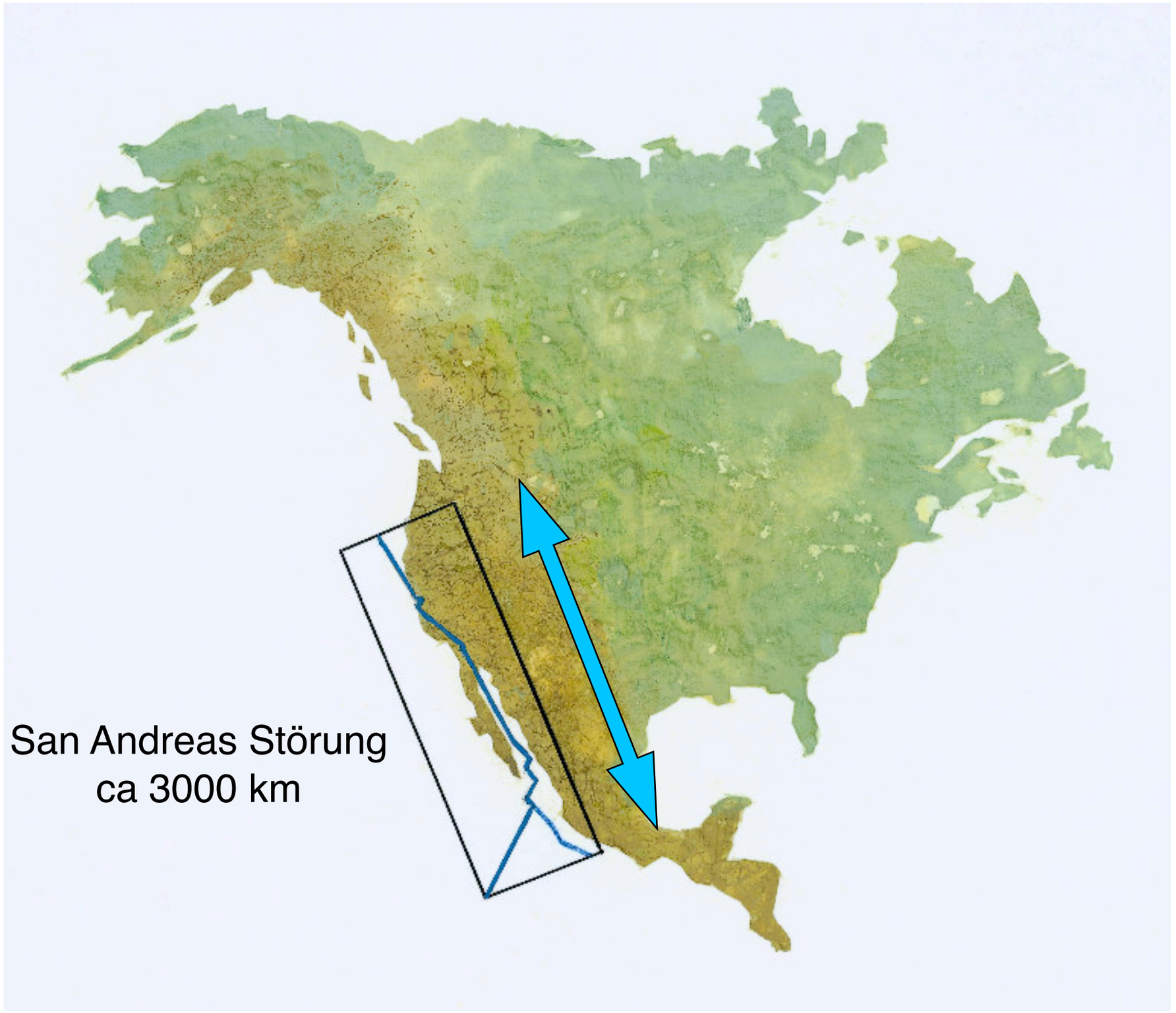
Seismologie an aktiven Vulkanen:

D A S

F r ü h w a r n w e r k z e u g ?

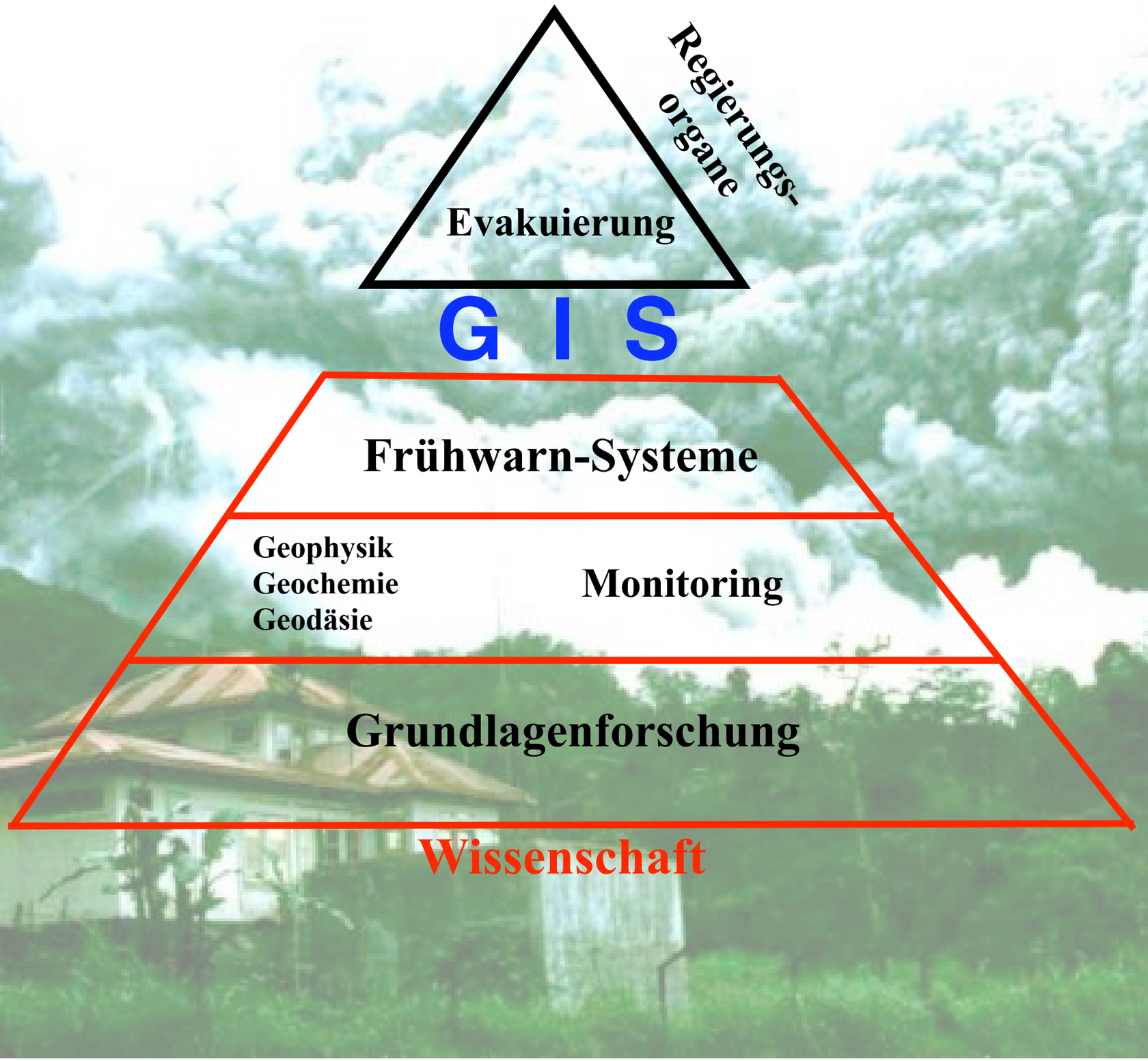
GEO LMU
Ludwig Maximilians University Munich

Vorhersage/Frühwarnung?



Vorhersage/Frühwarnung?

Wie es funktionieren sollte!



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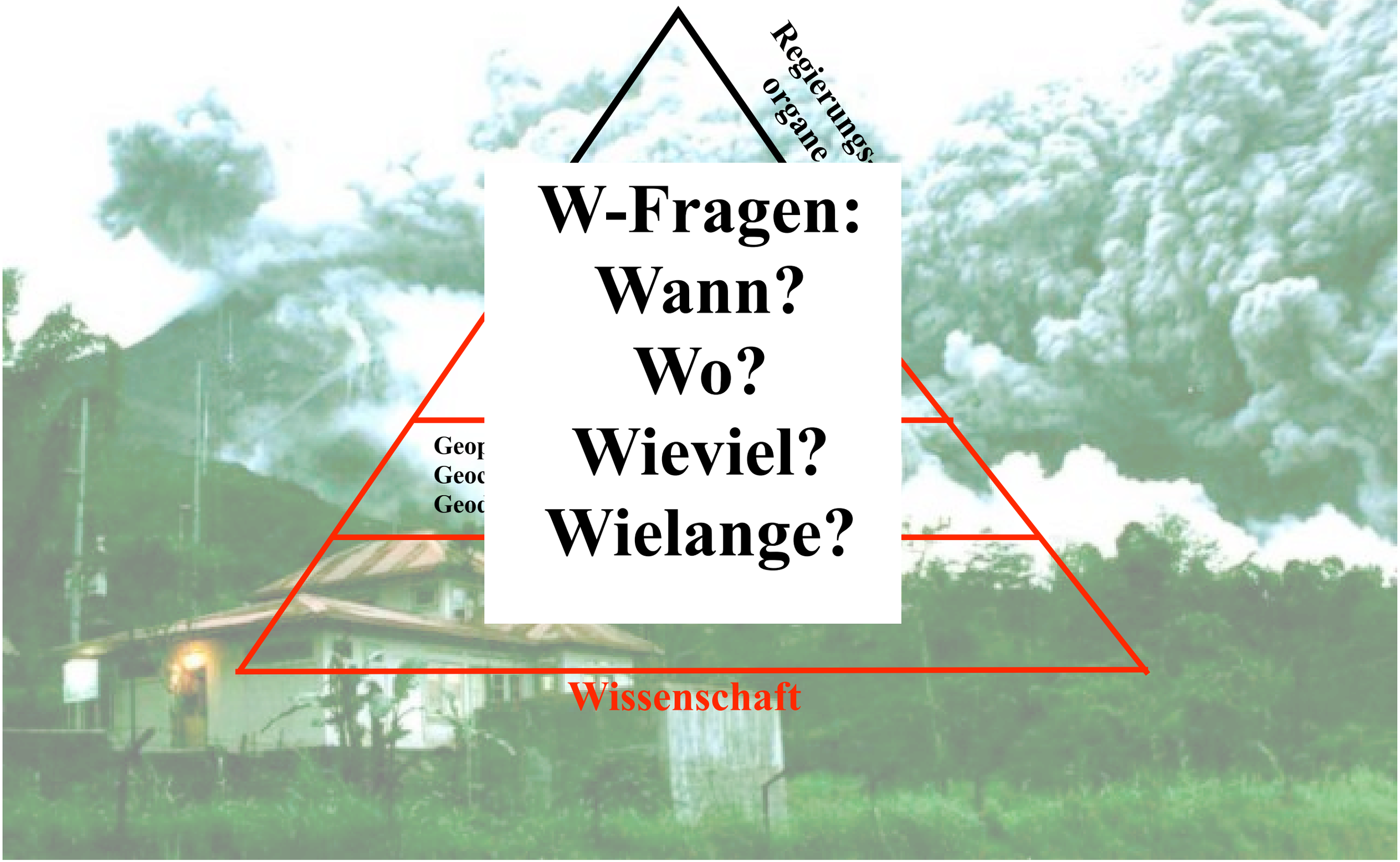
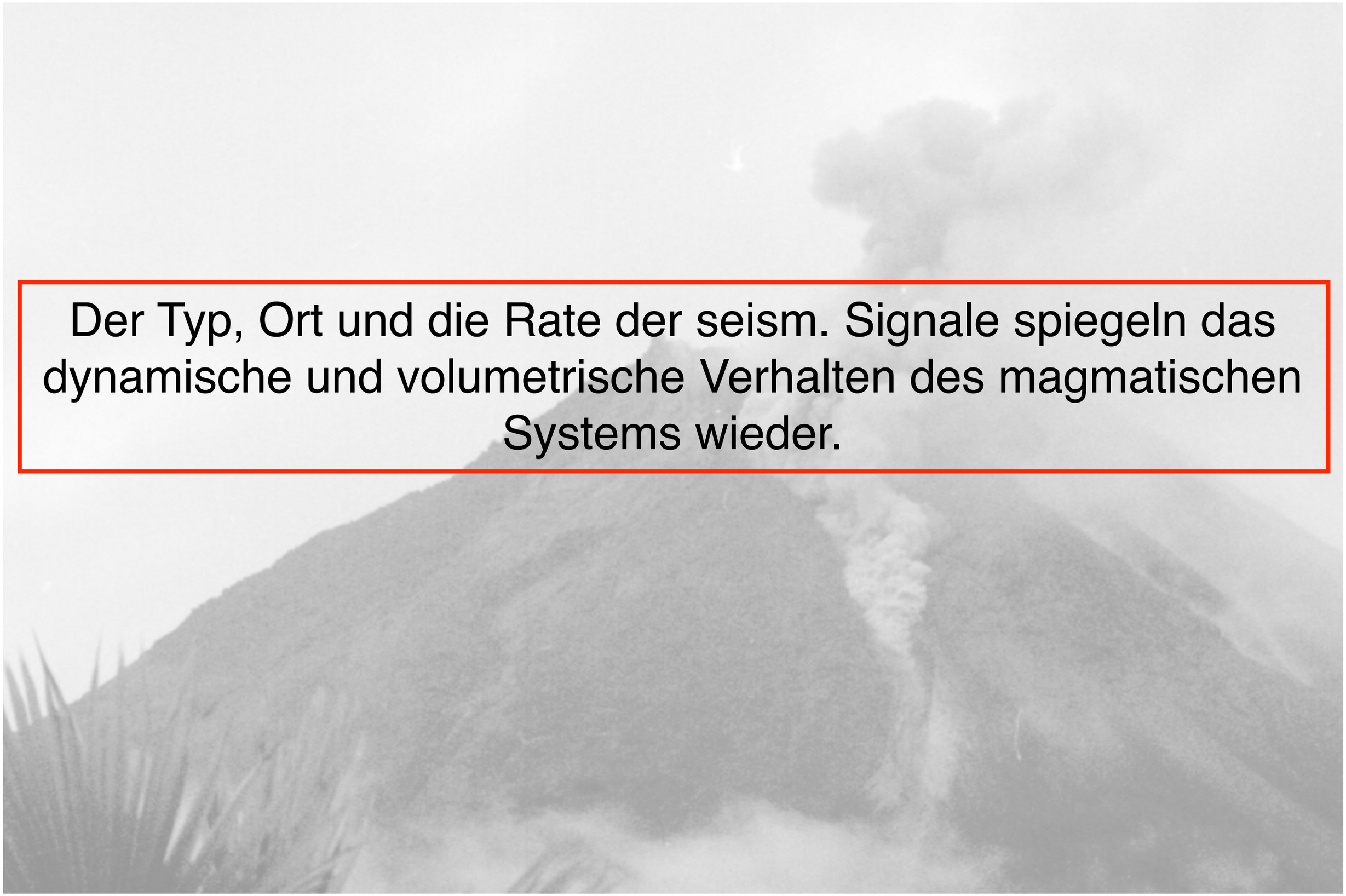
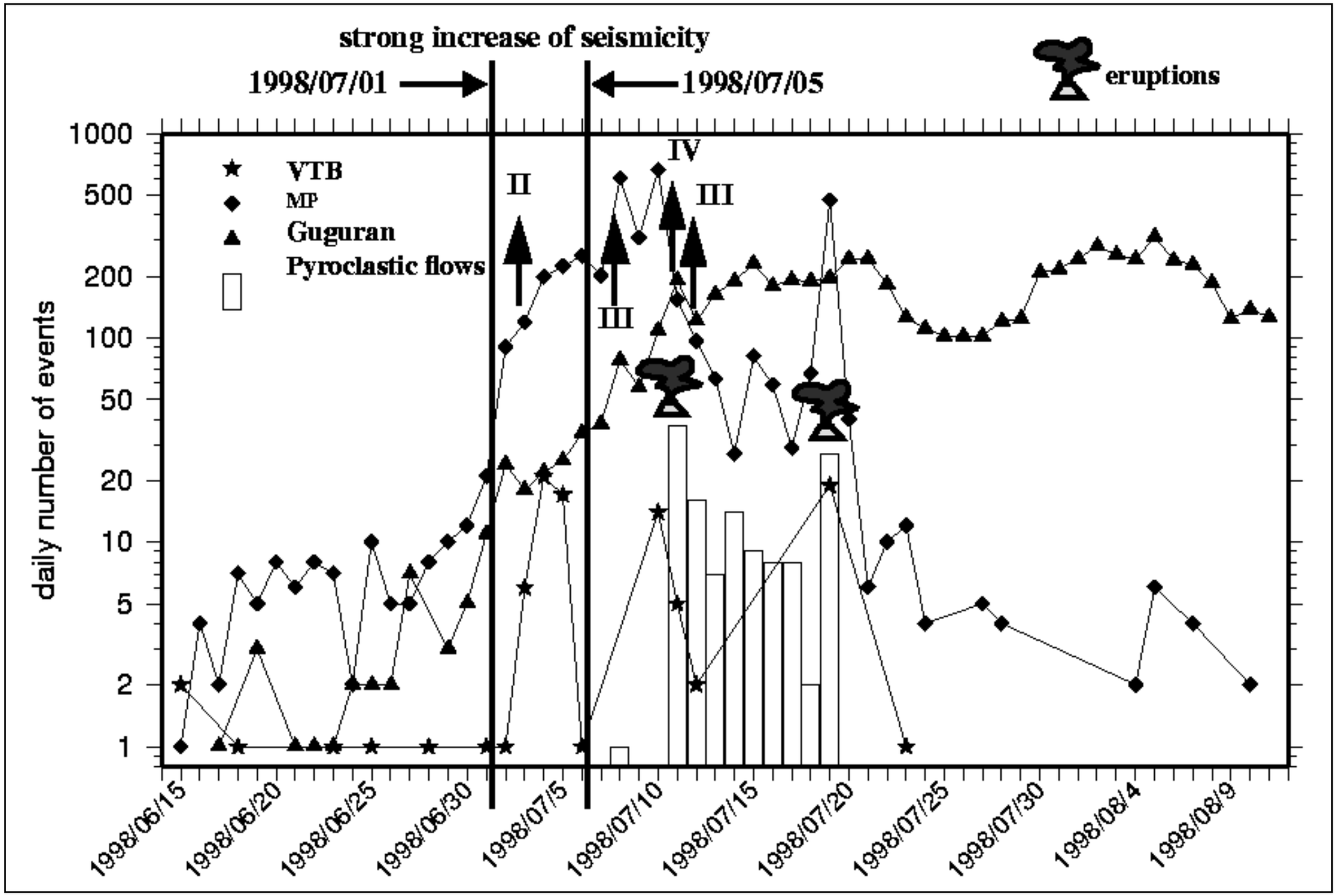


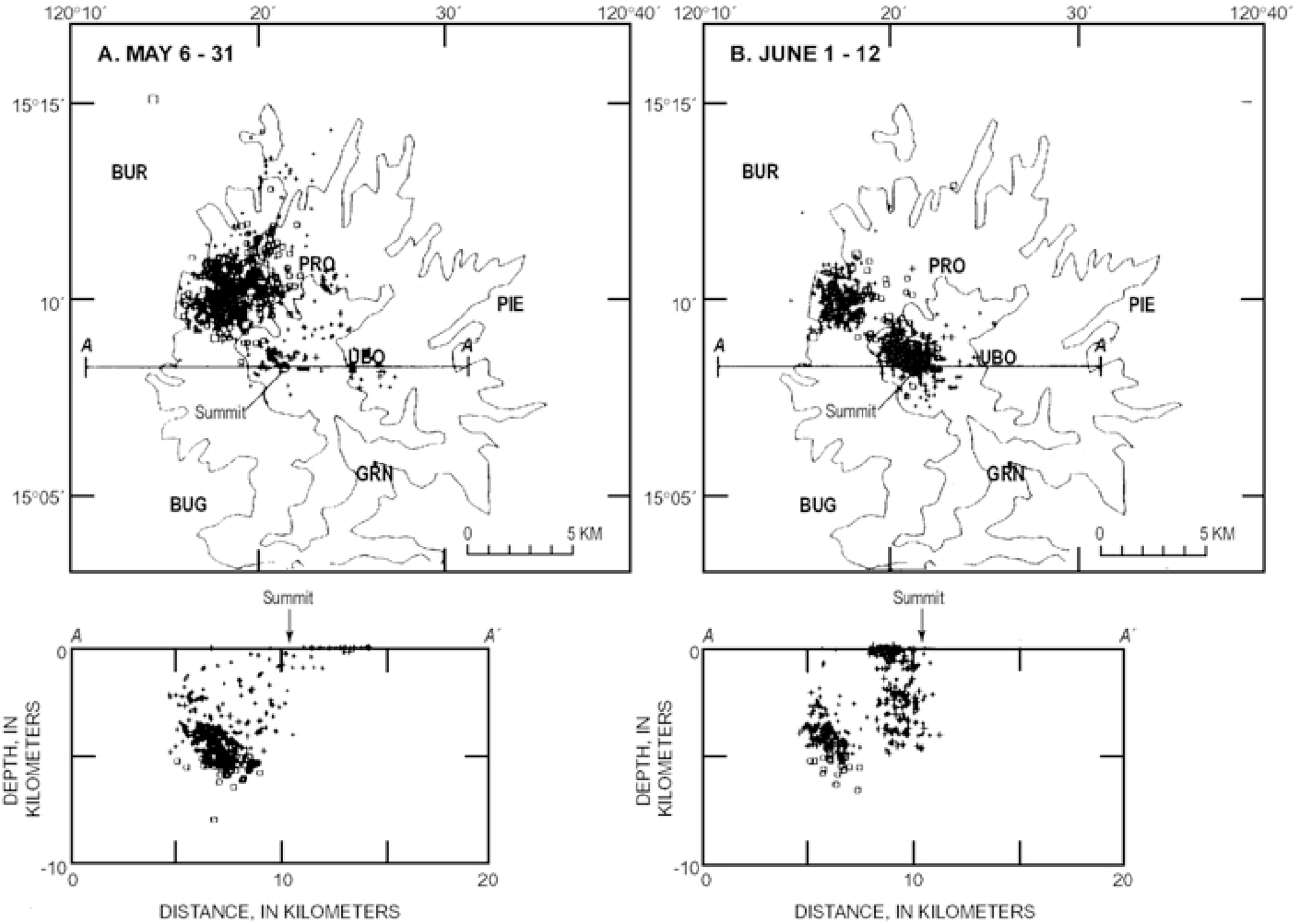


Der Typ, Ort und die Rate der seism. Signale spiegeln das dynamische und volumetrische Verhalten des magmatischen Systems wieder.

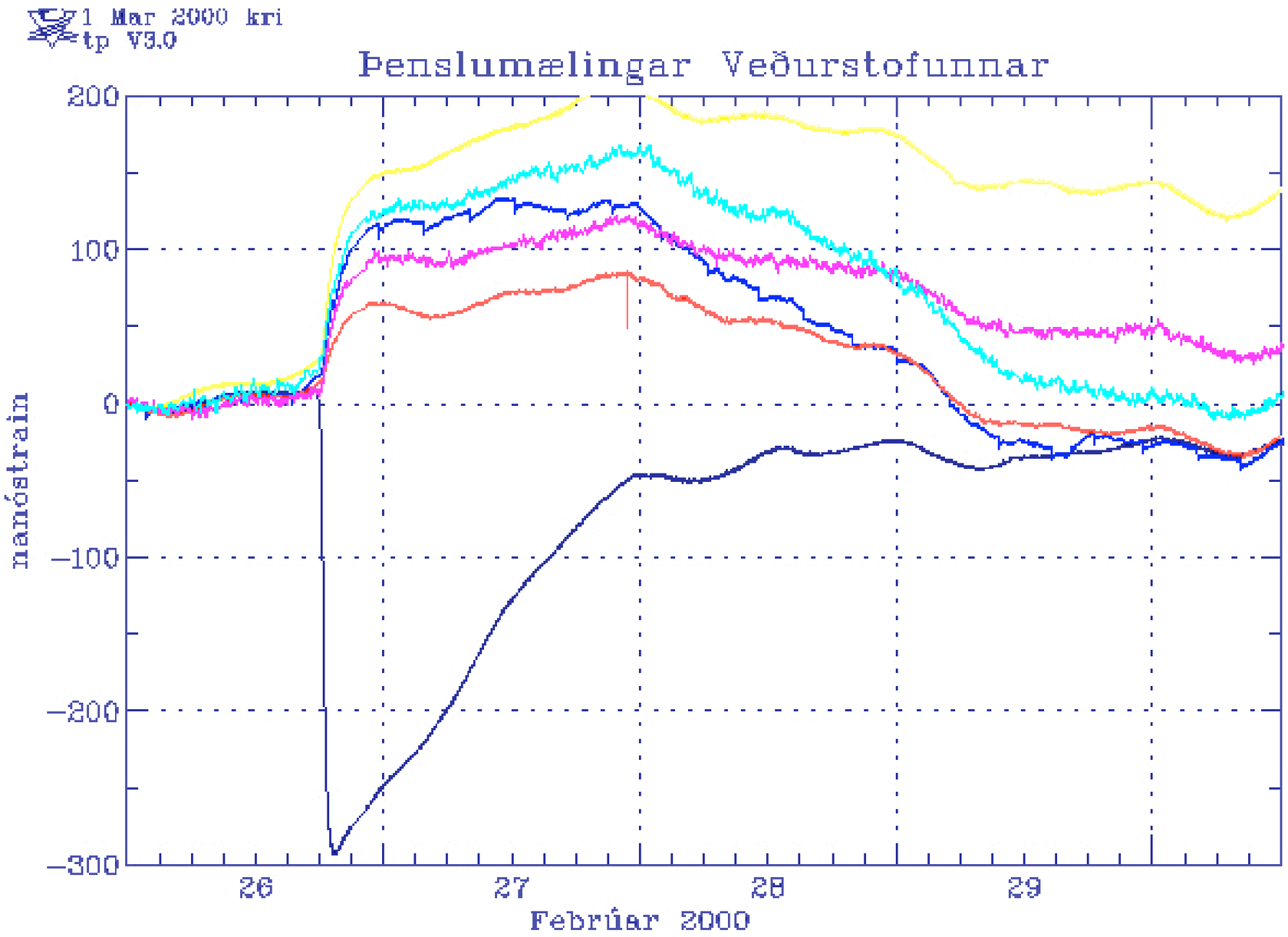
Erfolge - Typ


strong increase of seismicity
1998/07/01
1998/07/05
eruptions
VTB
MP
Guguran
Pyroclastic flows
II
III
III
IV
daily number of events
1000
500
200
100
50
20
10
5
2
1
1998/06/15
1998/06/20
1998/06/25
1998/06/30
1998/07/5
1998/07/10
1998/07/15
1998/07/20
1998/07/25
1998/07/30
1998/08/4
1998/08/9

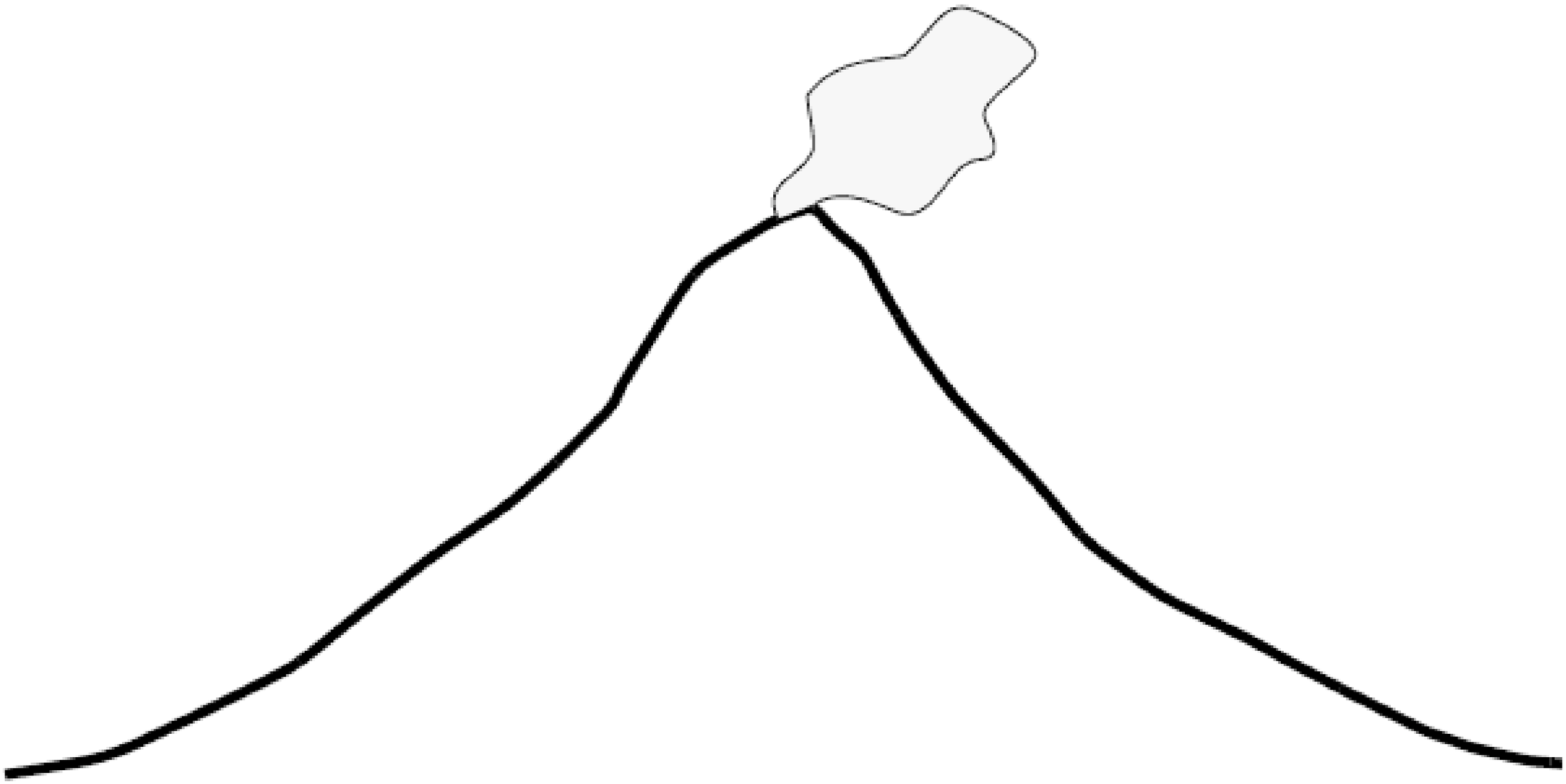
Erfolge - Lokalisierung



Erfolge - Modellierung



Der große Unbekannte (für Seismologen)



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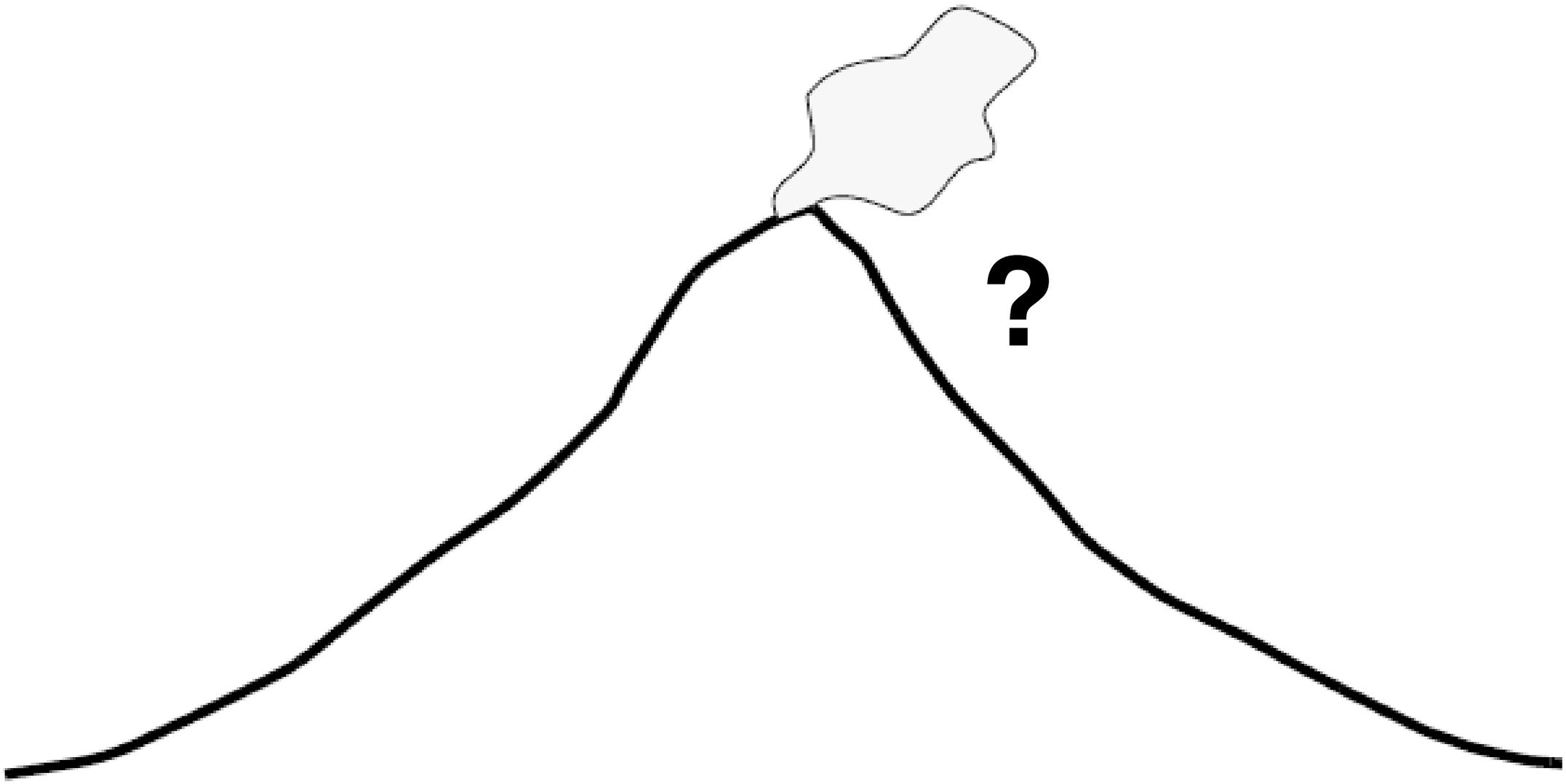

