Swiss
Seismological
Service

ETH Zurich

Seismotektonik und Spannungsfeld der Nordschweiz

N. Deichmann
Schweizerischer Erdbebendienst

Symposium zum Thema
Neotektonik-Erdbeben Nordschweiz

ETH Zürich, 2009/05/05

- Erdbeben in der Nordschweiz
- Herdtiefen-Verteilung
- Beispiele oberflächennaher Beben
- Die induzierten Beben von Basel
- Herdmechanismen
- Spannungsmessungen

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Historische Beben seit 250

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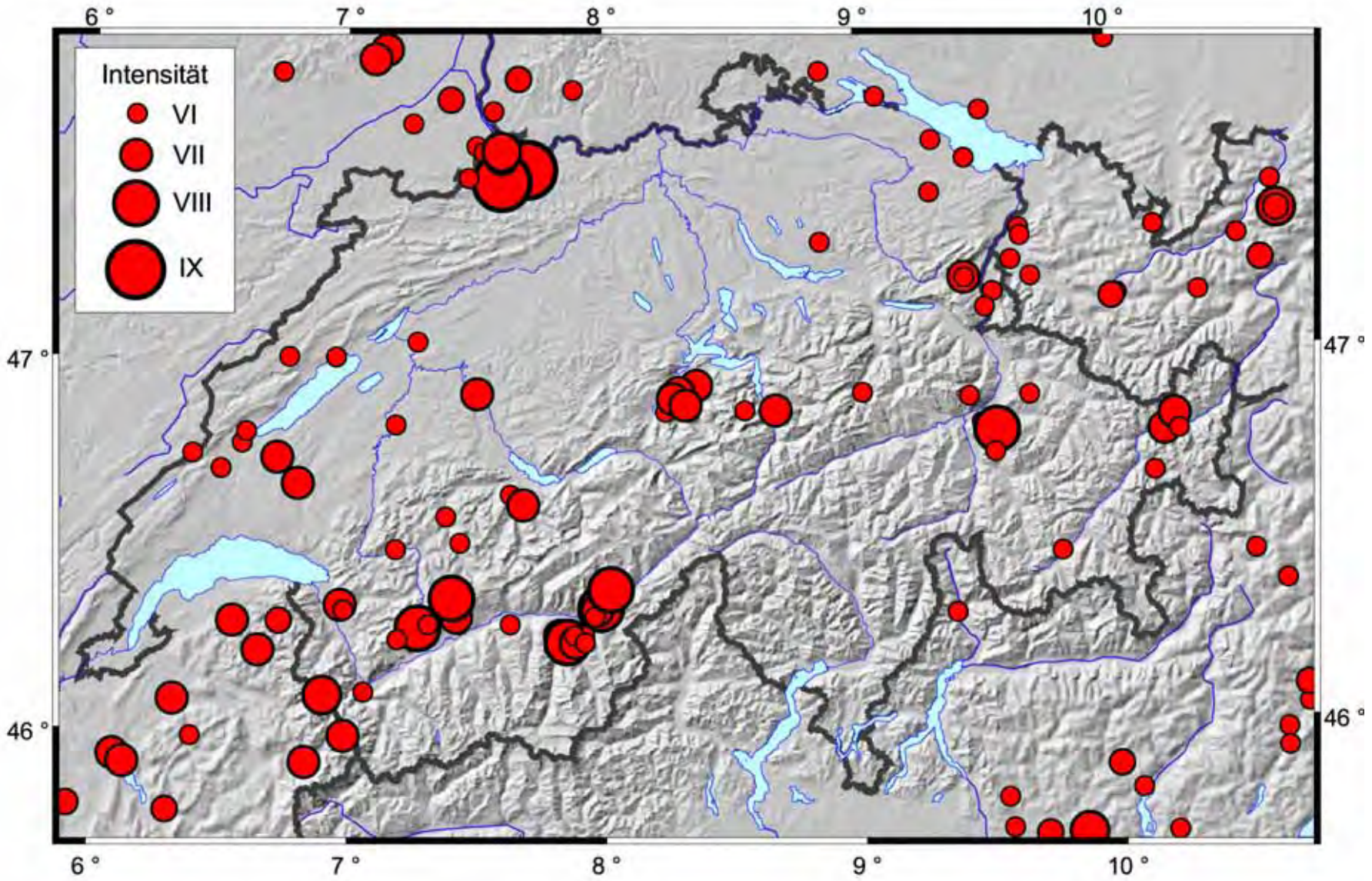

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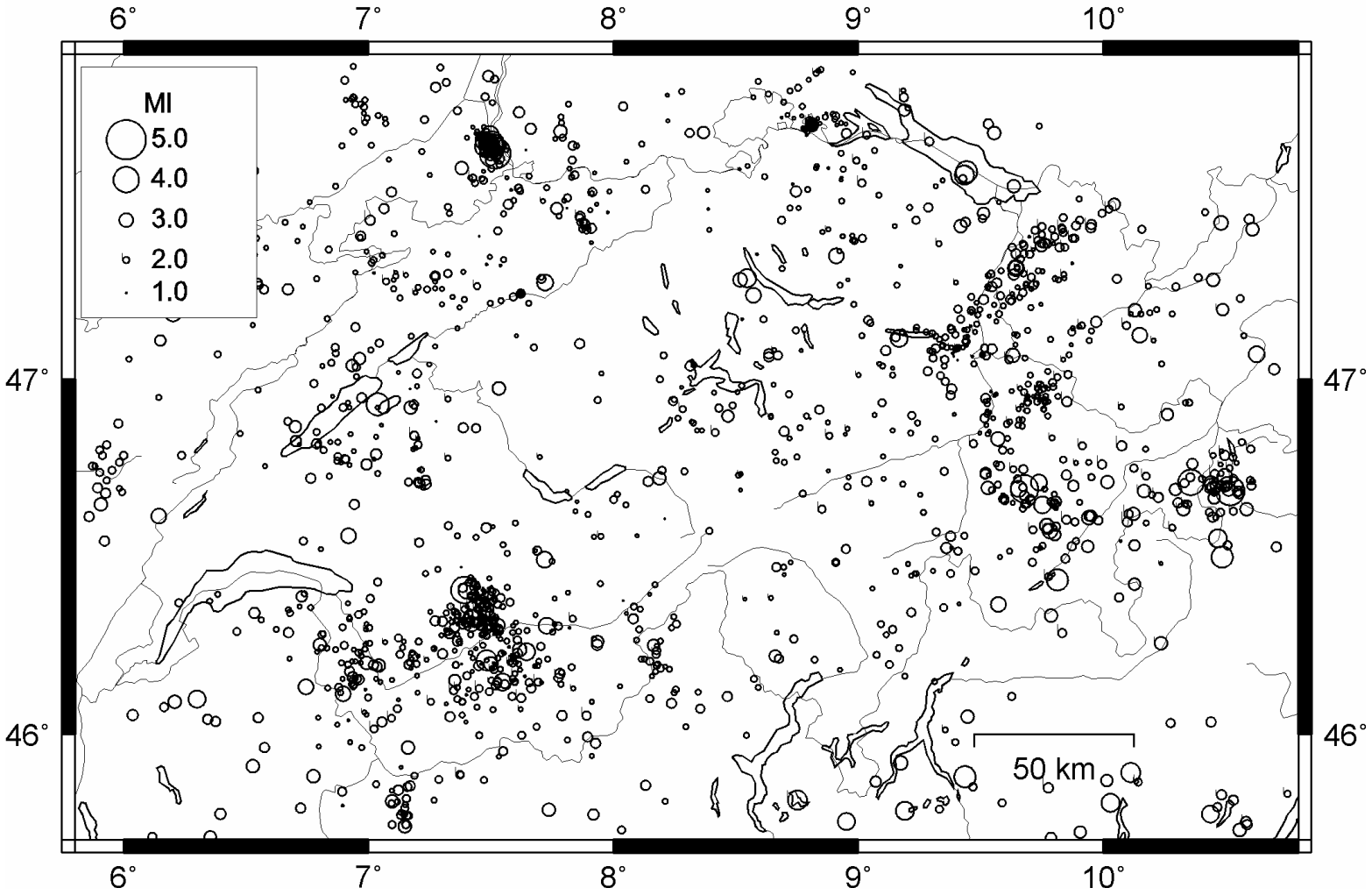
1975–1983



Deichmann, PRP, 2009/04/28

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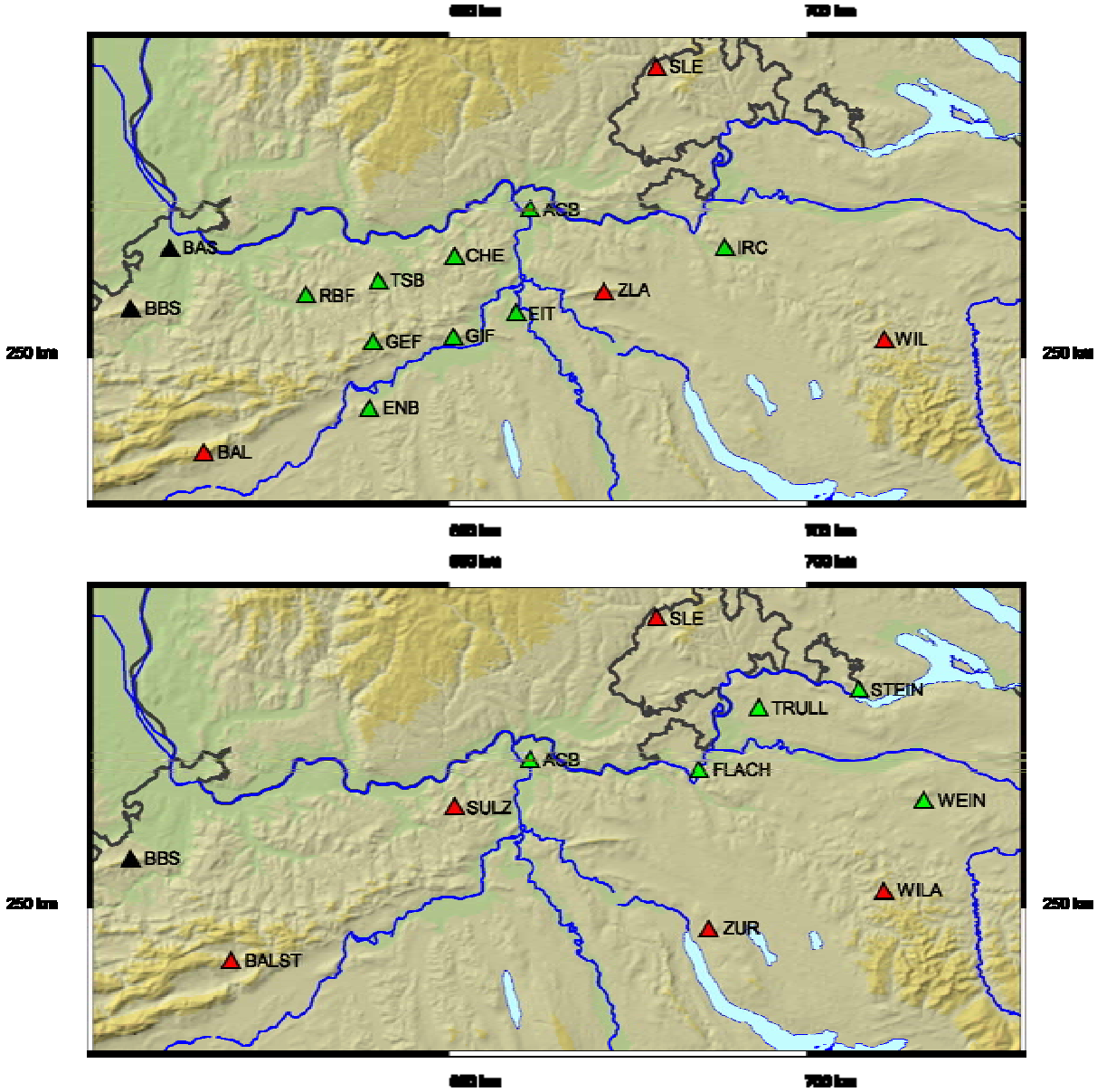

1984 - 1999

2003 - 2009

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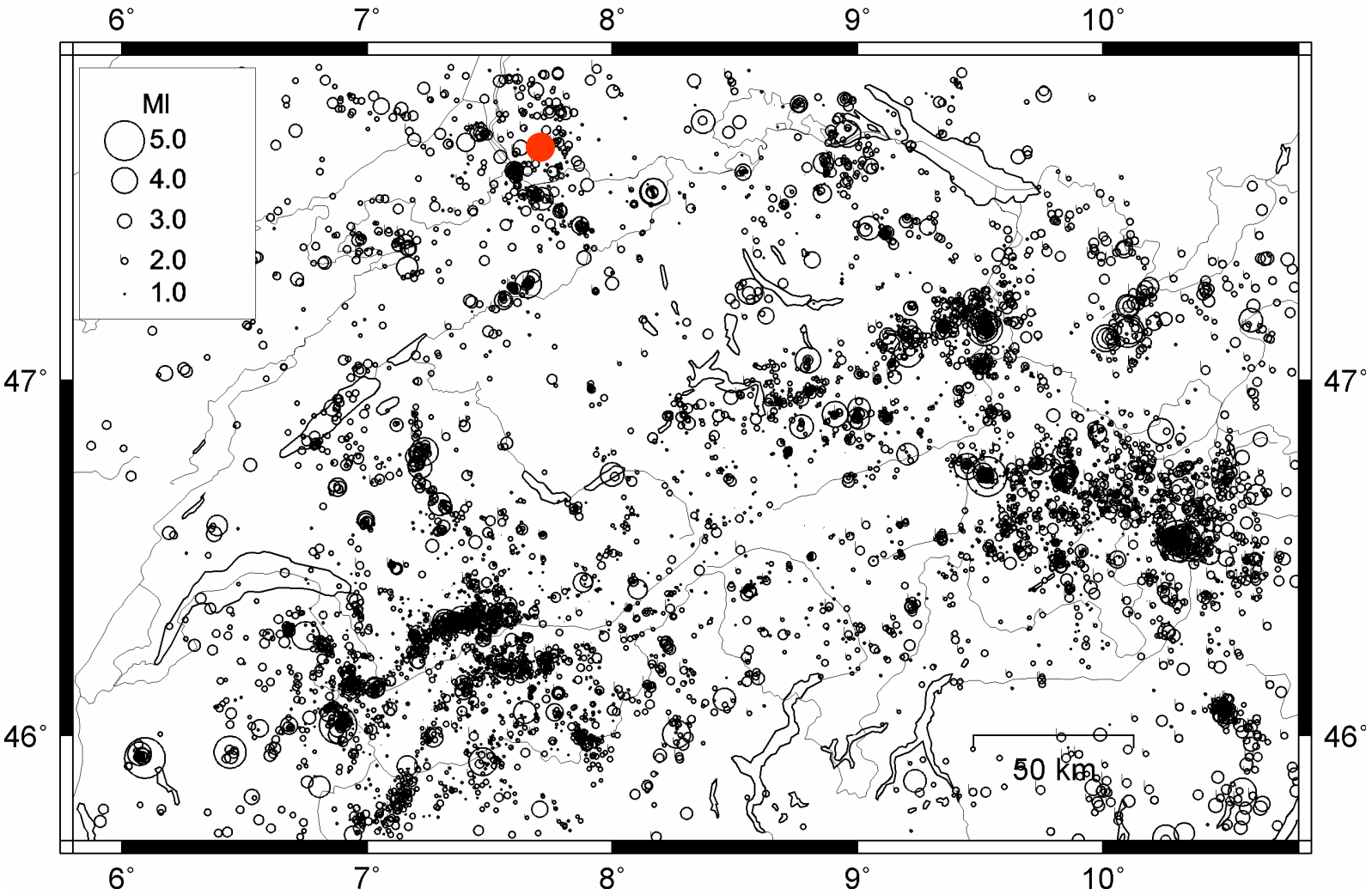
1984–2008



