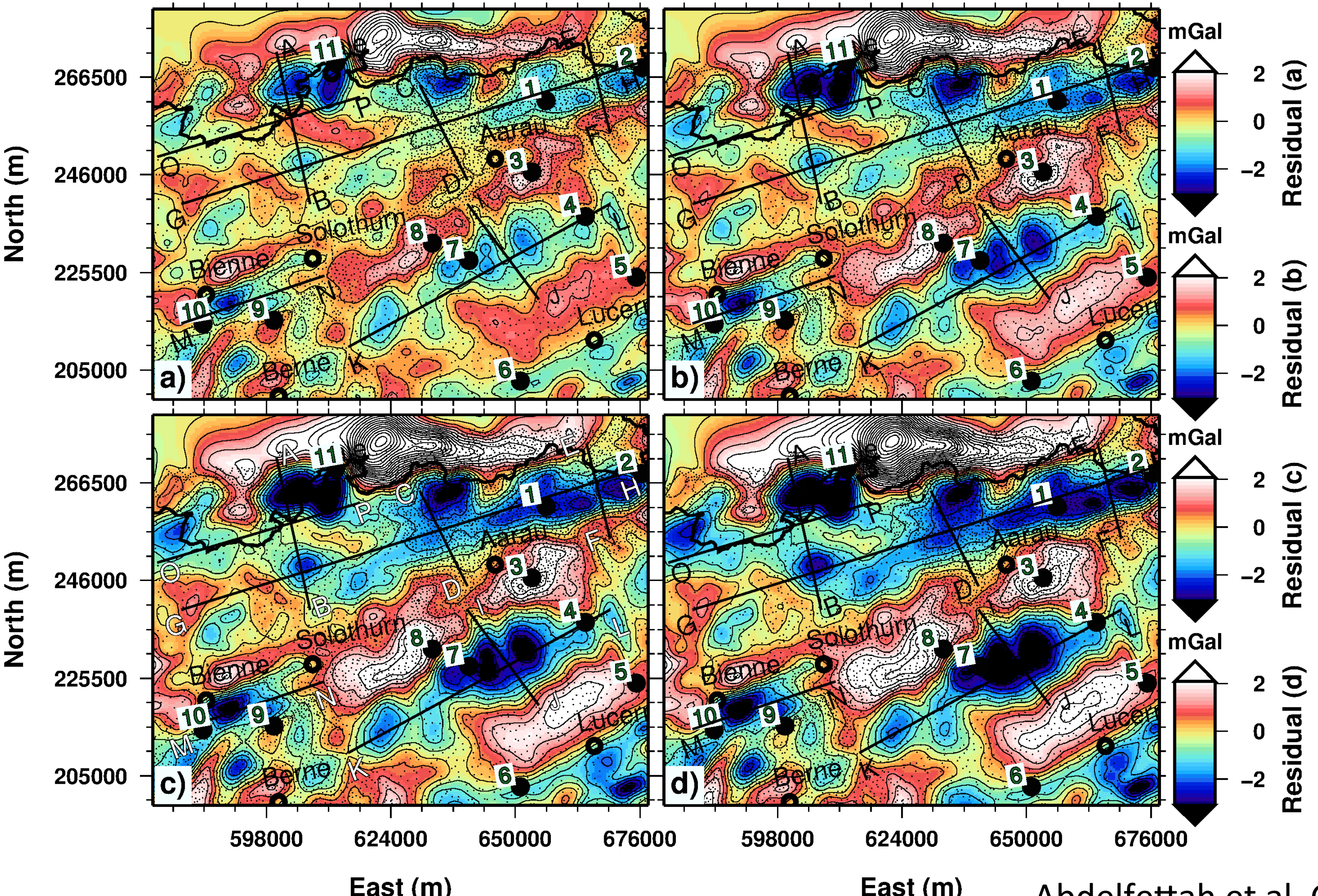

a)10-30km
b)10-40km
c)10-50km
d)10-60km

Abdelfettah et al, GJI, 2014