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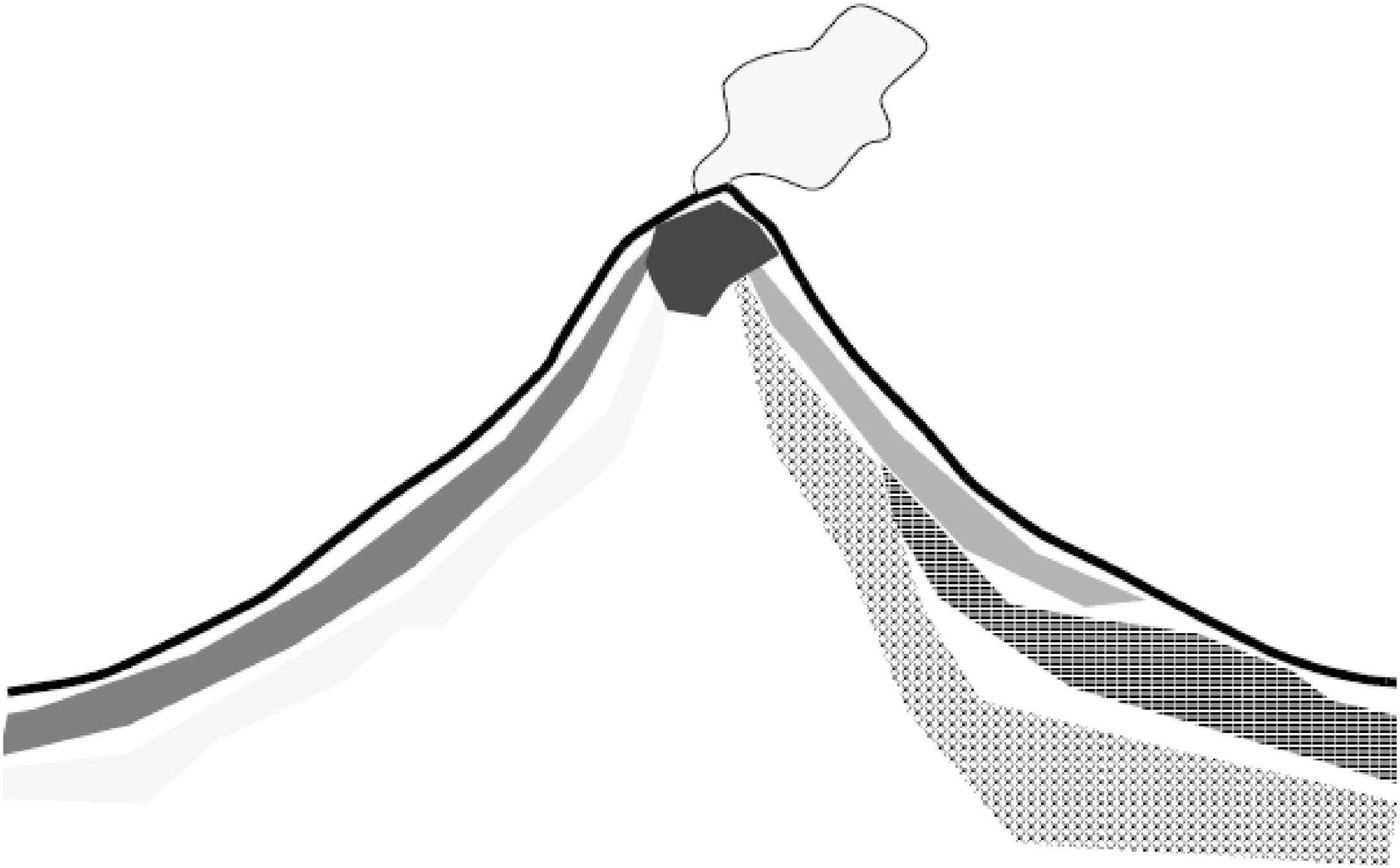

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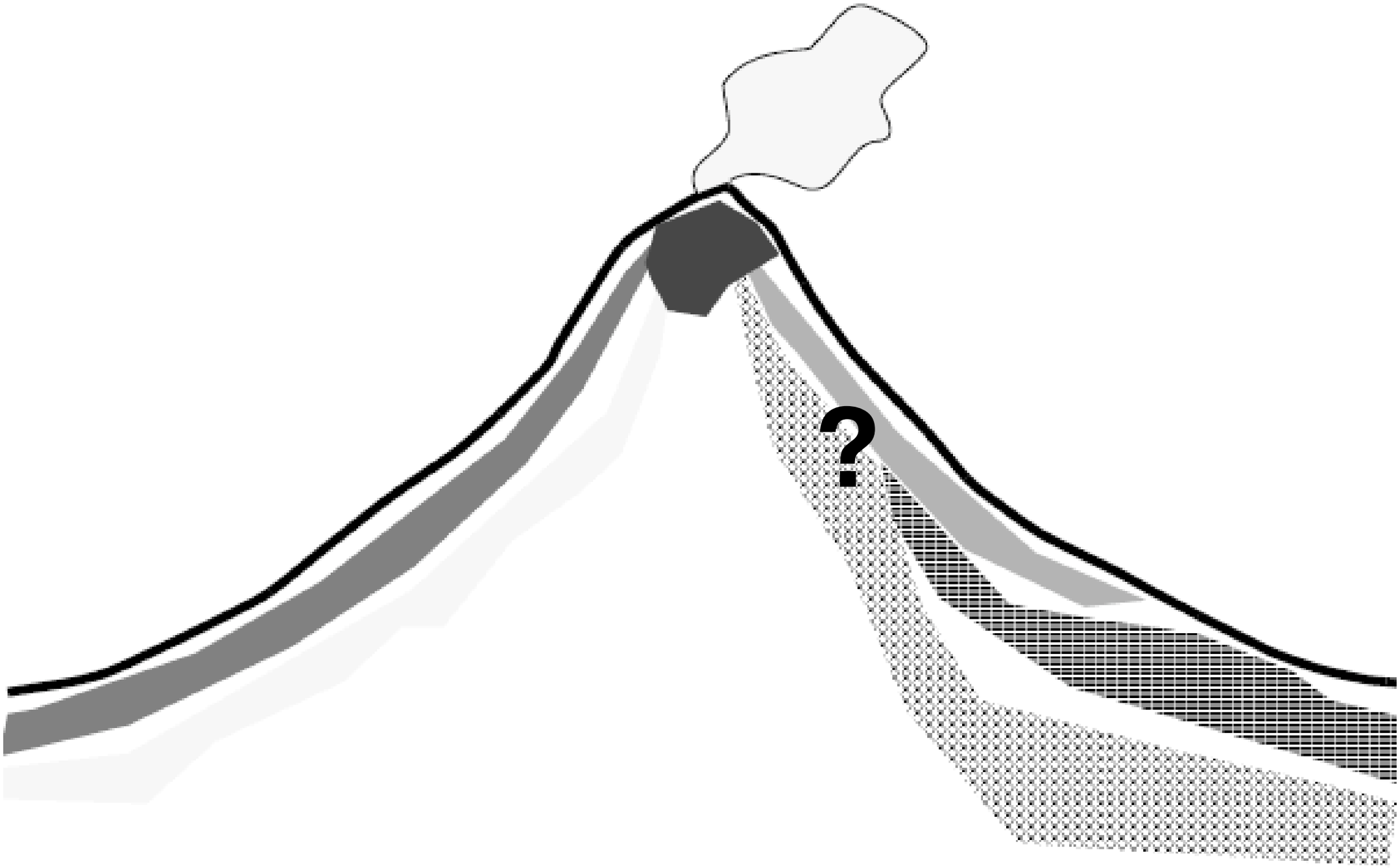

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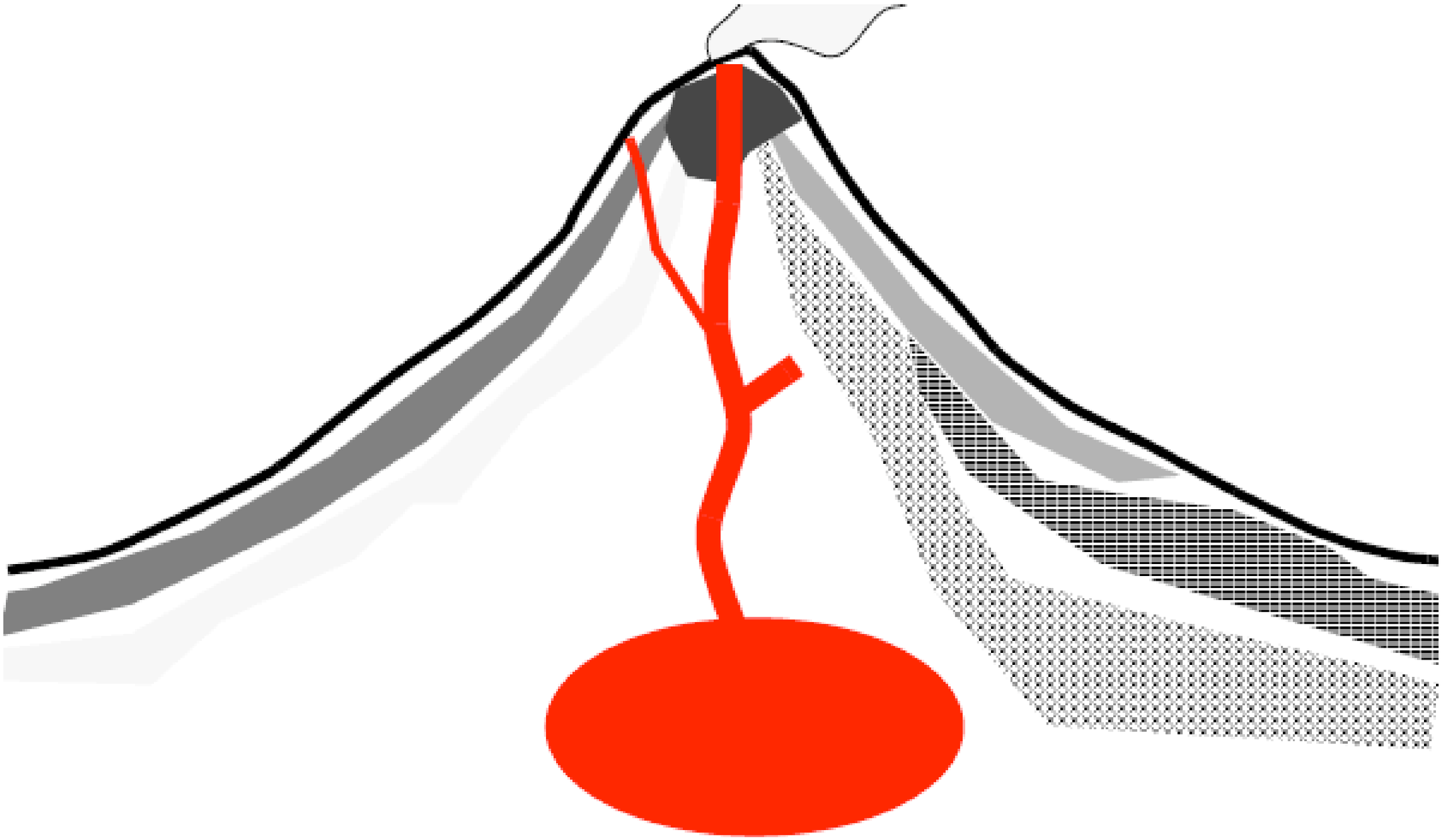

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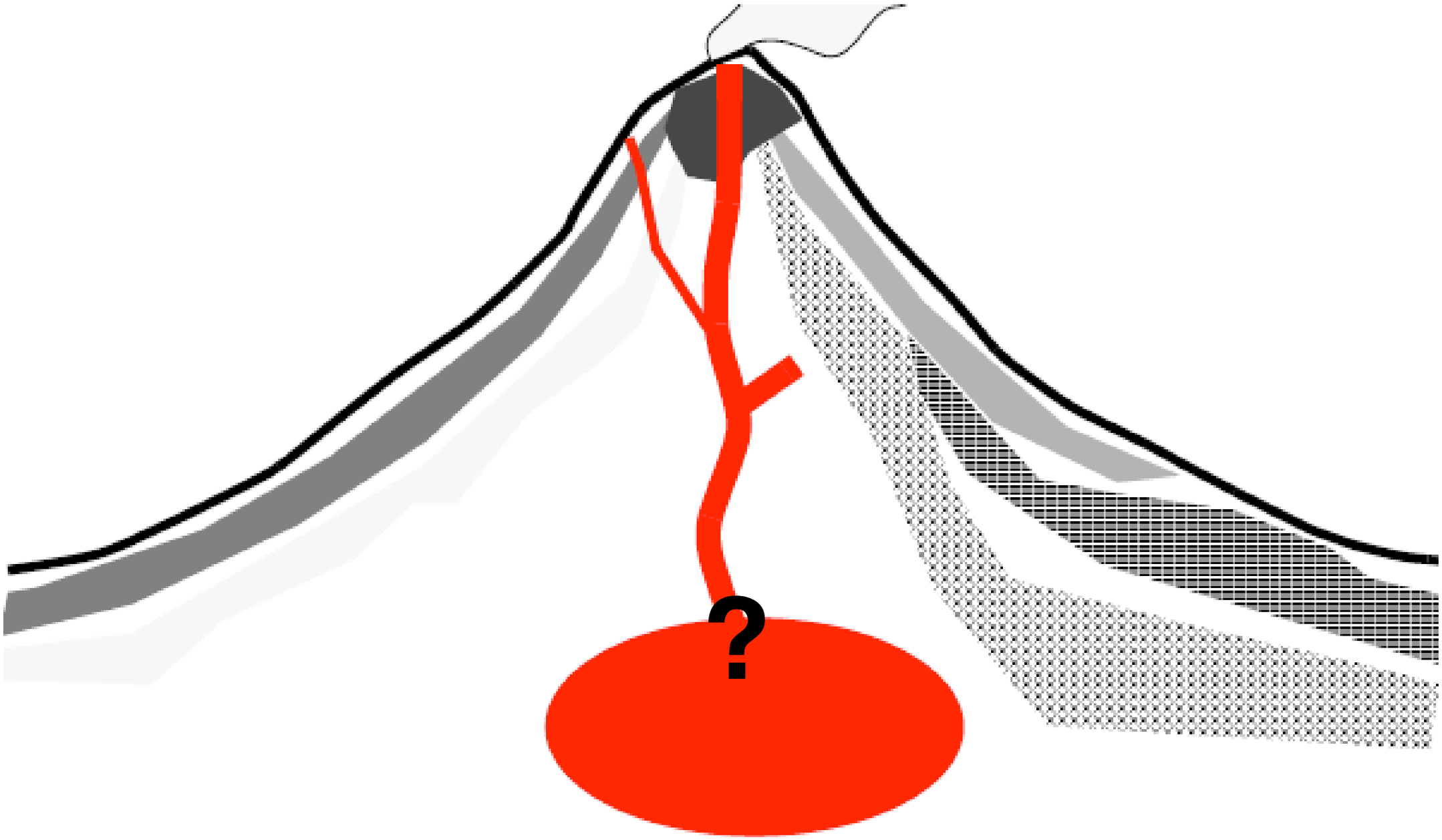

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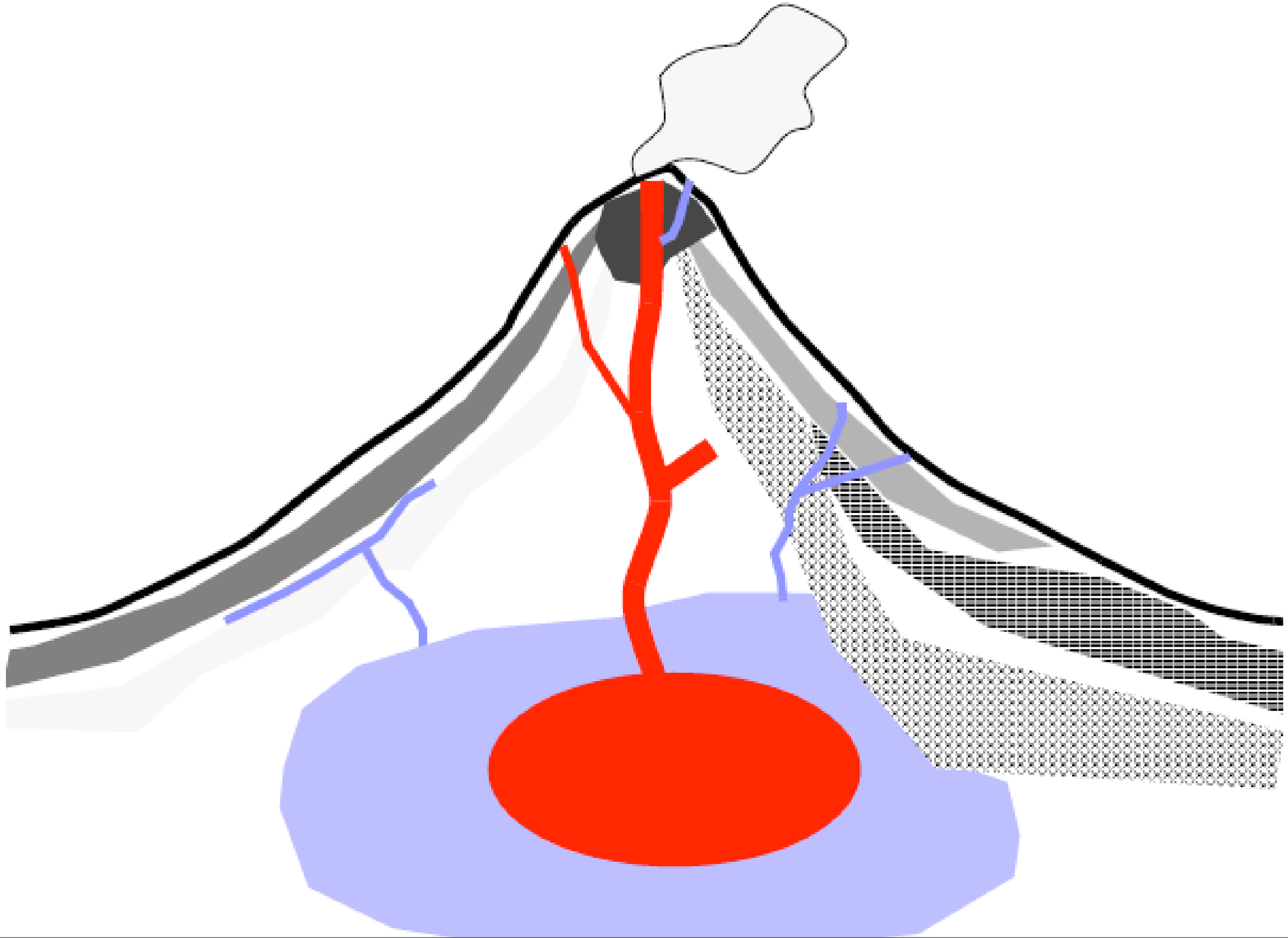

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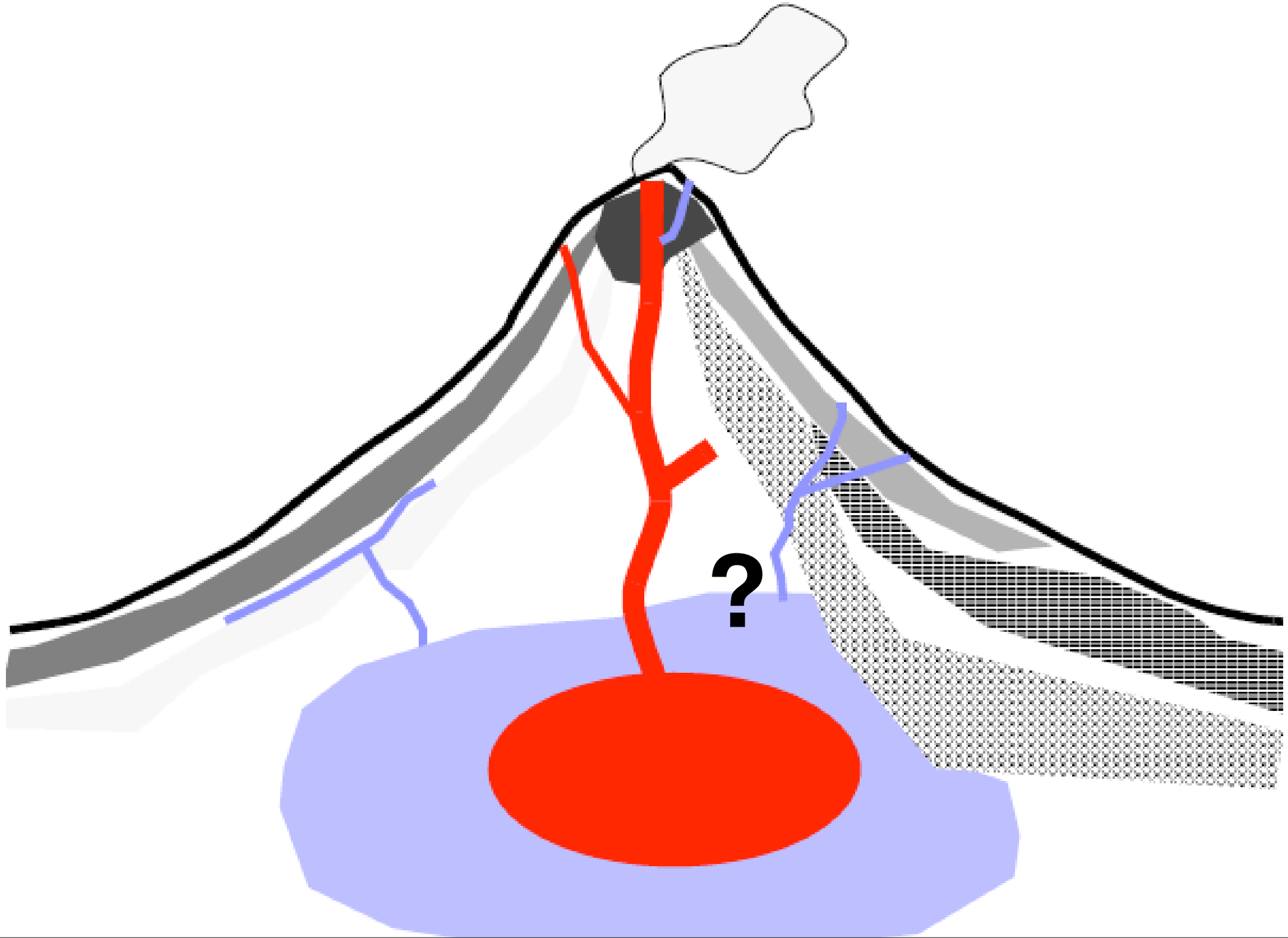

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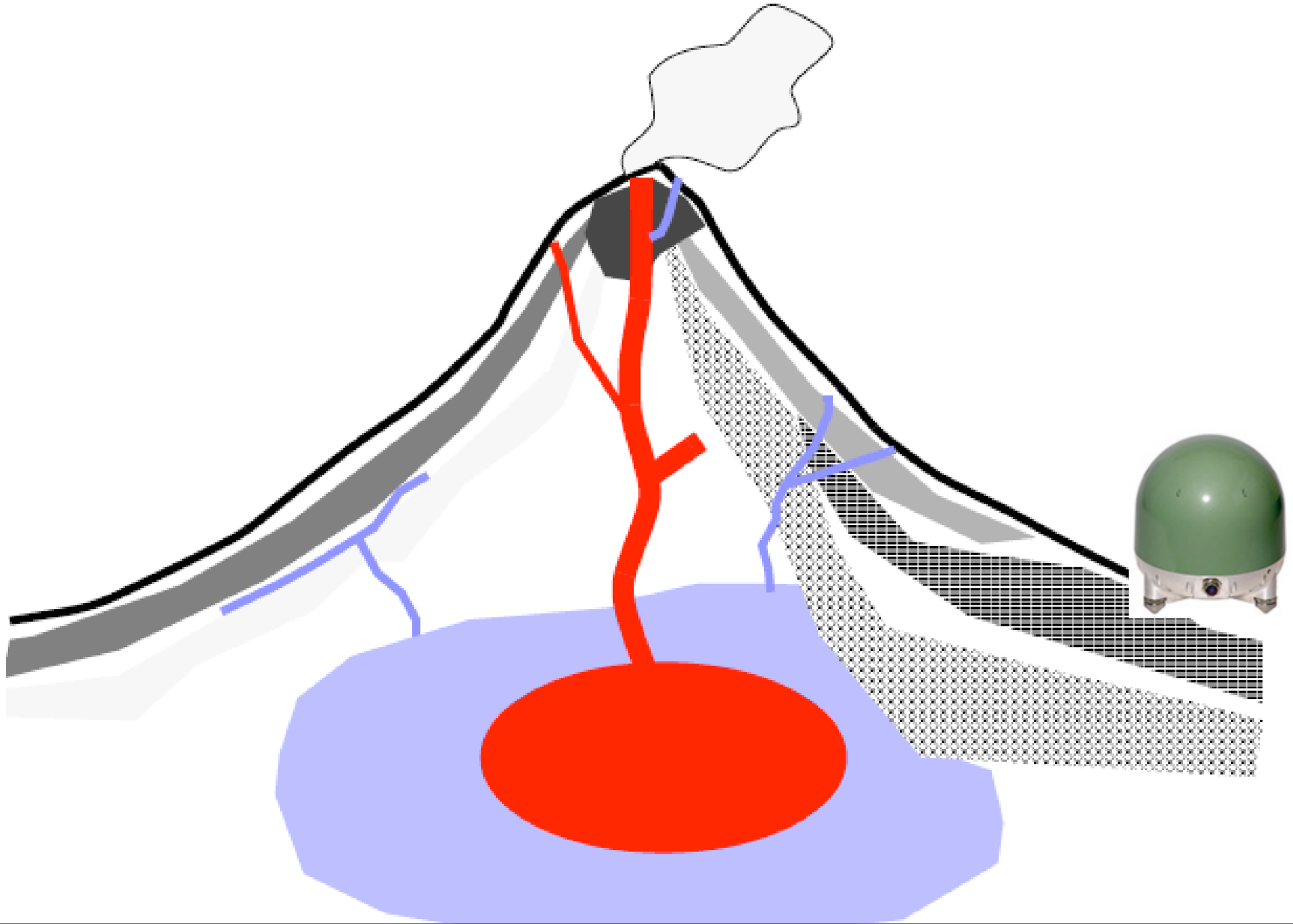

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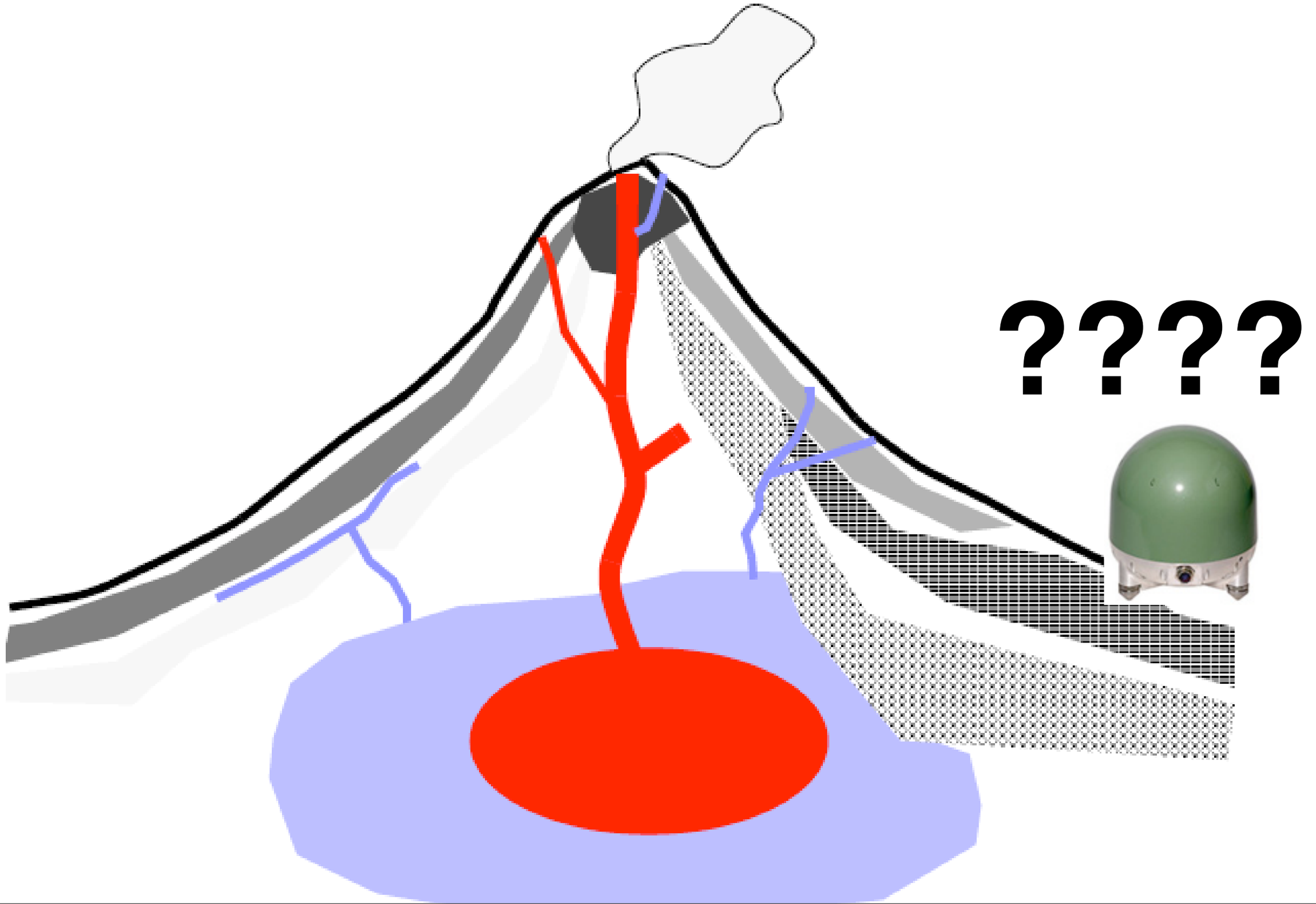

Wie kann die Seismologie bei der Verbesserung von Frühwarnsystemen helfen?