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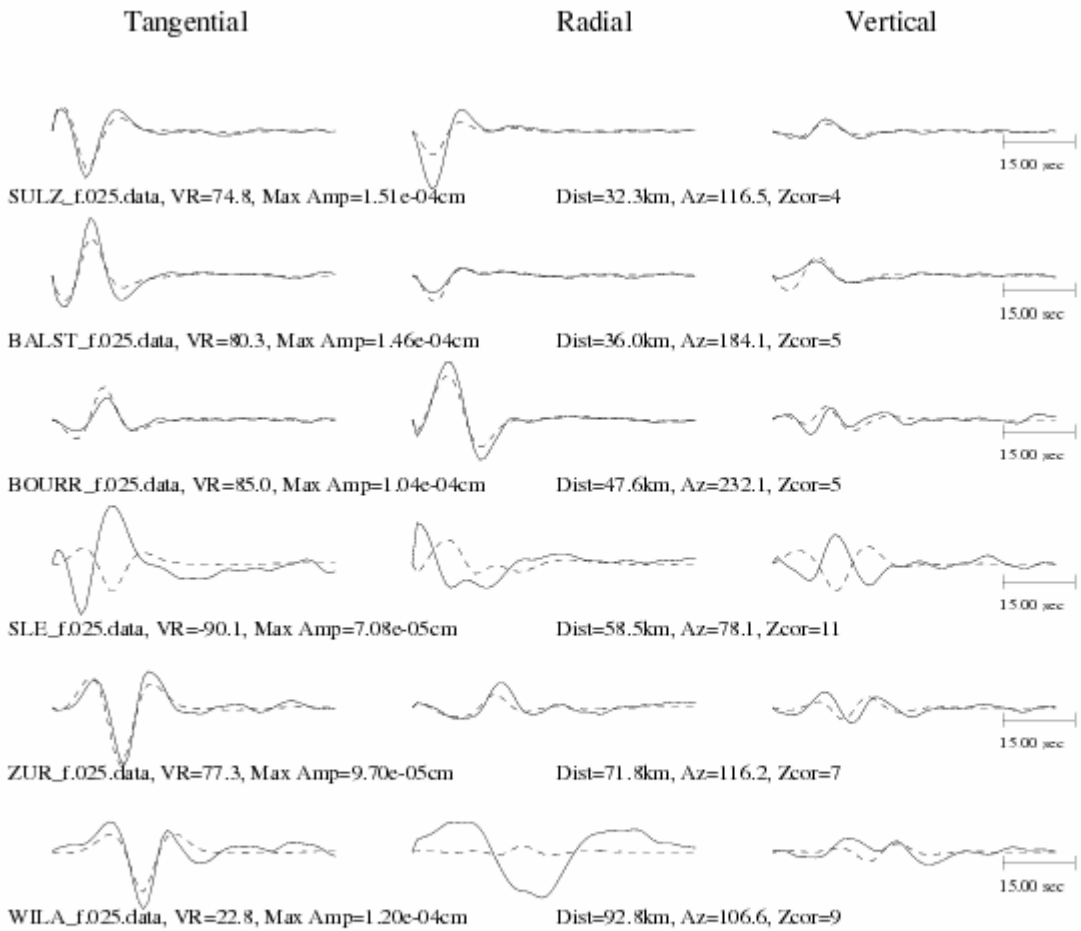
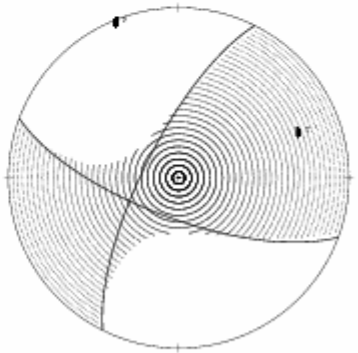
SED/ETHZ Automatic Solution - Network Info: Ml4.3 depth 15km 2009/5/5 1:39:25UTC



INVERSION SOLUTION

Depth =14 km
Strike=207 ; 110
Rake =20 ; 162
Dip =73 ; 71
Mo =2.73e+21 dyn-cm
Mw =3.6
Percent DC=76
Percent CLVD=24
Percent ISO=0
Variance=3.68e-10
Var. Red=3.61e+01
RES/Pdc.=4.86e-12



J. Clinton 2009/05/05

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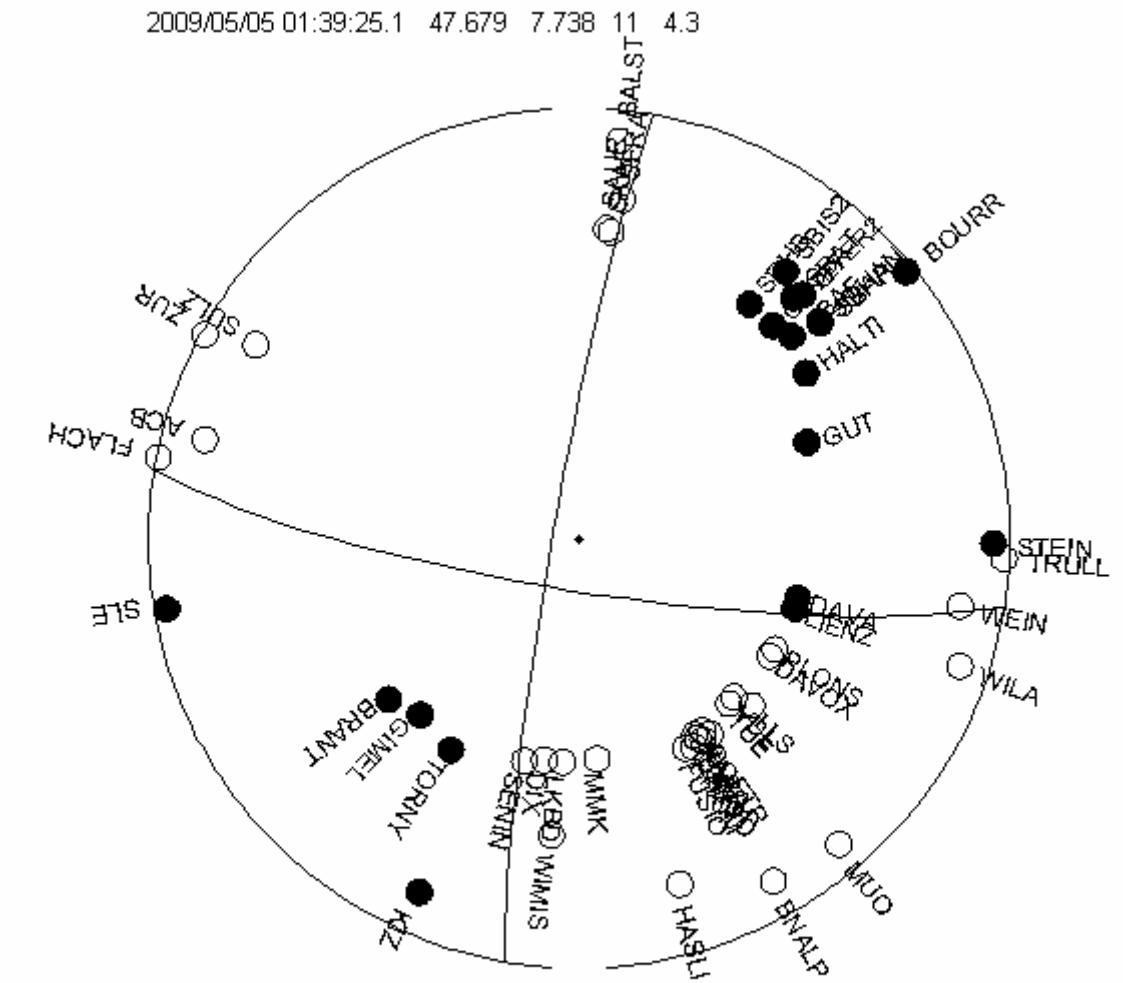

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Focal depths

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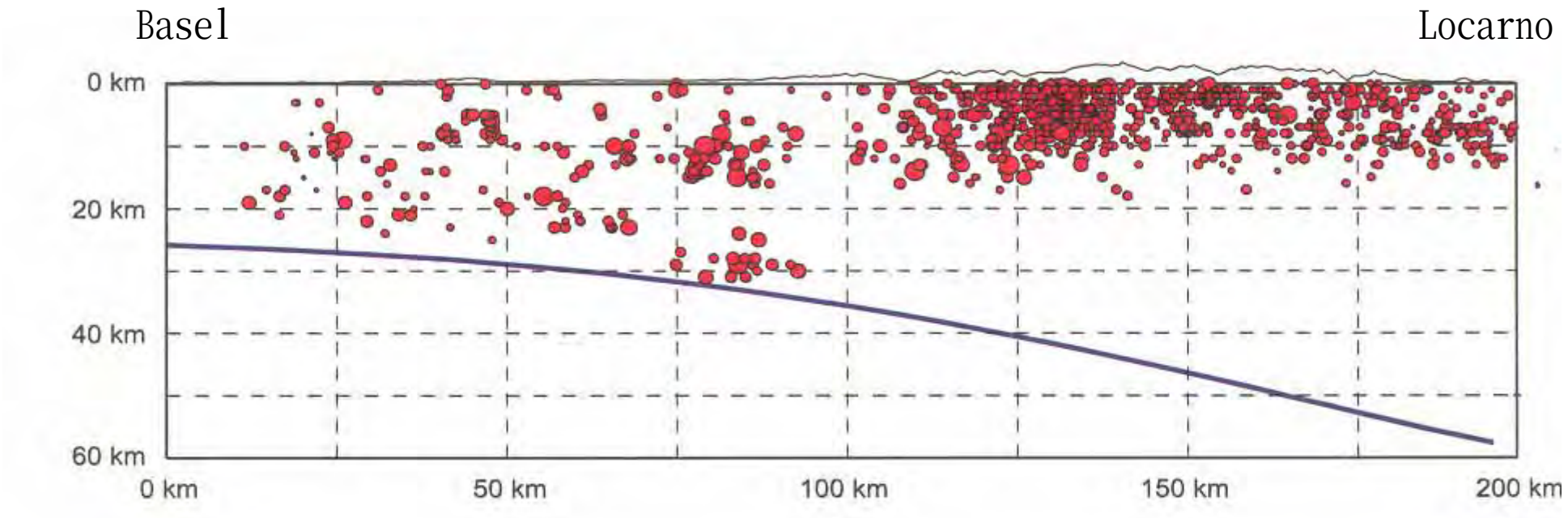

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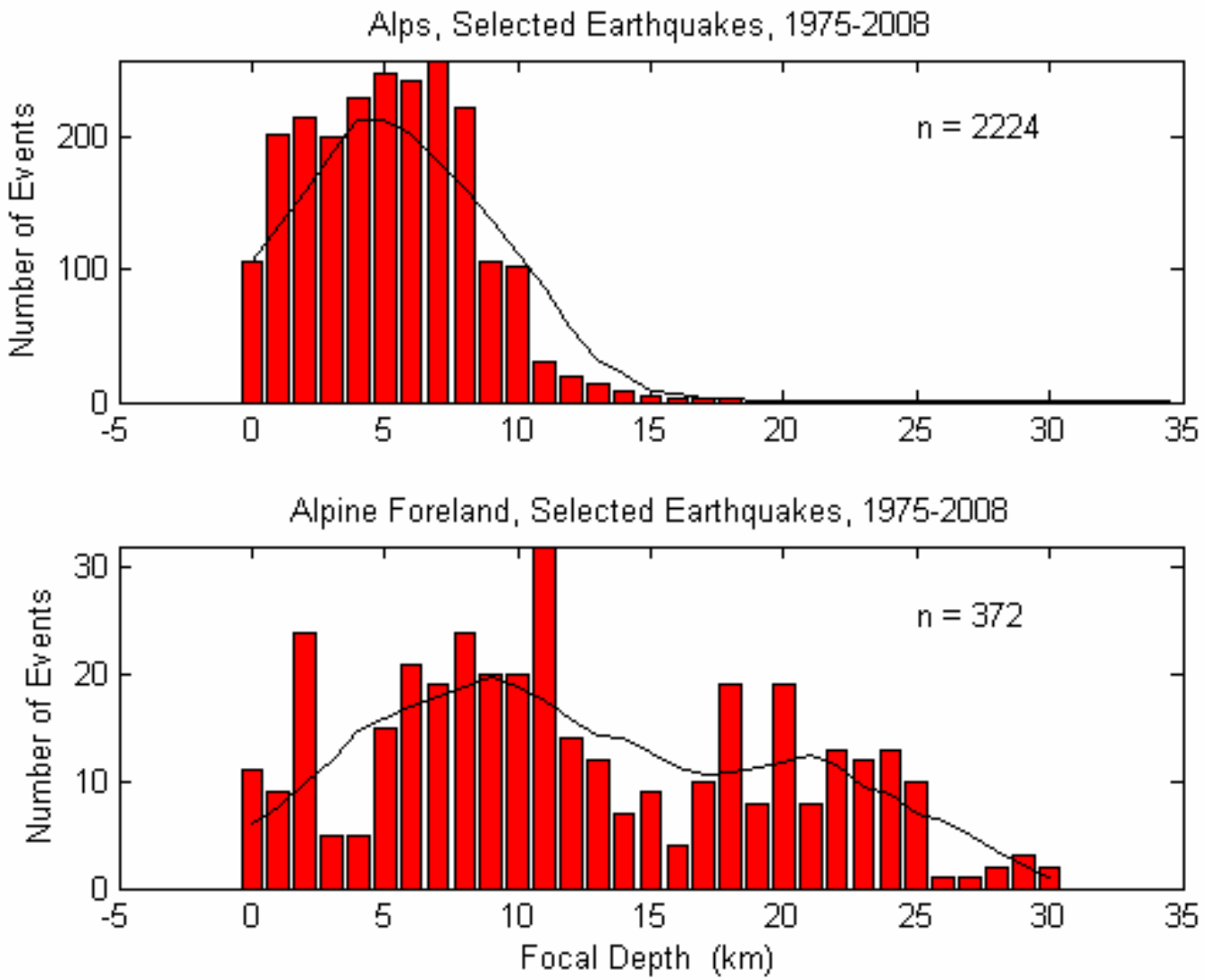

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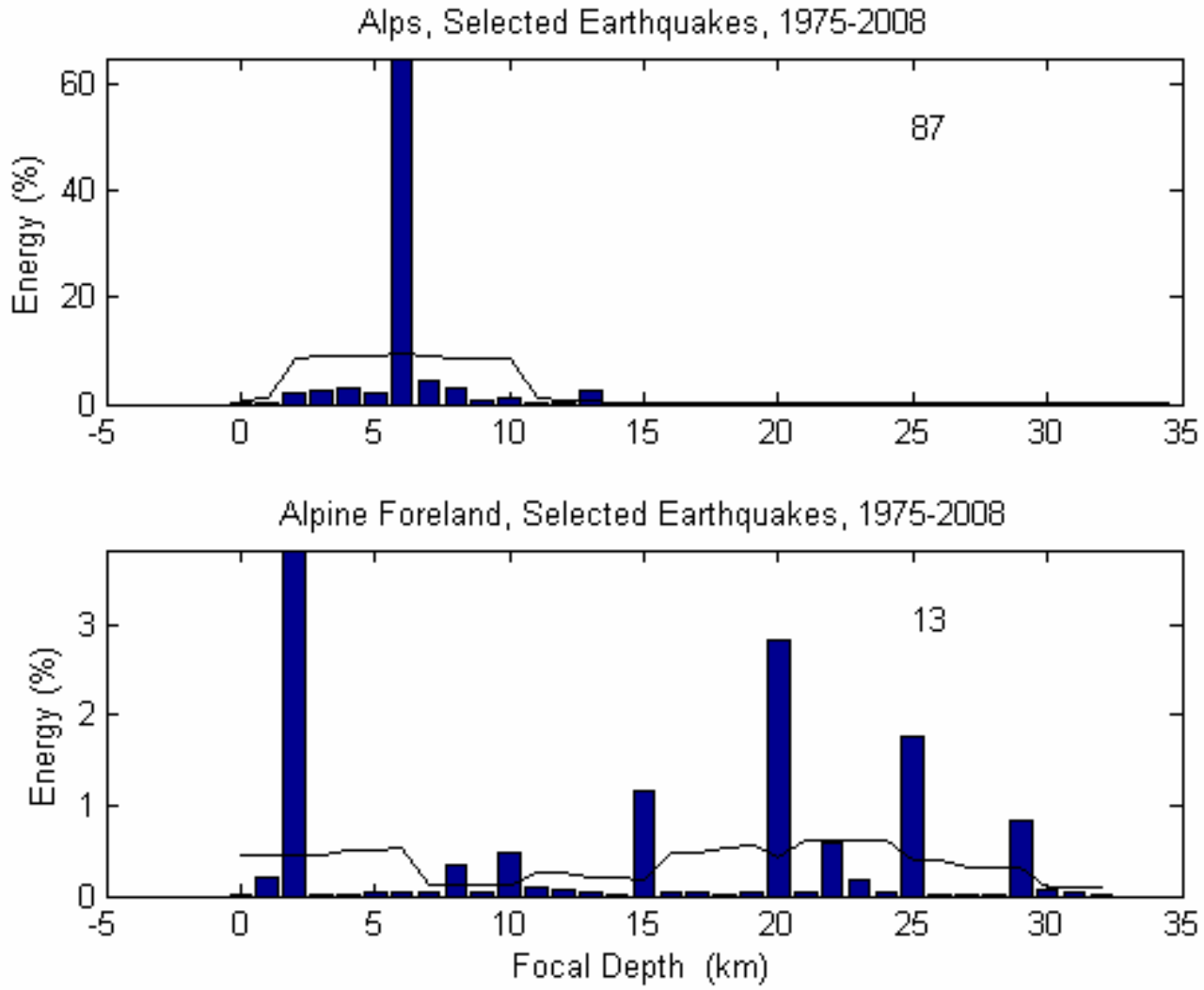