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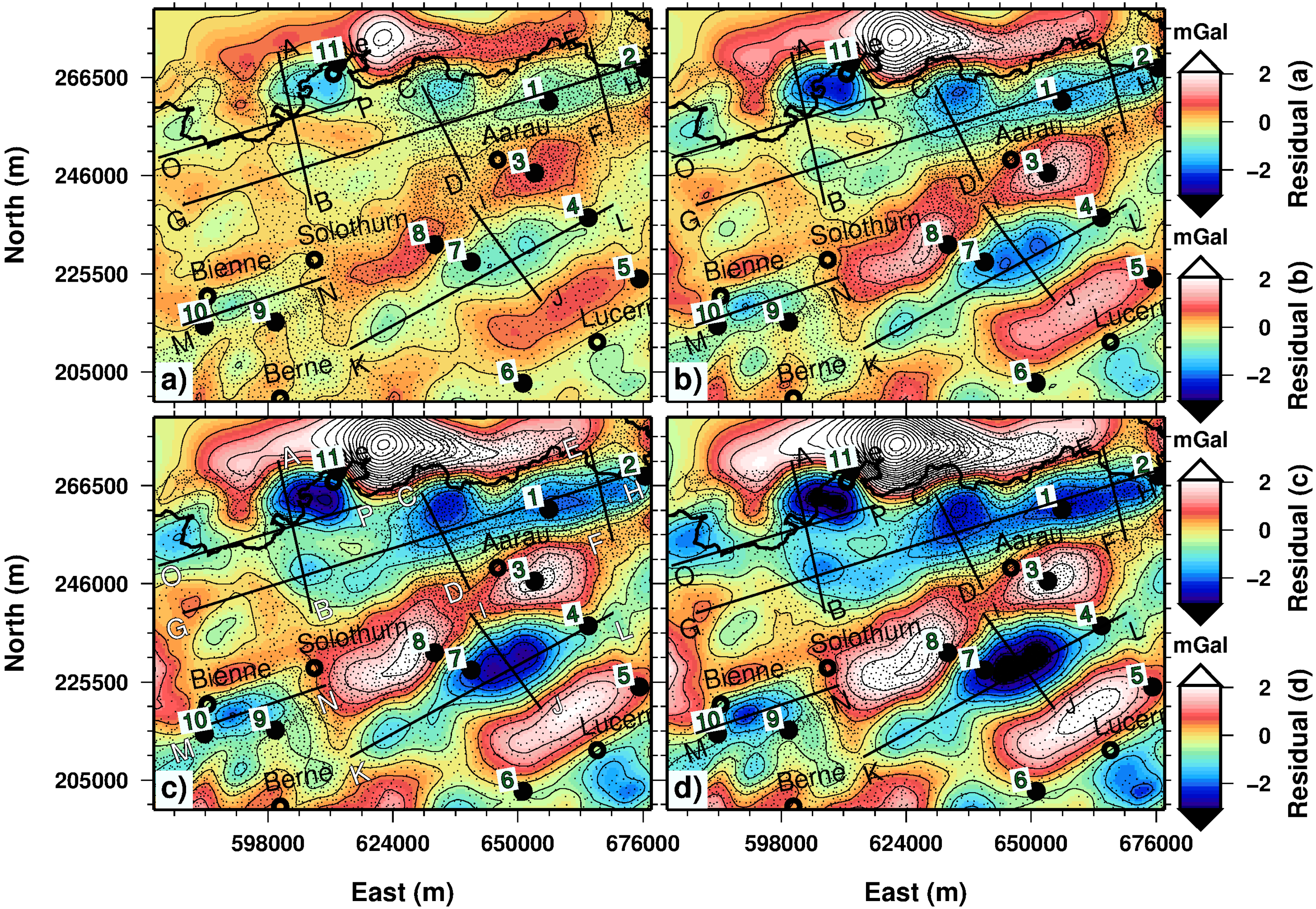