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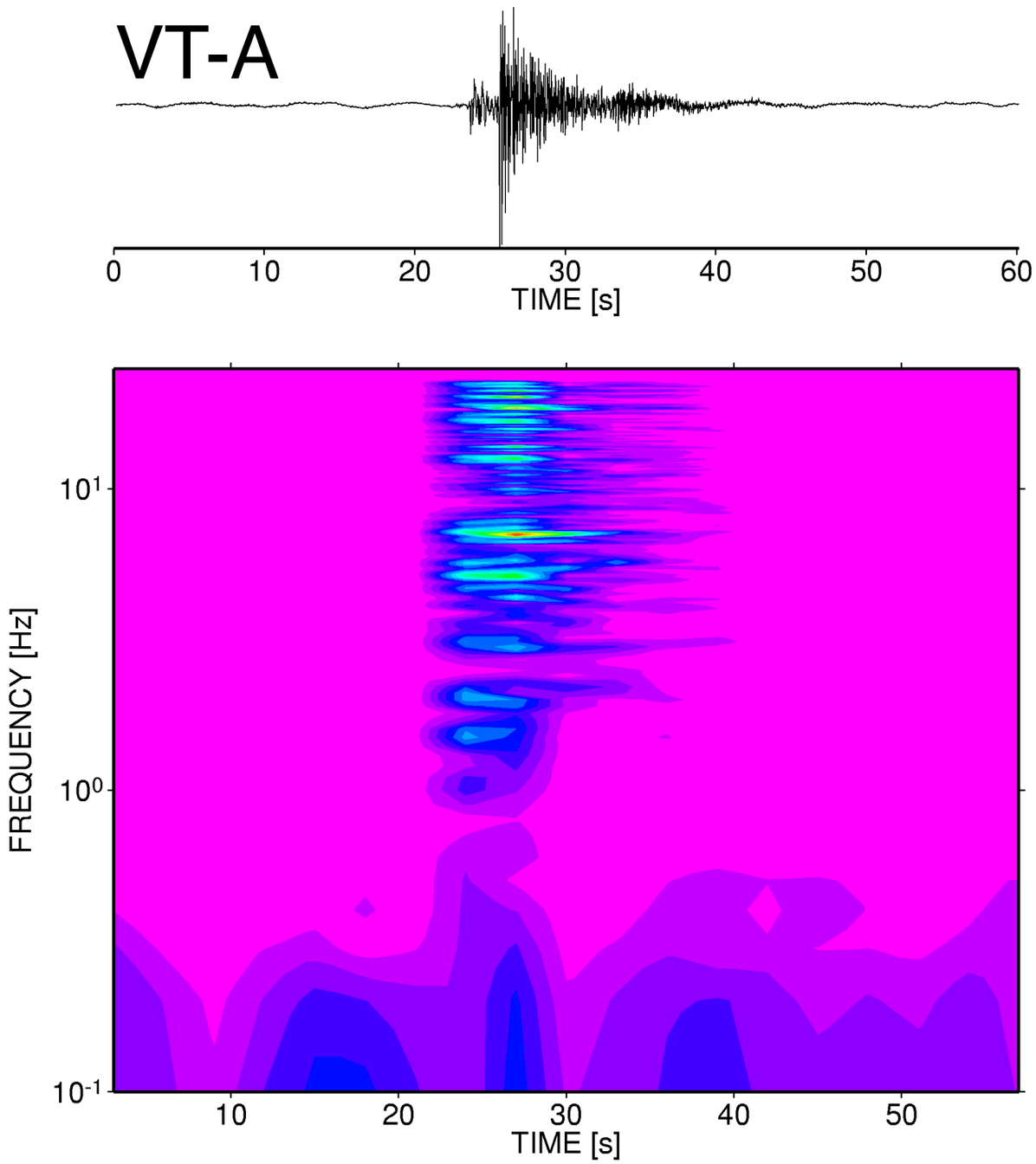
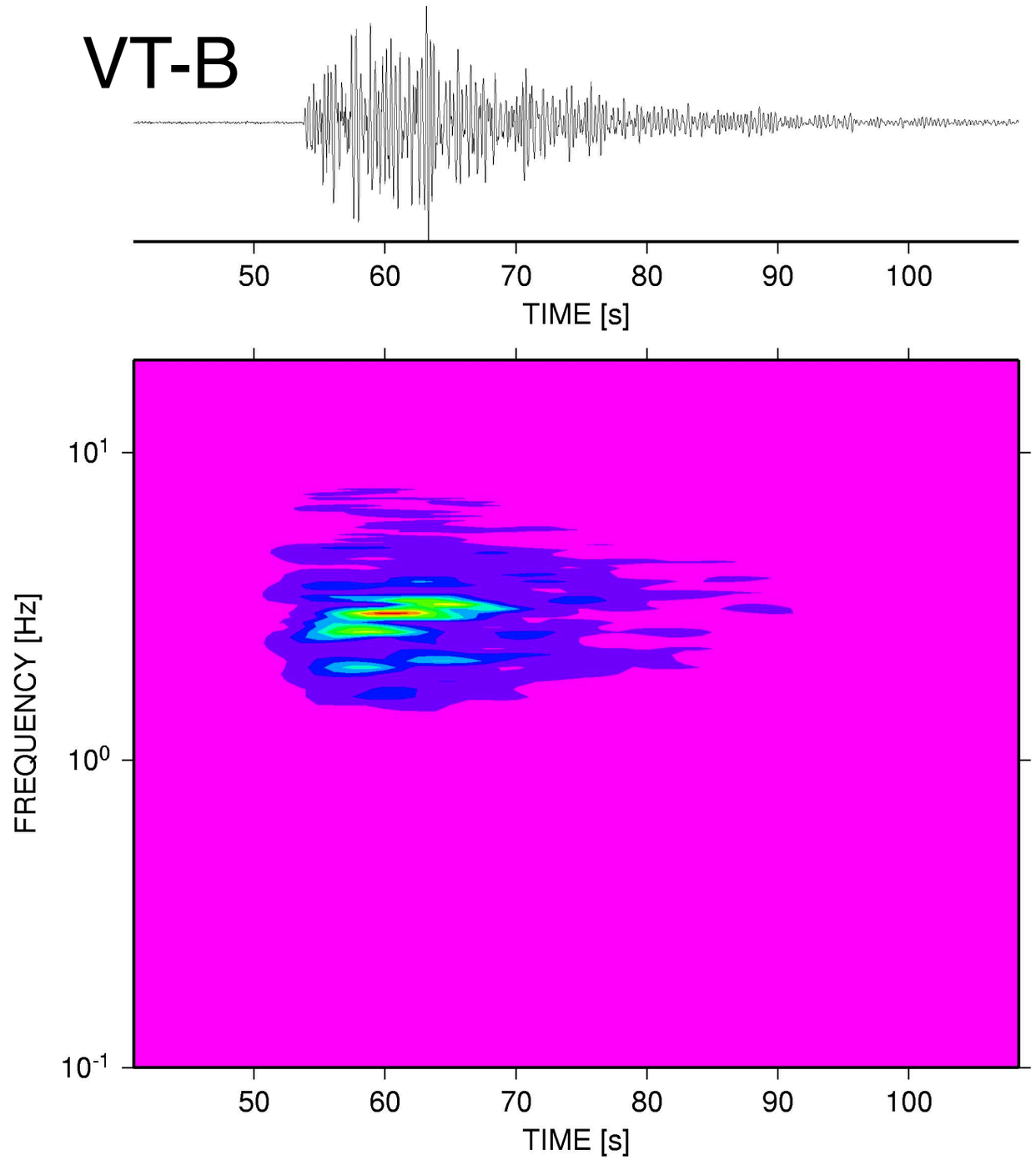
- Instabilität von Gebilden an der Oberfläche (z.B. Lava-Dom)
- Interaktion zwischen heissen magmatischen Körpern und kalter Umgebung (z.B., Magma – Wasser Interaktion)

Einige Beispiele





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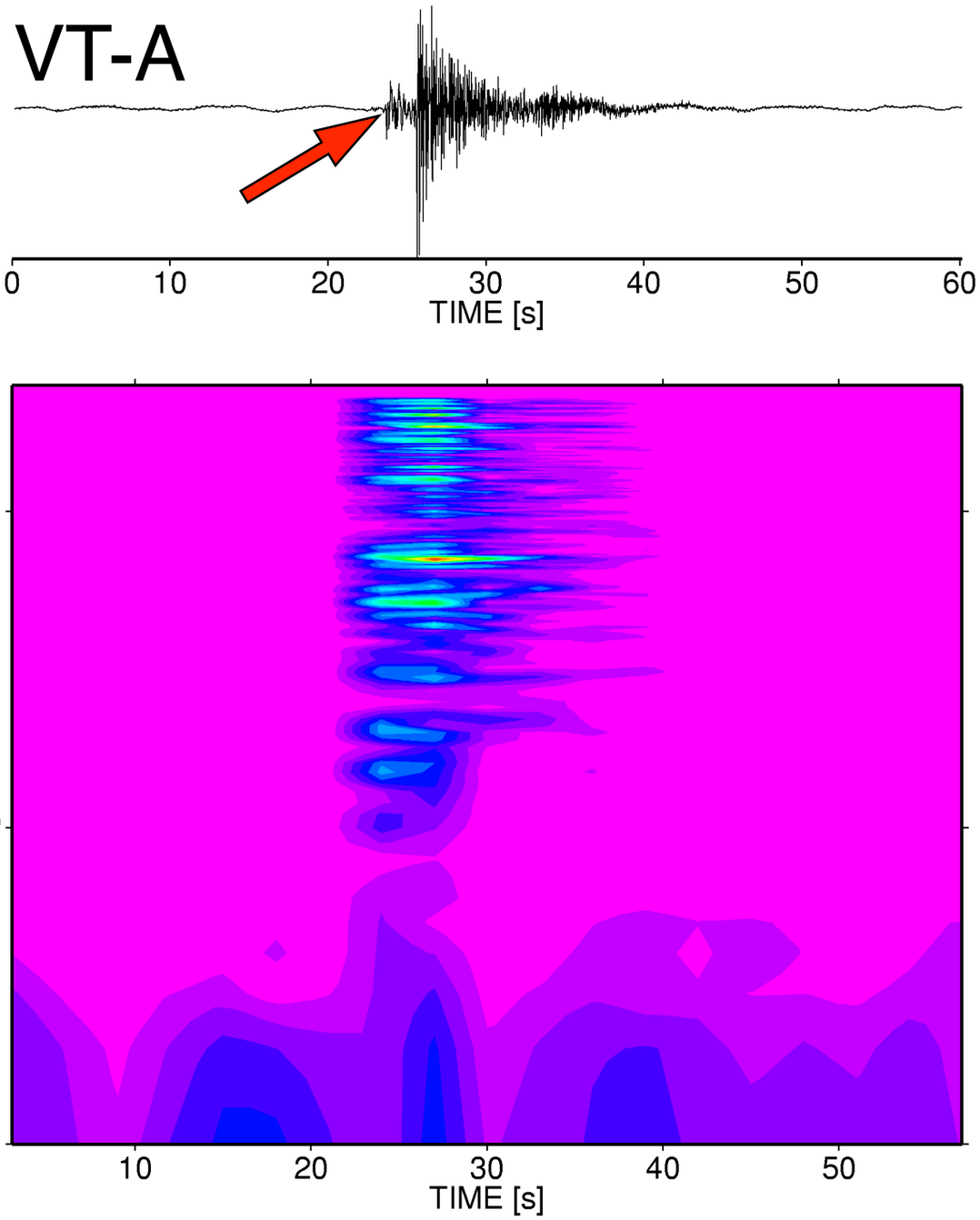
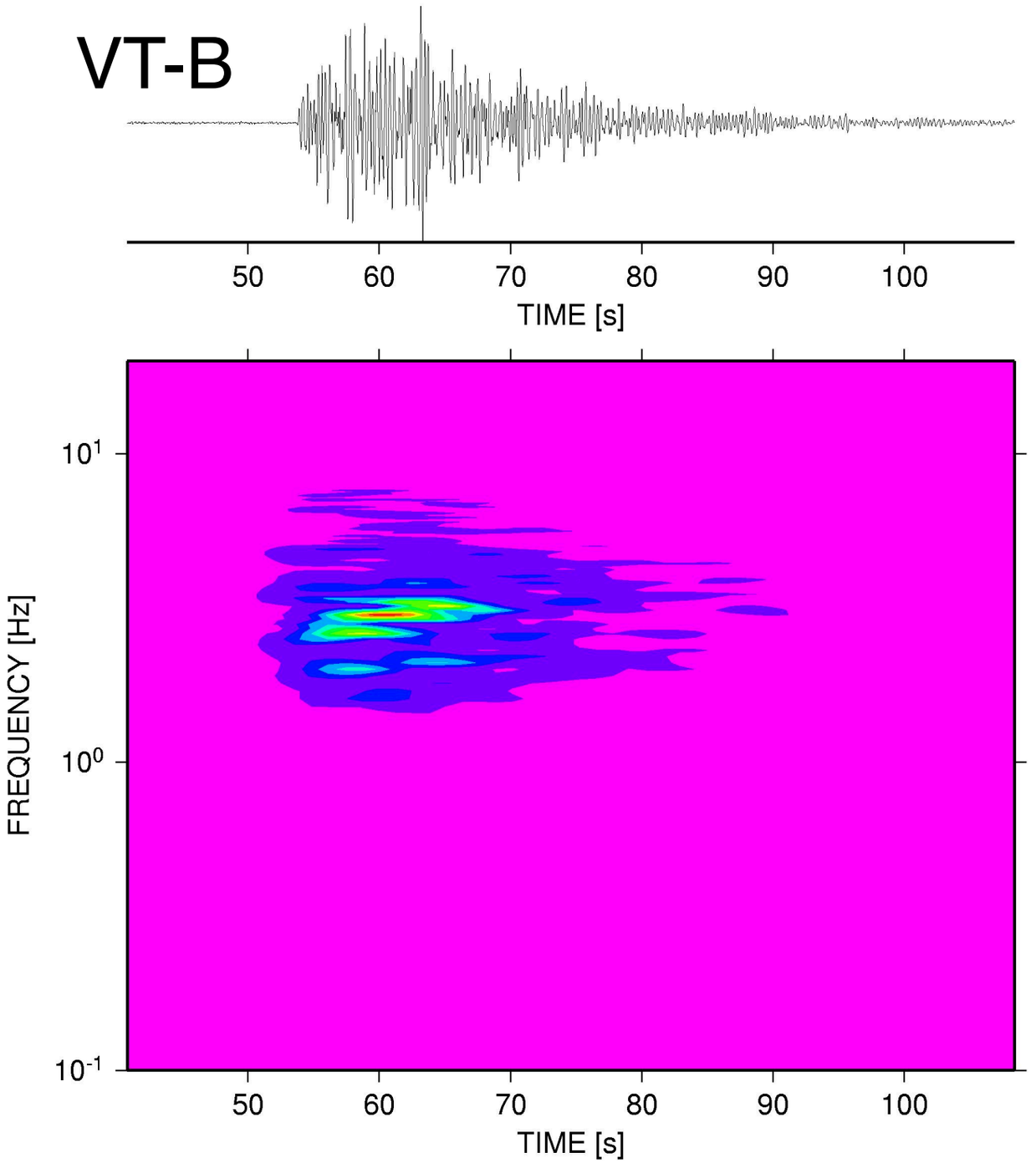
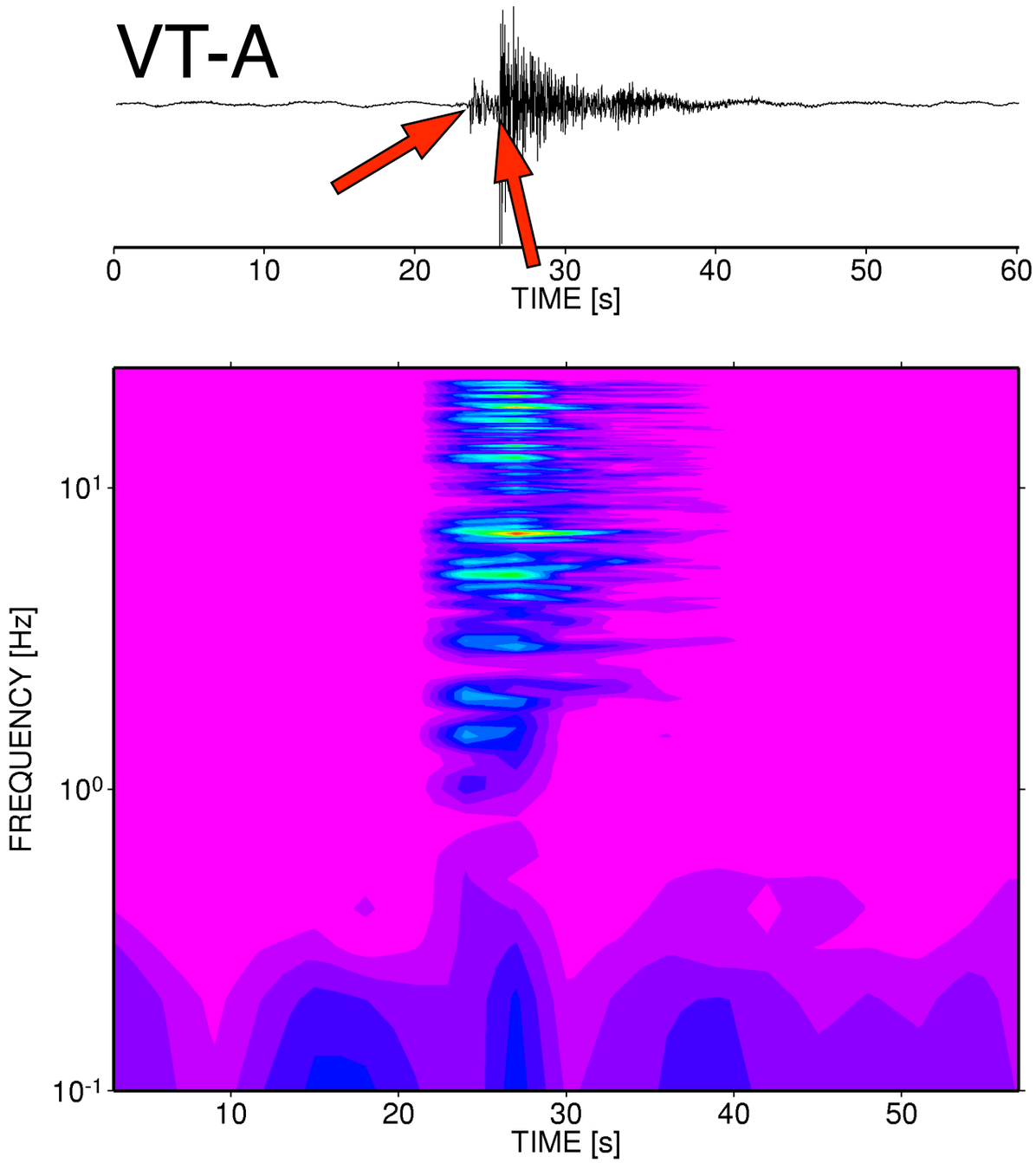
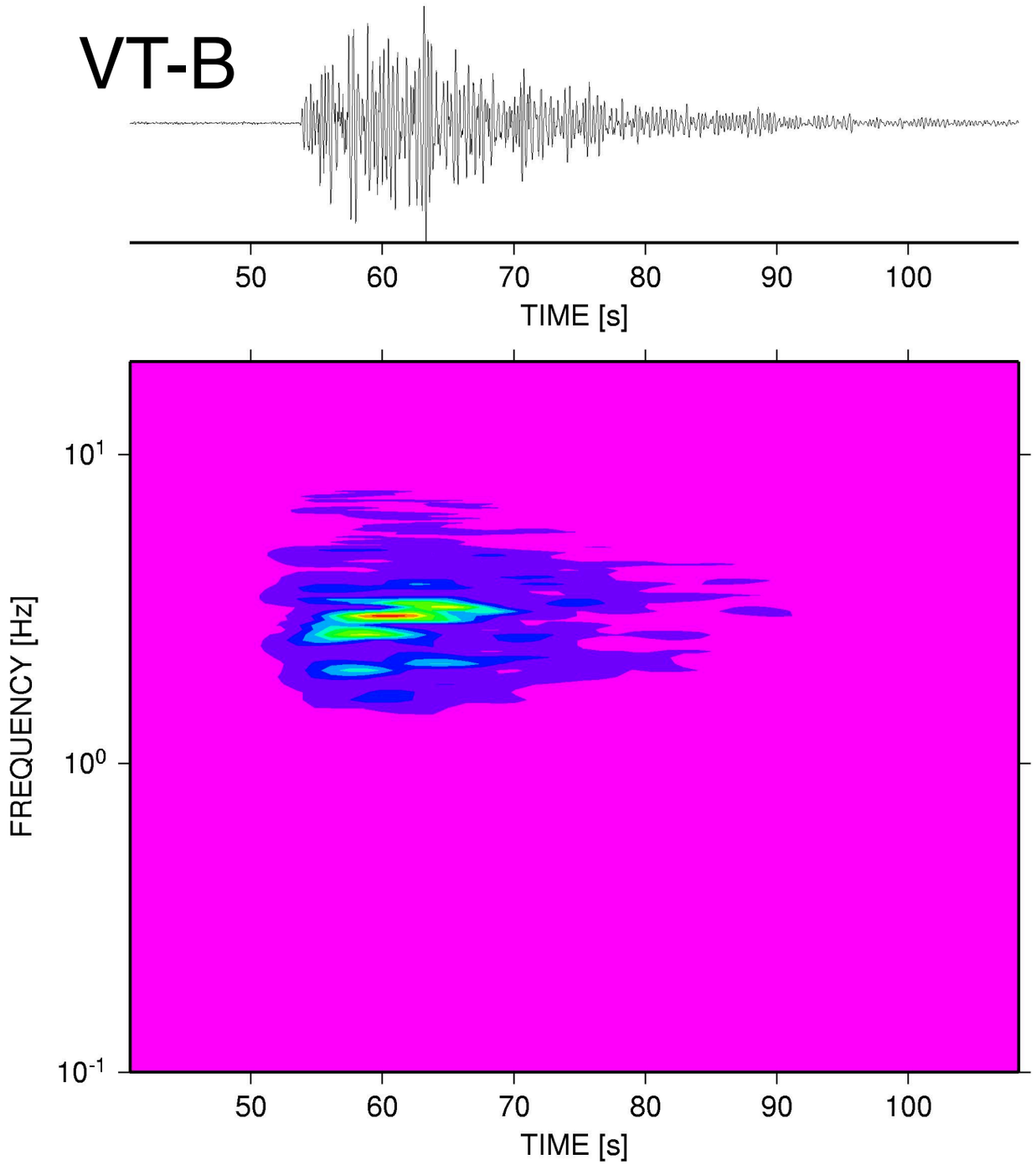


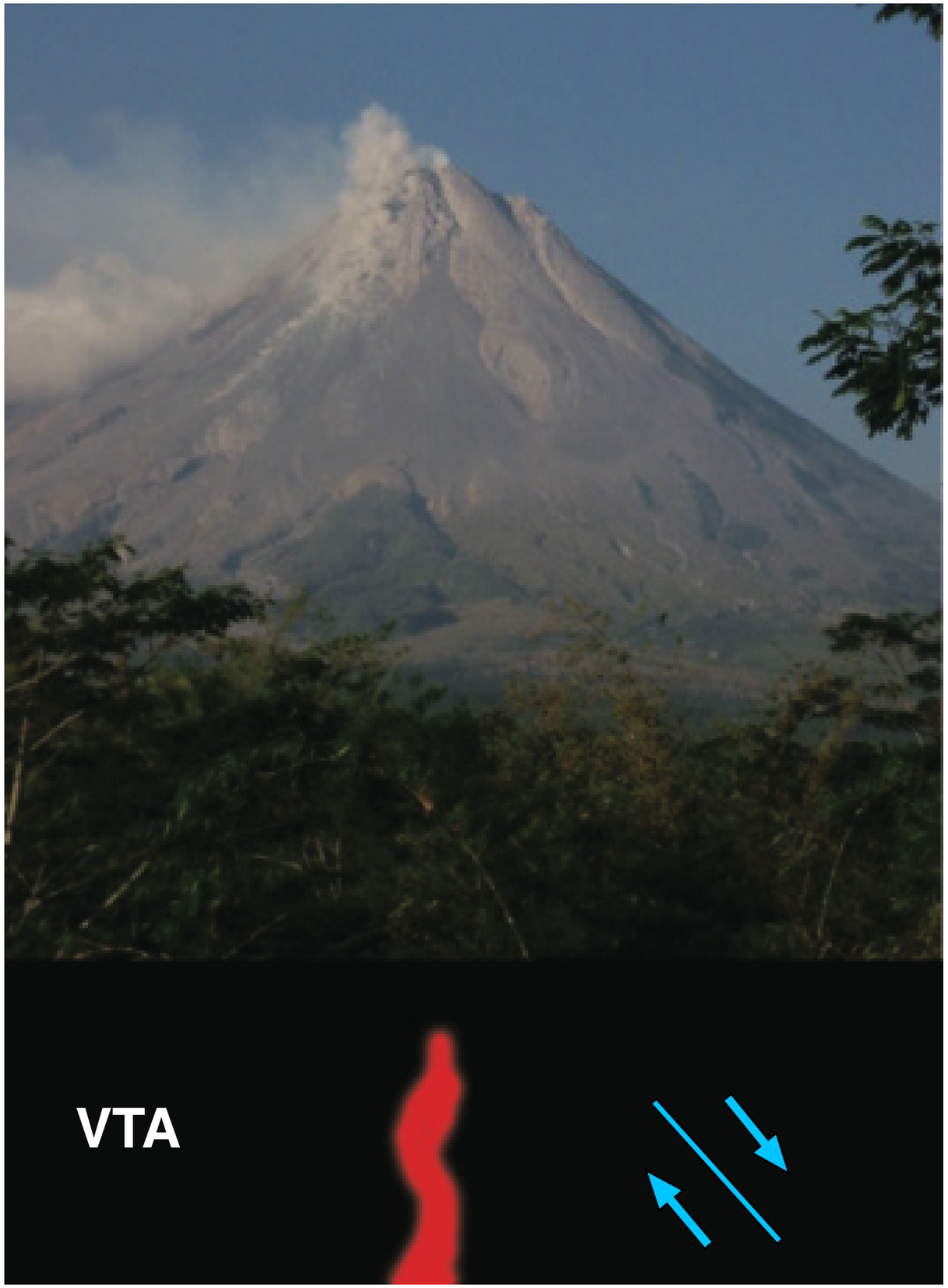


Einige Beispiele






VTA


VTA

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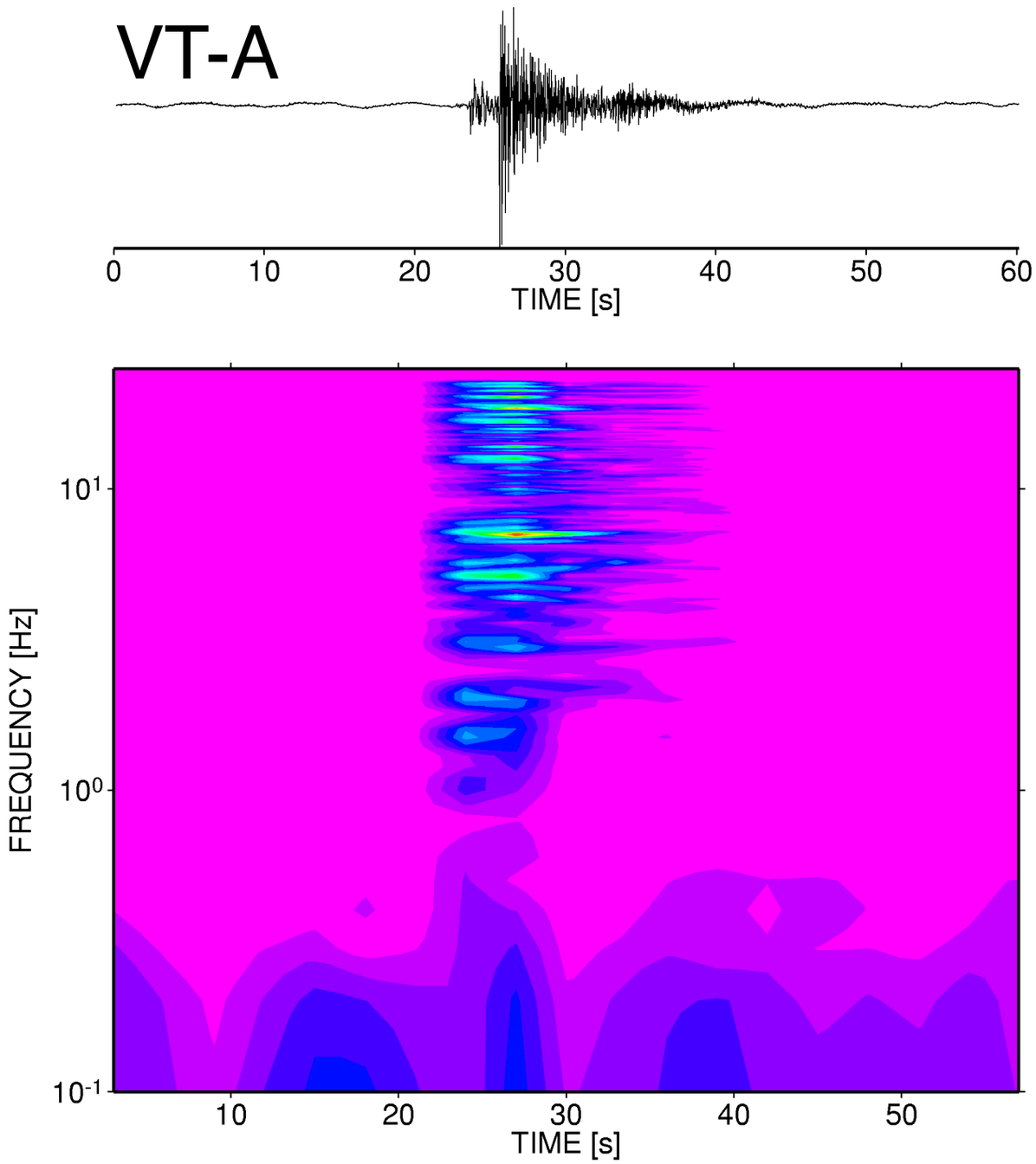