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Das Magnitude 5.3 Erdbeben von Annecy, 1996

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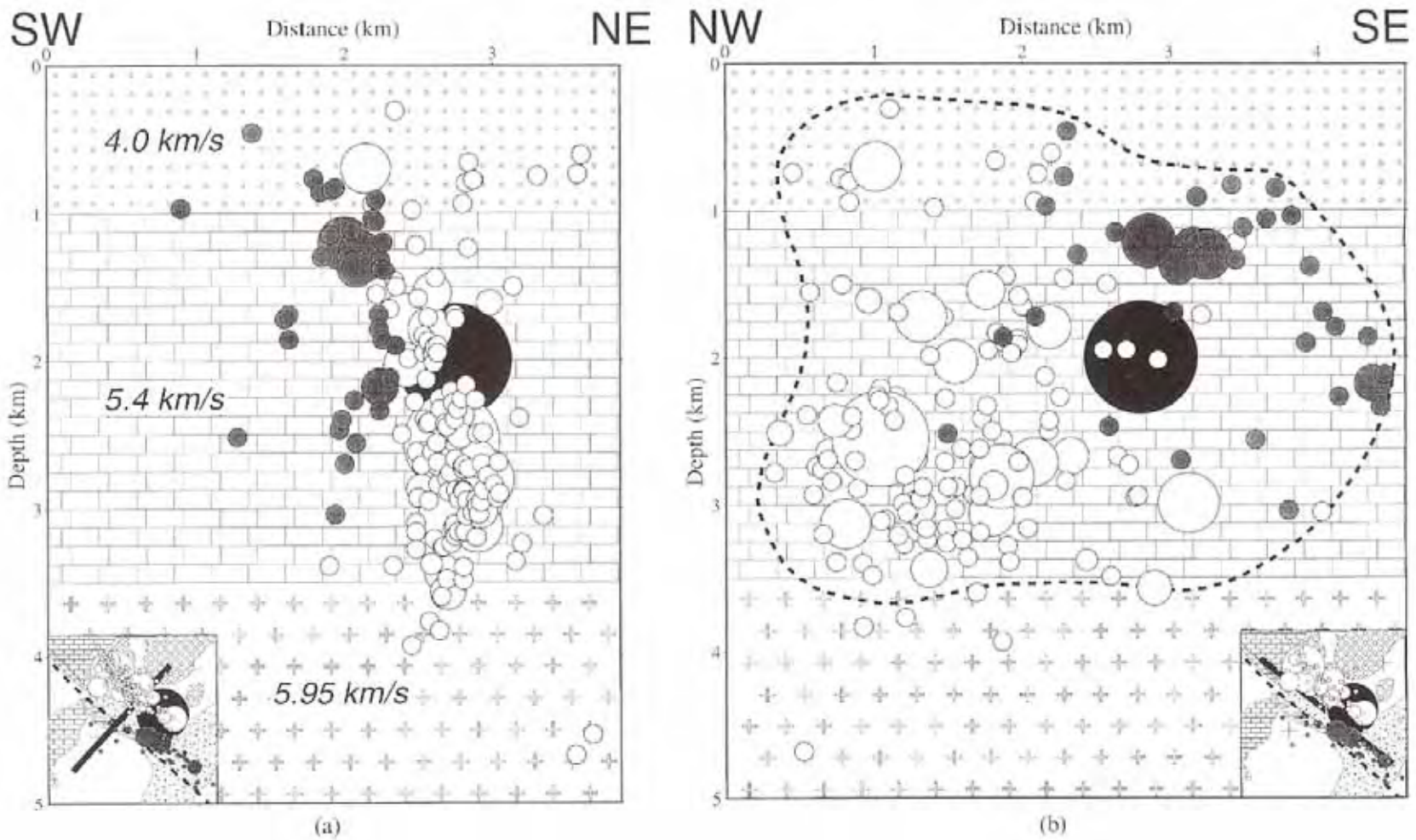

Thouvenot et al., GJI (1998)

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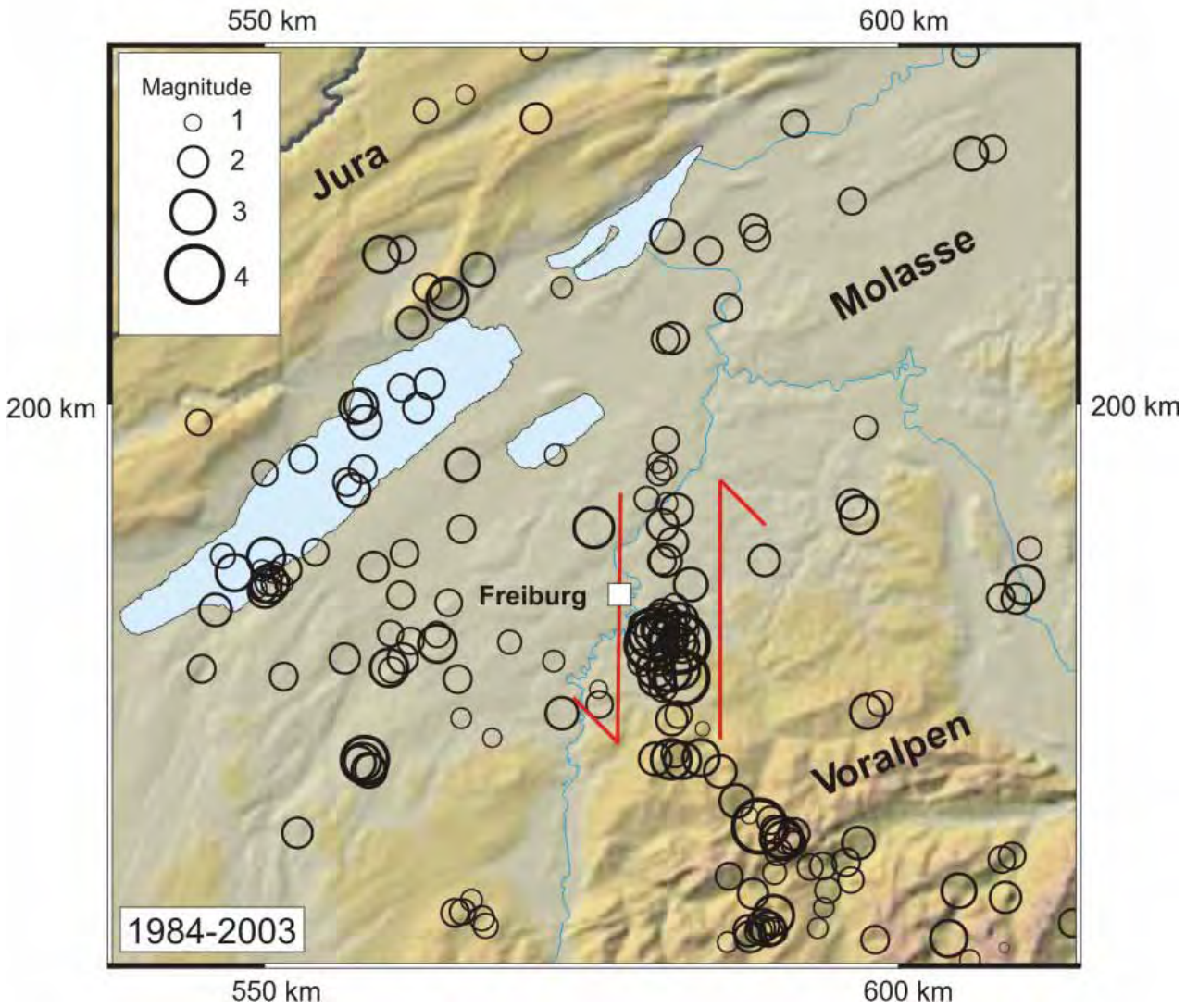
ETH Zurich



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Erdbeben von Fribourg

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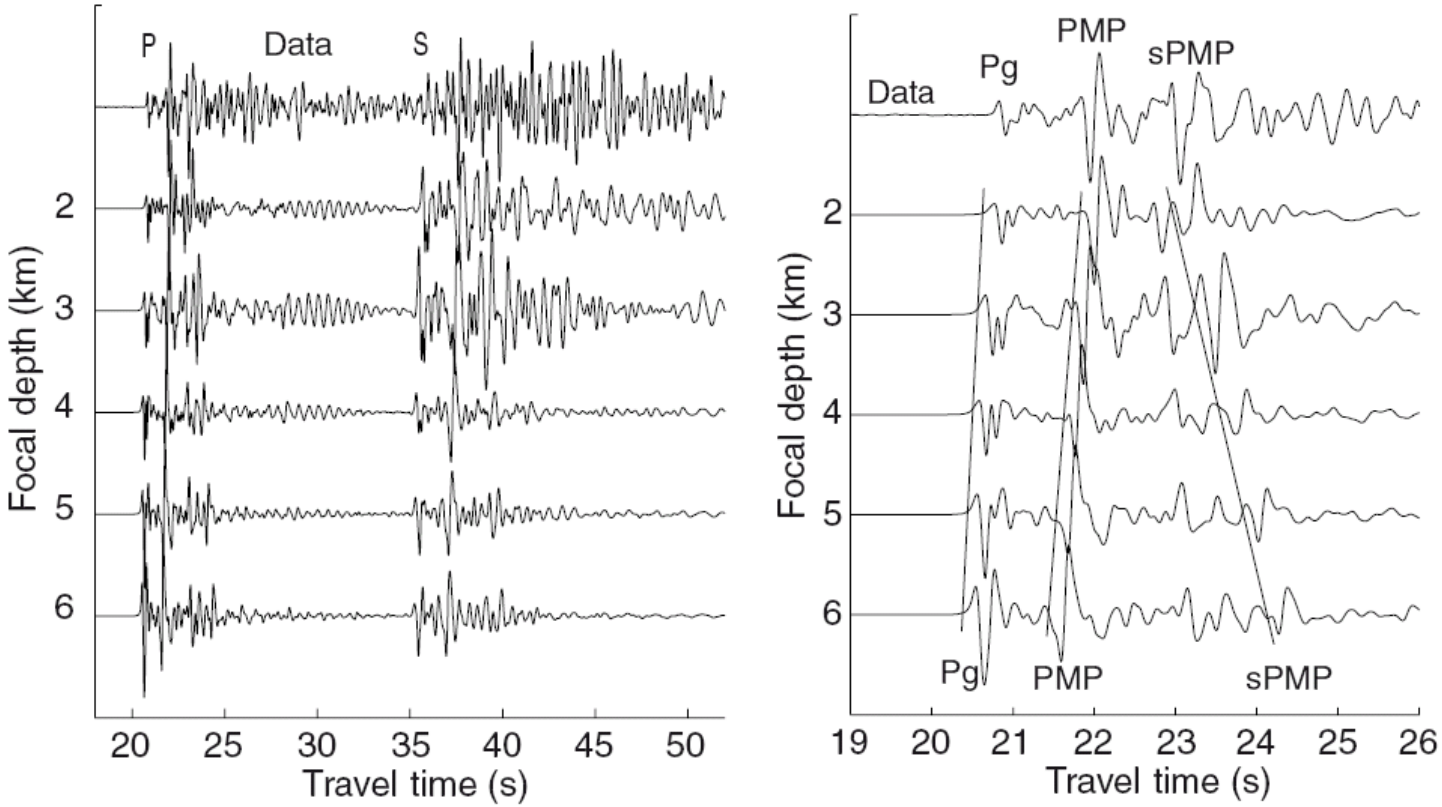
1987, 1995 und 1999 wurden SE von Fribourg drei Serien von total 30 Beben registriert. Die jeweils stärksten erreichten Magnituden von 3.9, 3.7 und 4.3.



Wellenform-Modellierungen zeigen, dass die Herdtiefe nur rund 2 km beträgt. Sie sind Ausdruck einer aktiven NS streichenden Verwerfung in den oberflächennahen Sedimentschichten

(Kastrup et al. GJI, 2007)

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Regen-induzierte Beben, August 2008

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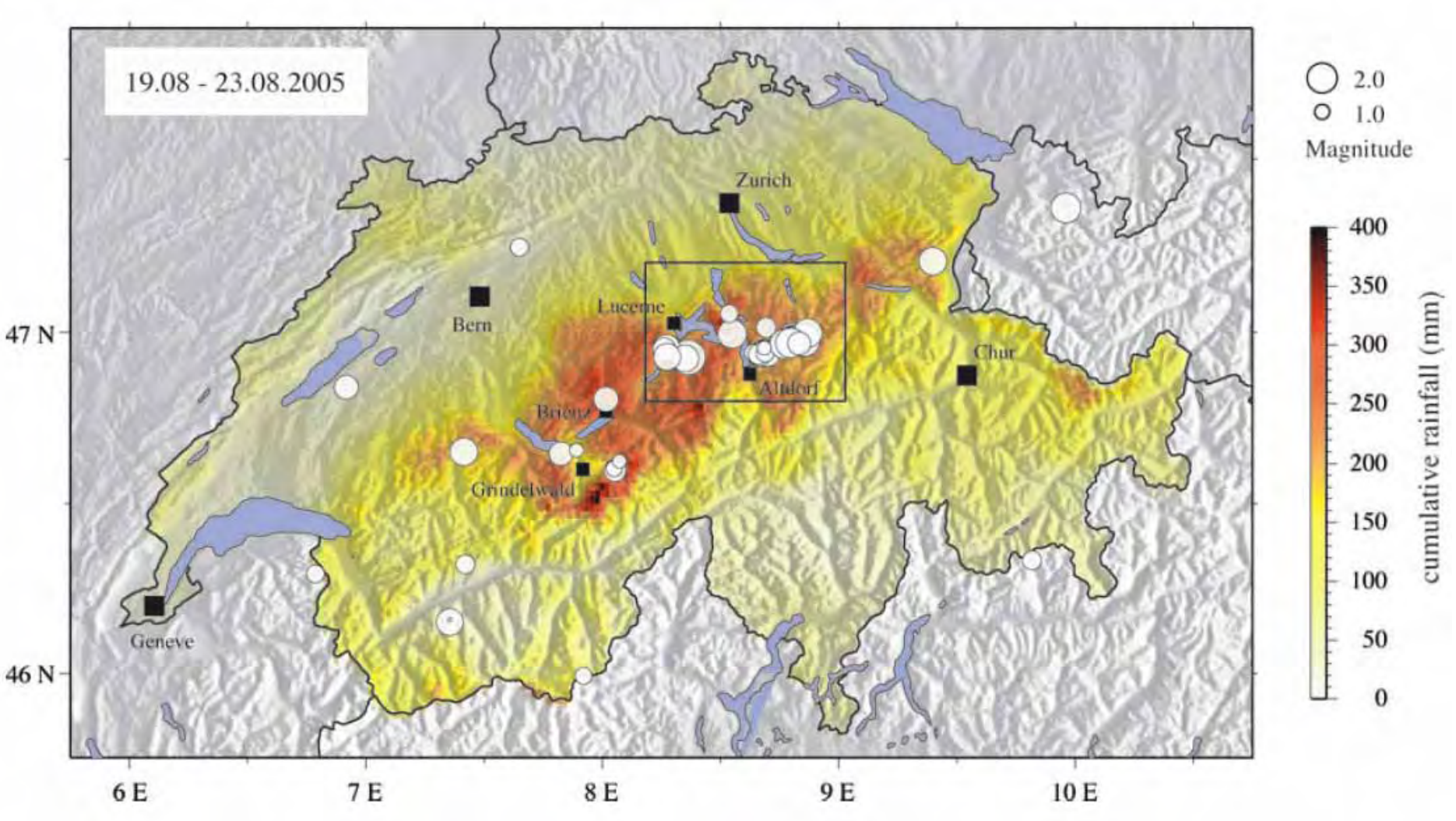