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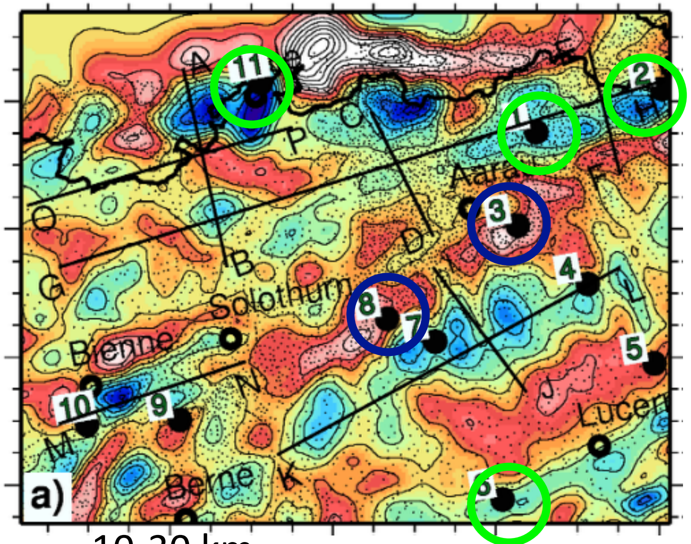
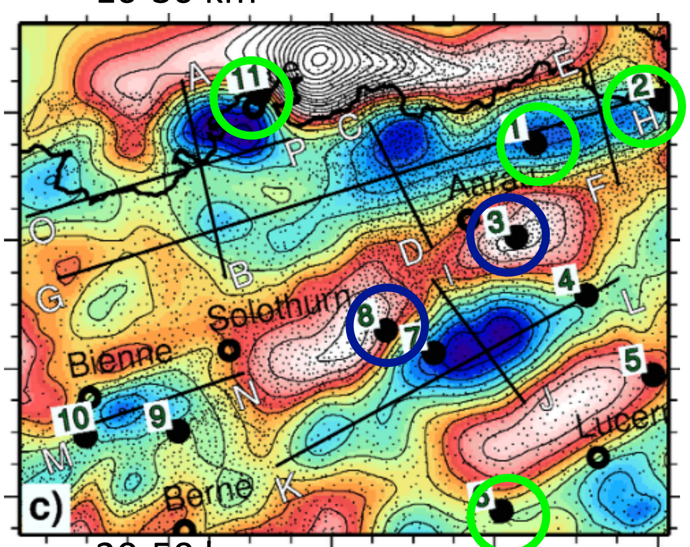


10-30 km



20-50 km

Gravity results vs. borehole infos.

PRESENCE OF PC = NEGATIVE GRAVITY ANOMALIES

1) Riniken1 (did not reach the Crystalline basement and crossed 984m of Permian formation)

2) Weiach1 (reach the Crystalline basement and crossed 572 m of PC formation)

6) Entlebuch1 (did not reach the Crystalline basement but it crossed 204 m of PC formation)

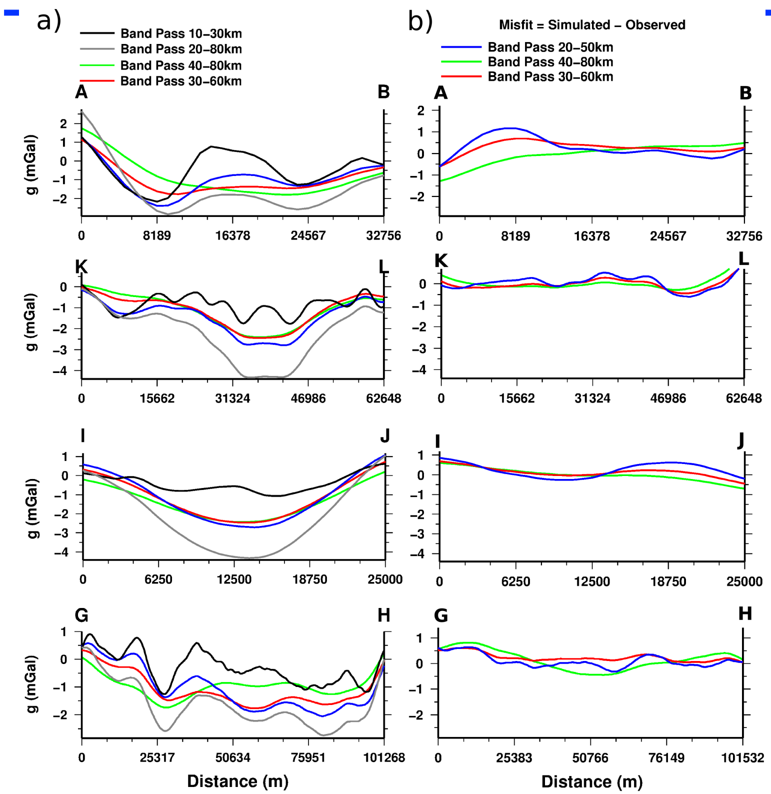
11) Otterbach (reached the Crystalline basement and crossed 809 m of Permian)