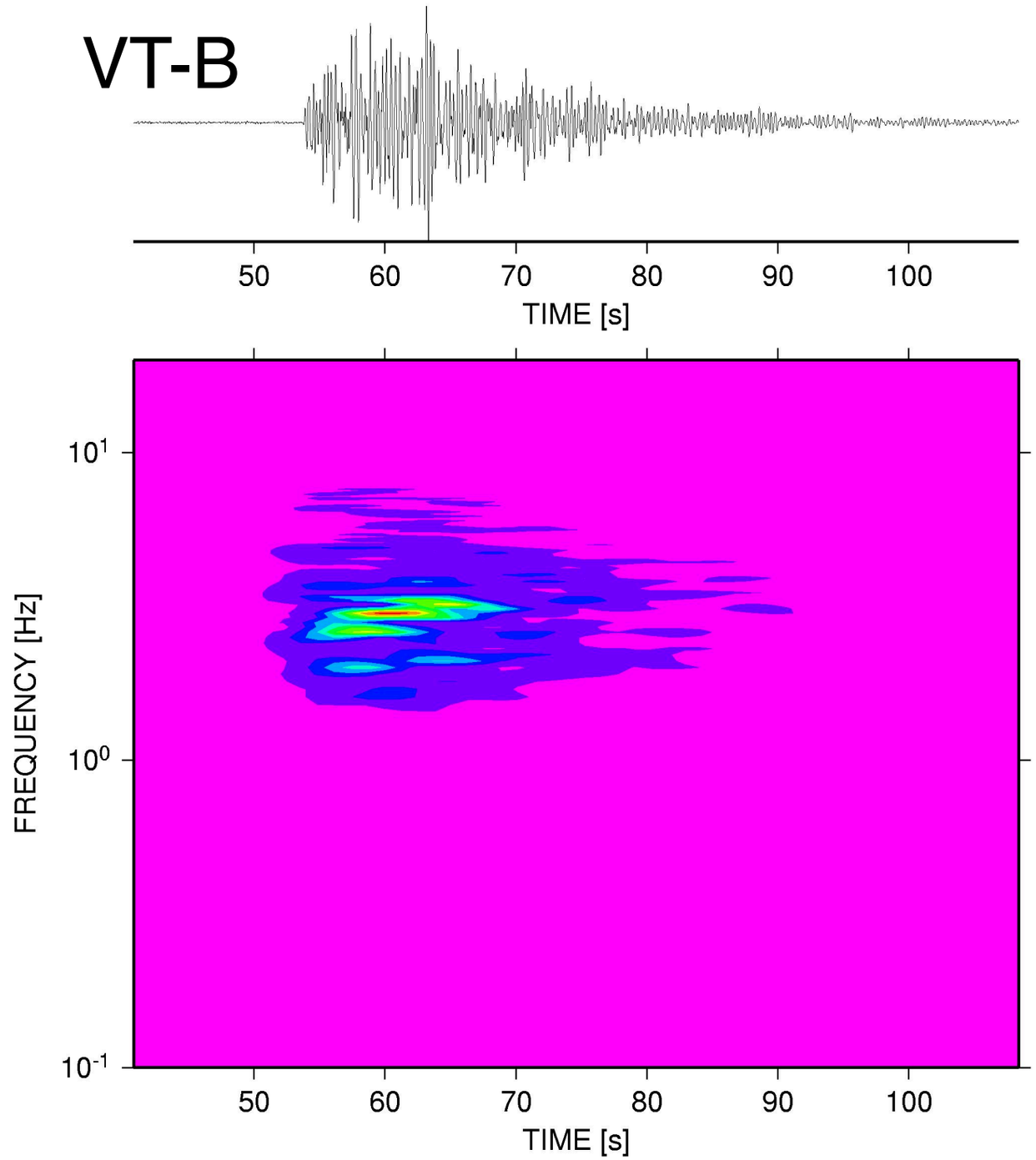

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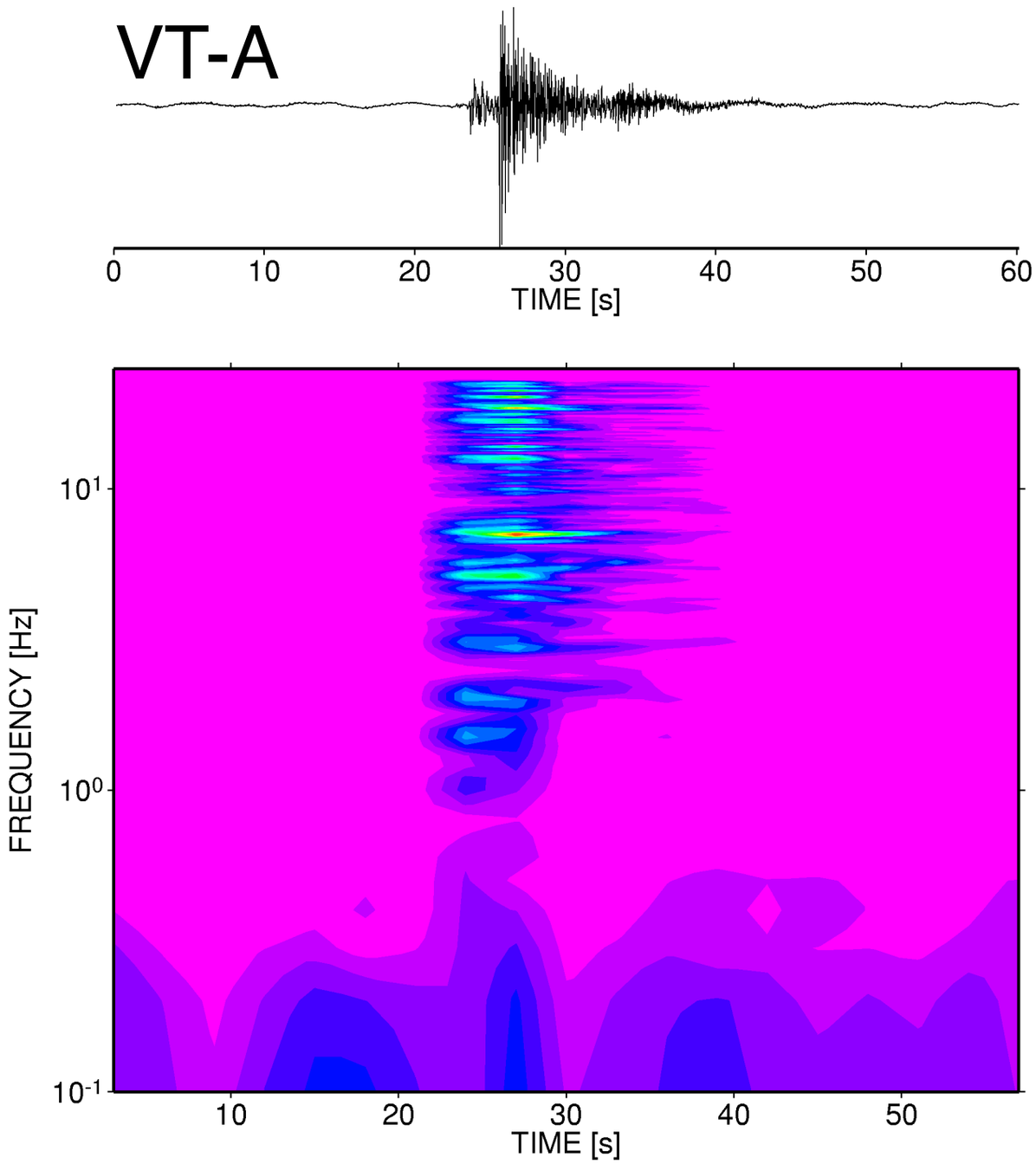
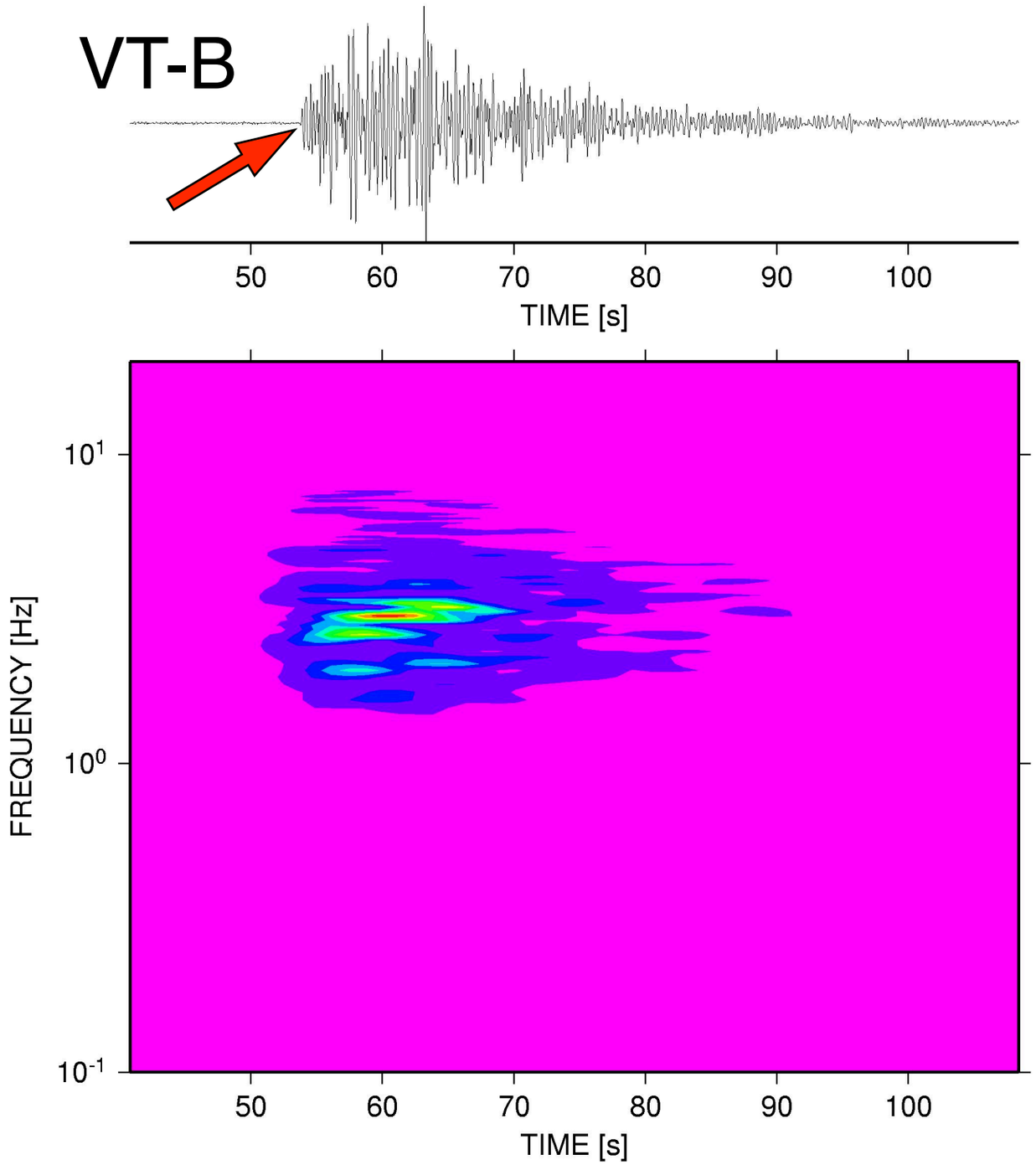
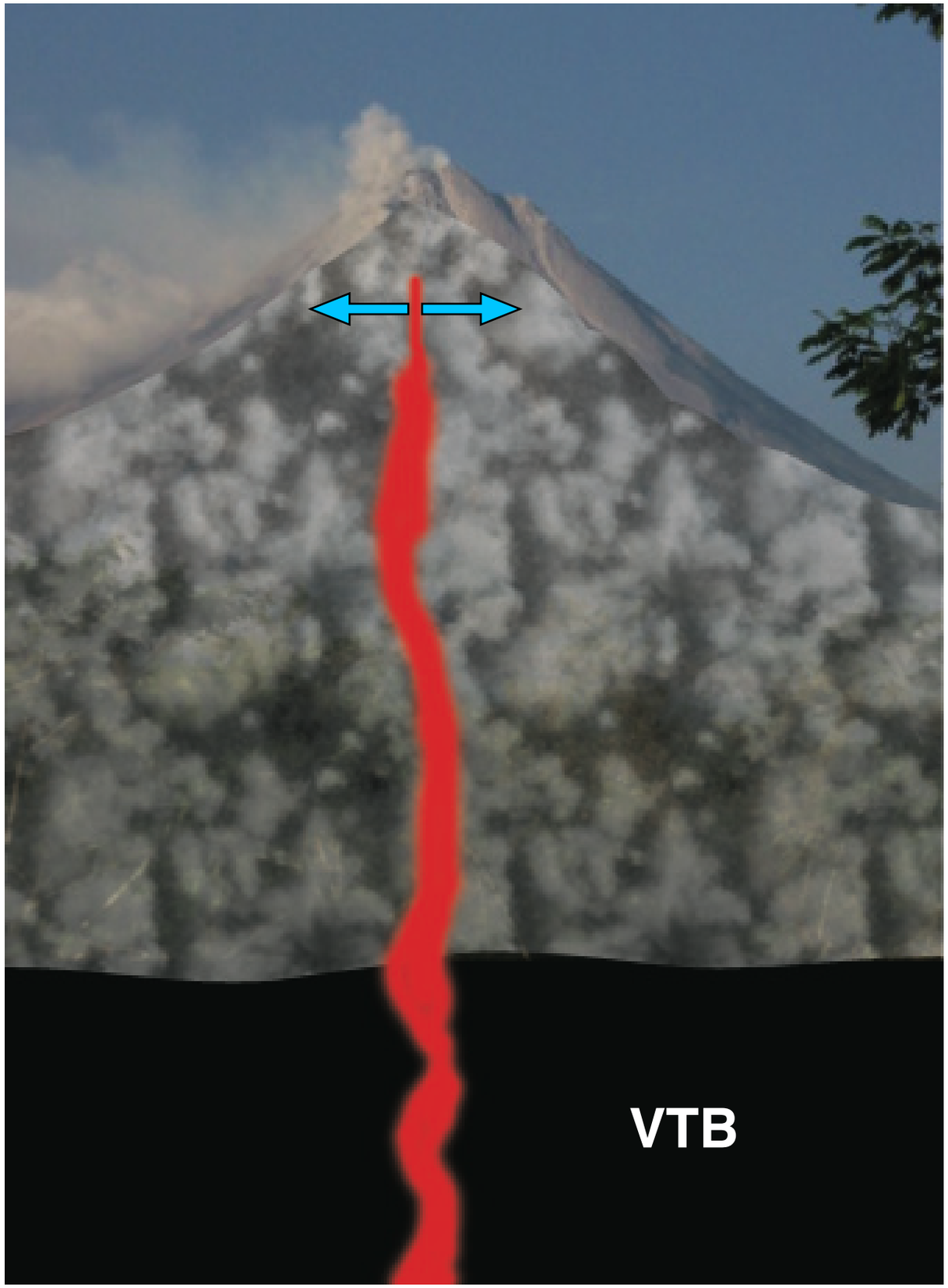
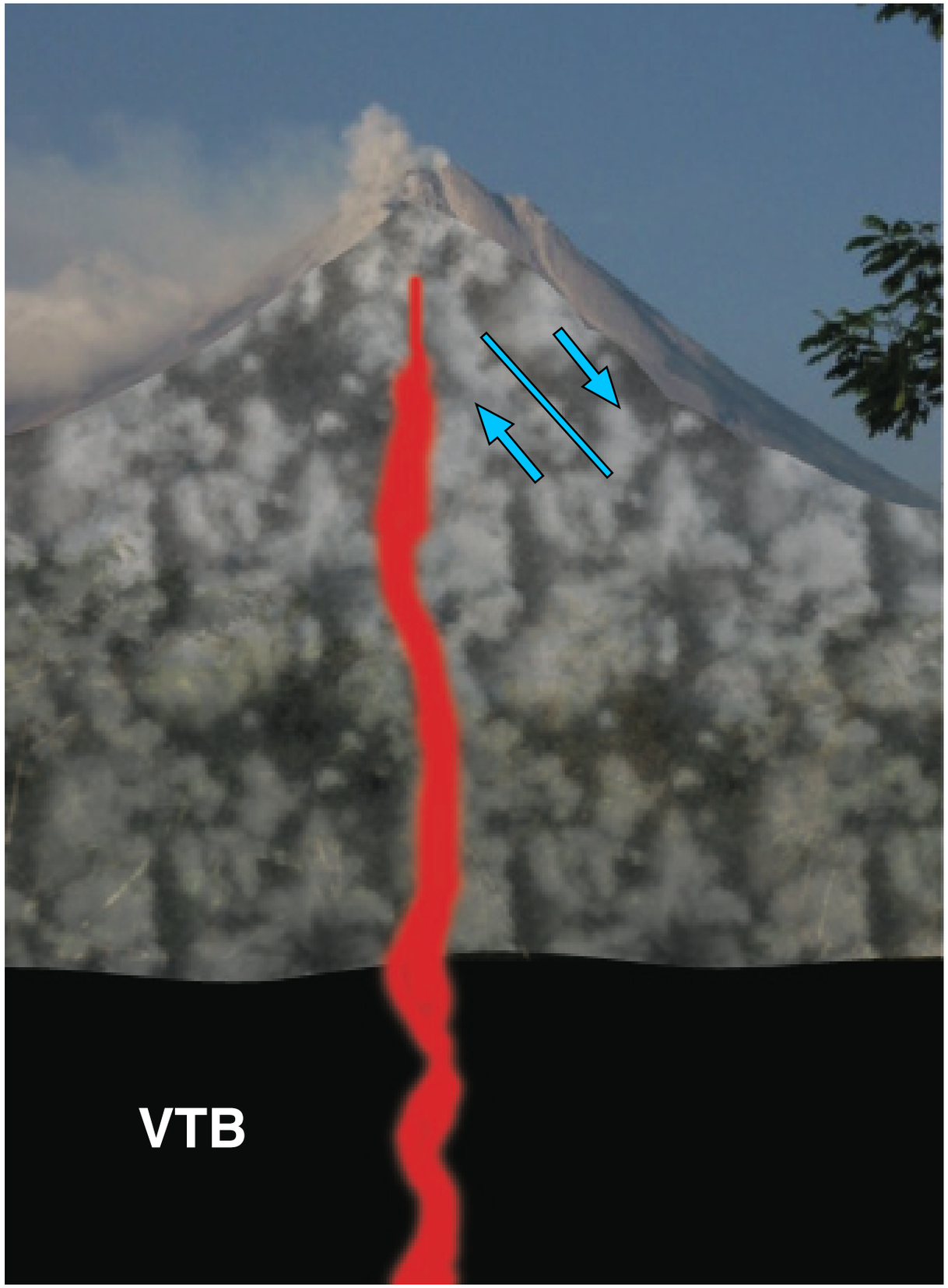


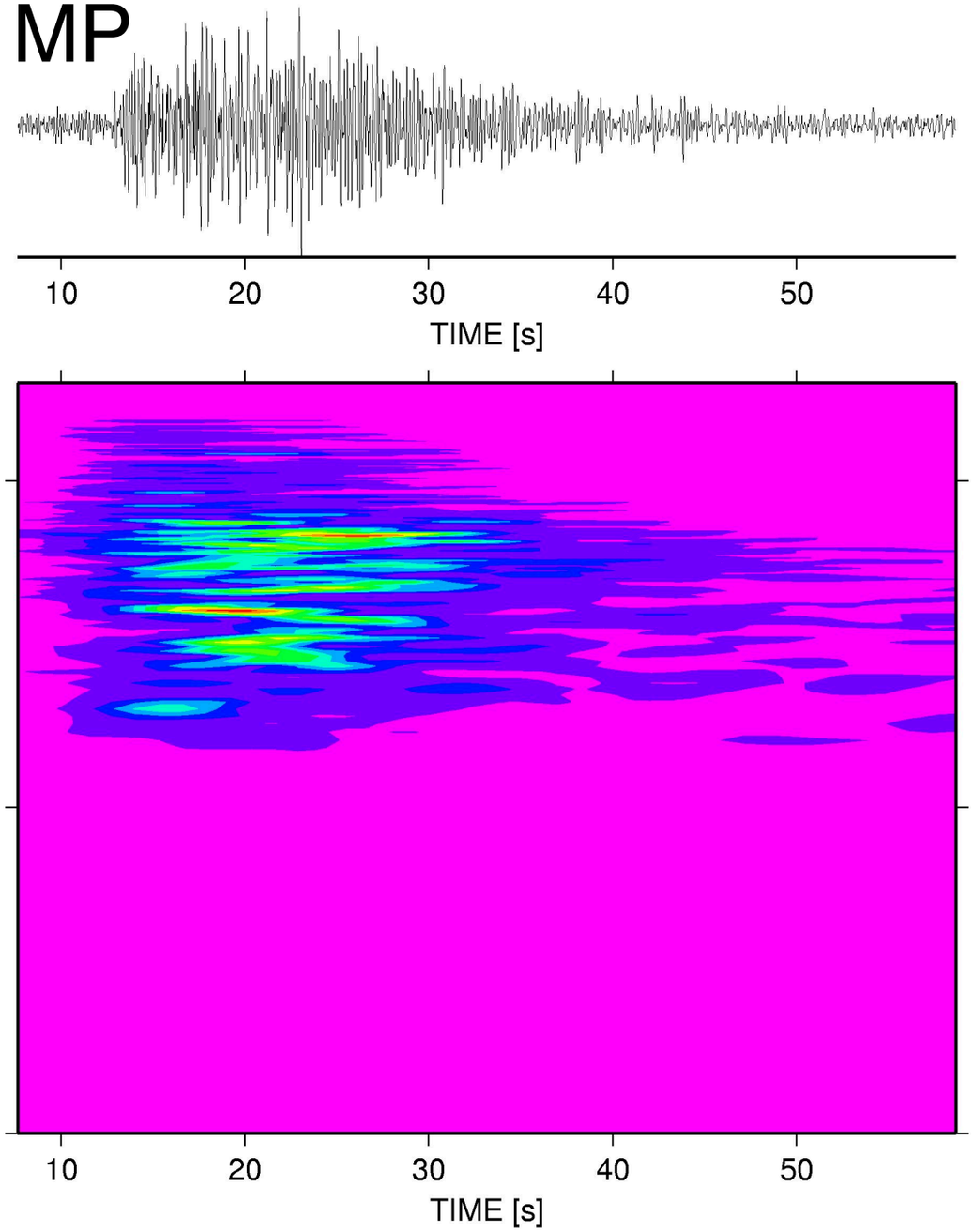



VTB

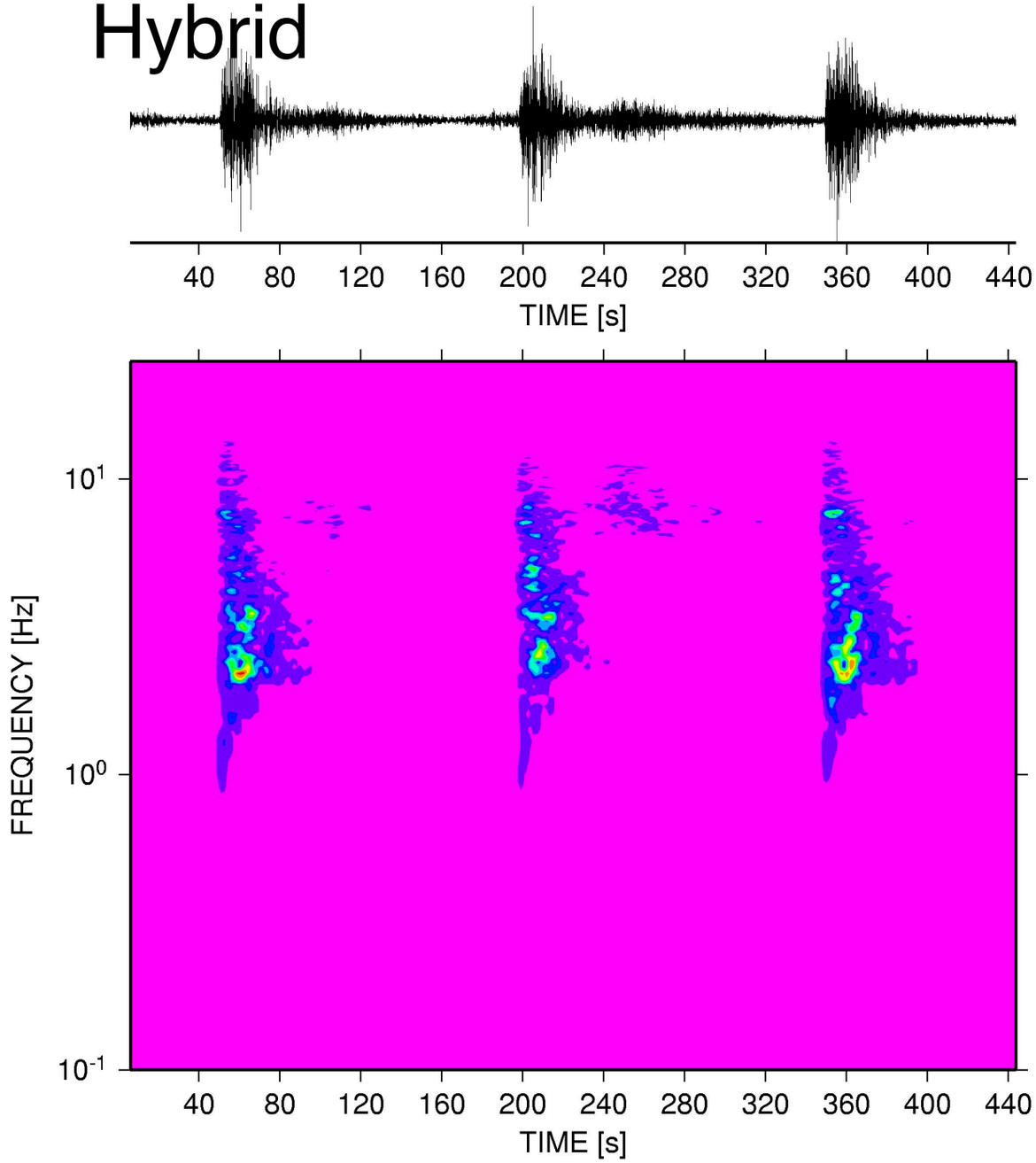

VTB

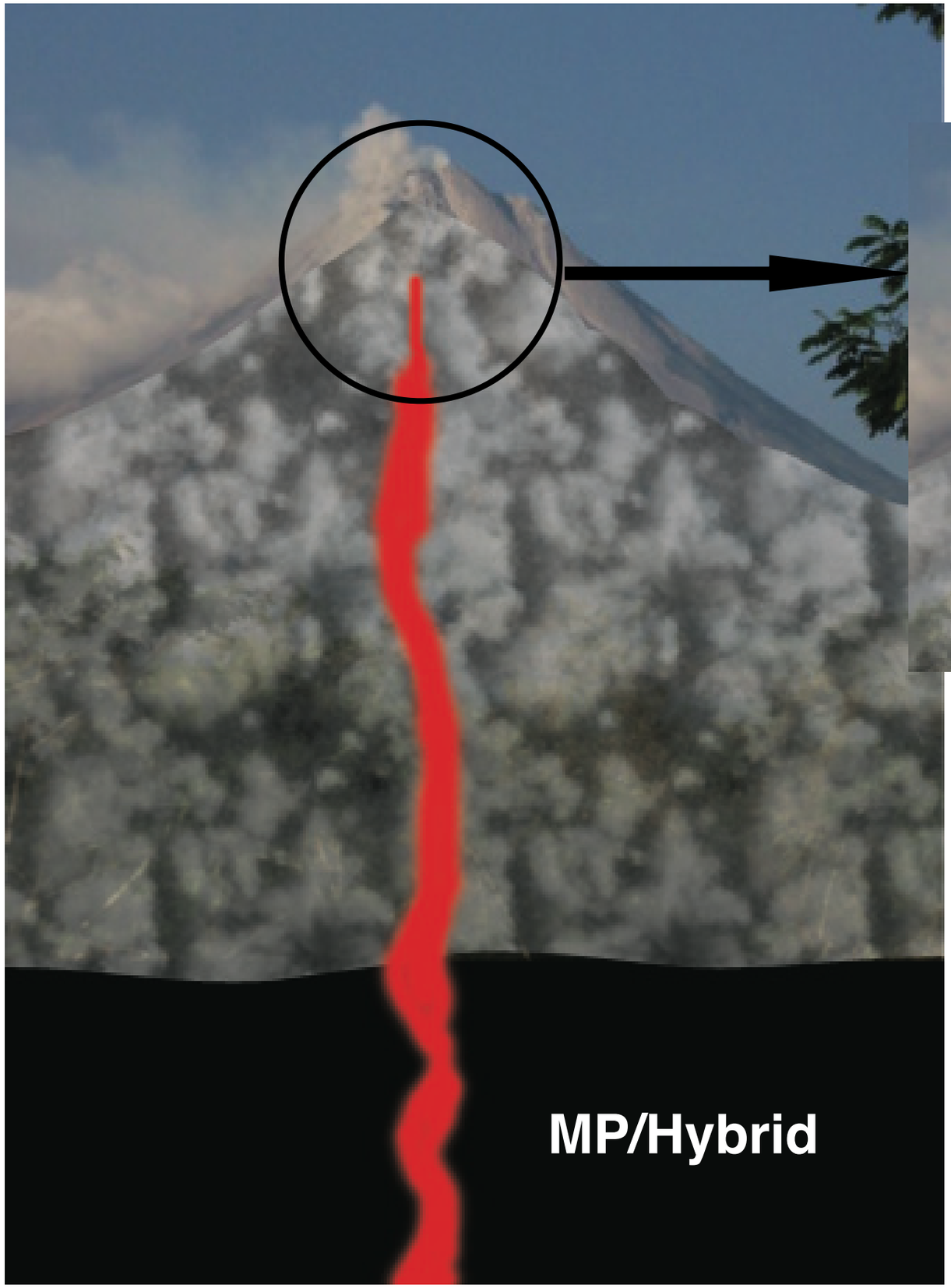
Einige Beispiele

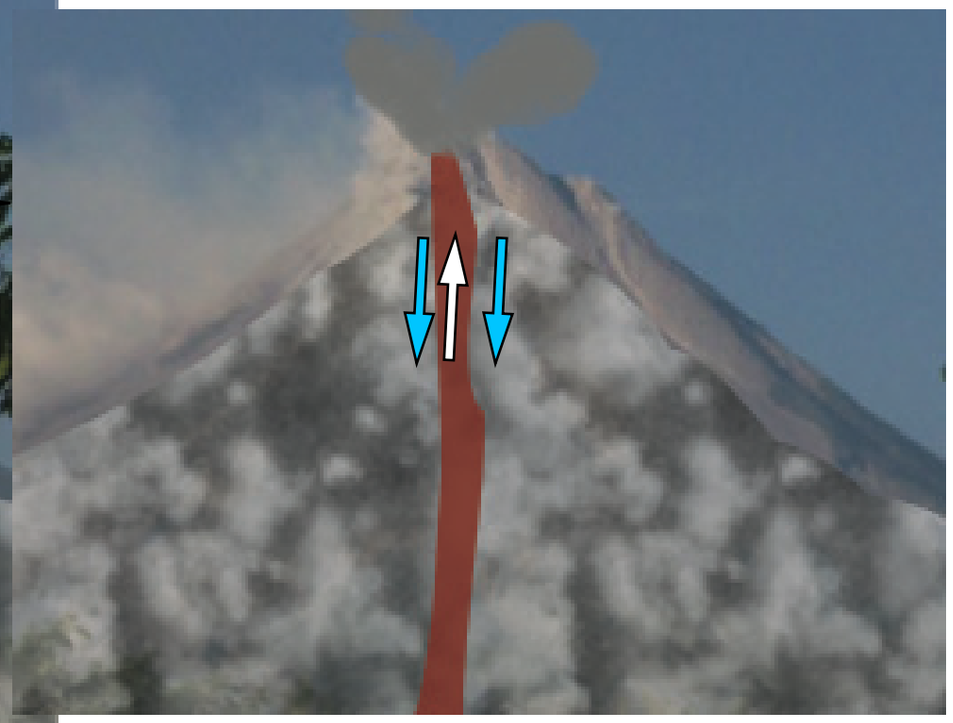
MP



Hybrid



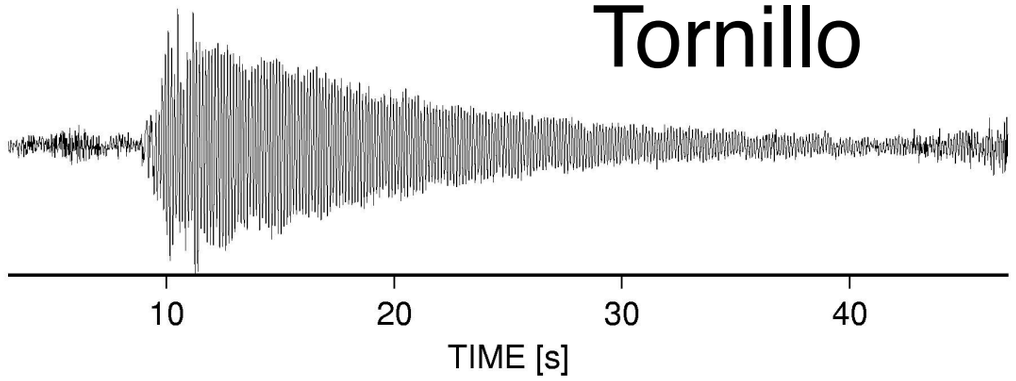


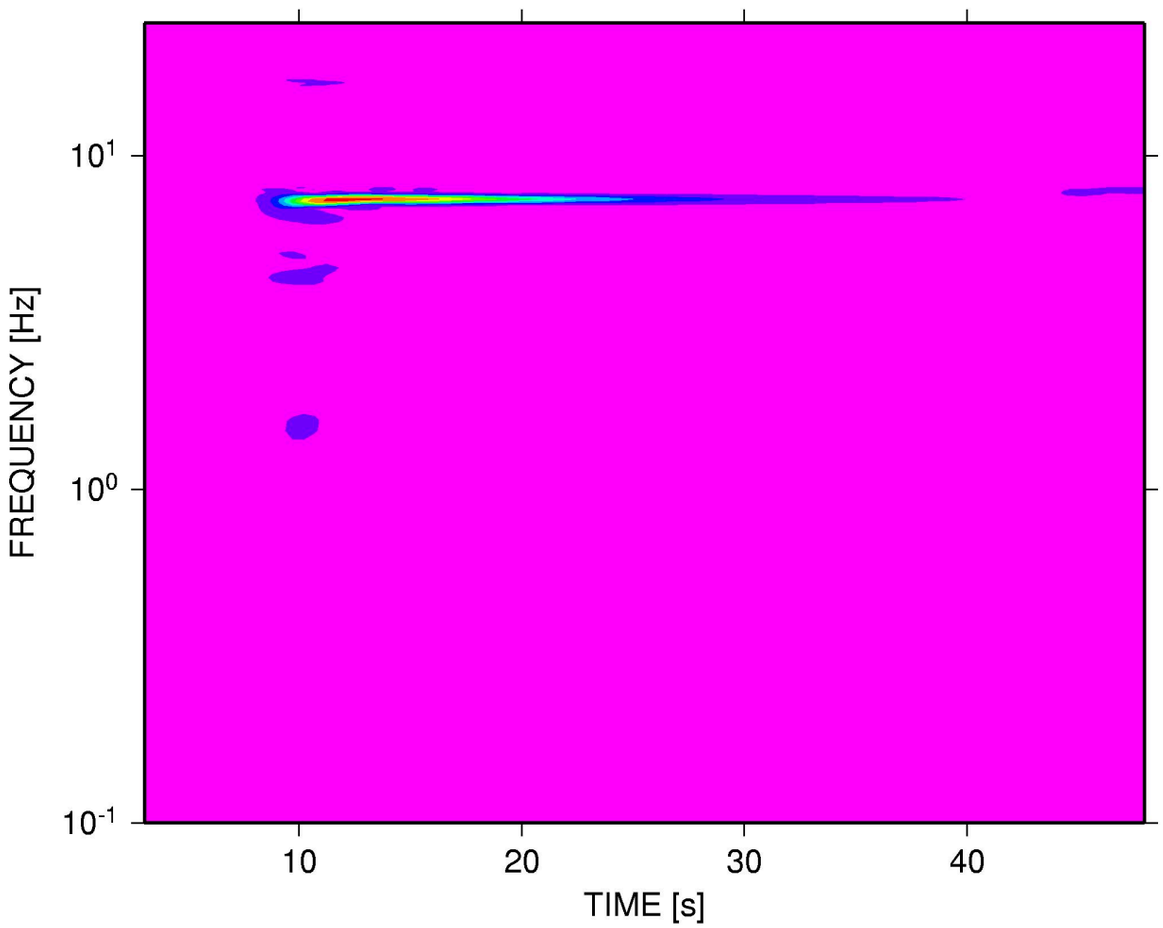


“Stick-Slip” oder
“instant Healing”