Husen et al. (2007)

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Regen-induzierte Seismizität, Hochstaufen

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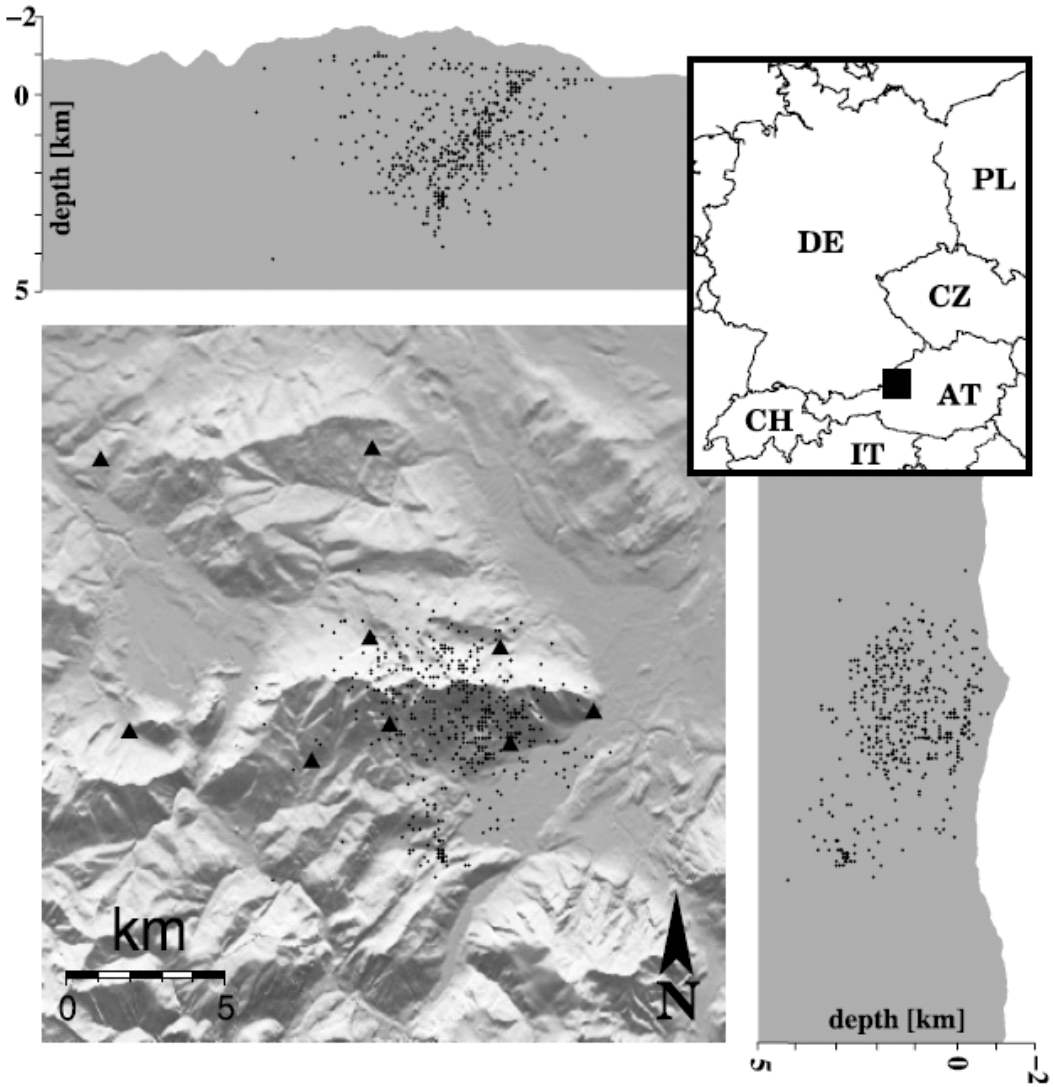

Hainzl et al., GRL (2006)
Kraft et al., GJI (2006)

1996/07/15 2 5.1 (F) Annecy

1997/11/22 1 3.8 (SG) Walensee

1999/02/14 2 4.3 (FR) Fribourg

1999/09/12 2 3.2 (ZH) Eglisau

2000/04/06 1 3.2 (JU) Saint Ursanne

2003/02/03 2 2.9 (NE) Neuchatel

2006/03/29 2 3.2 (NE) Cortaillod

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Basel Deep Heat Mining

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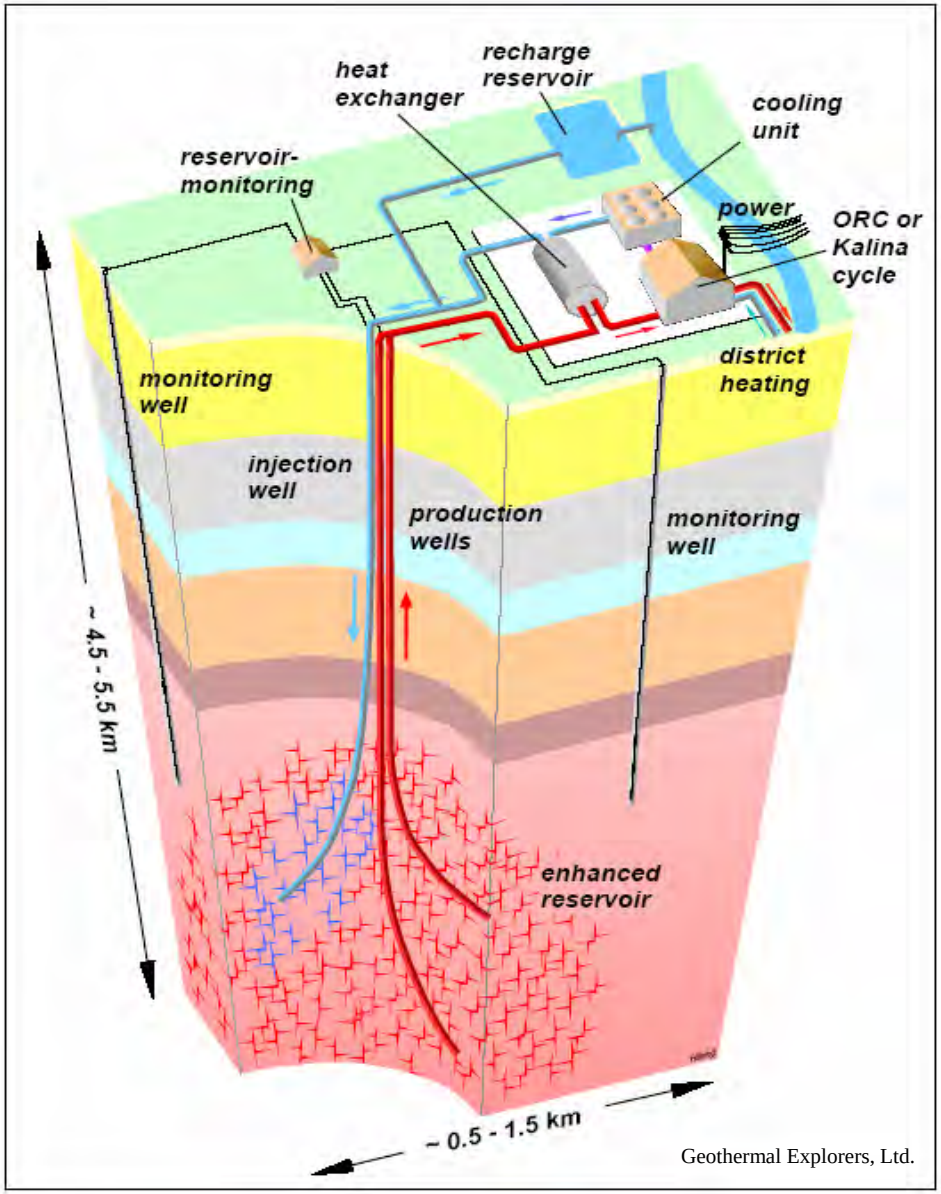

The project:
Geothermal heat and power for 5000 households:
3 MW electric and 20 MW thermal

The stakeholders:
Geopower Basel AG – a public/private enterprise

The contractors/developers:
Geothermal Explorers Ltd.

The permitting authority:
The Building Dept. of Canton Basel-Stadt

The role of the Swiss Seismological Service:
- Seismological consultants
- Monitor the potentially felt events
- Determine the "official" magnitude of the events
- Communicate PGA, PGV and magnitudes to the contractors as input to their "traffic light system"
- Inform the public in real-time (dedicated web-site www.seismo.ethz.ch/basel)

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Conceptual model of the induced events

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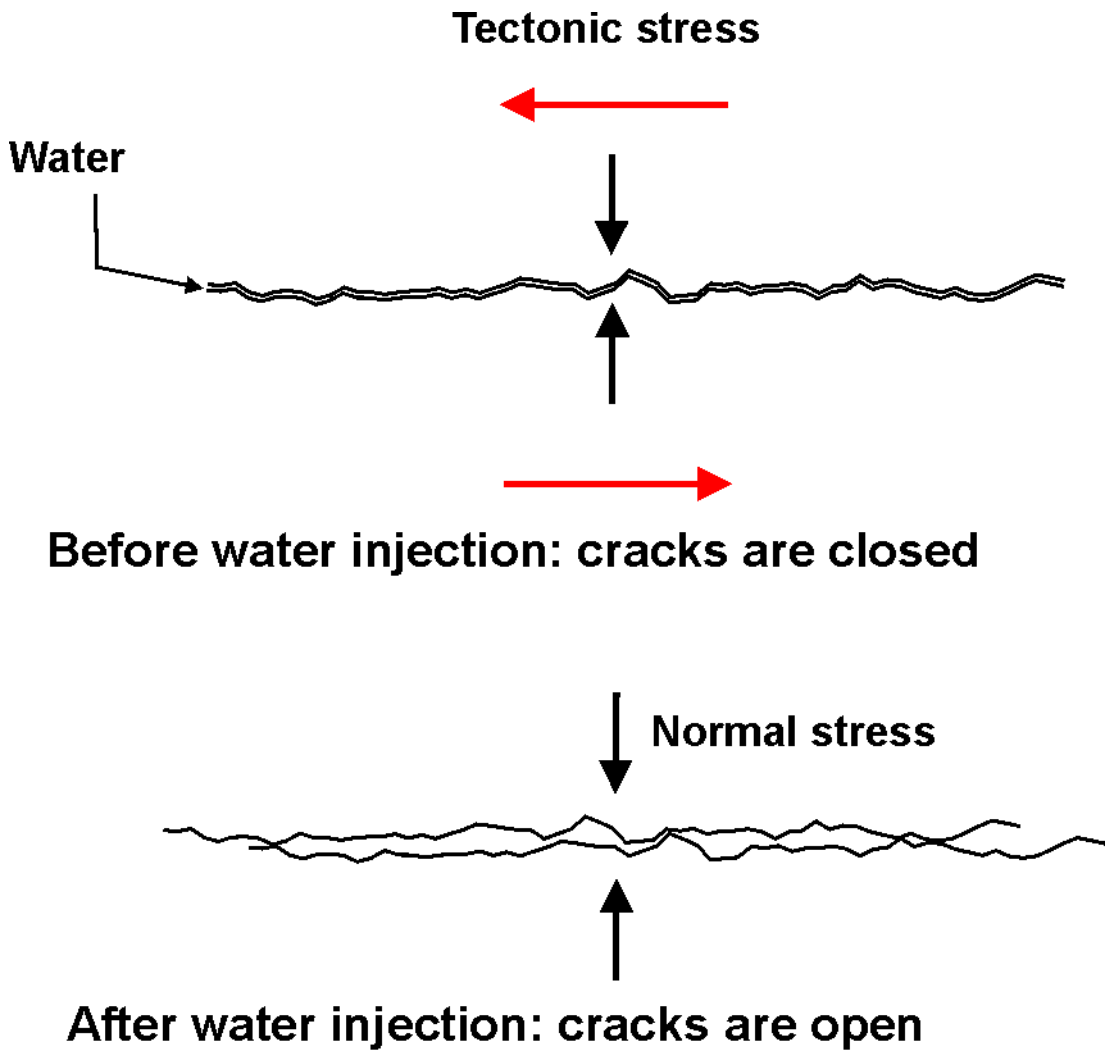

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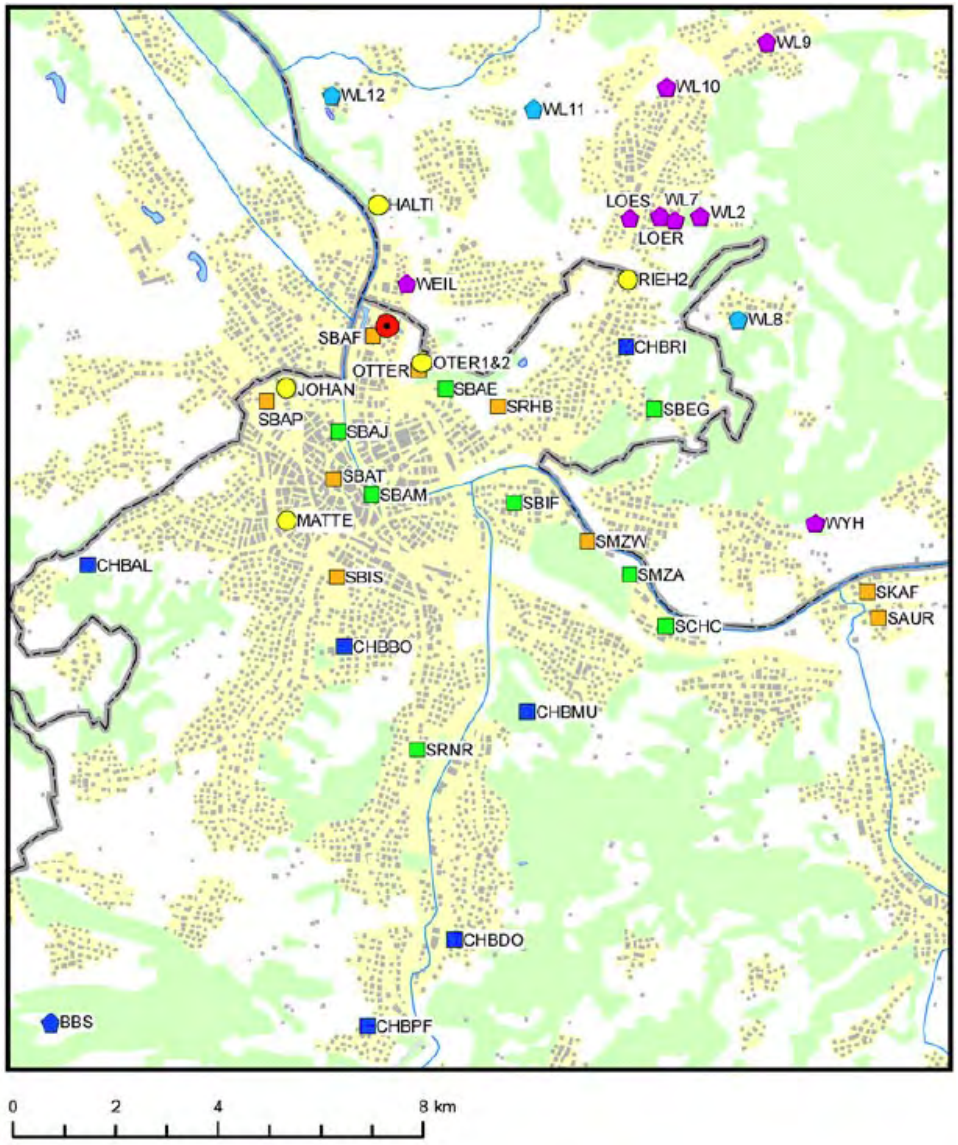
Seismic monitoring instruments in Basel