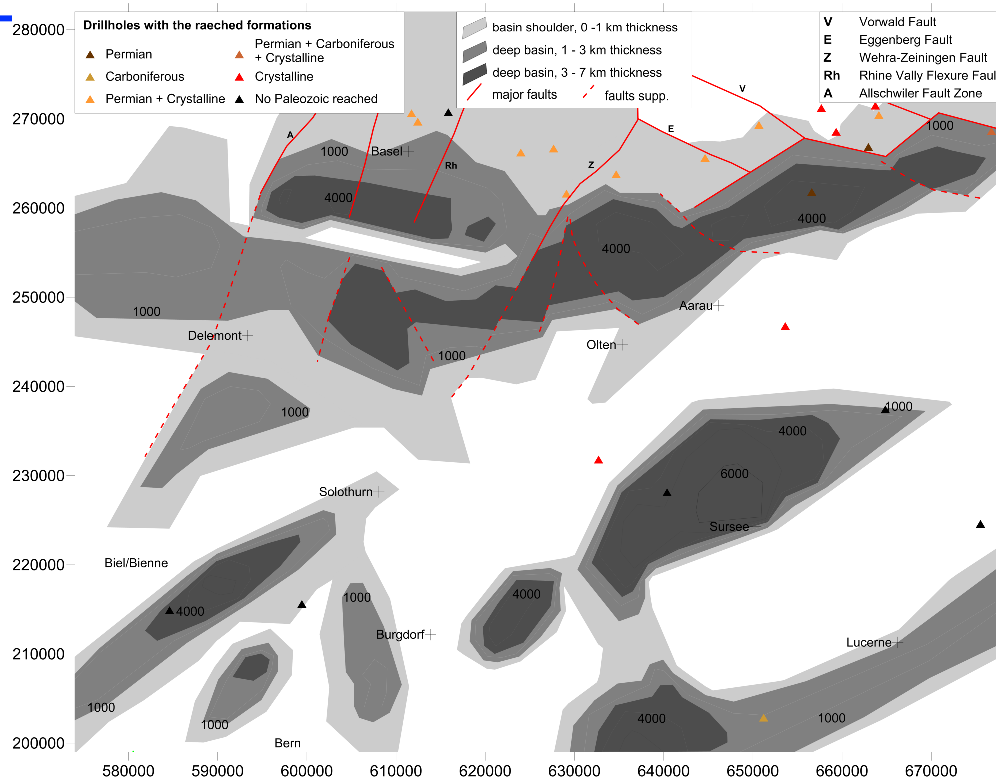
NO PC = POSITIVE GRAVITY ANOMALIES

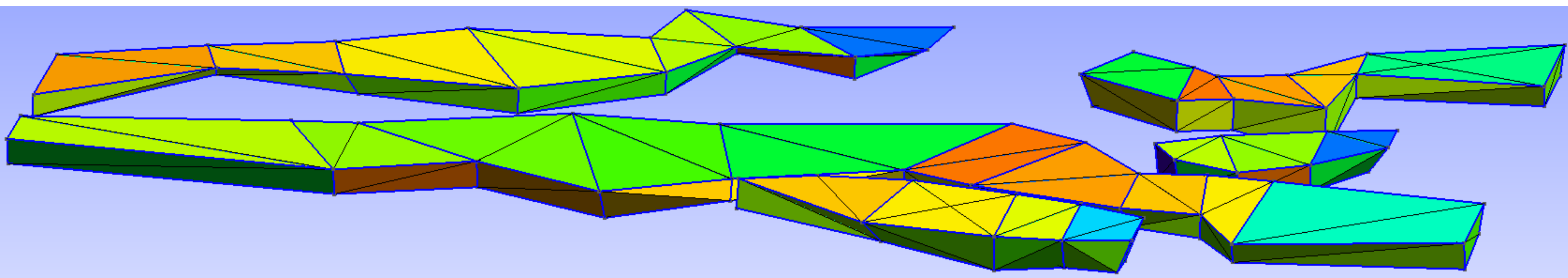
3) Schafisheim1 (reach the Crystalline basement and did not cross the PC formation)

8) Pfaffnau1 (reach the Crystalline basement but did not cross the PC formation)(Allenbach and Wetzel, 2006)