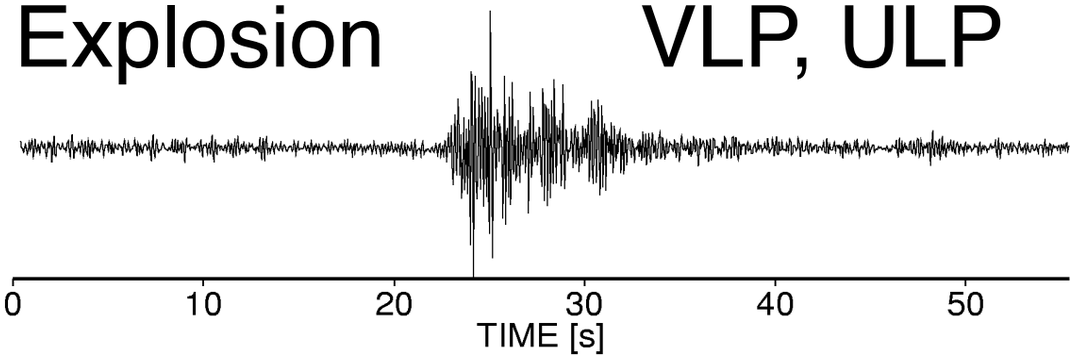
Einige Beispiele

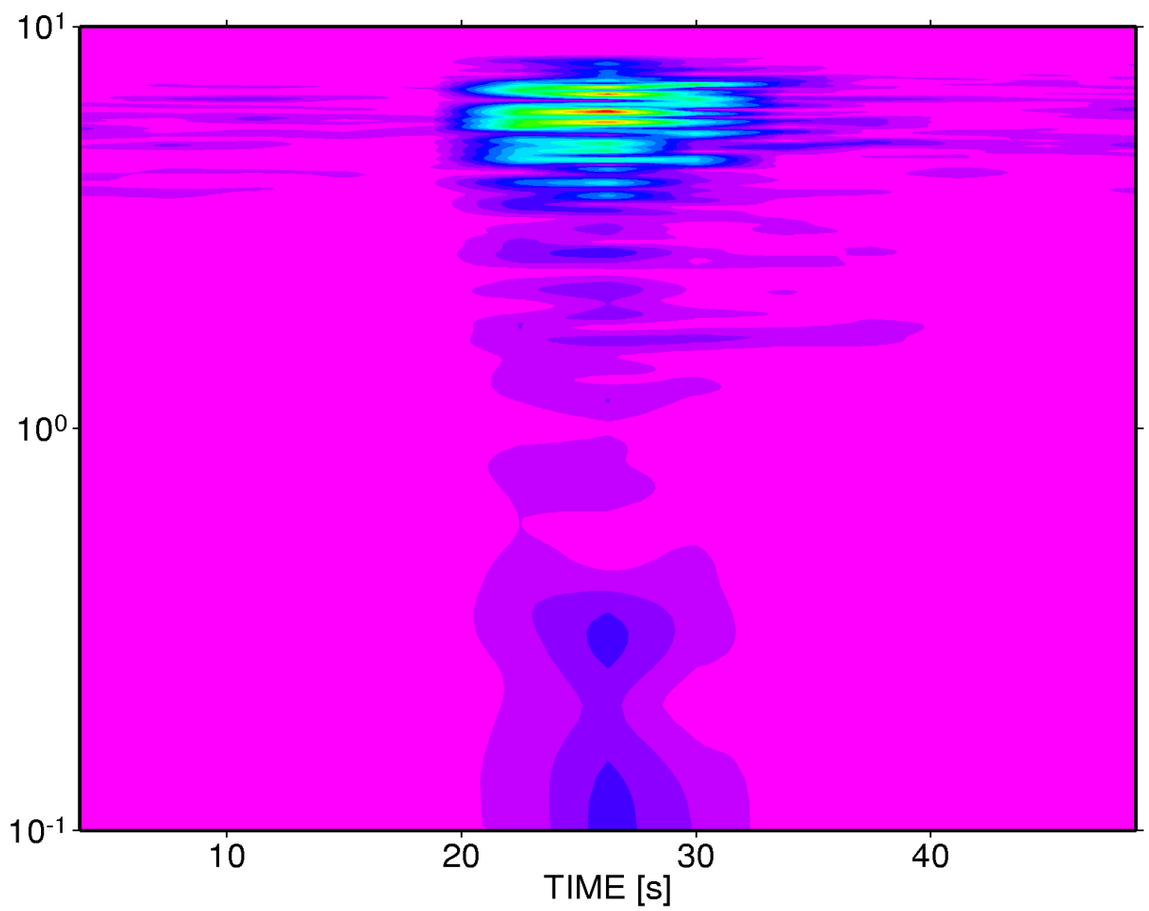
Tornillo

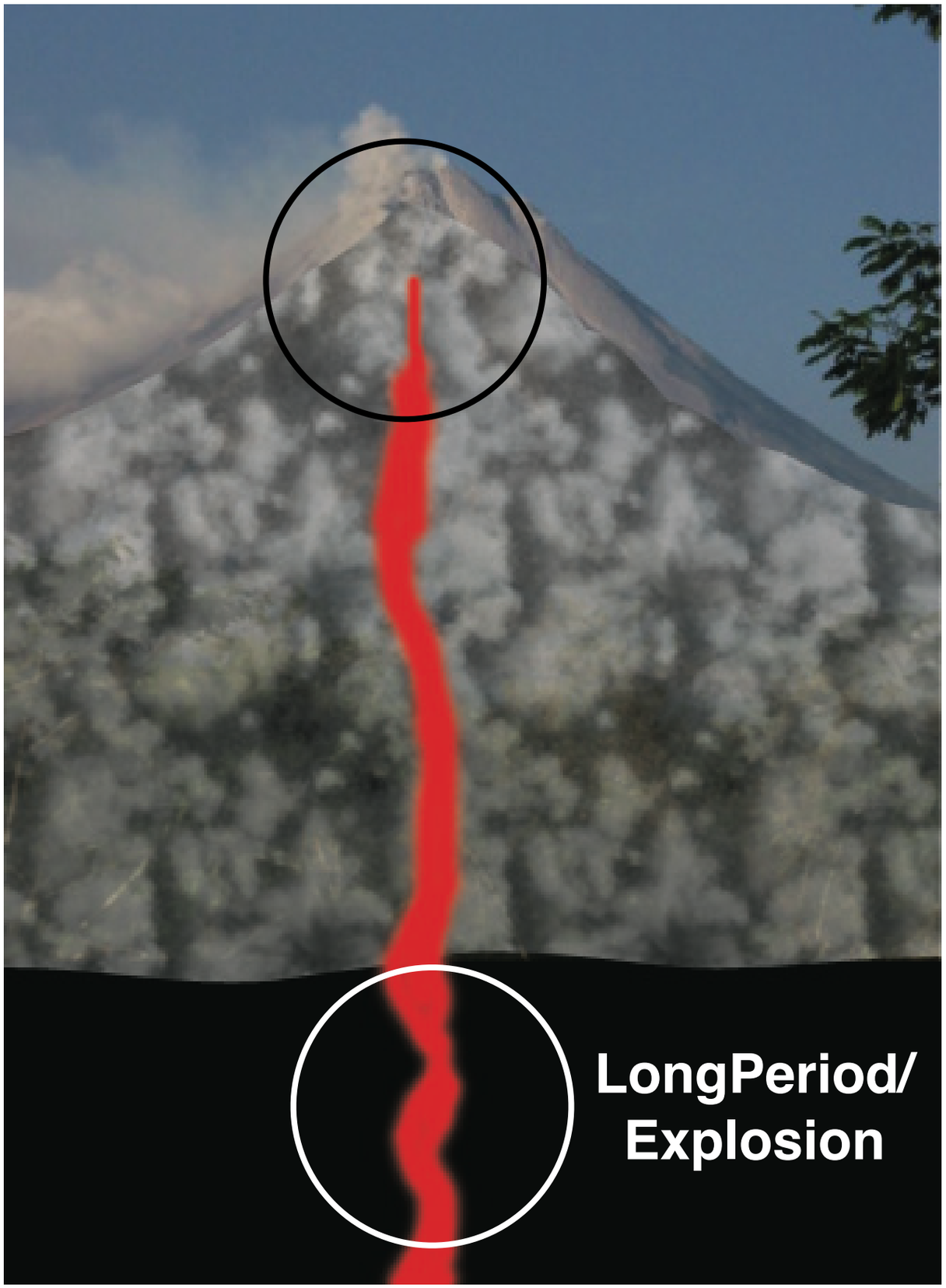


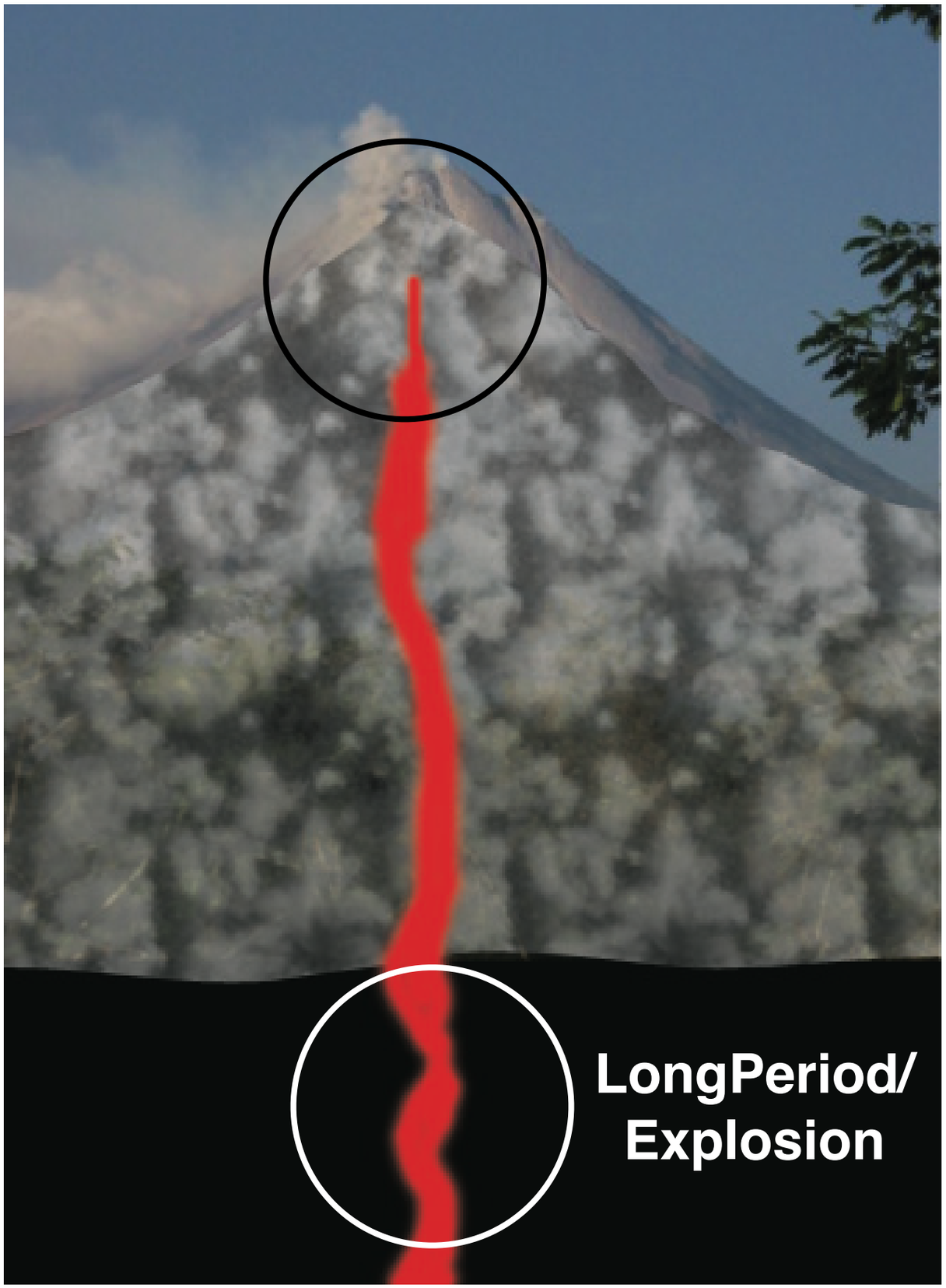


Explosion VLP, ULP






LongPeriod/
Explosion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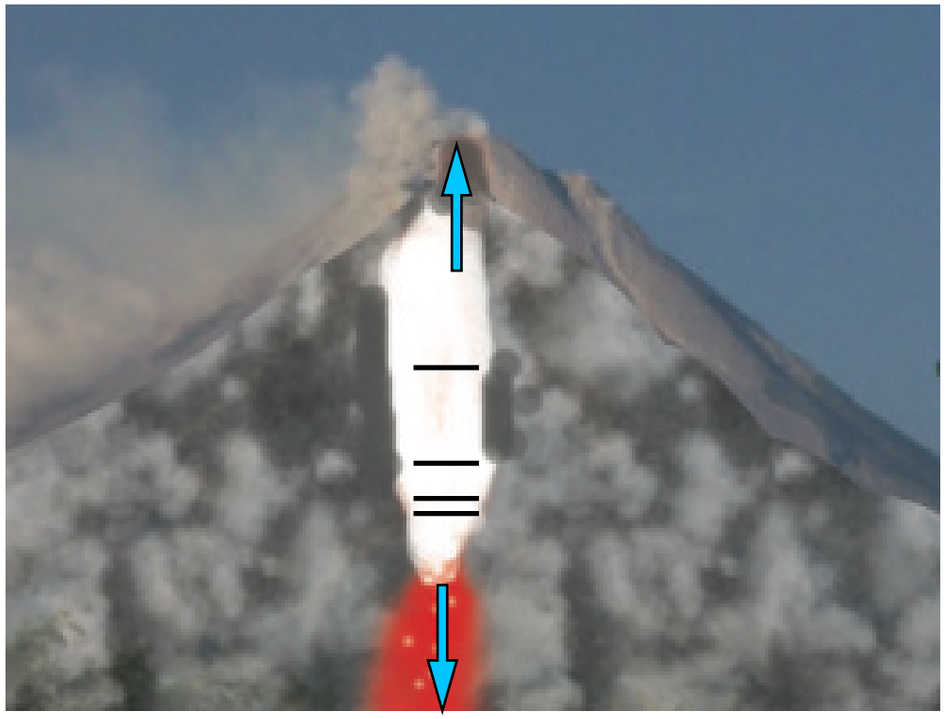

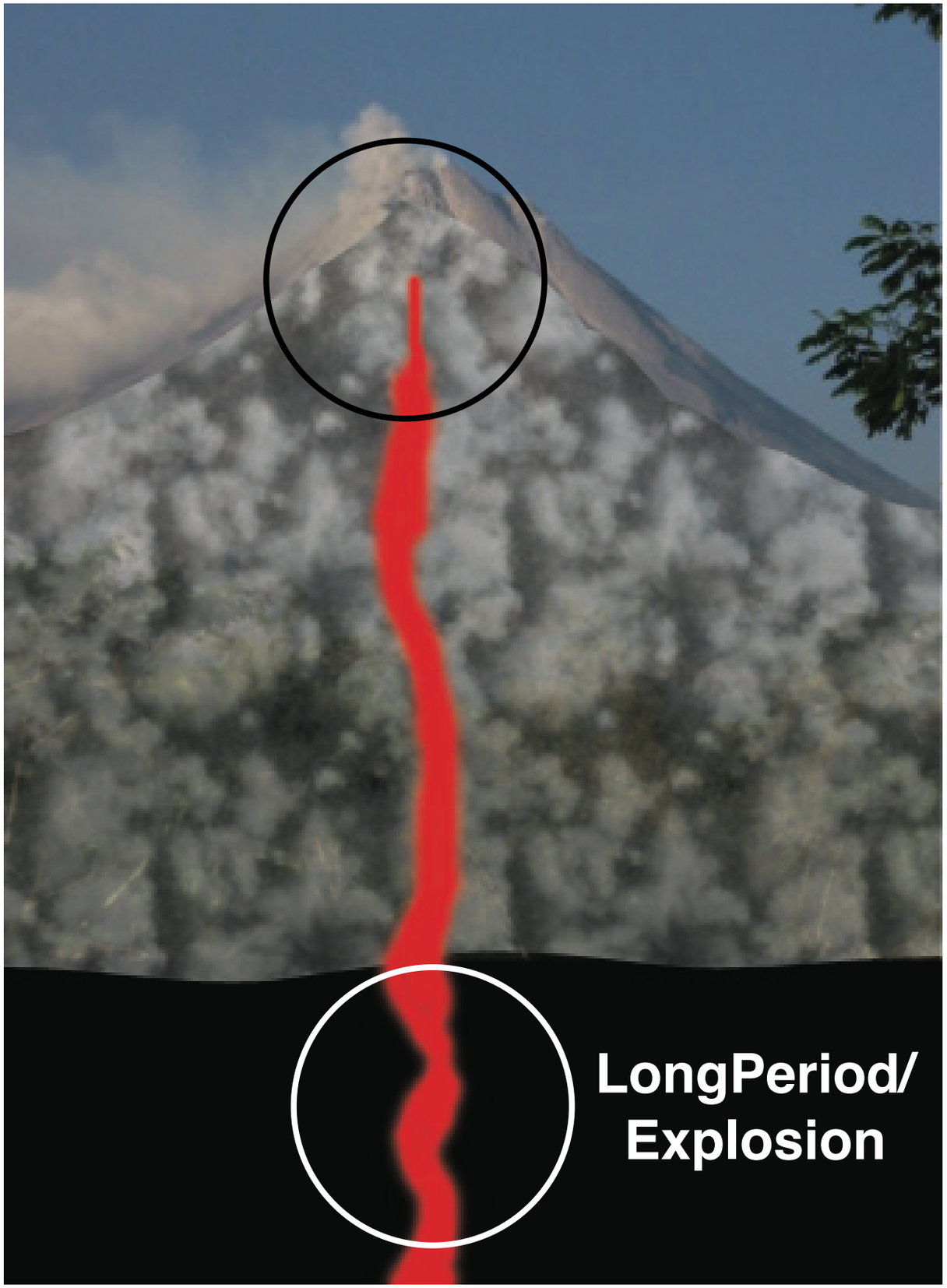
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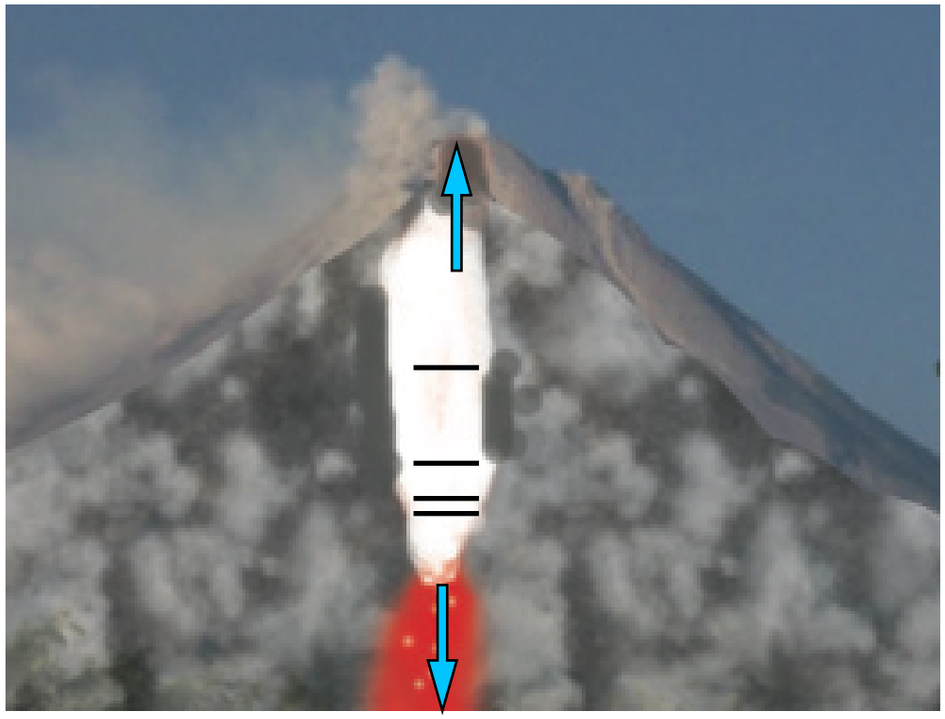

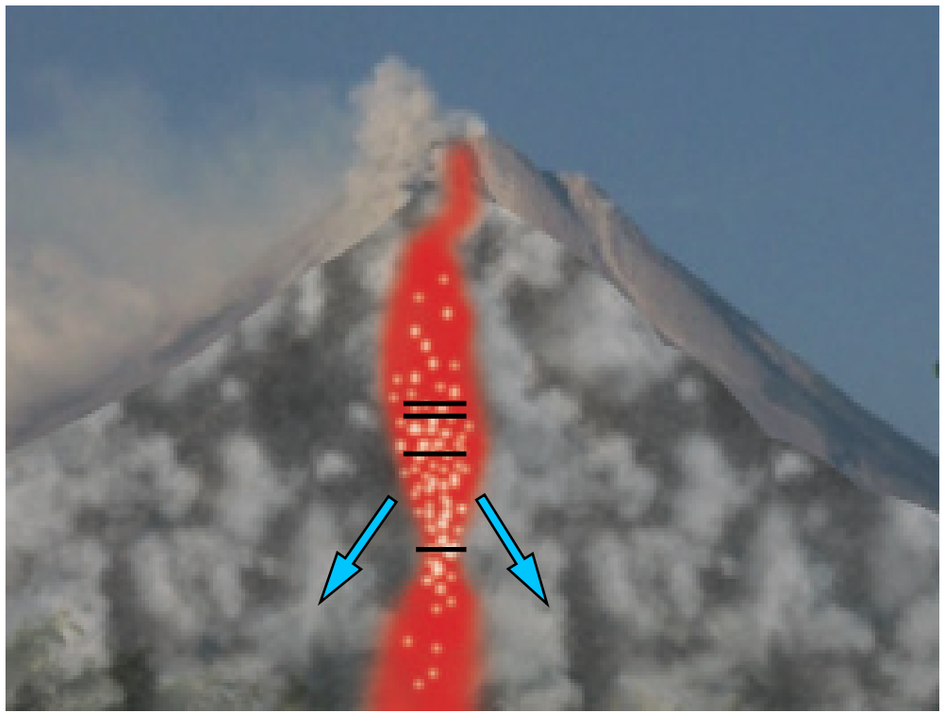

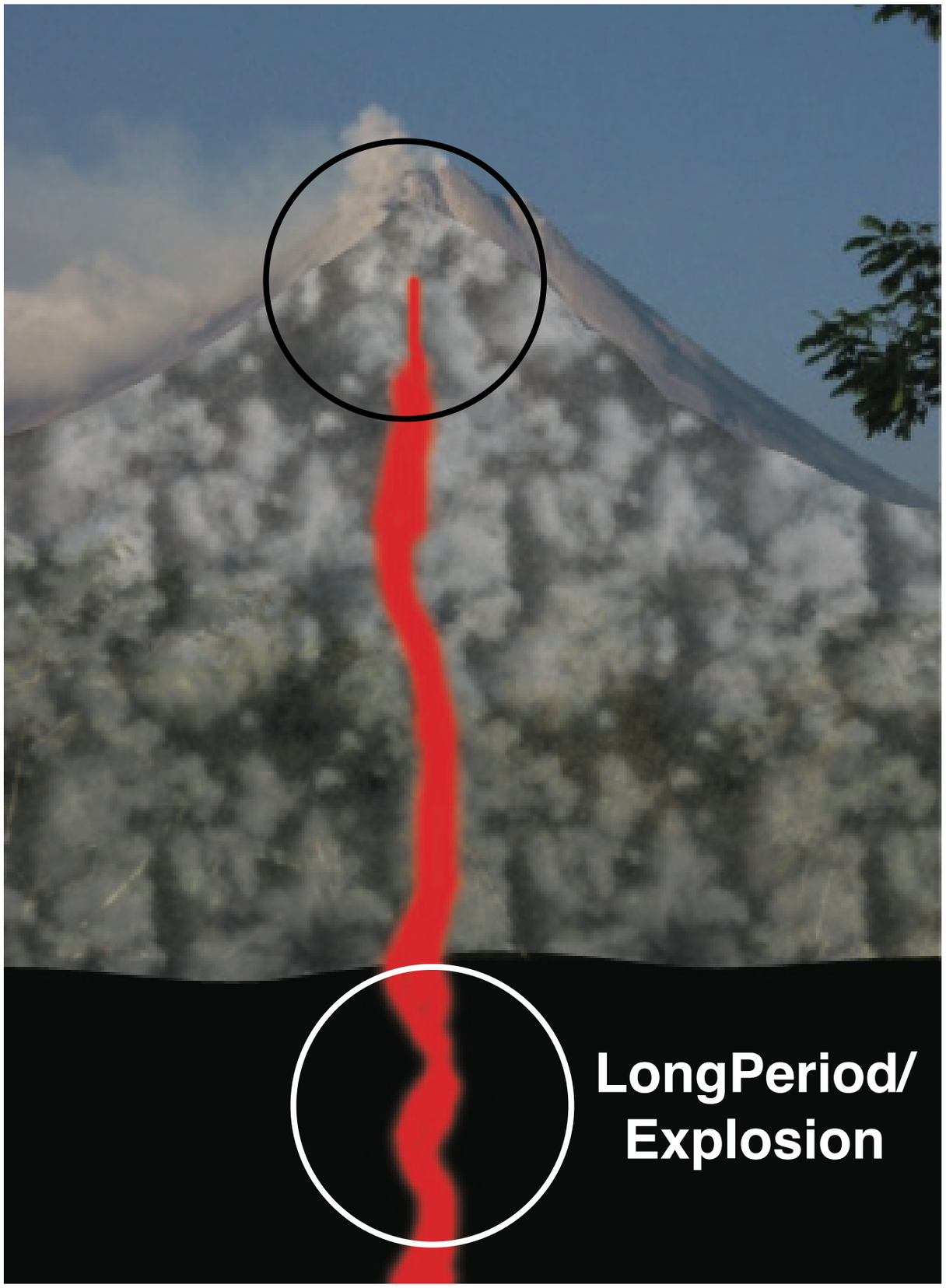
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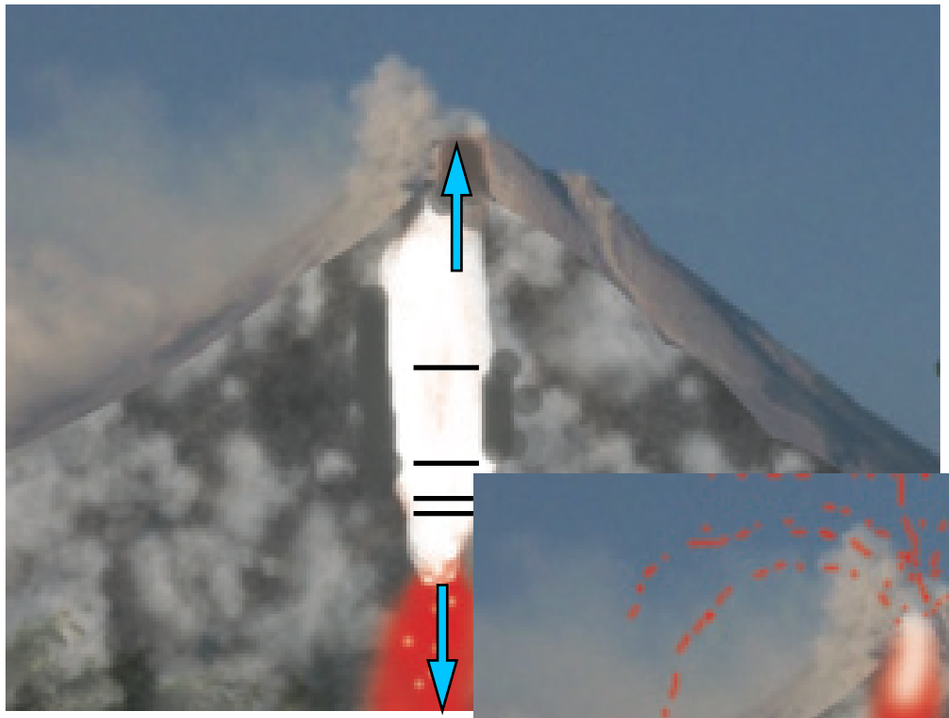
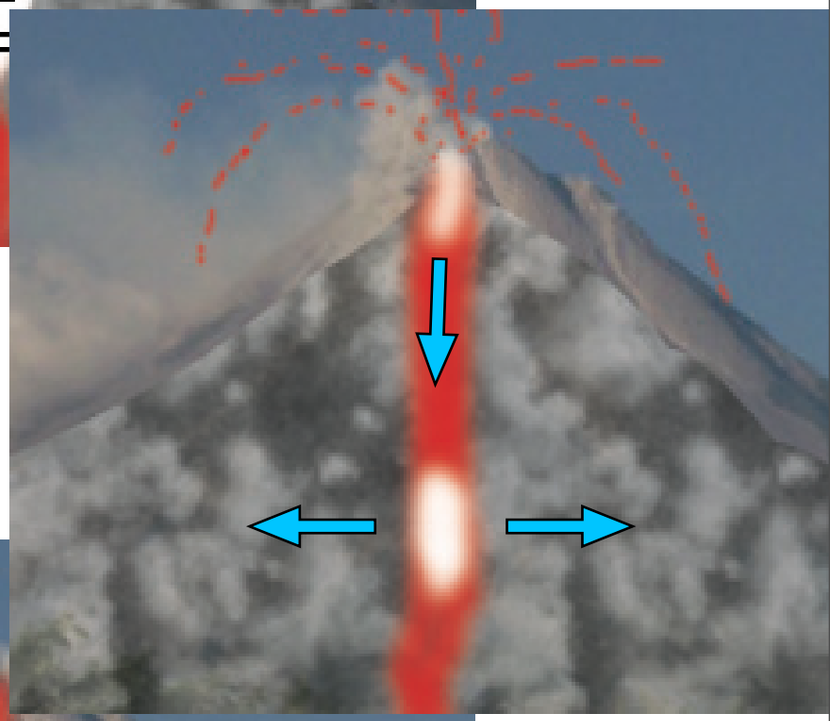
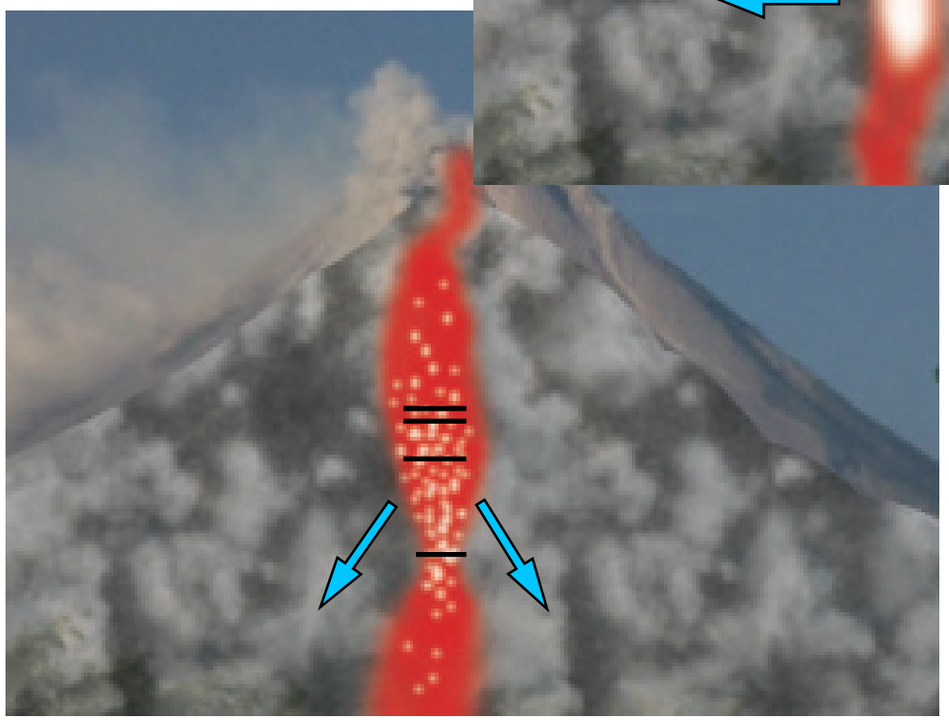
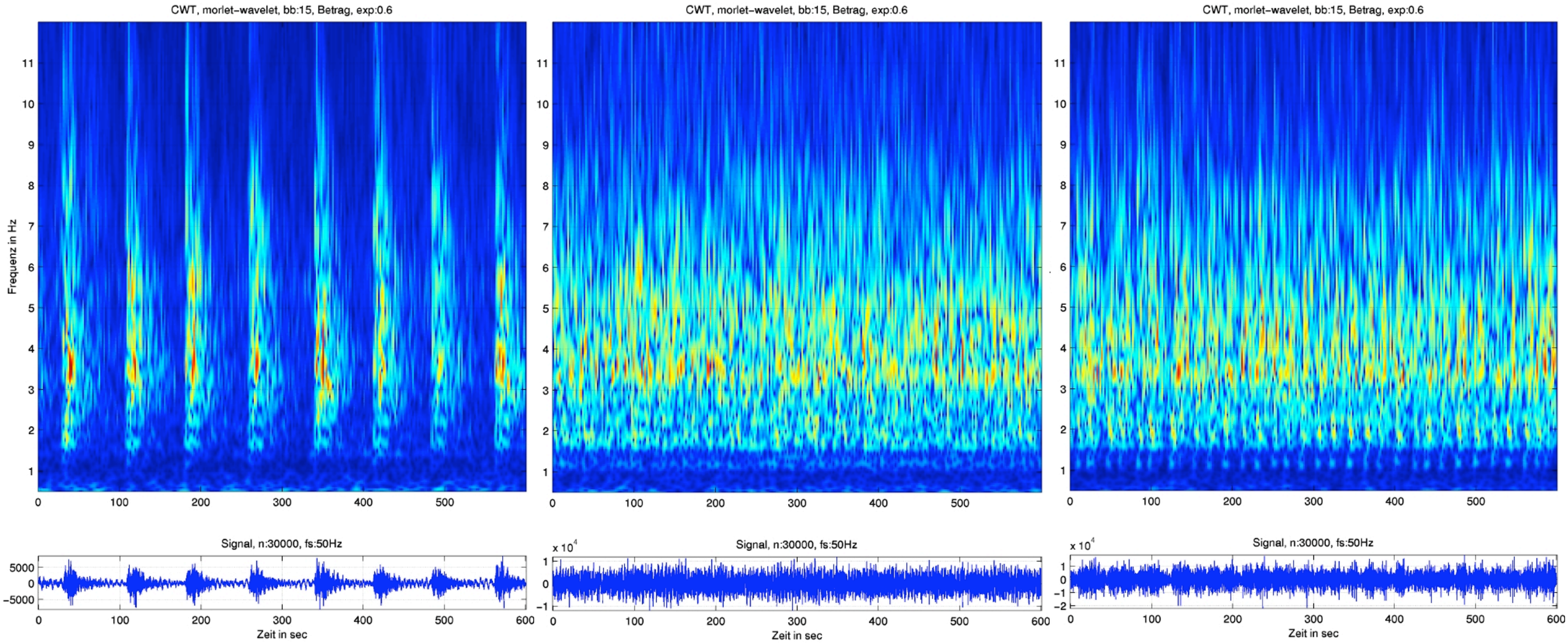