ETH Zurich



Legend

- Borehole
- Borehole sensors Geothermal Explorers
- Online accelerometers SED
- Offline temporary accelerometers SED
- Offline permanent accelerometers SED
- High-gain seismometer-network LED
- High-gain temporary seismometers LED
- Accelerometers LED

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Reservoir stimulation phase

Swiss Seismological Service

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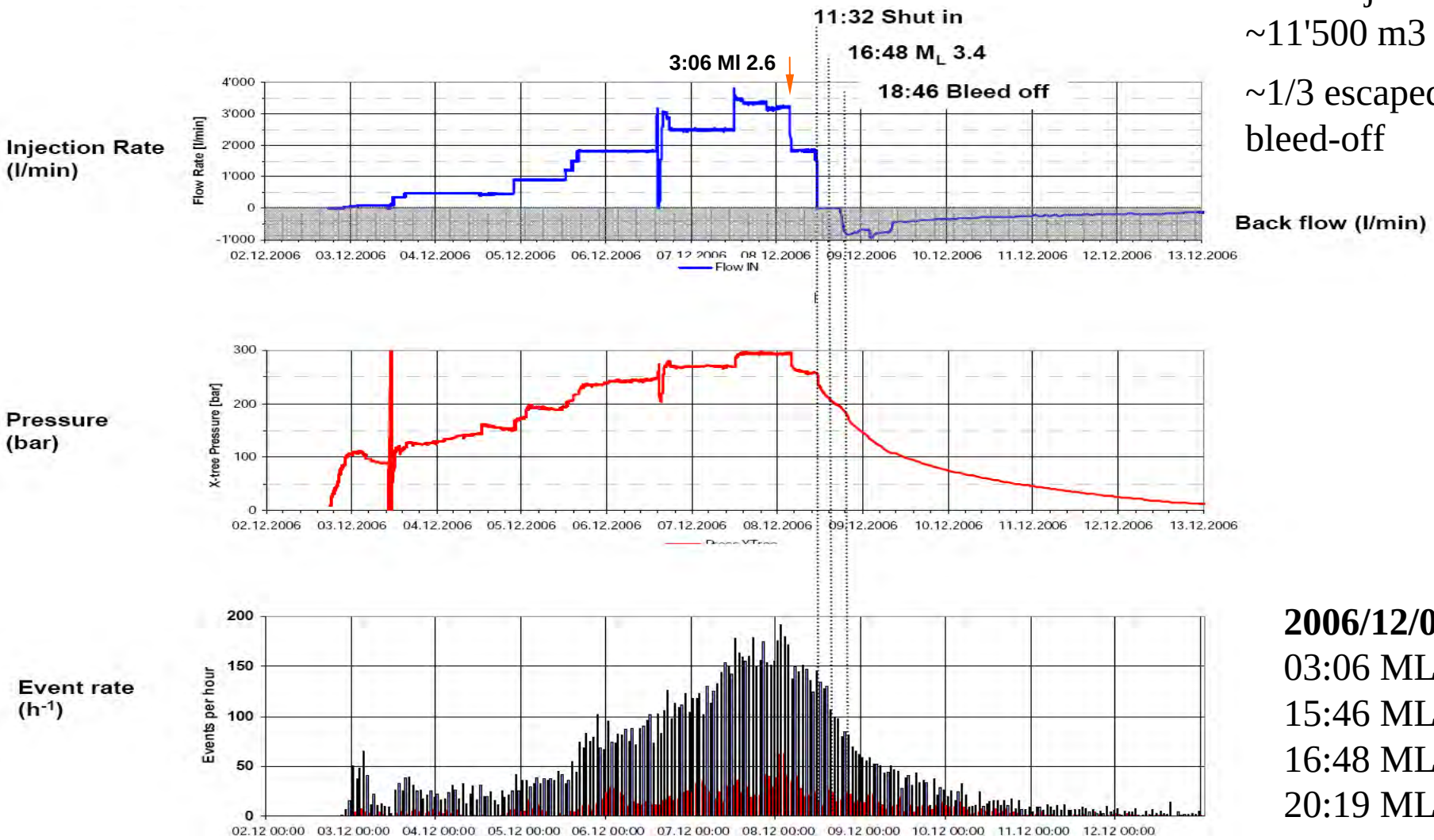
Total injected volume: ~11'500 m3

~1/3 escaped after bleed-off



2006/12/08

03:06 ML 2.6

15:46 ML 2.7

16:48 ML 3.4

20:19 ML 2.5

Häring et al. (2008)

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Hypocenters of events during stimulation

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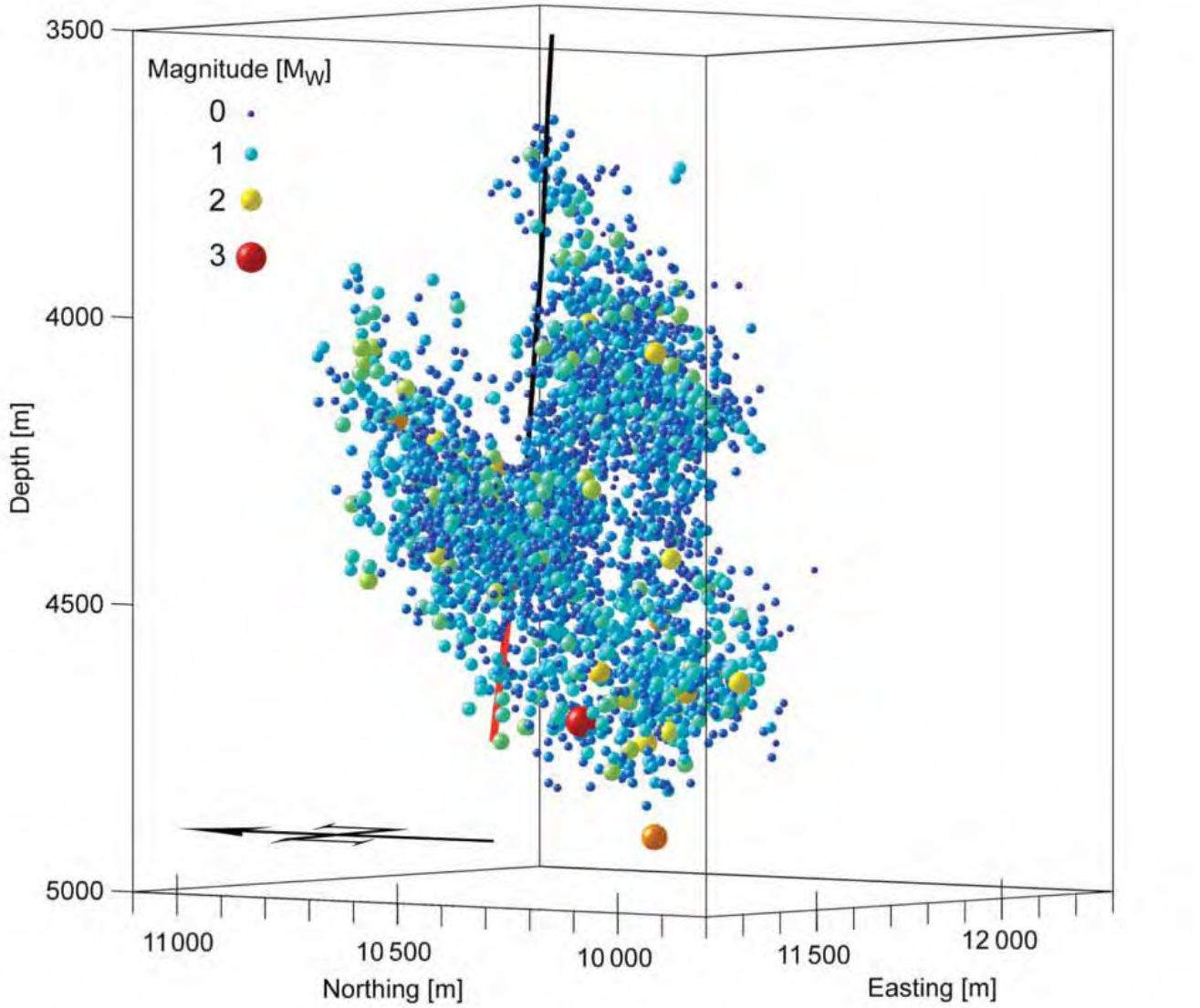

Dyer et al. (2008)

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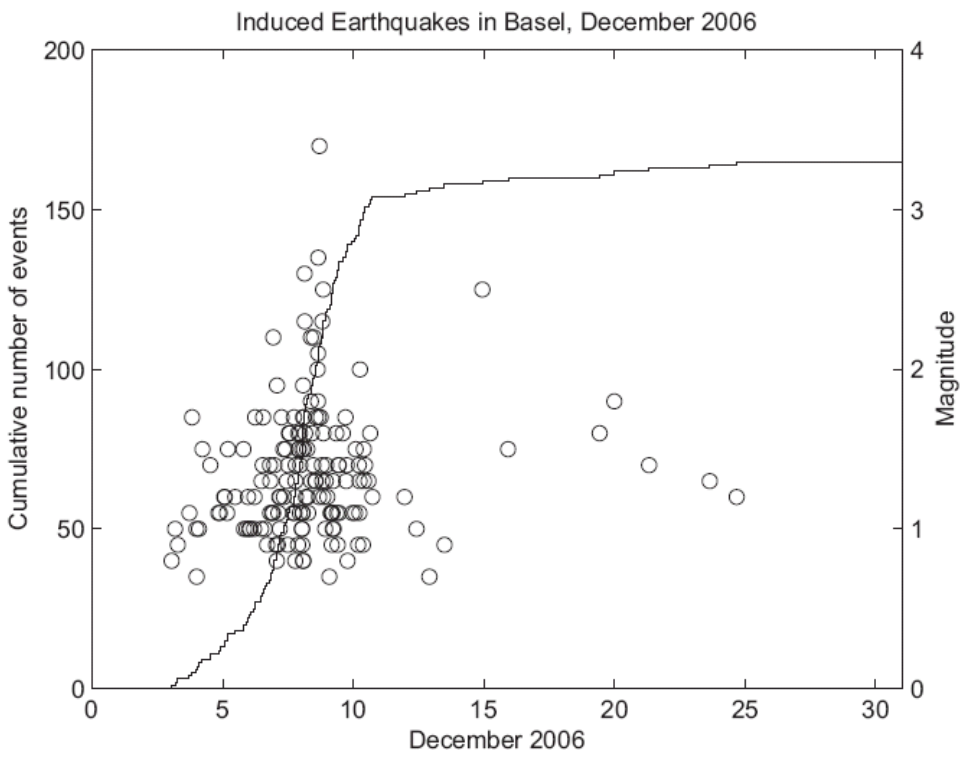
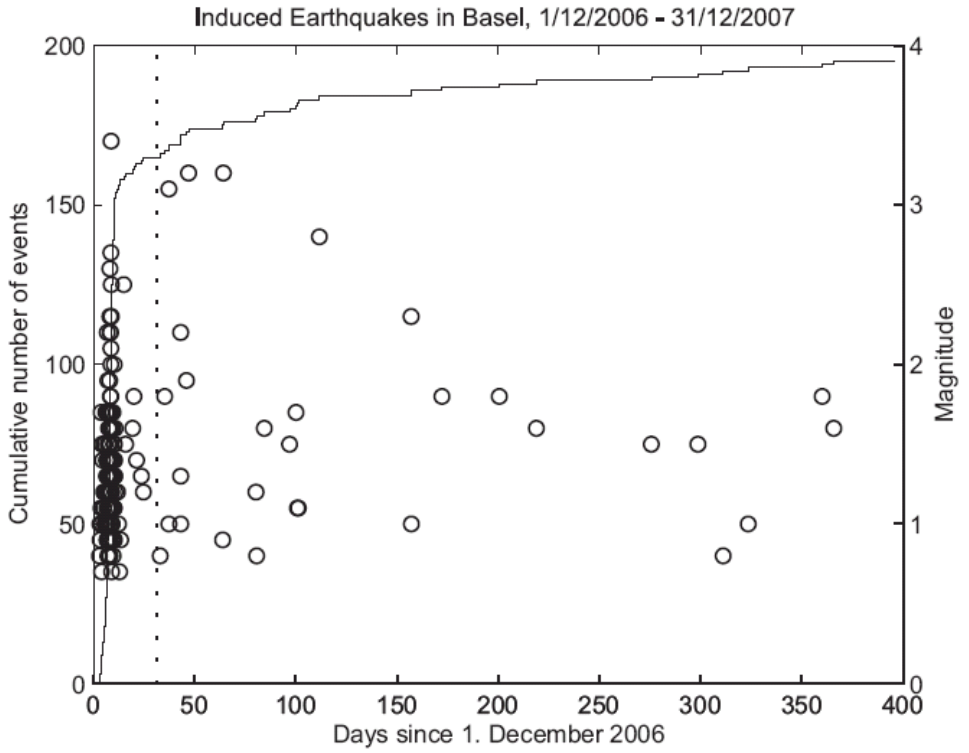
Basel induced seismicity recorded by SED

ETH Zurich





Temporal evolution of cumulative number of events and magnitude

Deichmann & Giardini (subm.)

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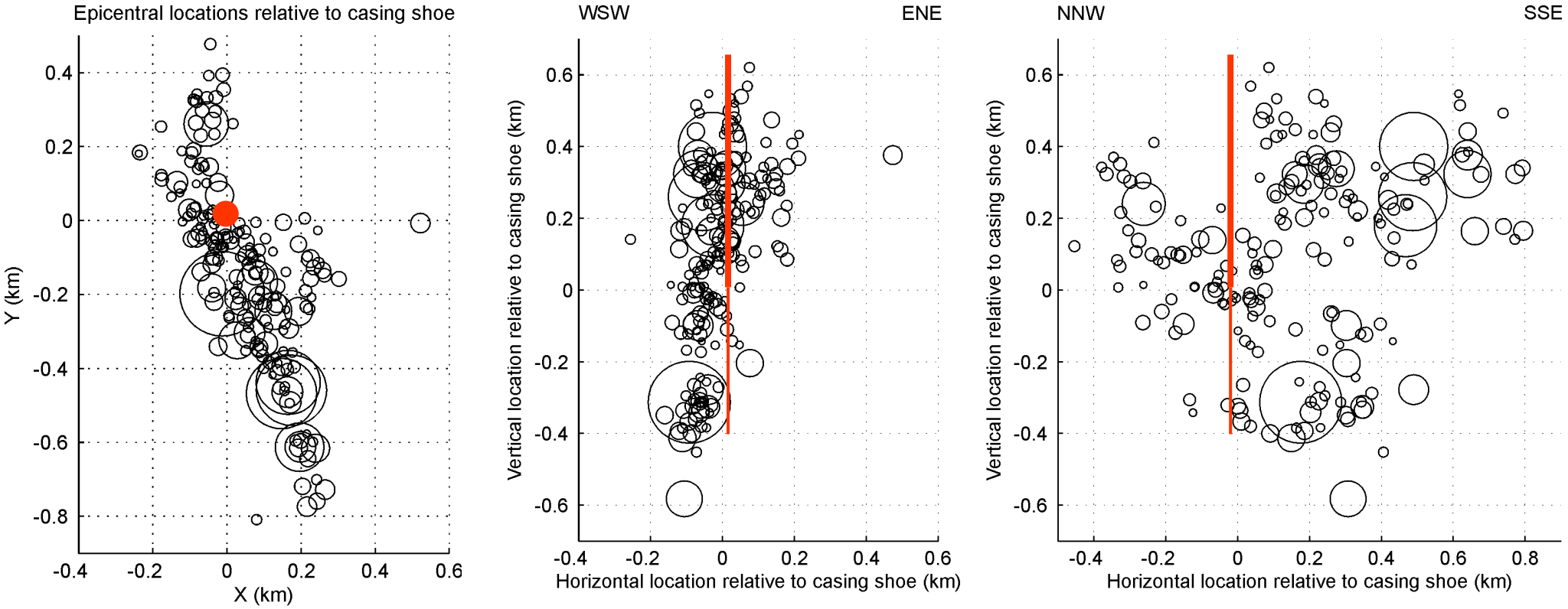
Master-event relocation of the strongest events