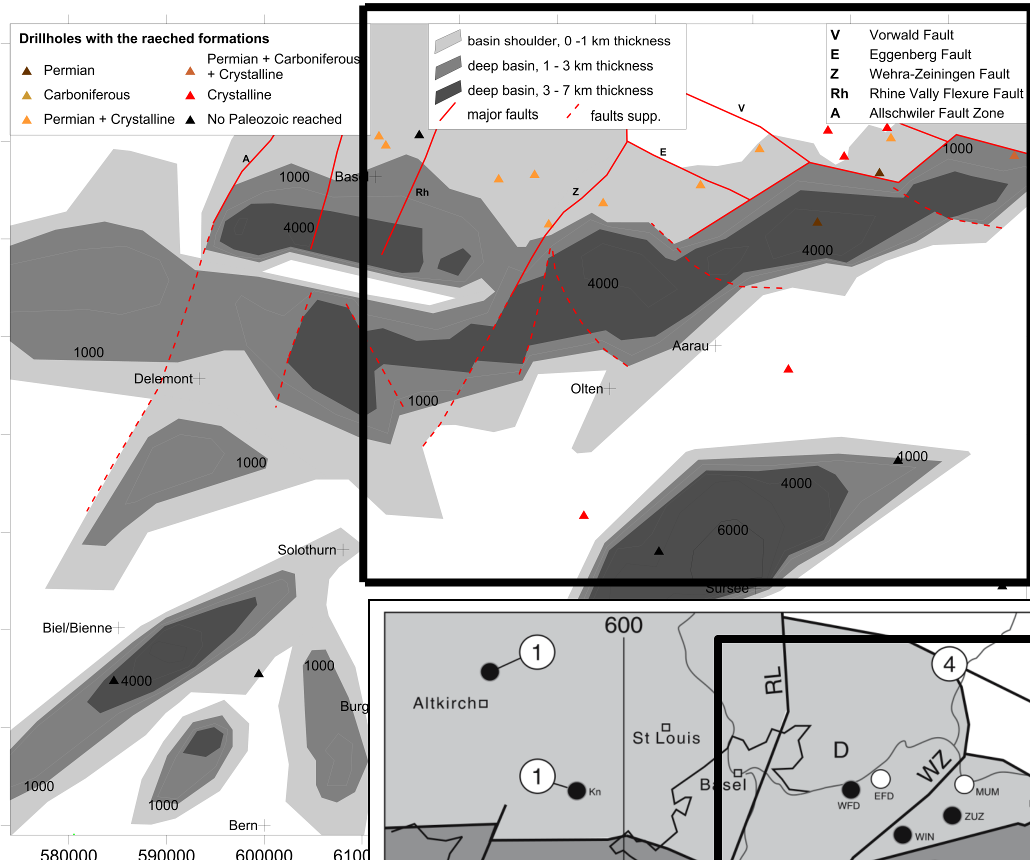
NW CH application – proposed geometries of PCs