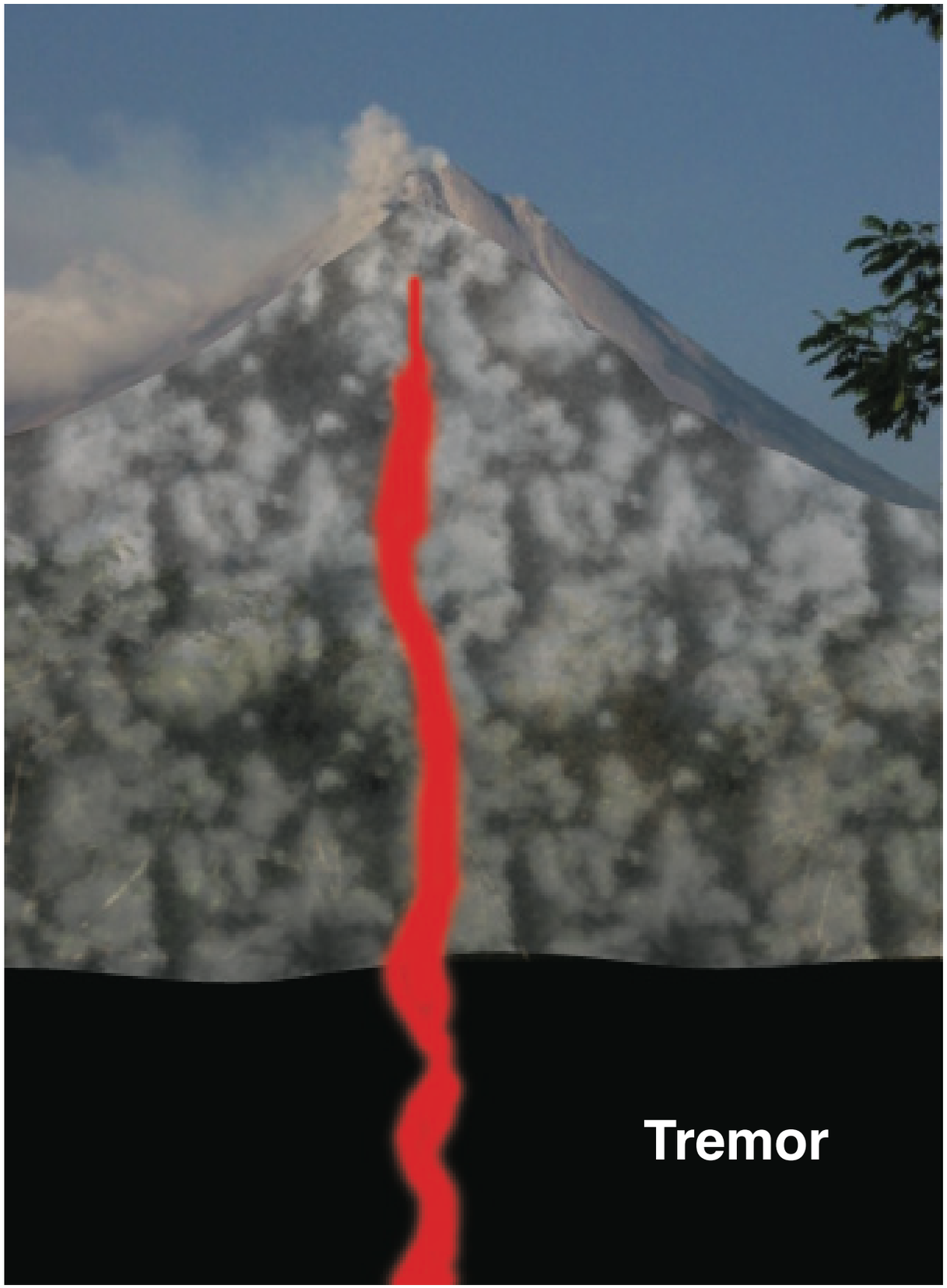


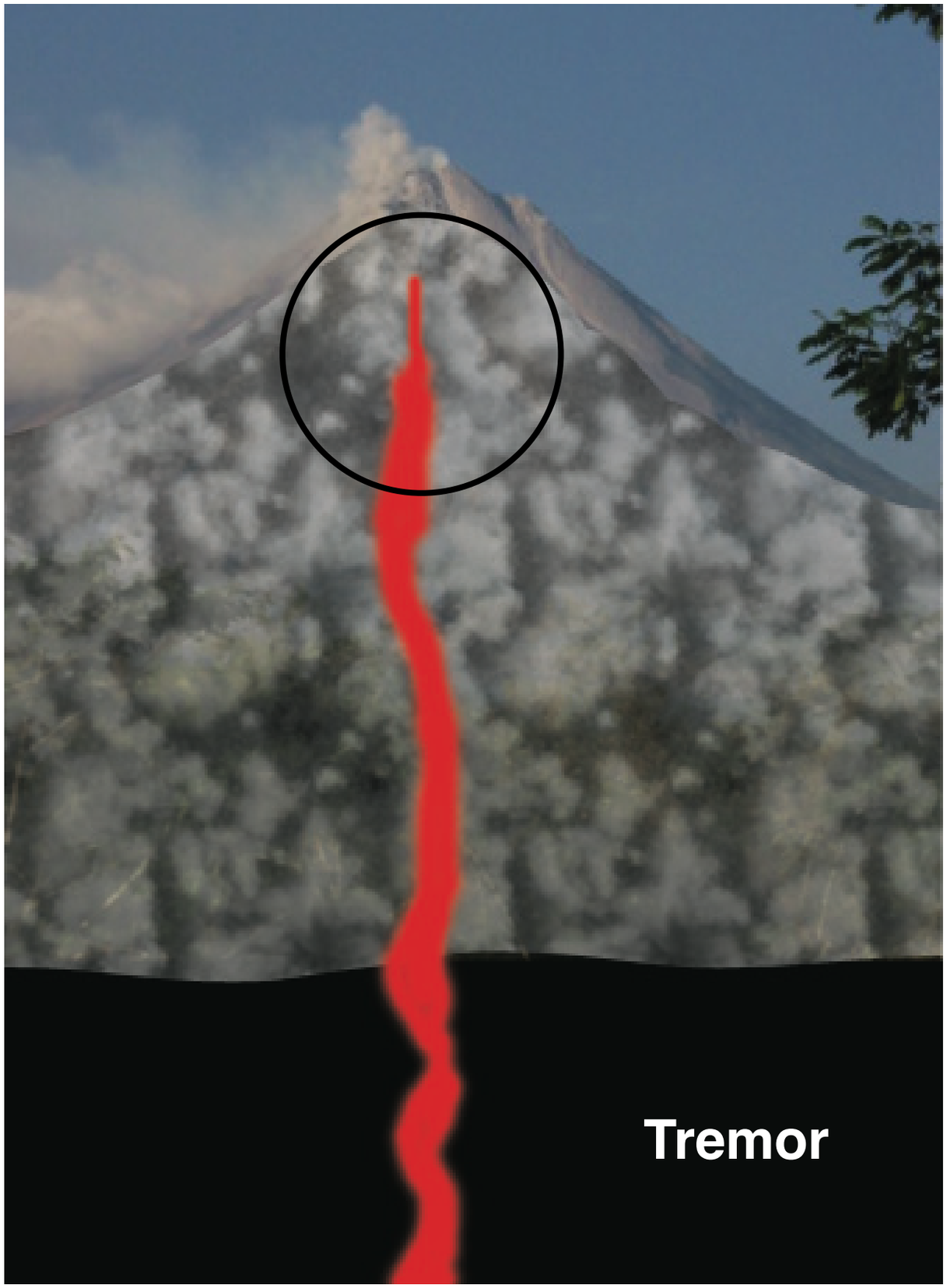


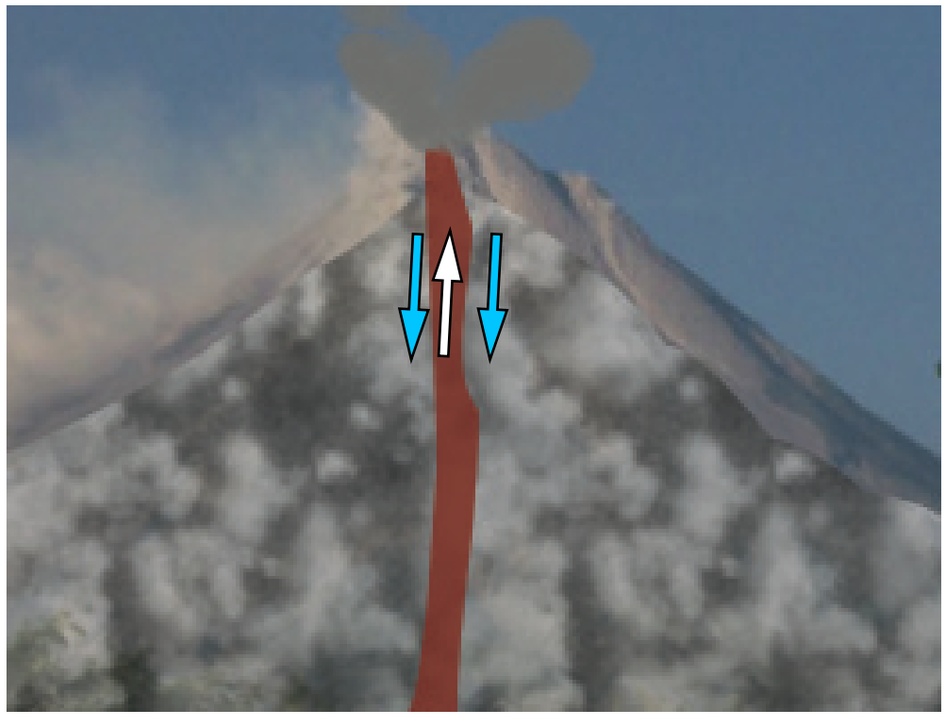
Einige Beispiele

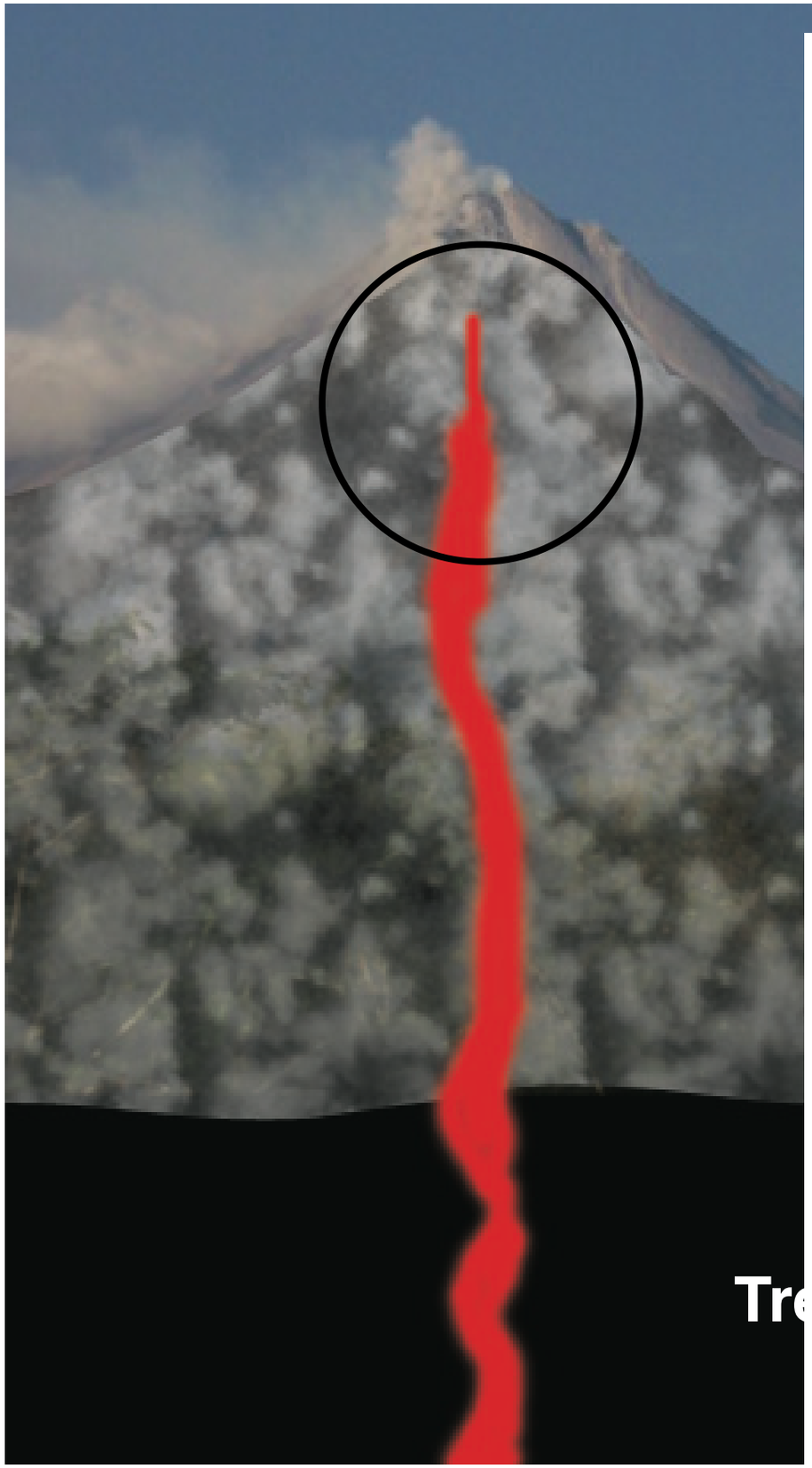
Ein Typ des vulkanischen Tremor

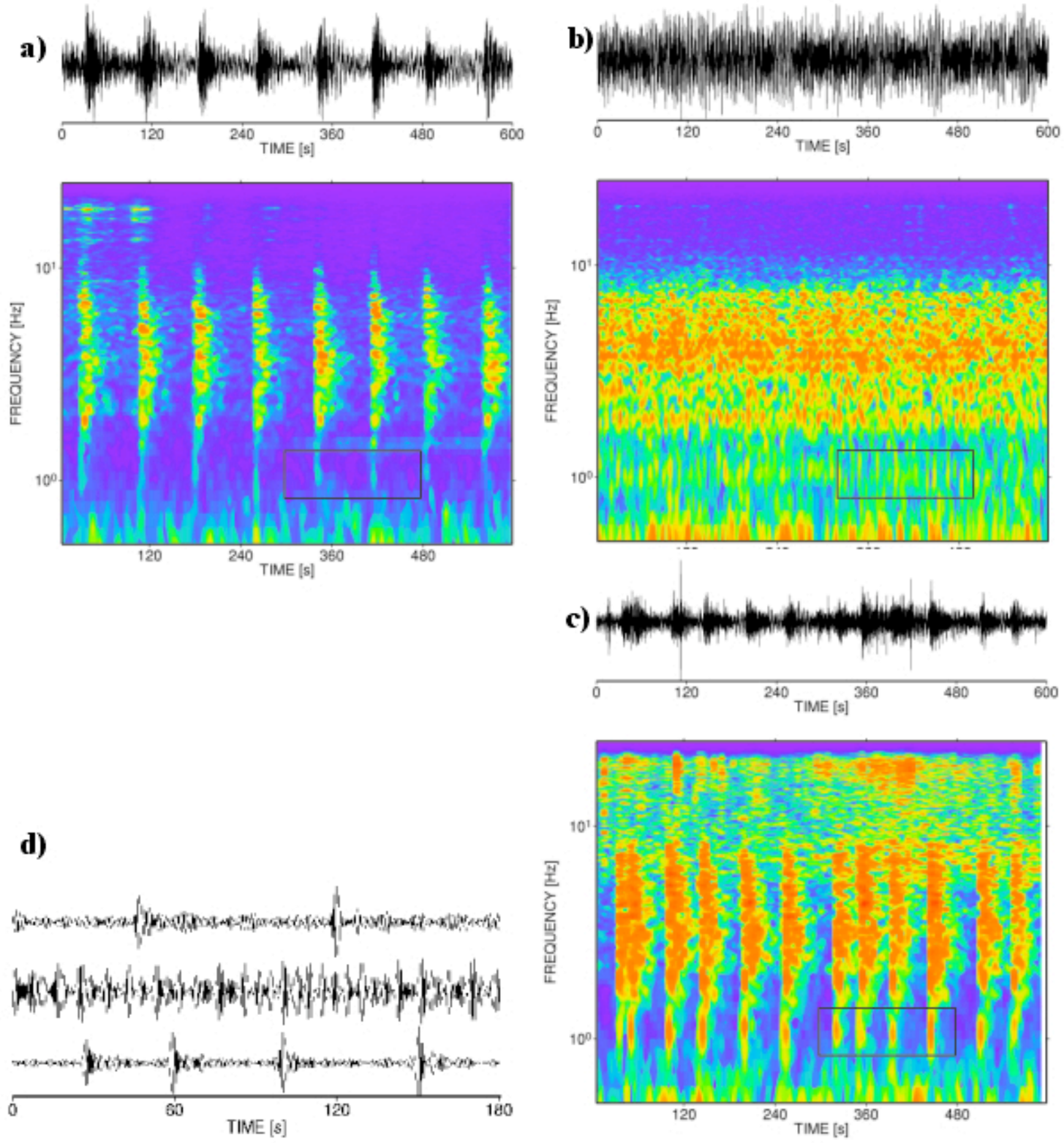


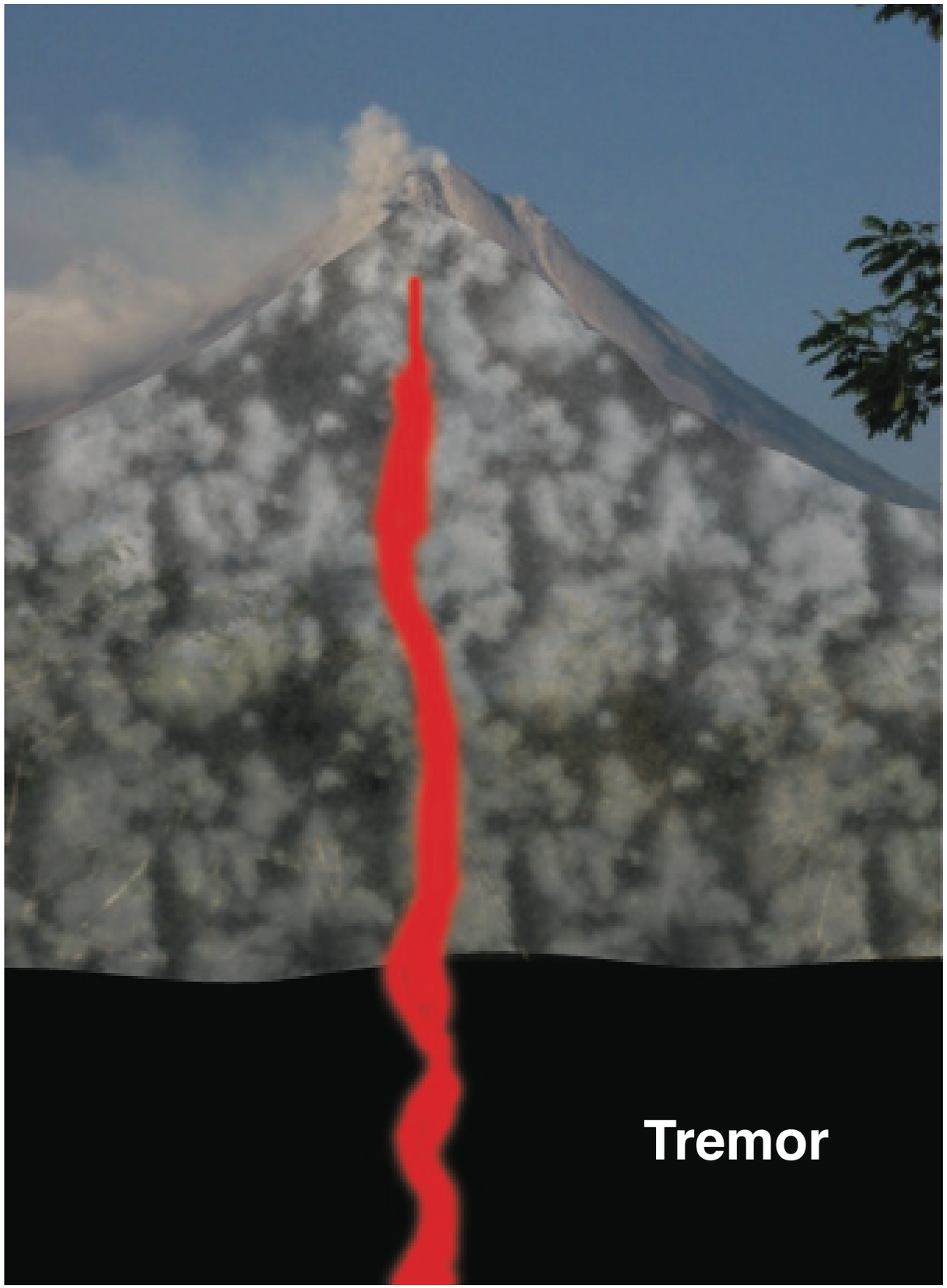

Tremor

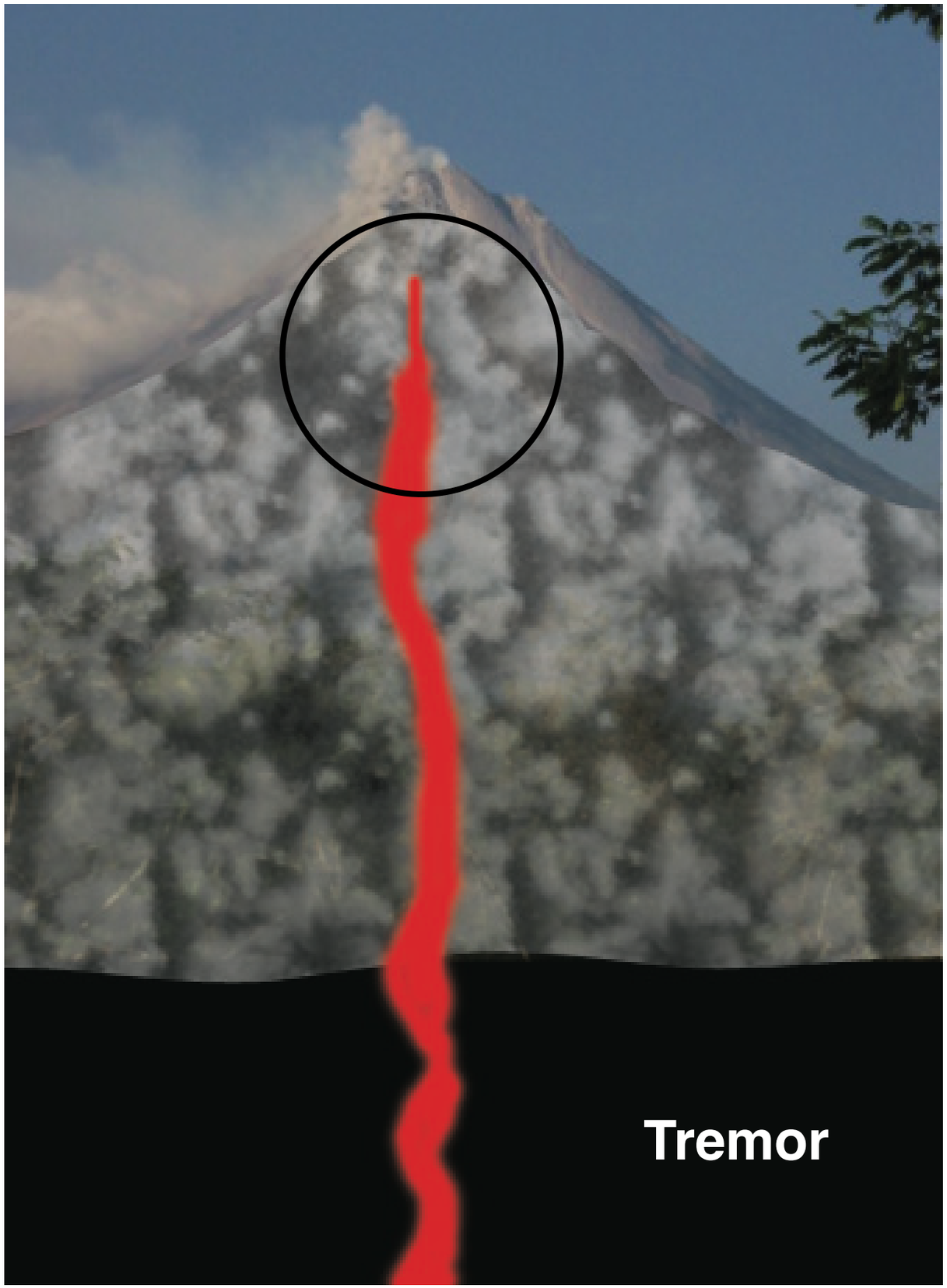

Tremor

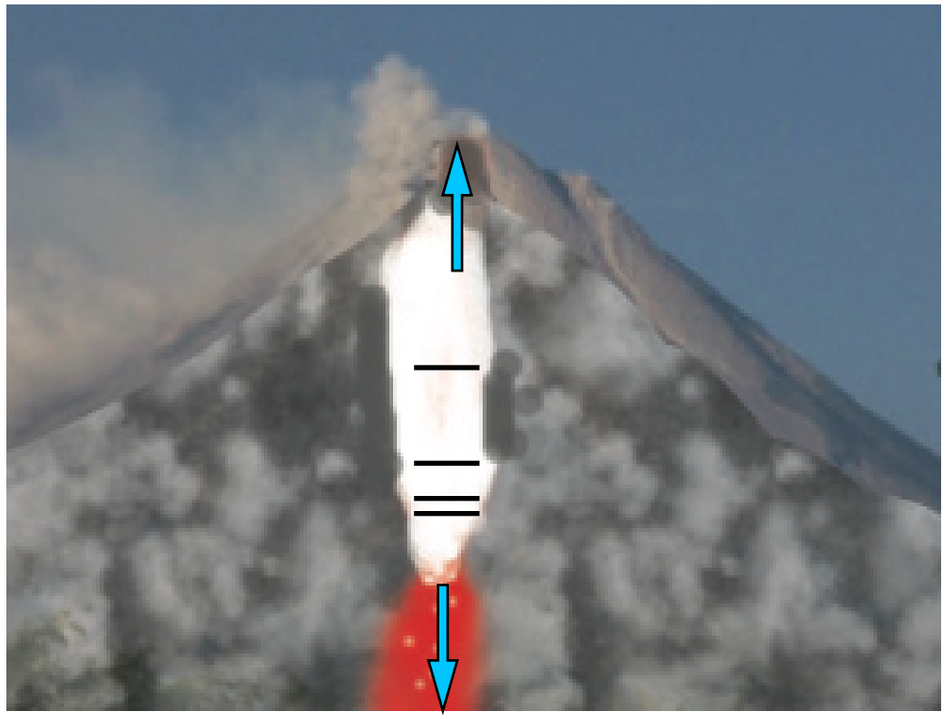


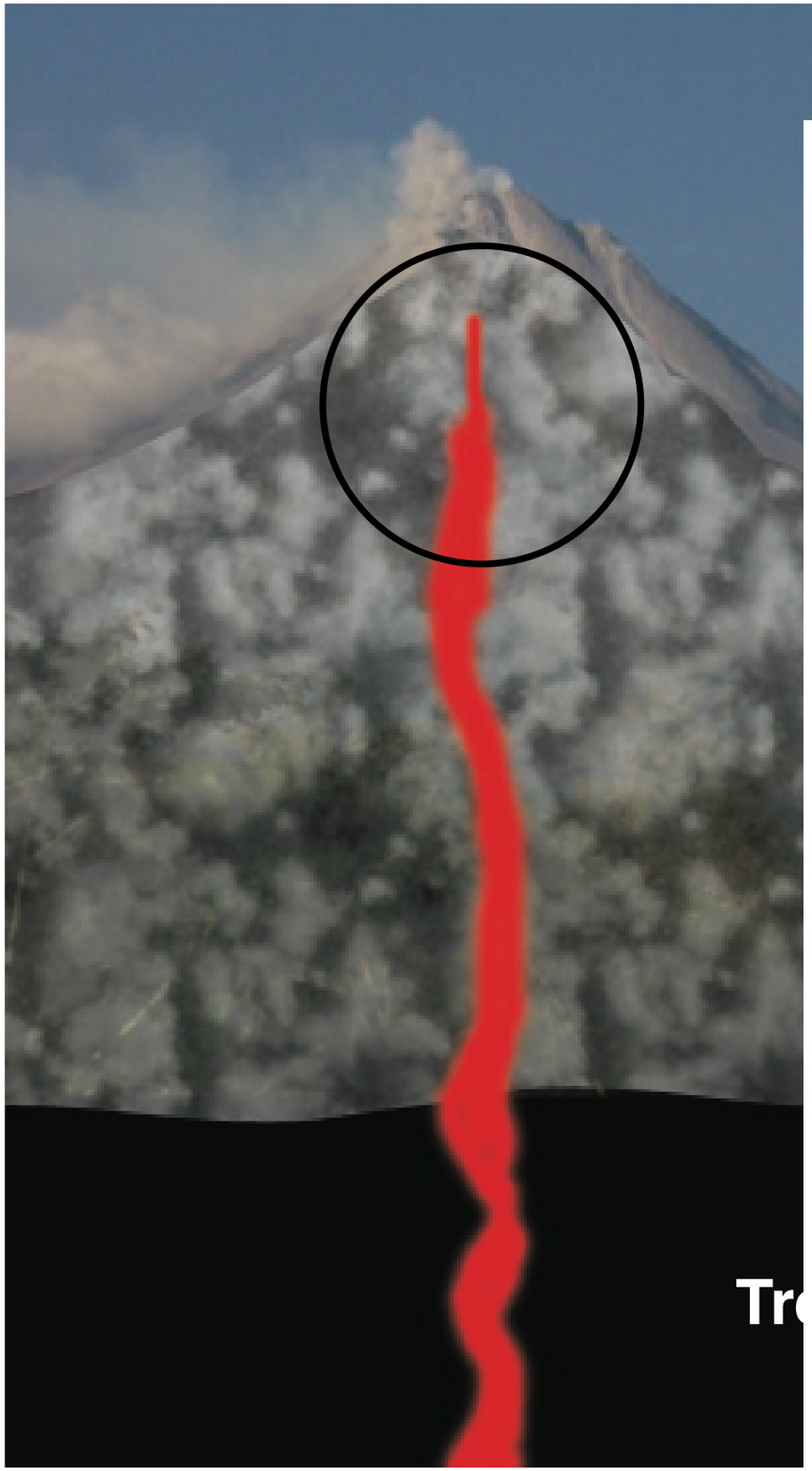

Tre


a)
b)
c)
d)
TIME [s]
FREQUENCY [Hz]
10^1
10^0
0
120
240
360
480
600
60
180


Tremor


Tremor

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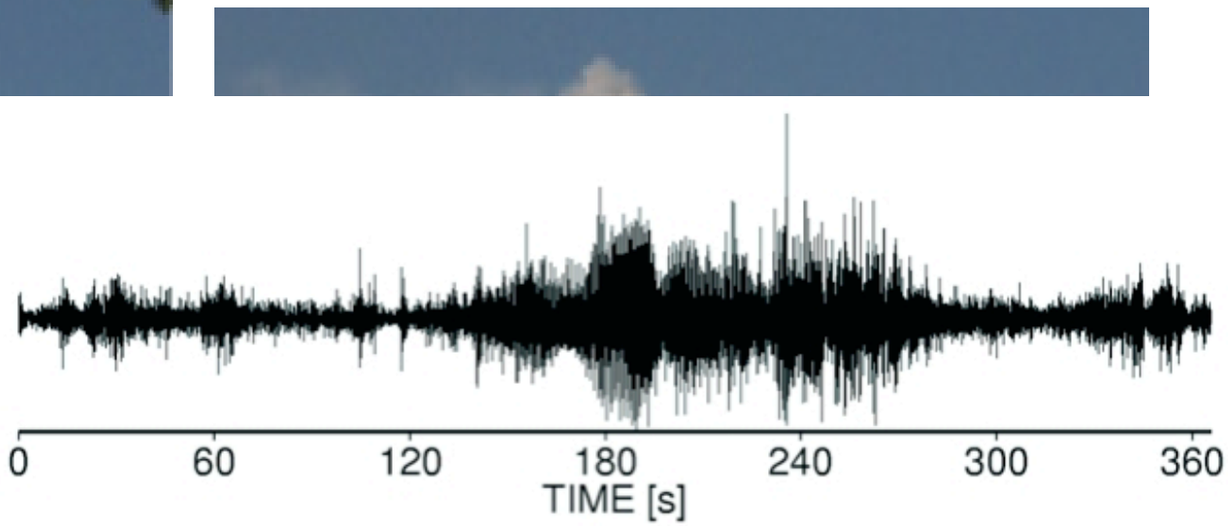
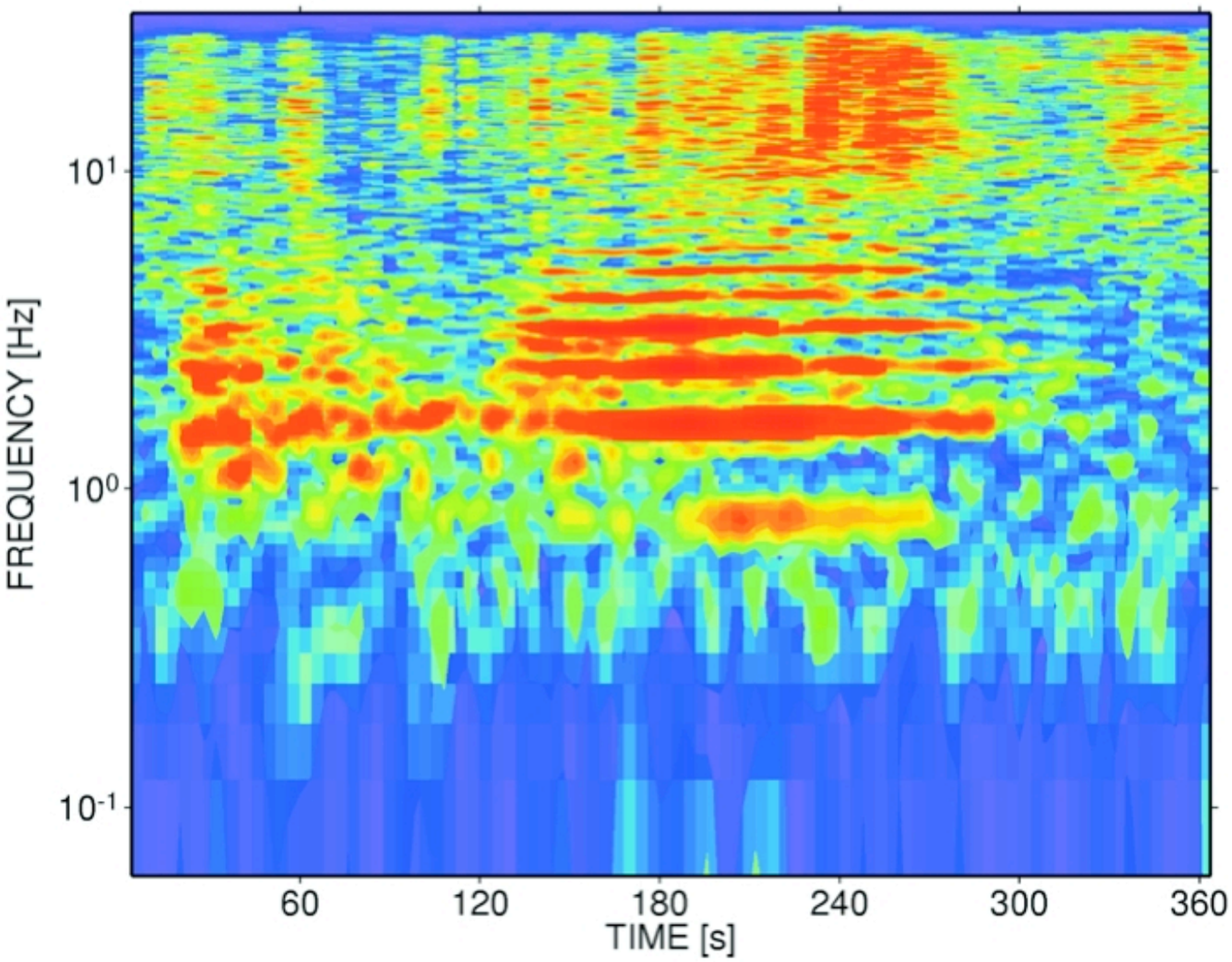
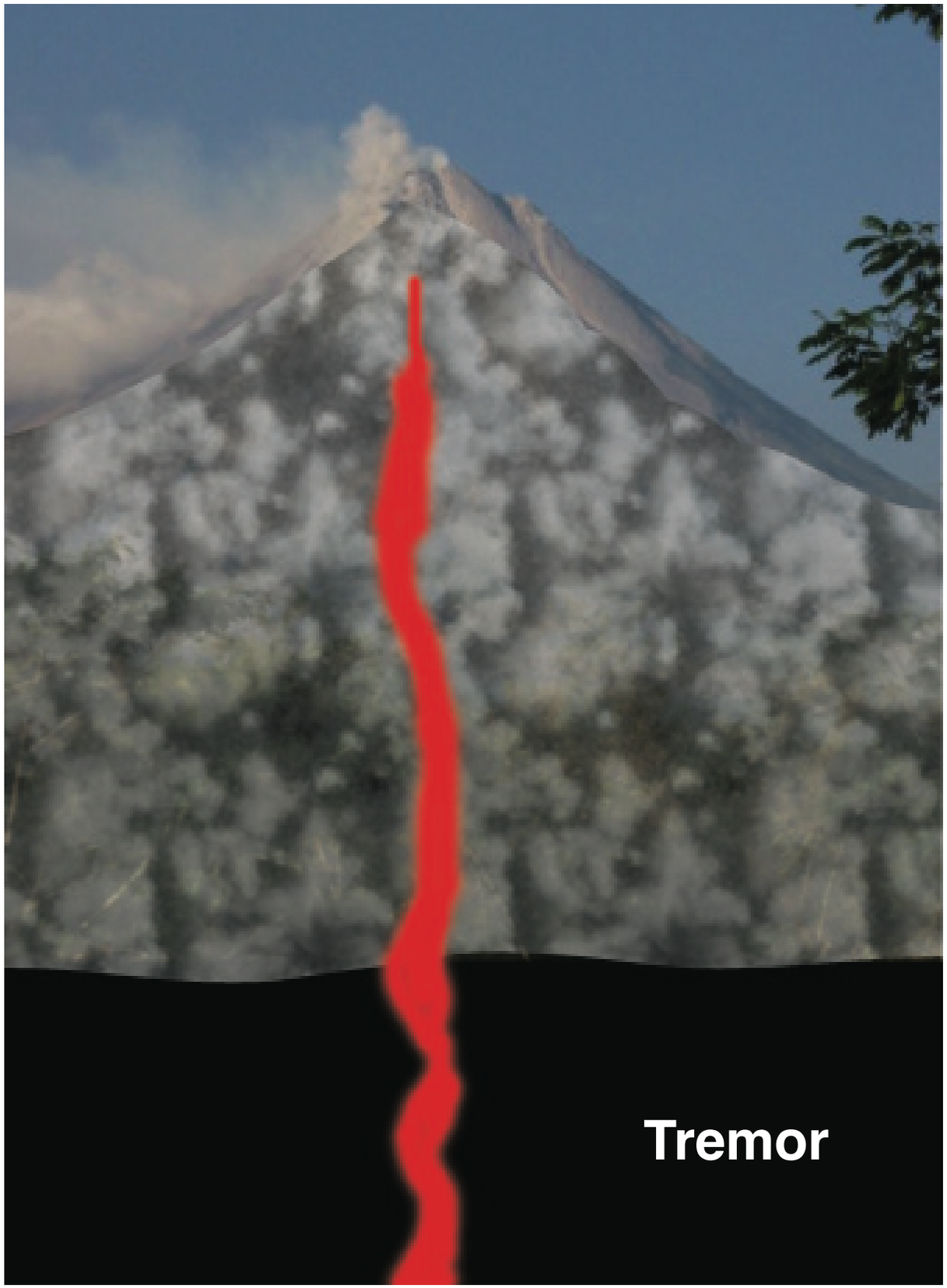