ETH Zurich



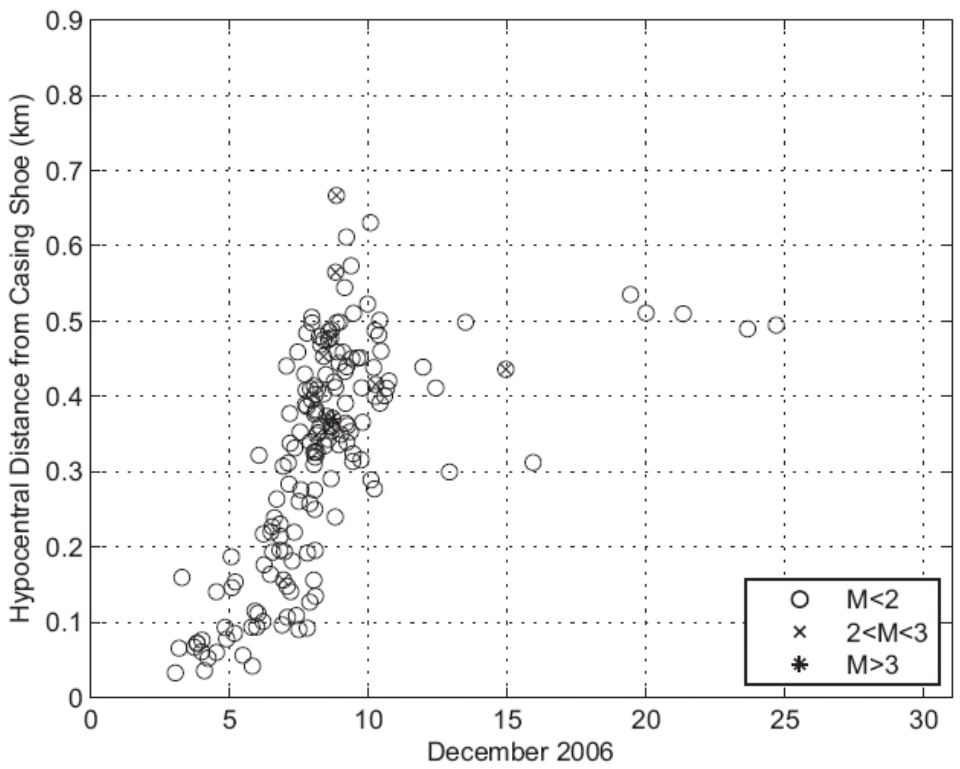
Relative epicenter locations and focal dephts of the 195 strongest induced events (Dec. 2006 – Nov. 2007). Symbol-size is proportional to seismic moment.

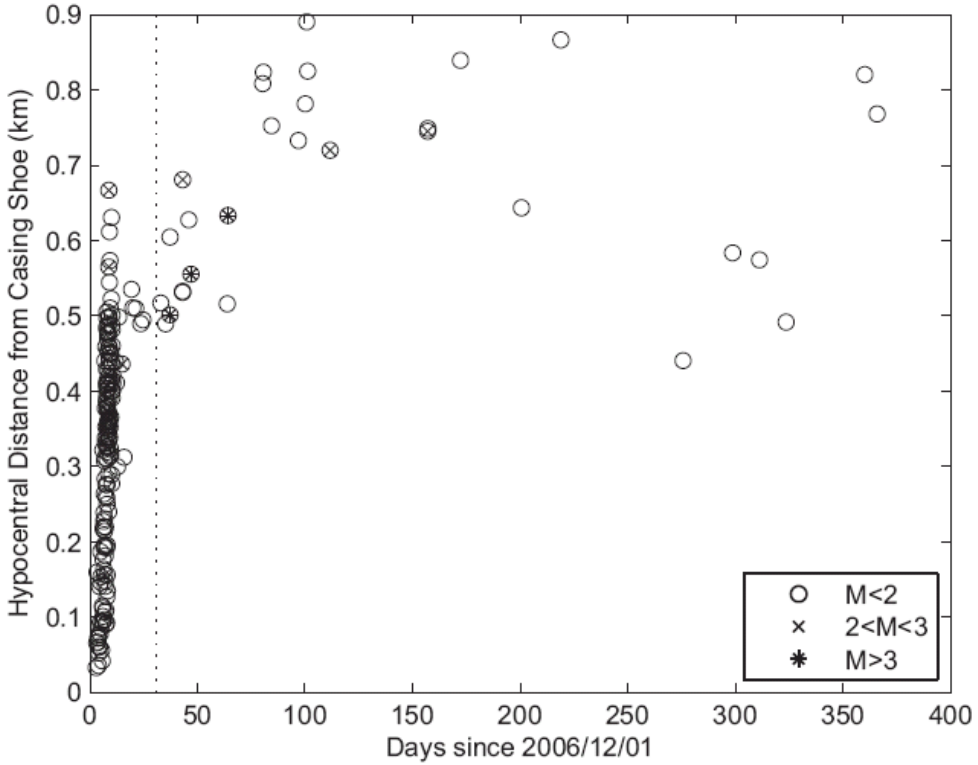
Deichmann & Giardini (subm.)

Swiss Seismological Service

Basel induced seismicity recorded by SED

ETH Zurich





Migration of hypocenters away from injection site

Deichmann & Giardini (subm.)

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Basel: borehole stress orientation

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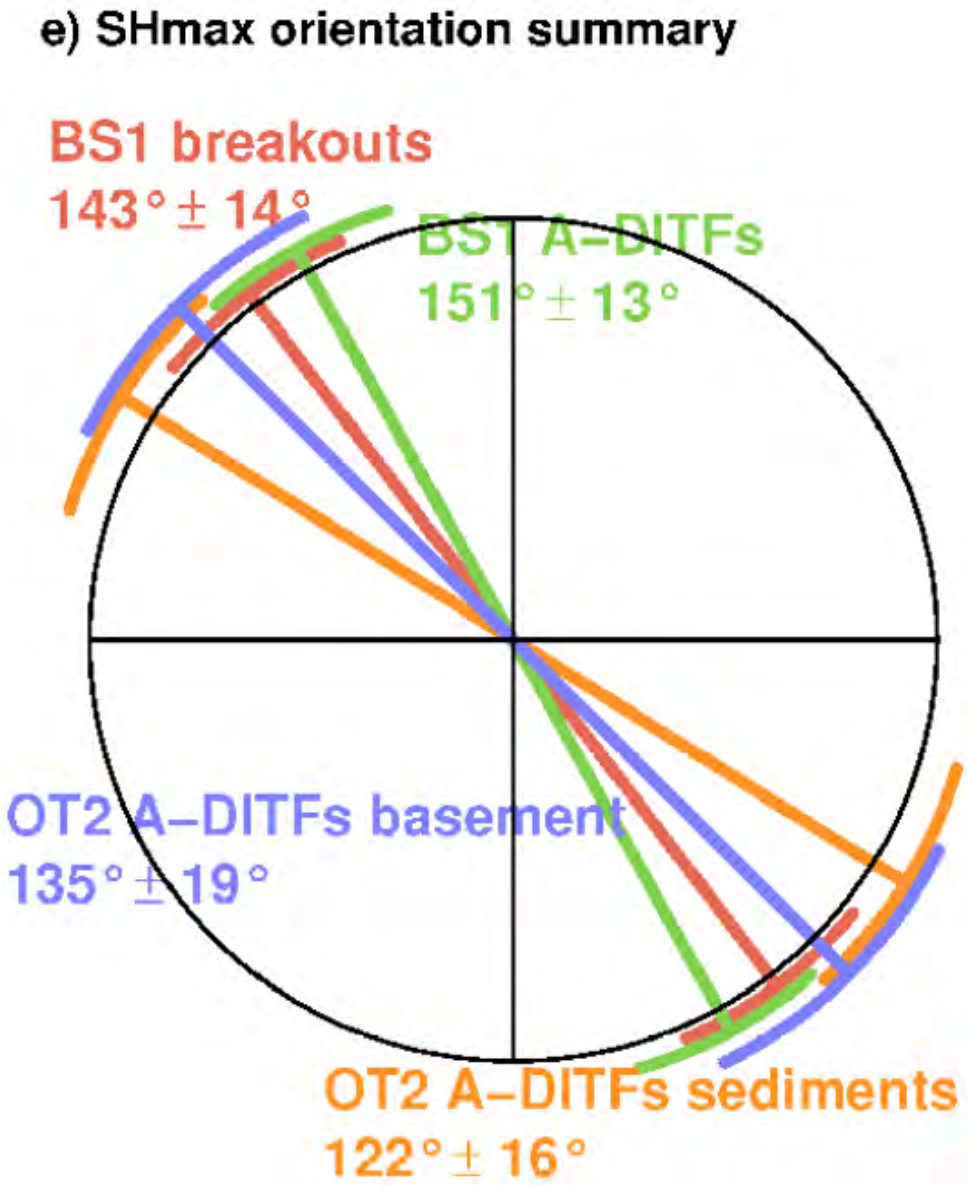

Valley & Evans (subm.)

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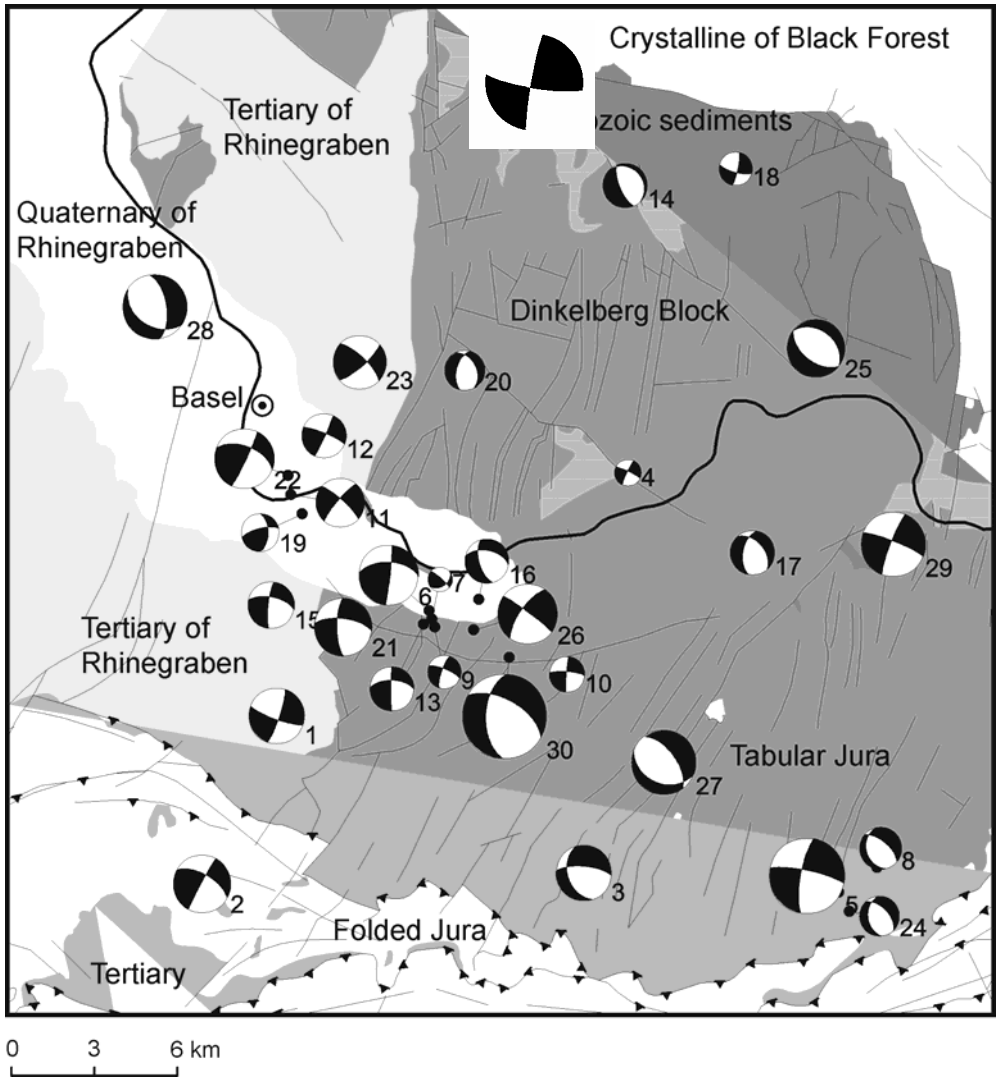
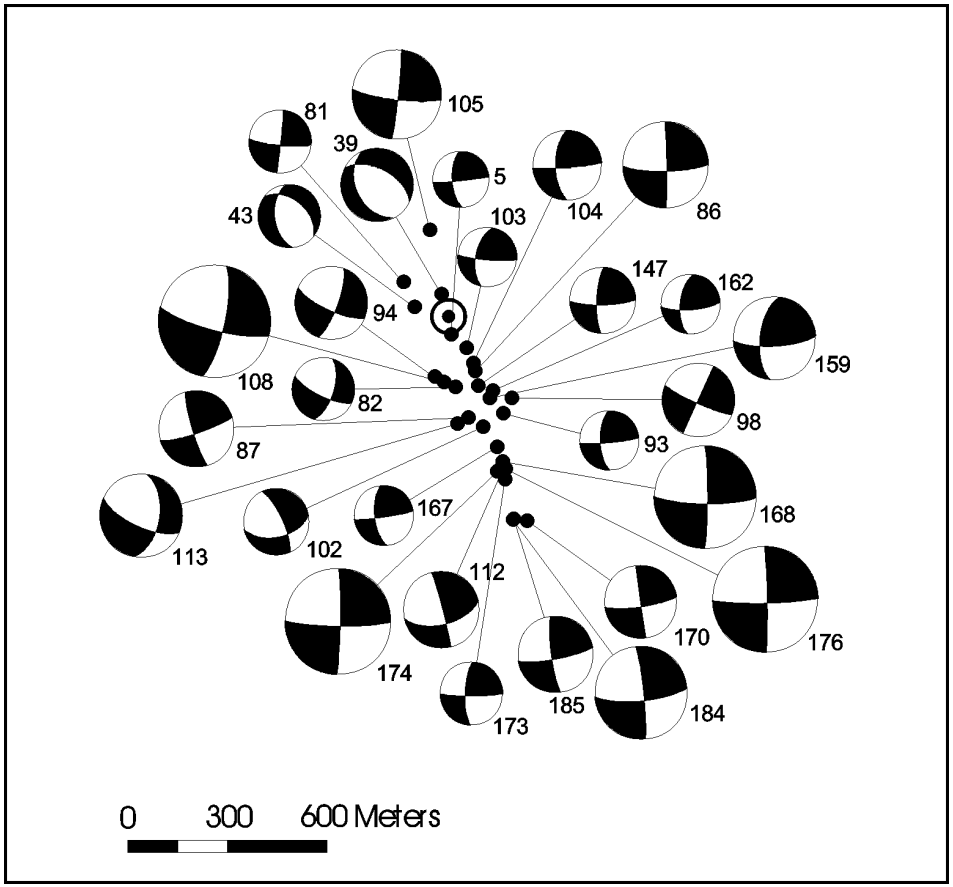
Natürliche Seismizität Region Basel - Induzierte Seismizität Stadt Basel





Deichmann & Giardini (subm.)