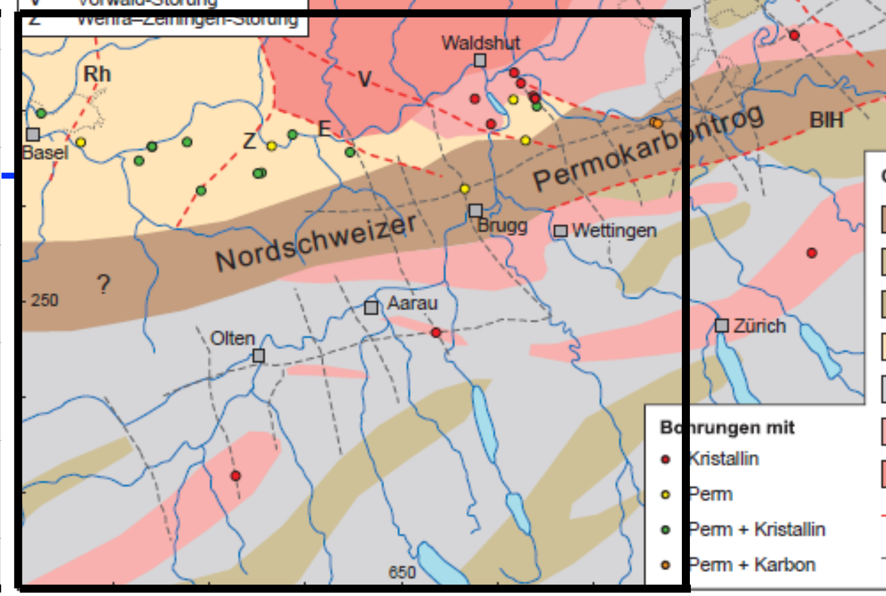




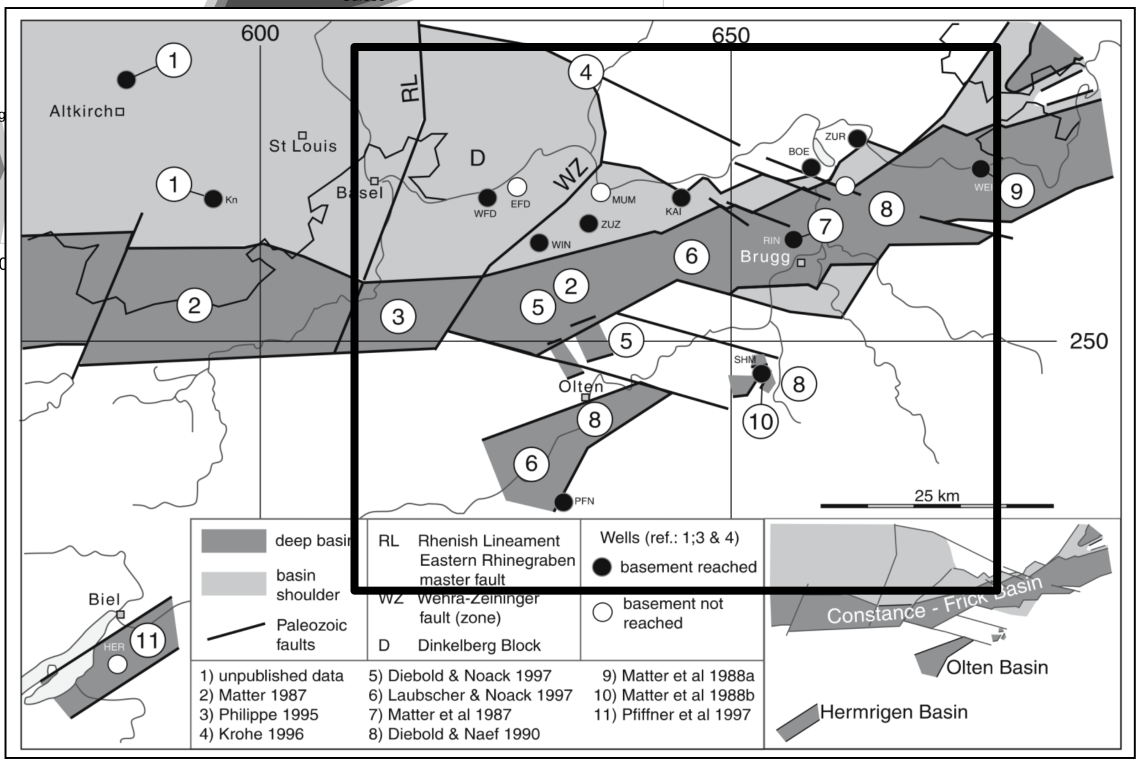
Abdelfettah et al, GJI, 2014



Abdelfettah et al, 2014



NAGRA, 2008



Allenbach et Wetzel, 2006

CONCLUSIONS

3D Geology / 3D gravity FwD modeling :

- 3D geological model derived from 2D/3D seismic can be improved by a gravity
- Using FEM approach to resolve a gravity FwD modeling is an essential tool to modeling the real case study especially where the layer dip is more pronounced (or complex structures)
- Geometry of Permo-Carboniferous graben can be delineated using a gravity FwD modeling and interpretation
- Gravity FwD modeling using FEM can help, to remove the ambiguities meet during the seismic interpretation

Bouguer / Residual anomalies :

- High- Band pass Butterworth filter using different wavelength (i.e. Pseudo-tomography) can bring useful information about the vertical and lateral extension, and the density contrast of the PC graben

Gravity method can help the final interpretation to get more realistic geological model

Thank you for your attention !

UNIVERSITÉ DE STRASBOURG

Questions . . .

Dr. Yassine Abdelfettah

Institut de Physique du Globe de Strasbourg, University of Strasbourg, France
Institute for Nuclear Waste Disposal (INE), KIT, Karlsruhe, Germany

Yassine.abdelfettah@unistra.fr
Yassine.abdelfettah@kit.edu

Ecole et Observatoire des Sciences de la Terre

LABEX G-EAU-THERMIE PROFONDE

Karlsruhe Institute of Technology

More details in :

1) Yassine Abdelfettah, Eva Schill & Pascal Kuhn, 2014. Characterization of geothermally relevant structures at the top of crystalline basement in Switzerland by filters and gravity forward modelling. *Geophysical Journal International*, 199 (1): 226-241, doi: 10.1093/gji/ggu255

2) Abdelfettah Y. & Schill E. Exploration of geothermally relevant structures in the crystalline basement of Switzerland using gravity constrained by seismic data. *Proceed. European Geothermal Congress, EGC 2013, Pisa,* 9 pp, ISBN 978-2-8052-0226-1, 2013.