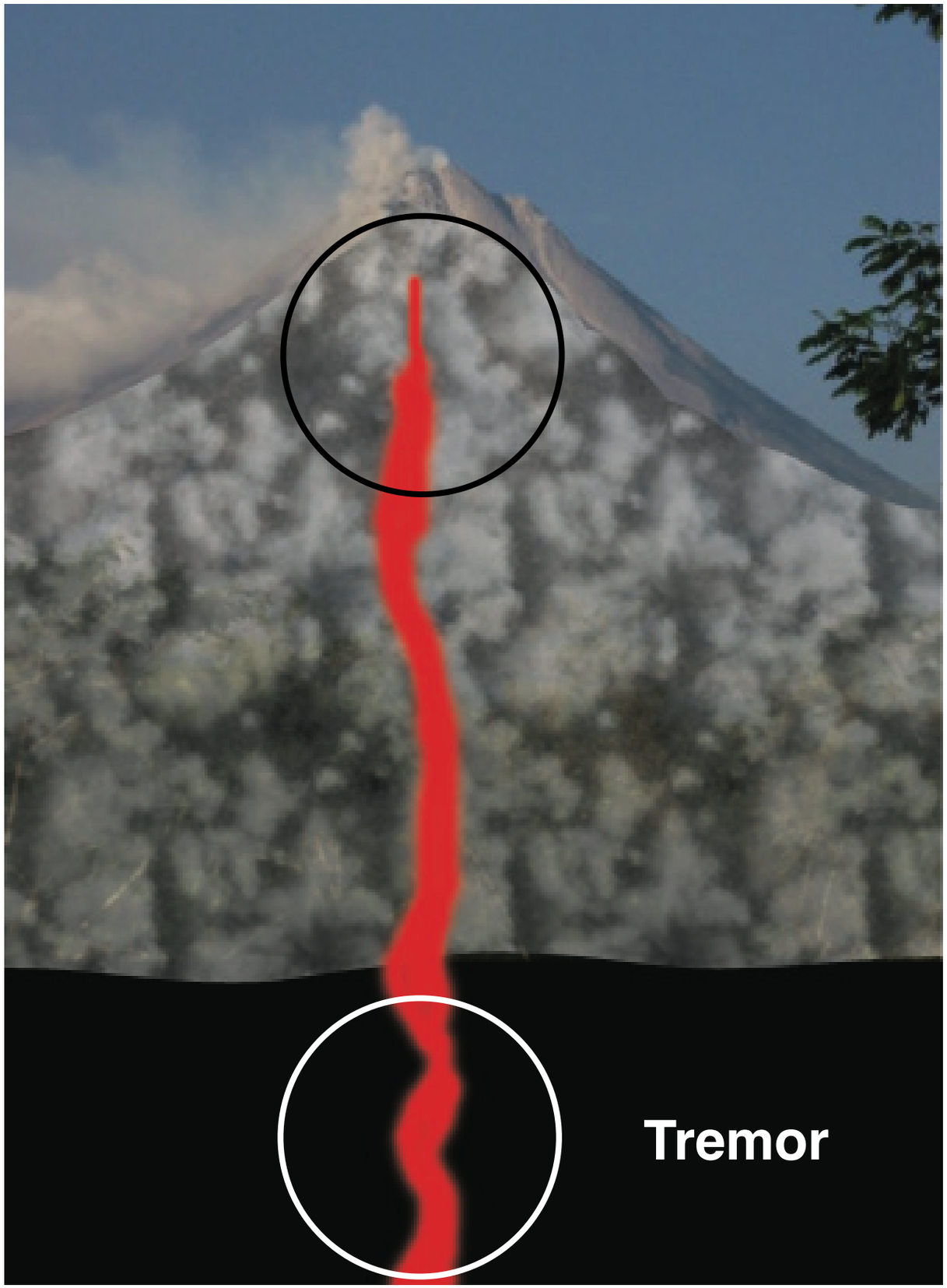
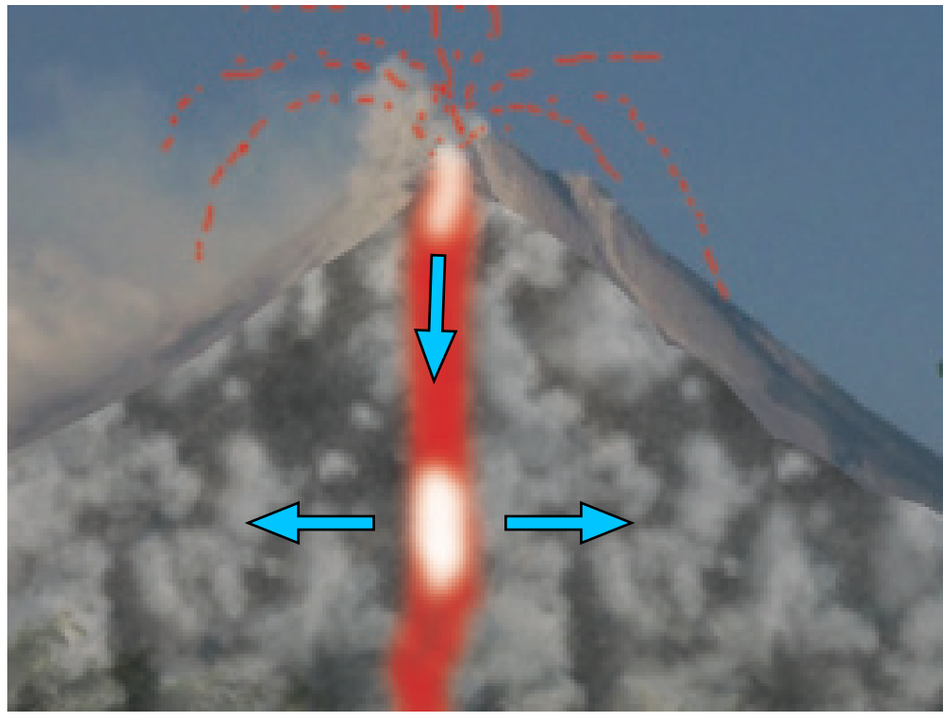
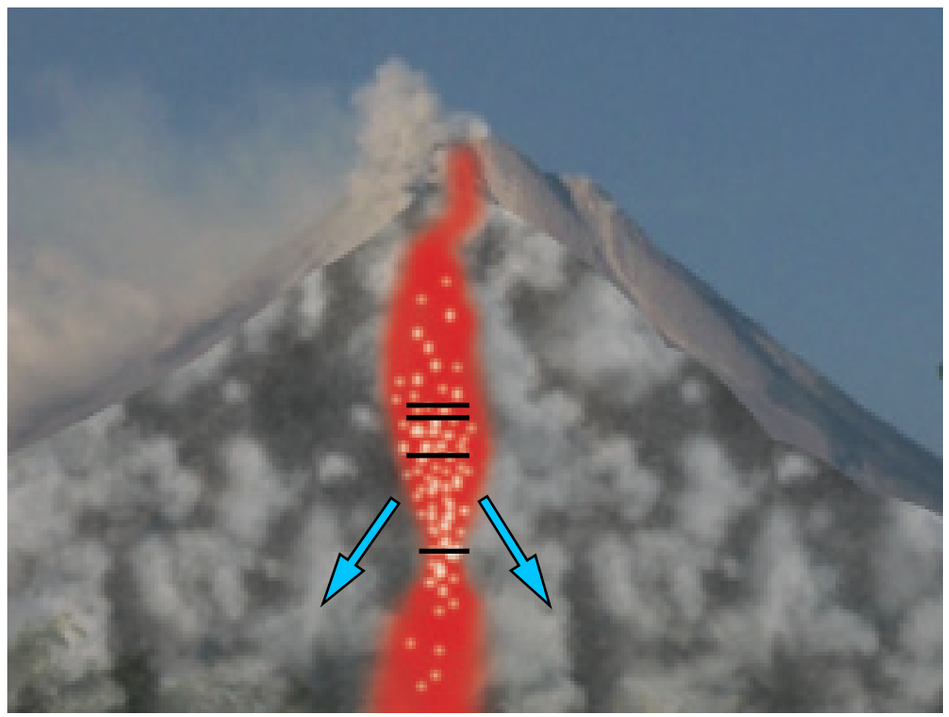

0
60
120
180
240
300
360
TIME [s]

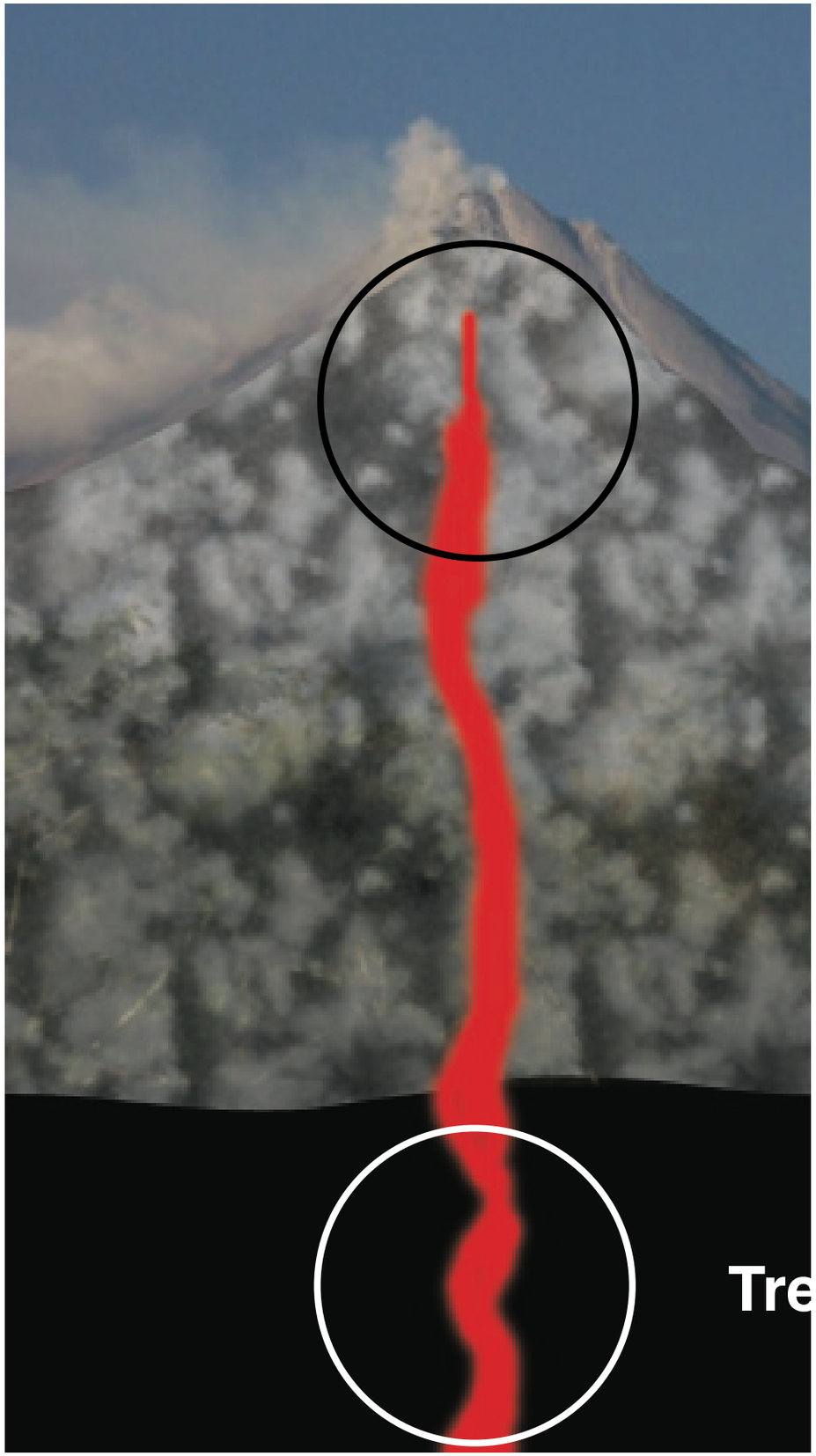

10^1
10^0
10^{-1}
FREQUENCY [Hz]
60
120
180
240
300
360
TIME [s]


Tremor


Tremor



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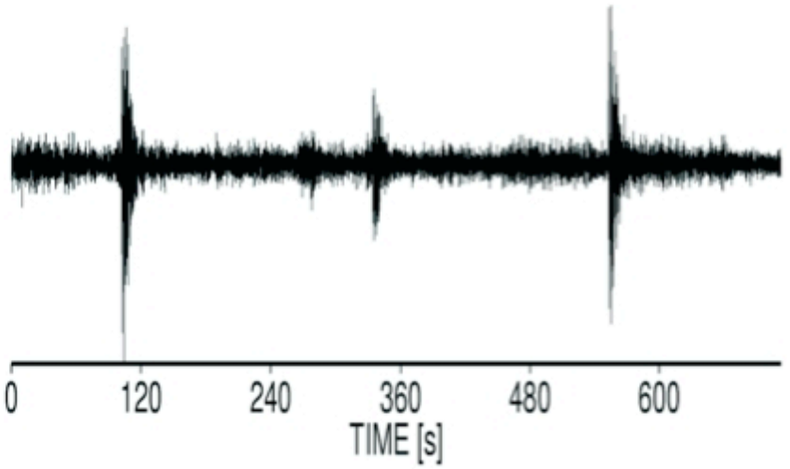
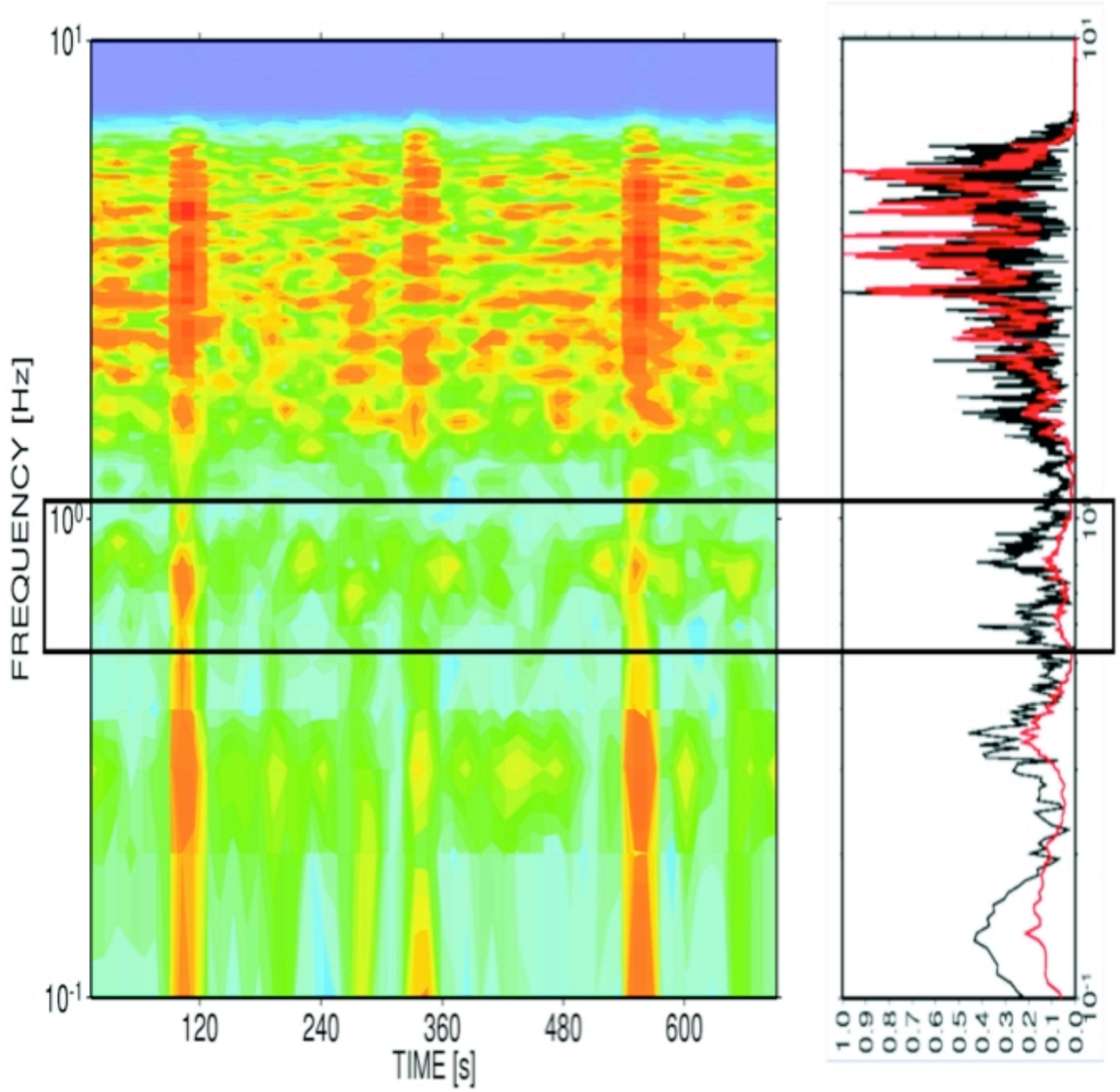
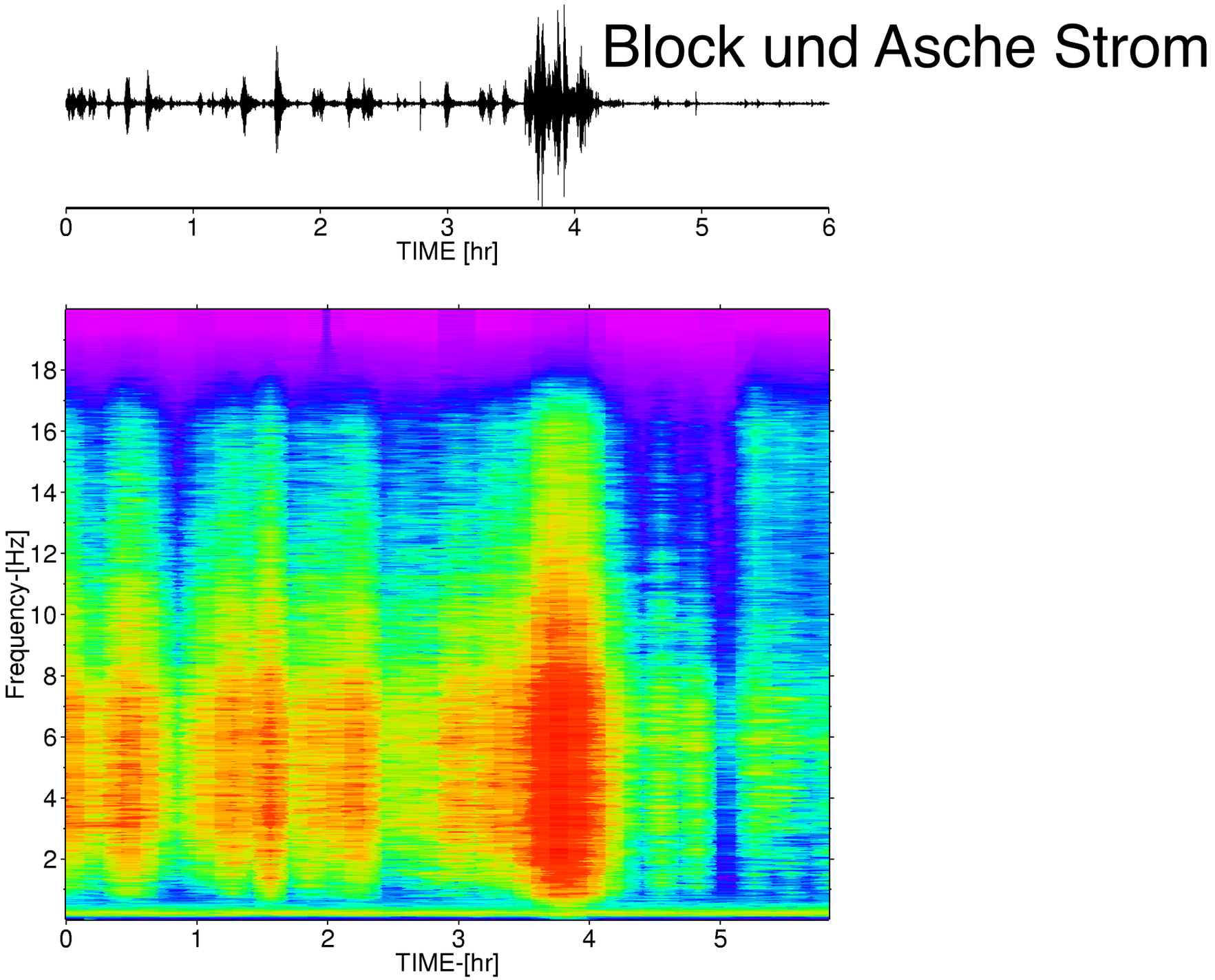
a)


0
120
240
360
480
600
TIME [s]

b)


10^1
FREQUENCY [Hz]
10^0
10^{-1}
120
240
360
480
600
TIME [s]
10^1
10^{-1}
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

Einige Beispiele




Rockfall/BaF

Was müssten wir wissen?