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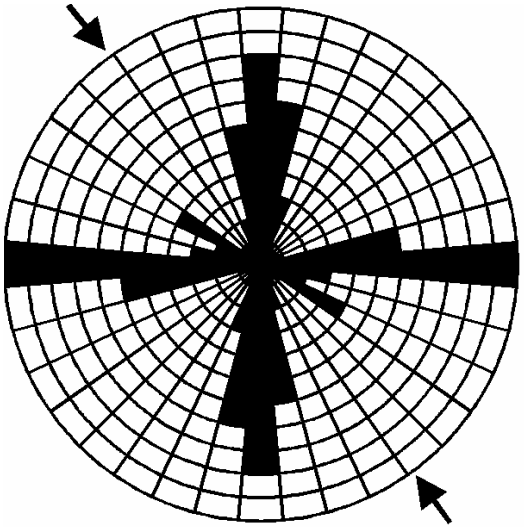
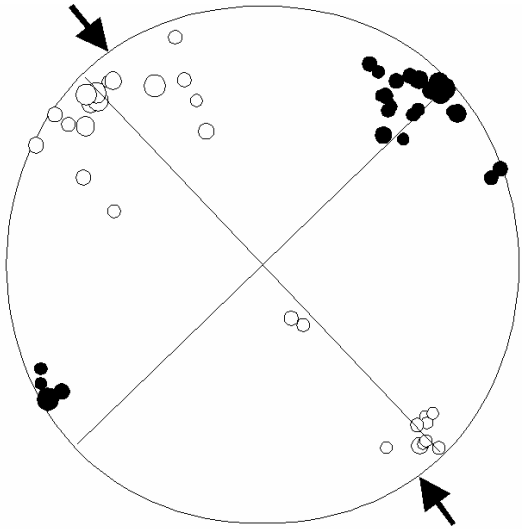
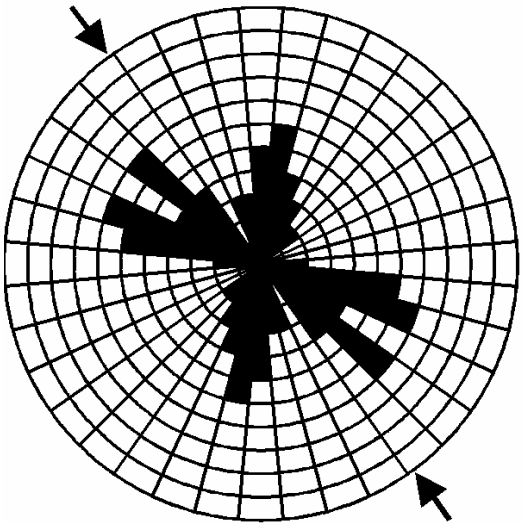
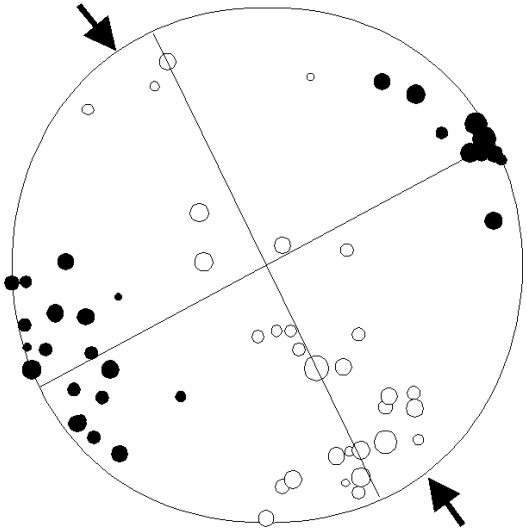




Stadt Basel:

Induzierte Beben





Region Basel:

Natürliche Beben

Deichmann & Giardini (subm.)

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Cluster analysis: faultplane of the ML 3.4 event

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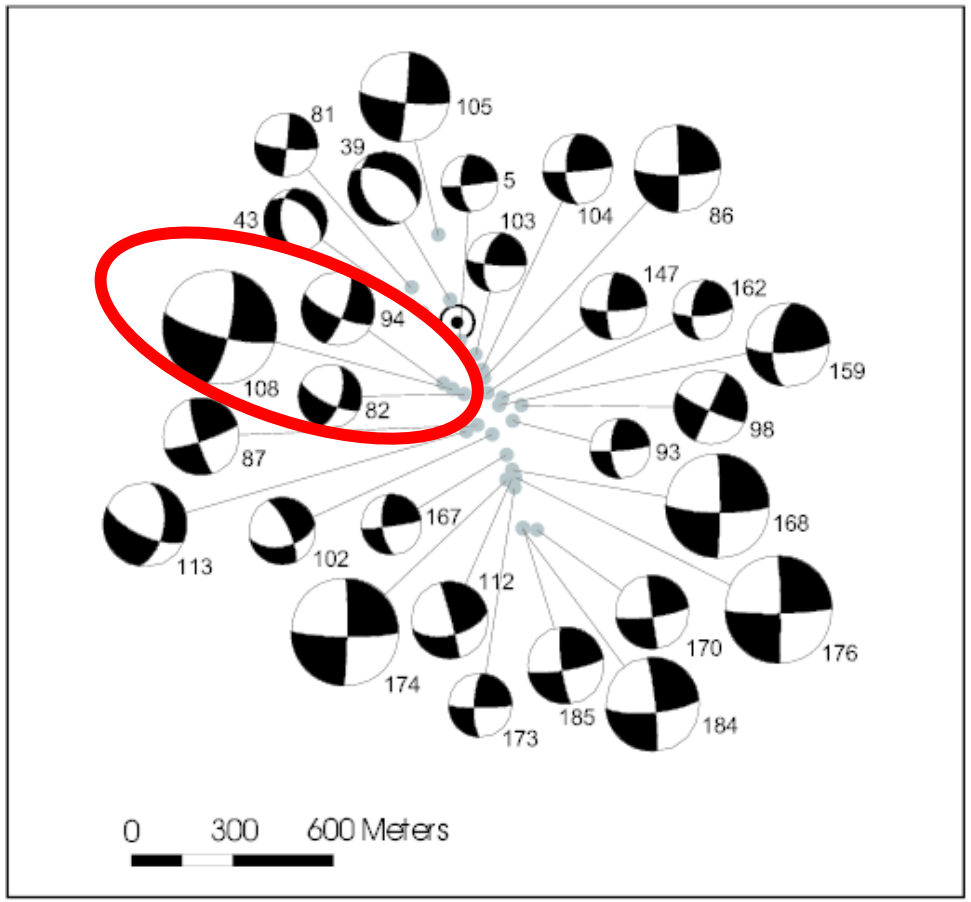

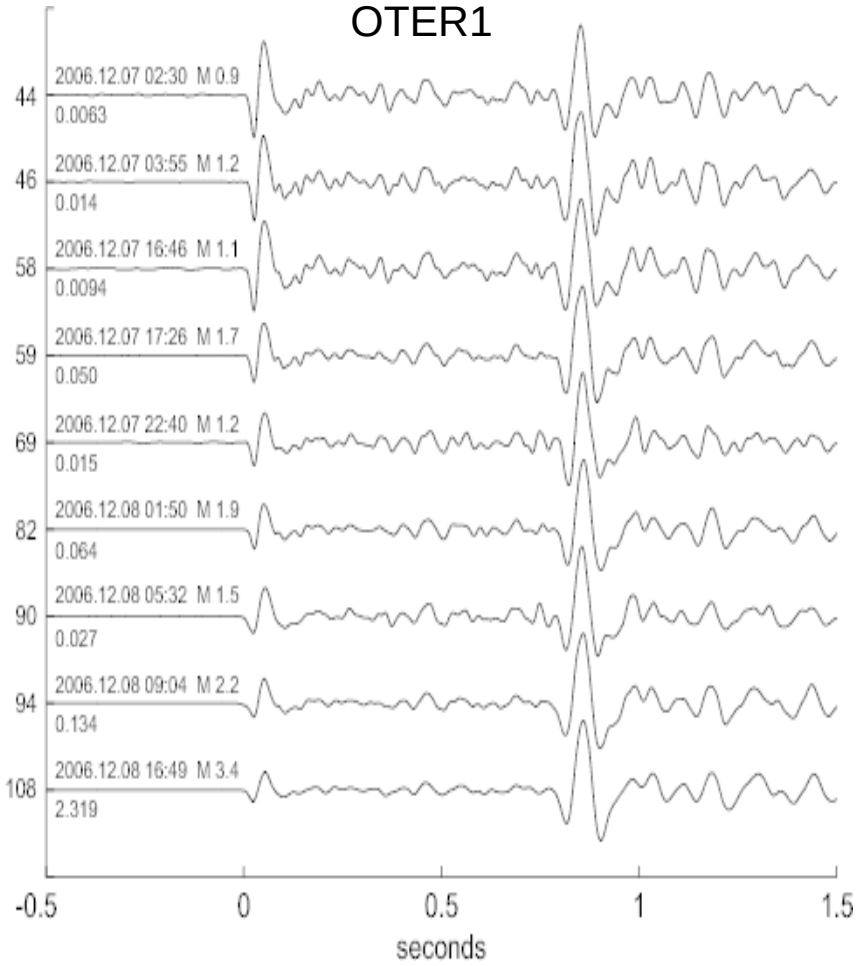

Deichmann & Giardini (subm.)

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Ein Vergleich der maximalen horizontalen Bodenbeschleunigungen

Ereignis 2009/05/05 ML 4.3

- SFRA (Frenkendorf): 0.54 m/s2
- SAUR (Kaiseraugst): 0.25 m/s2
- OTTER (Otterbach): 0.13 m/s2

Ereignis 2006/12/08 ML 3.4

- SBAT (Basel): 0.51 m/s2
- OTTER (Otterbach): 0.55 m/s2

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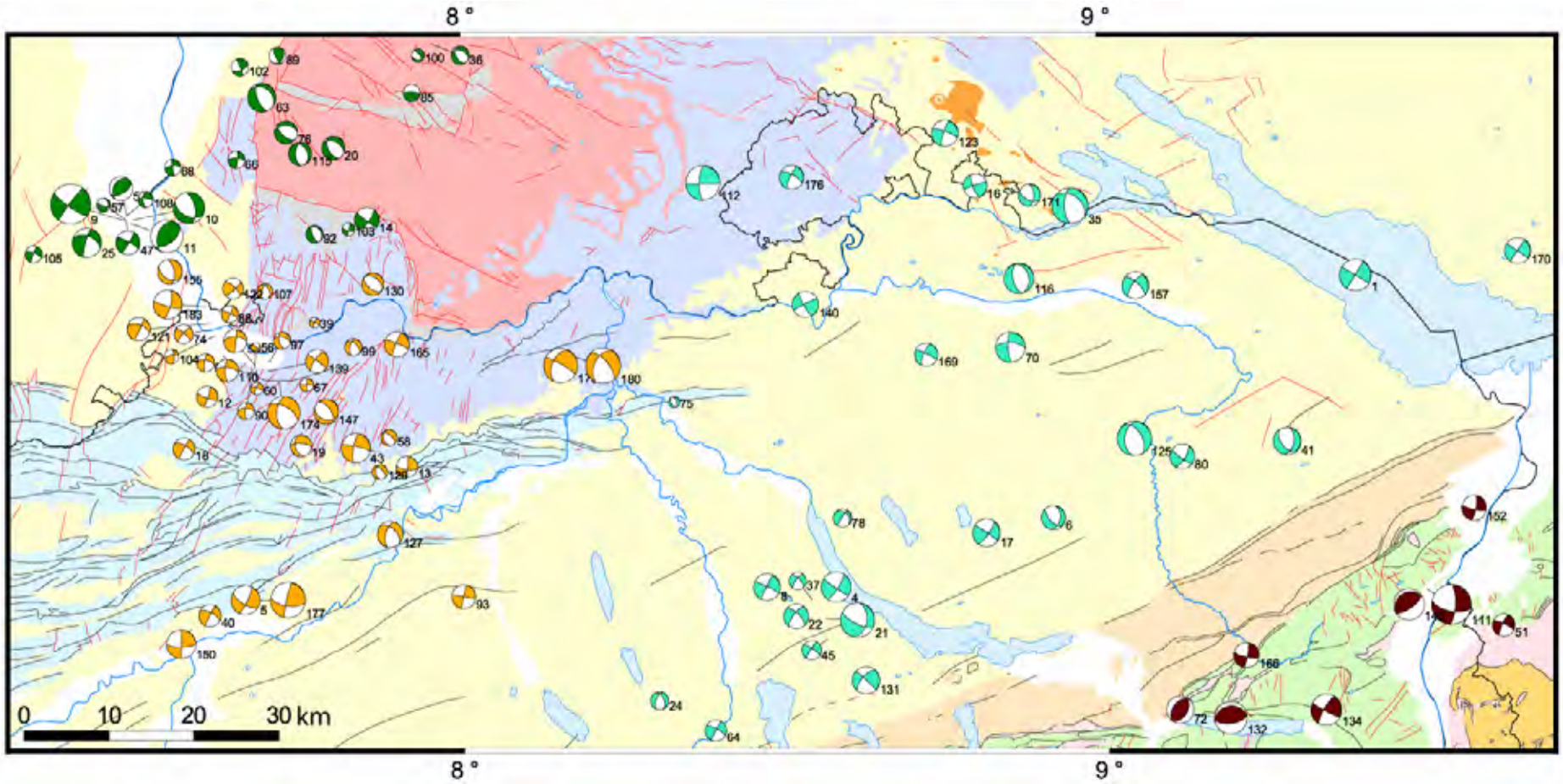

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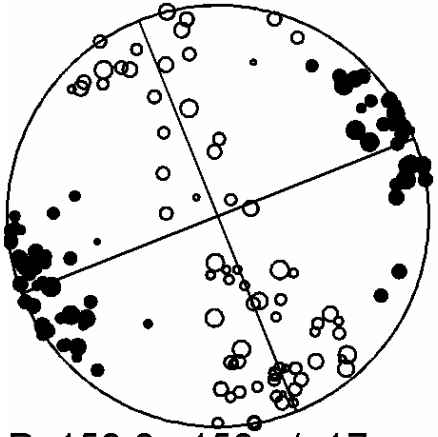
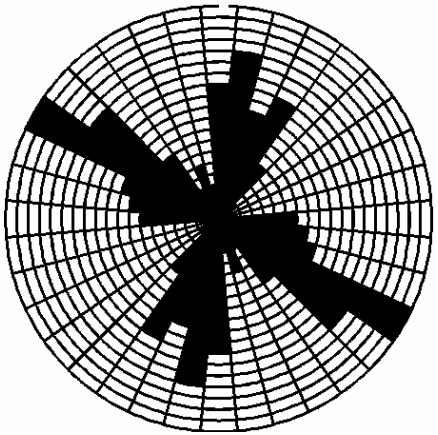
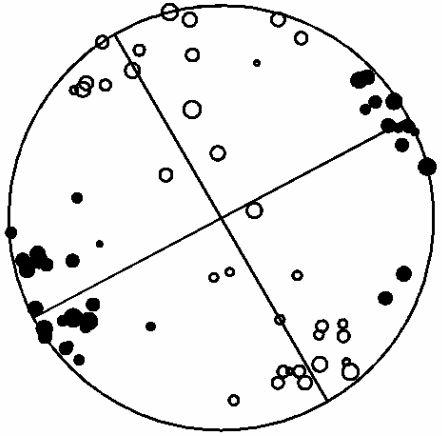
Nordschweiz



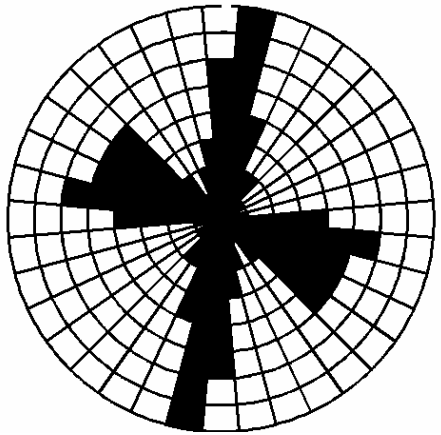
P: 158.0, 158 +/- 17
T: 248.5, 248 +/- 16



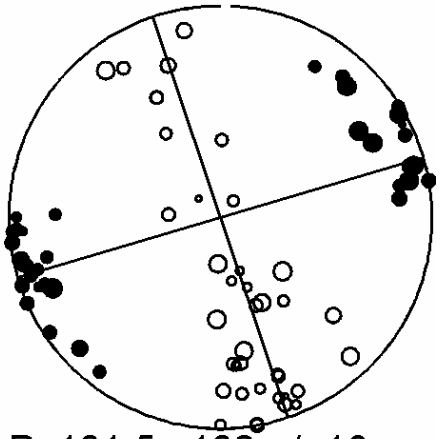
Herdtiefe < 16 km



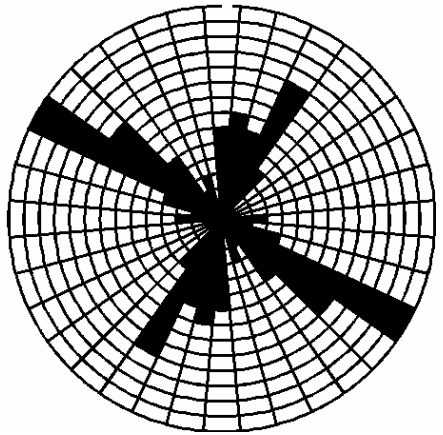
P: 150.0, 154 +/- 20
T: 242.0, 245 +/- 18



Herdtiefe > 15 km



P: 161.5, 162 +/- 13
T: 253.5, 250 +/- 15



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Stress field

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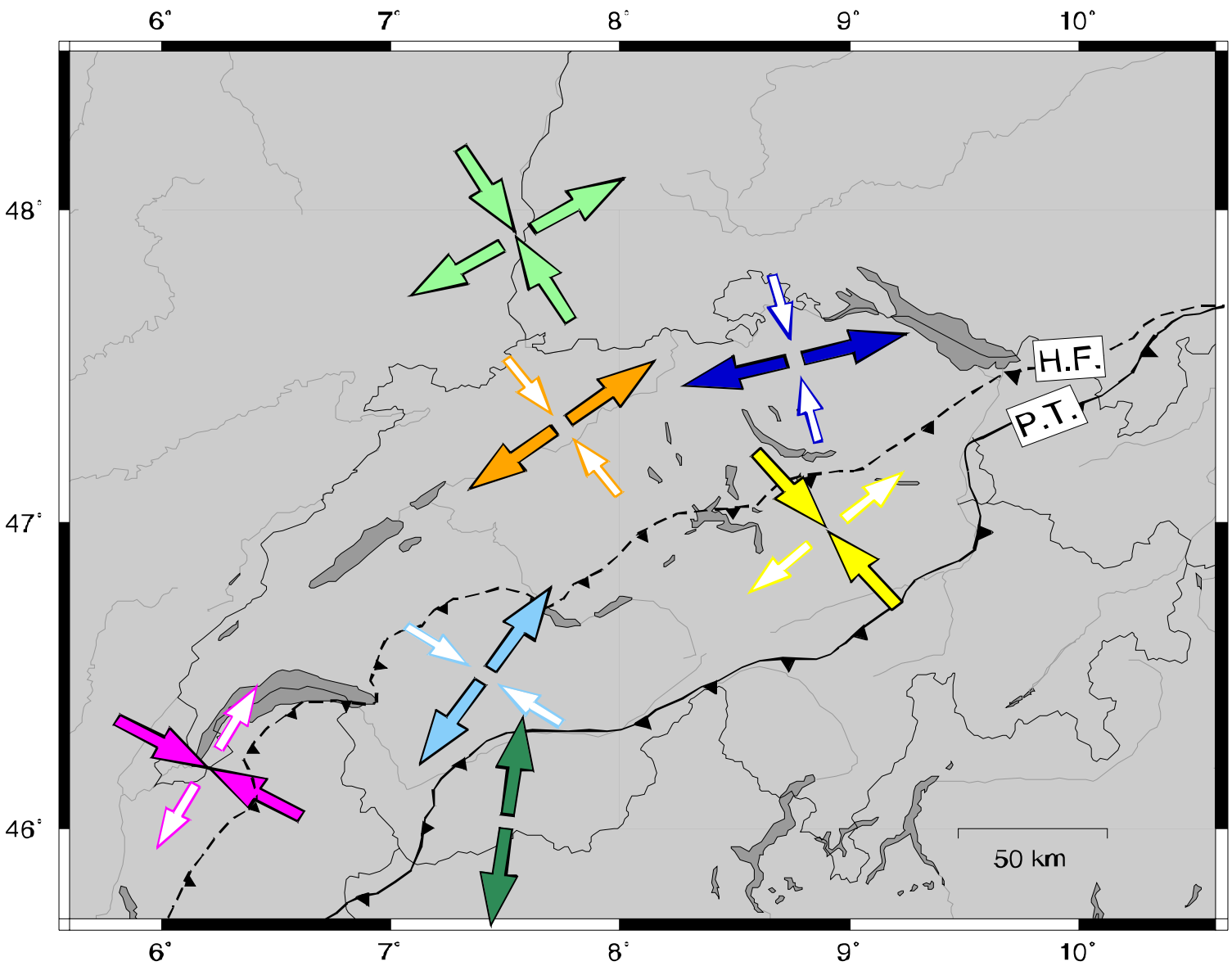


Stress regimes

Strike-slip

Sh_{min}

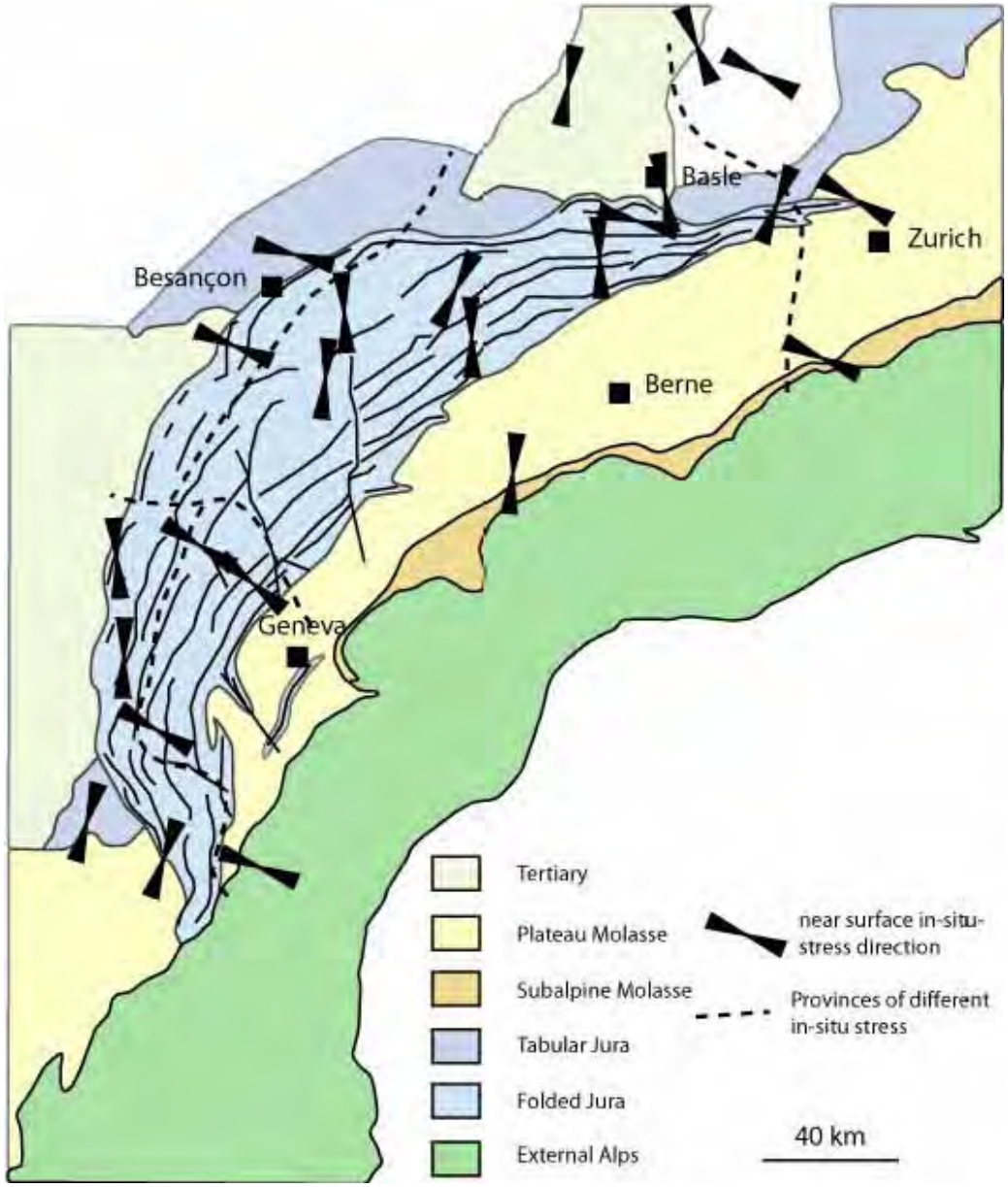
SH_{max}

Strike-slip to thrust faulting

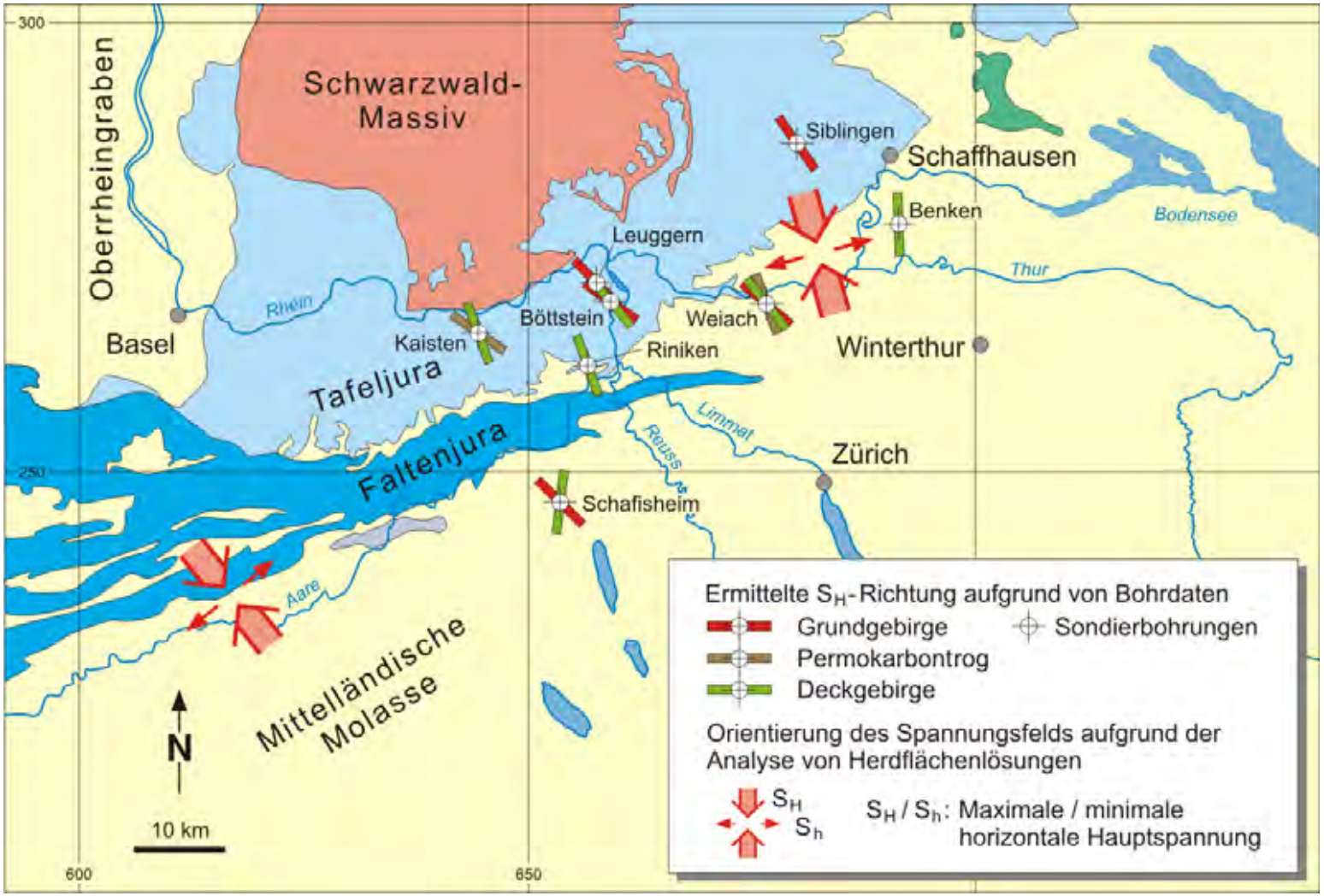
Strike-slip to normal faulting

Normal faulting

U. Kastrup (2002)



Nach Becker (2002)
Aus Mosar et al. (2008)
NAB 08-07



Aus: Müller et al. (2002) NTB 99-08

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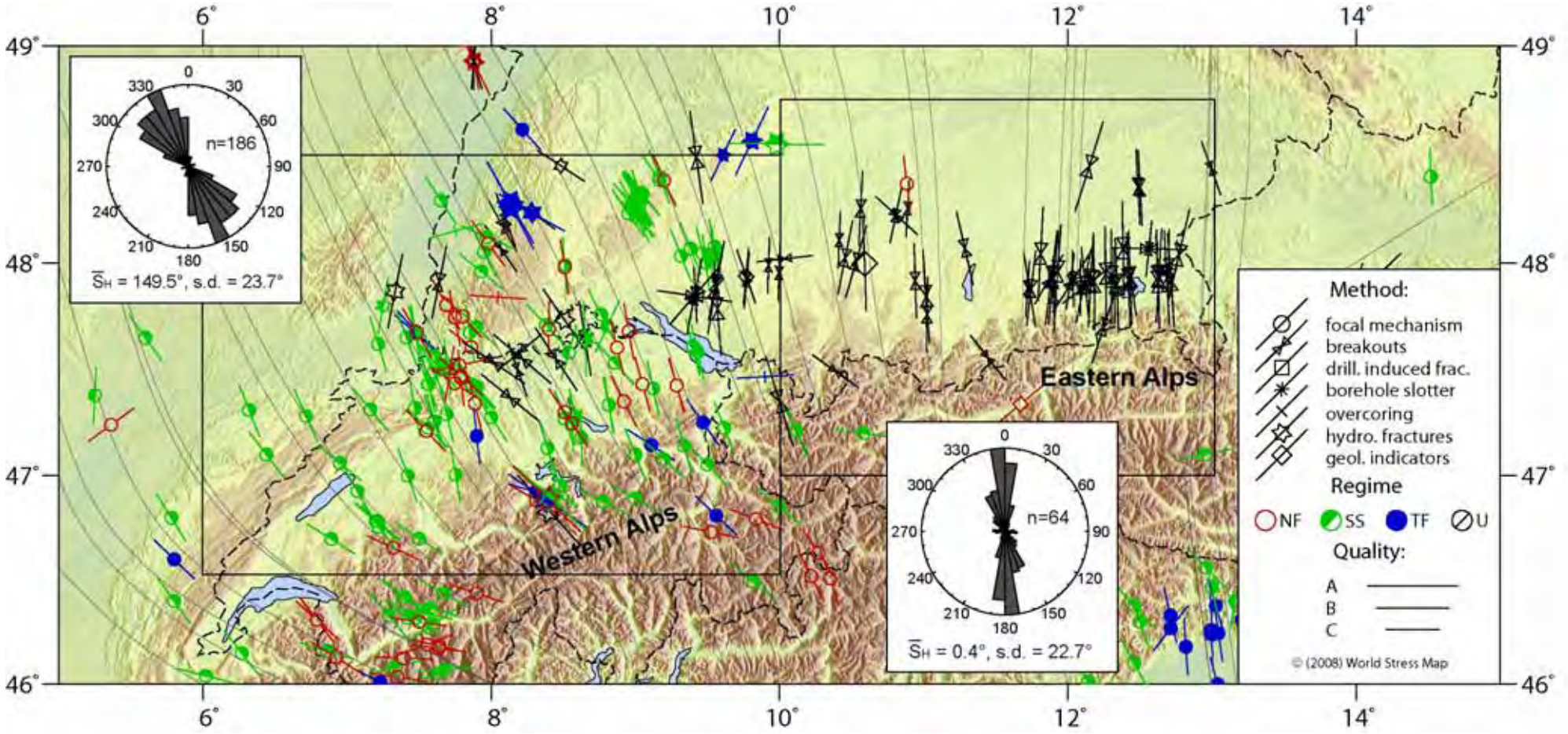

Reinecker et al. (2009)

- Die Erdbebenherde in der Nordschweiz sind über die gesamte Kruste verteilt.
- Beben können auch in geringen Tiefen auftreten (1-2 km).
- Die Herdmechanismen der induzierten Beben in Basel stehen im Einklang mit den Mechanismen der natürlichen Seismizität und mit den in situ gemessenen Spannungen im Grundgebirge.
- Die Herdmechanismen in der Nordschweiz entsprechen praktisch ausschliesslich Blattverschiebungen und Abschiebungen.
- Herausragendes Merkmal ist die horizontale und stabile ENE-WSW Ausrichtung der T-Achsen und entsprechender NNW-SSE ausgerichteter Kompression.
- Die Spannungen im Deckgebirge scheinen gegenüber dem Grundgebirge leicht im Uhrzeigersinn gedreht zu sein.