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- präzise Ortsbestimmung, um Fluidmigrationen zu erkennen und die Ausdehnung magmatischer Körper zu bestimmen

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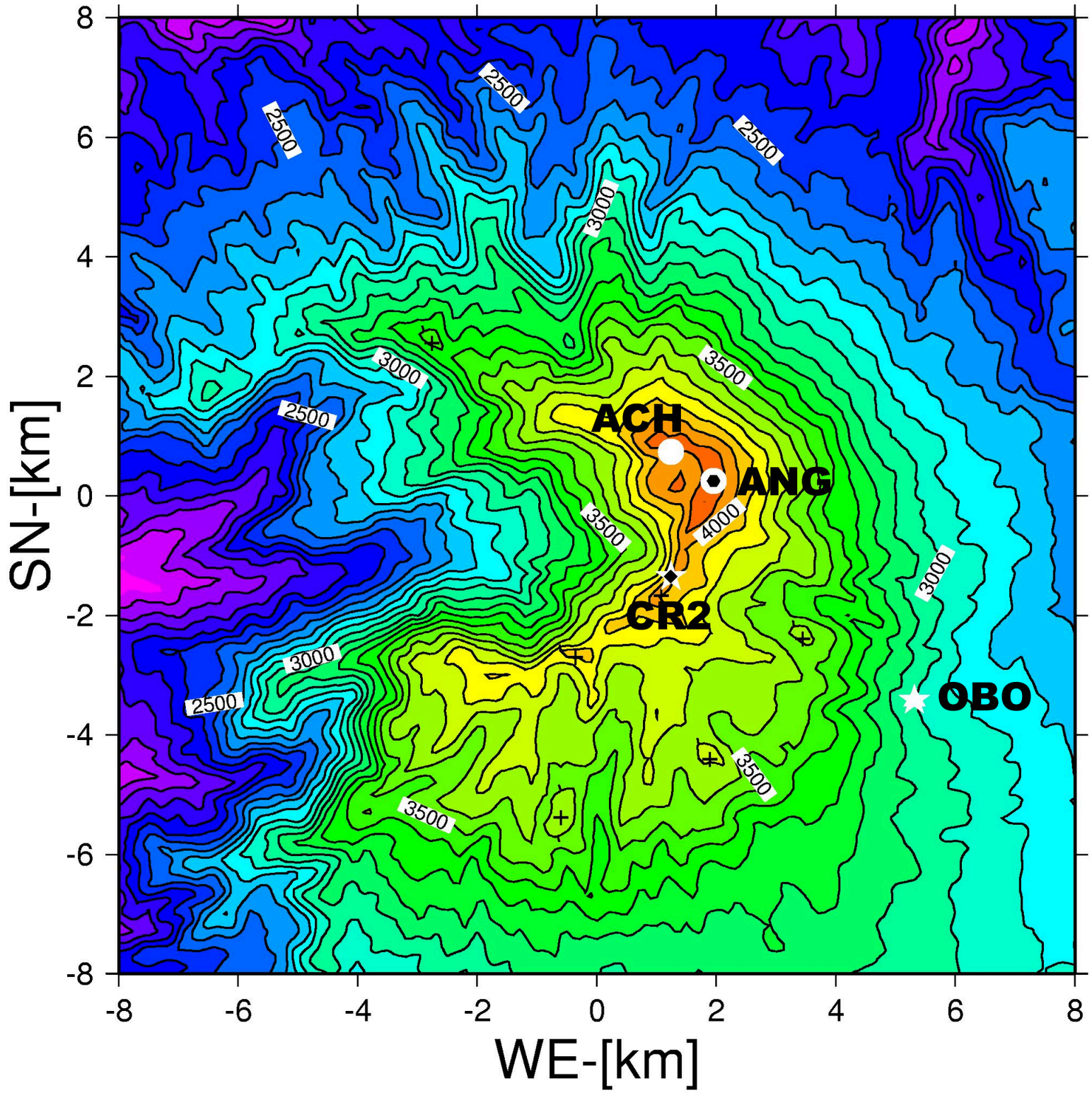
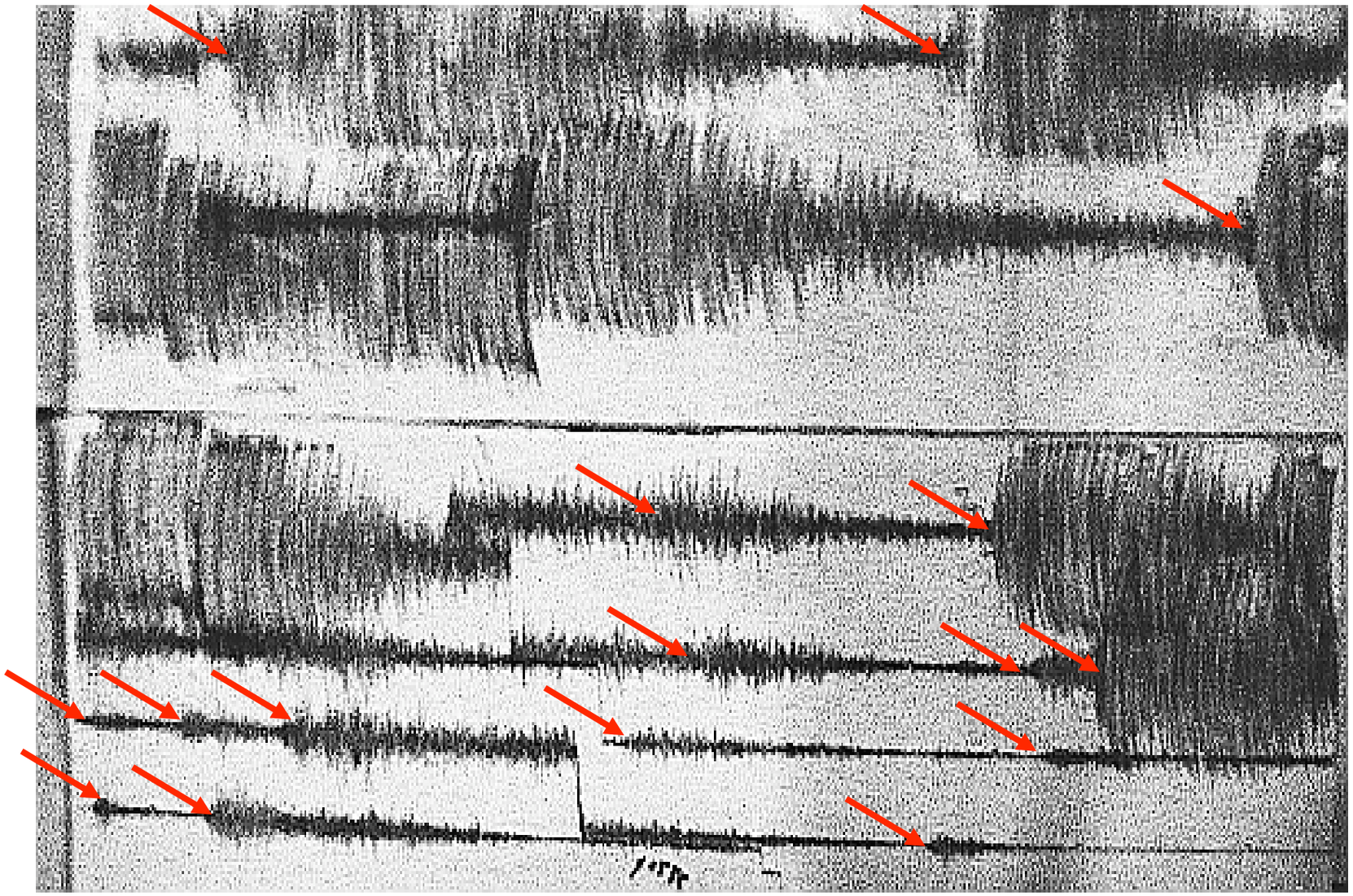
- Langzeitverhalten der Seismizität
- Einfluss von externen Kräften auf sowohl das vulkanische System als auch auf die Schlüsselparamater des Überwachungssystems

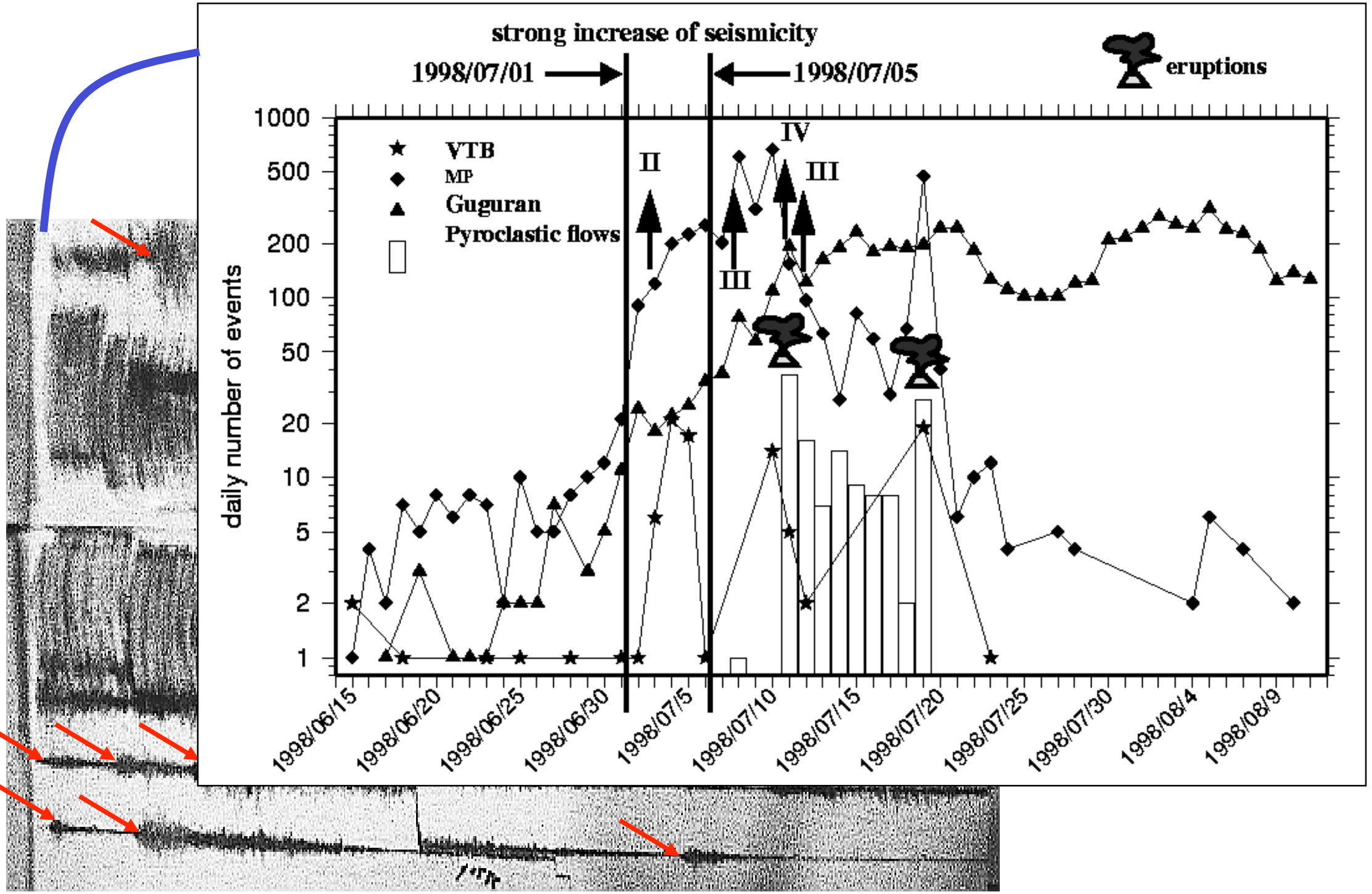
Typische Anwendung: Seismische Netze



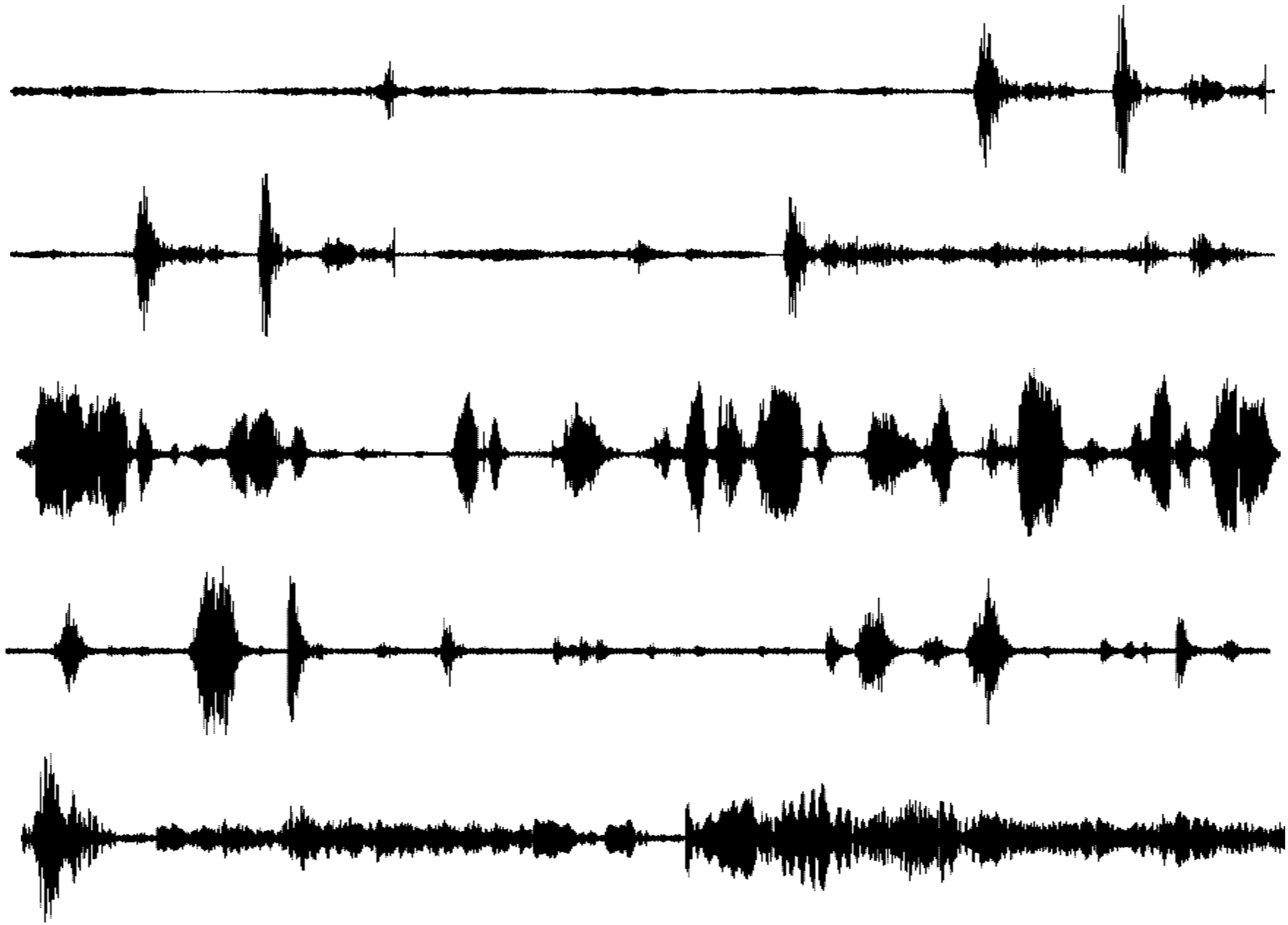
Klassifizierungsproblem



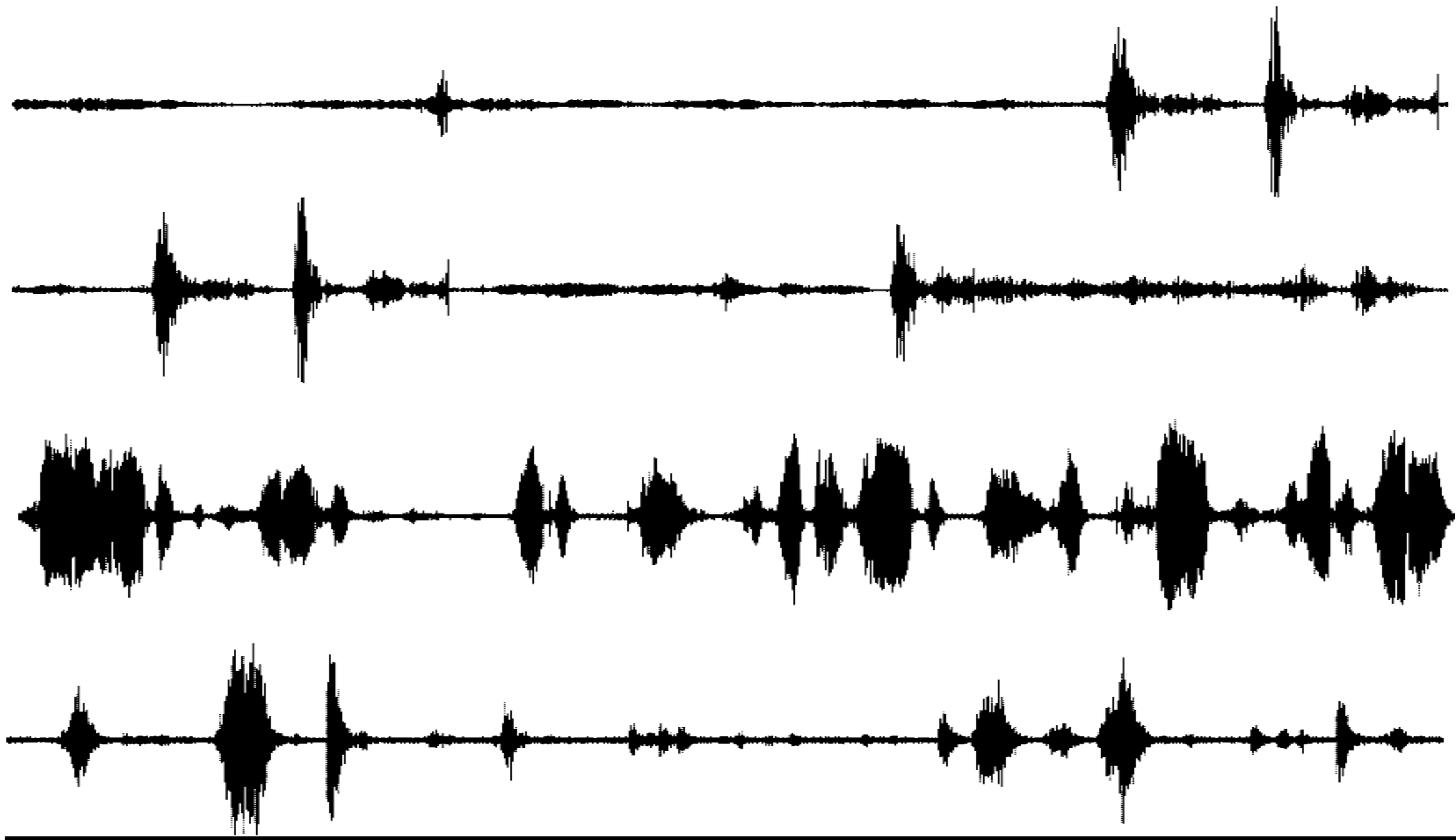
Klassifizierungsproblem



Klassifizierungsproblem

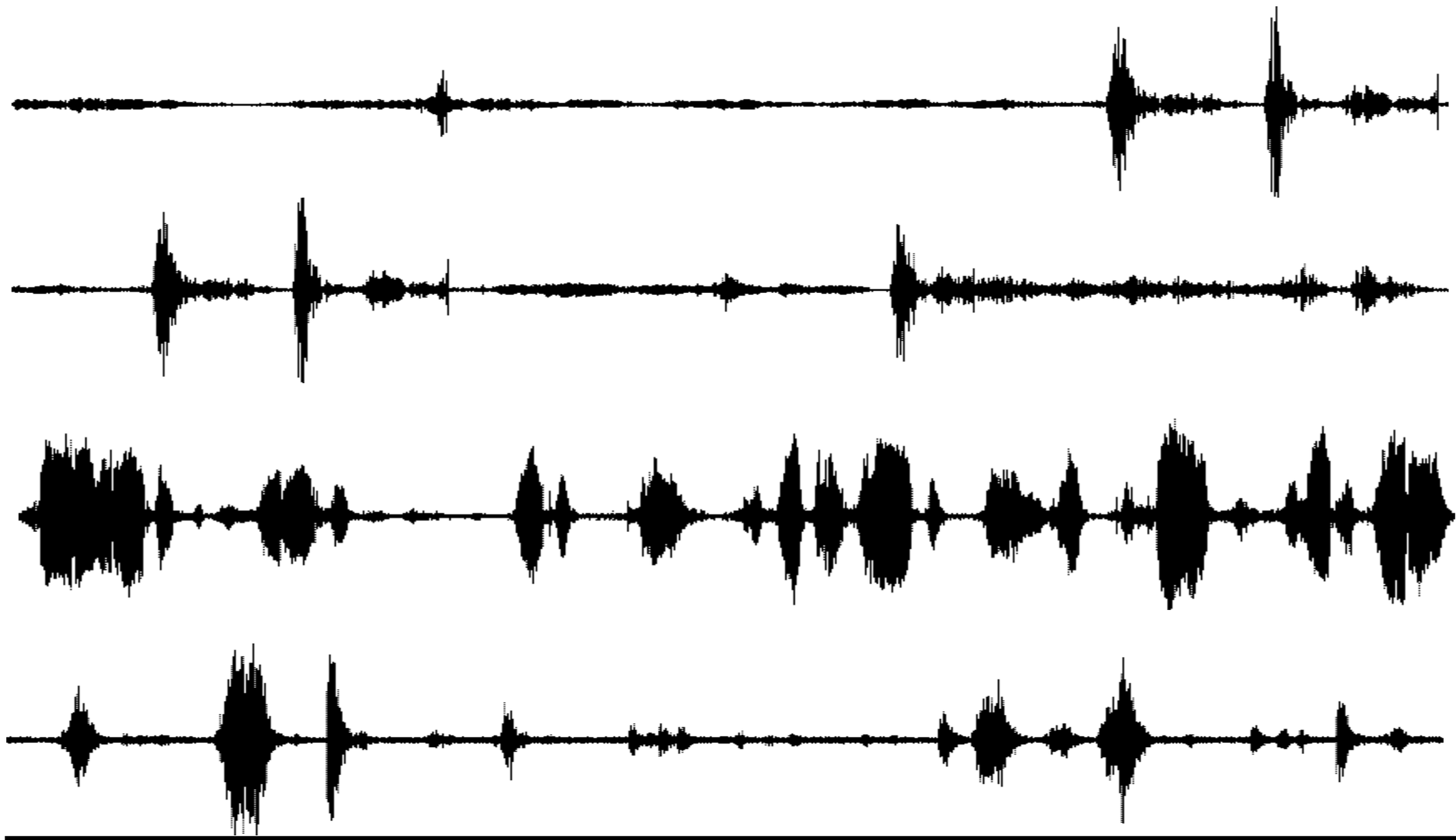


Klassifizierungsproblem



Arenal - vulkanischer Tremor (fs = 8000 Hz)

Klassifizierungsproblem



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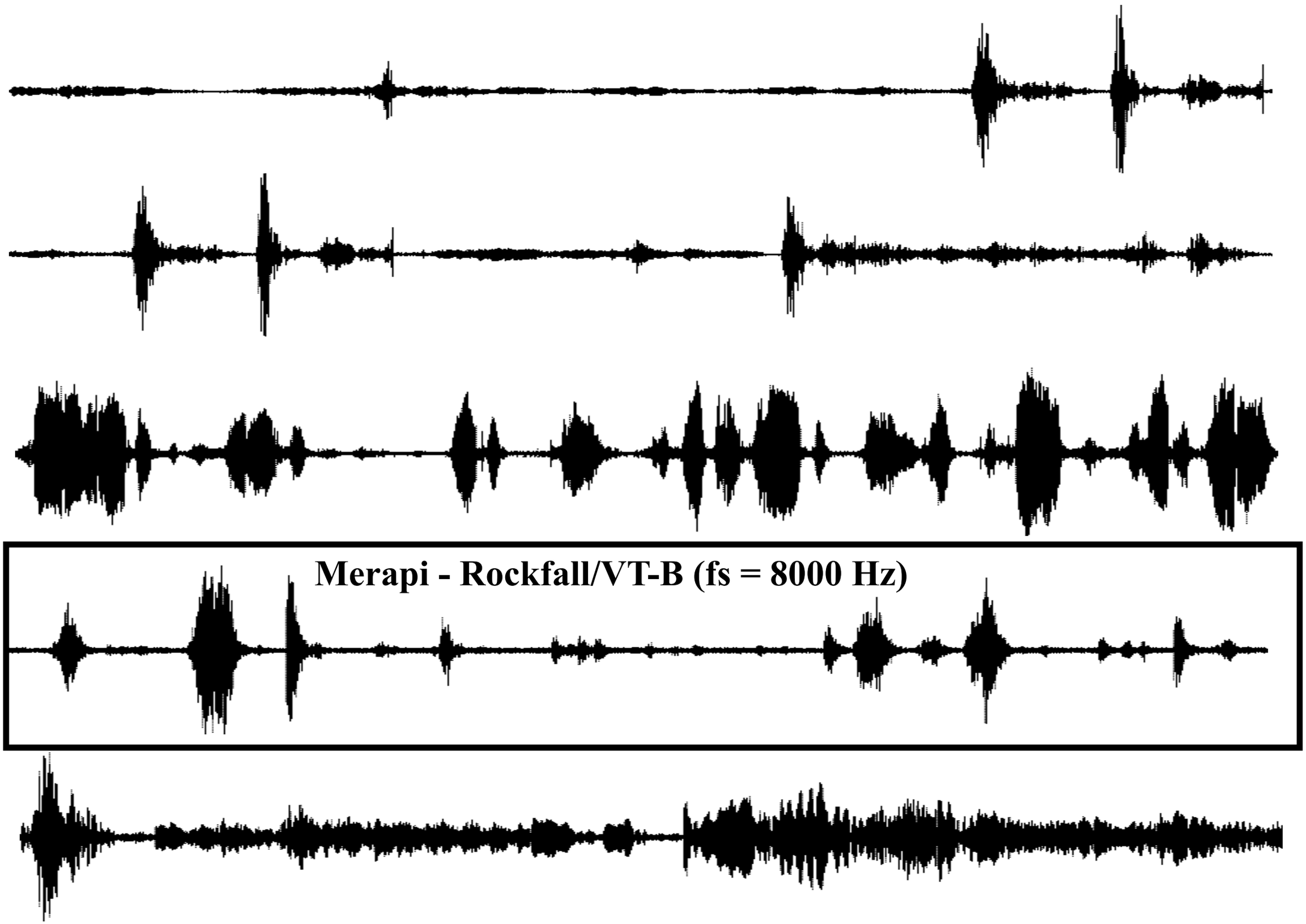
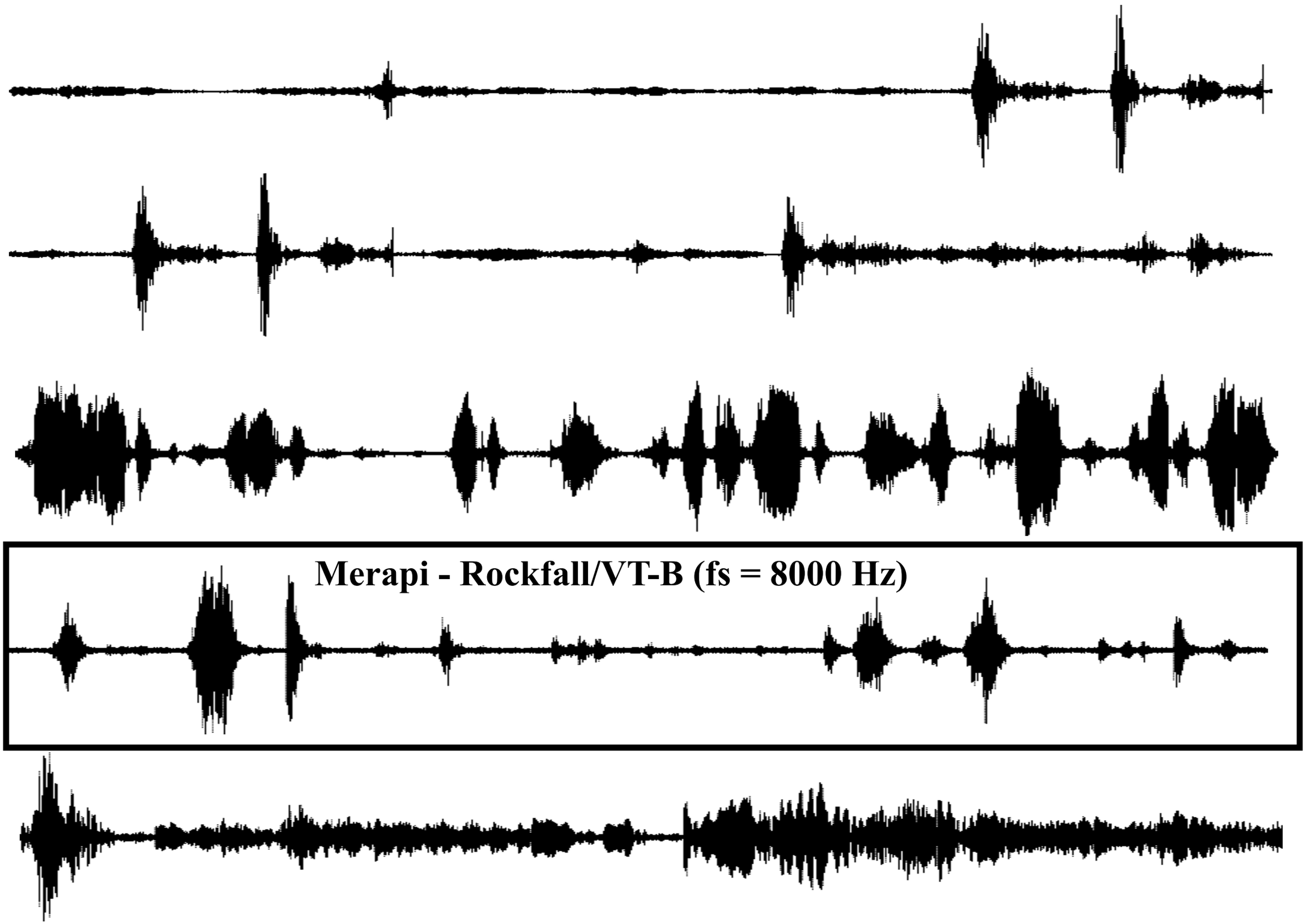
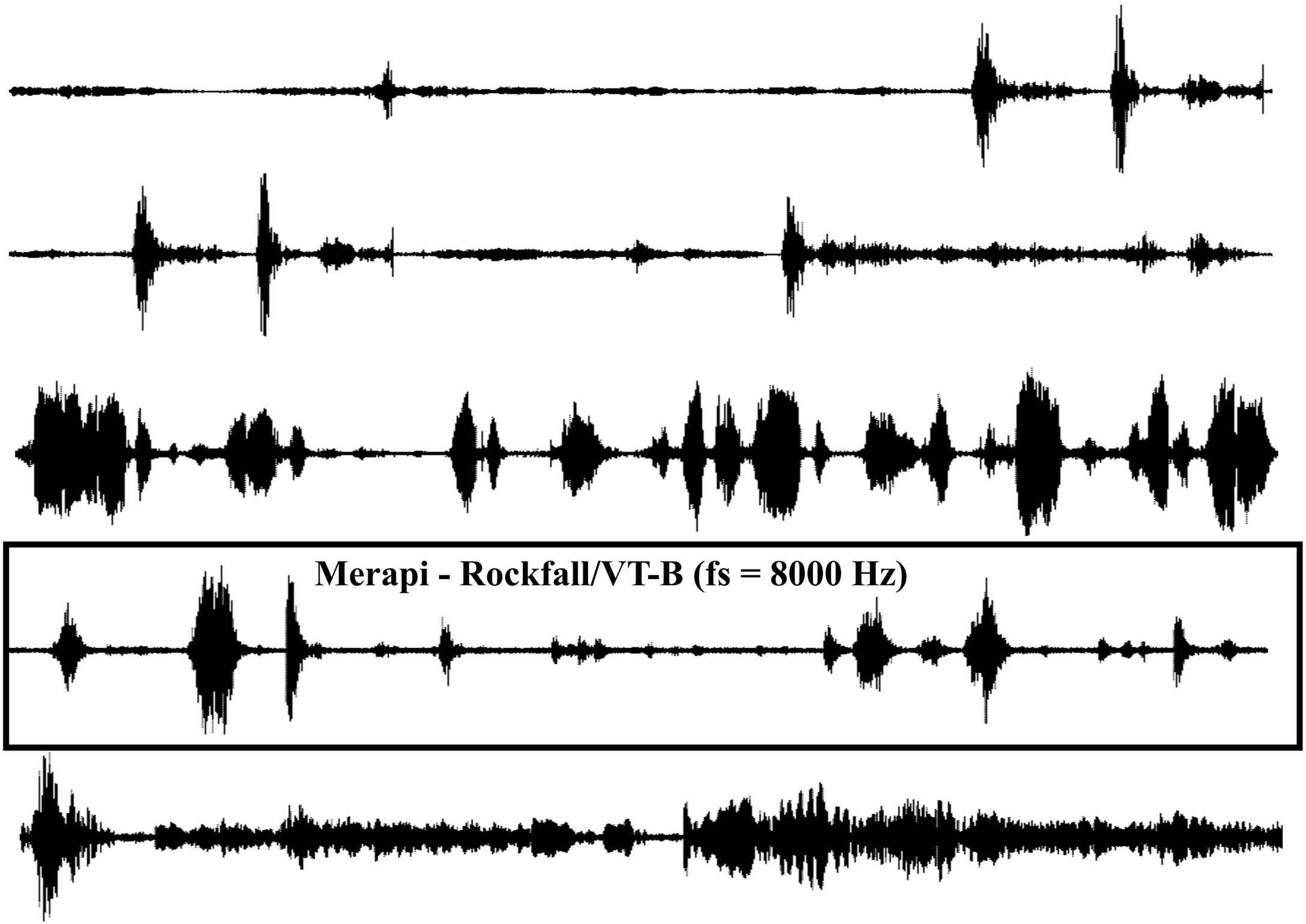


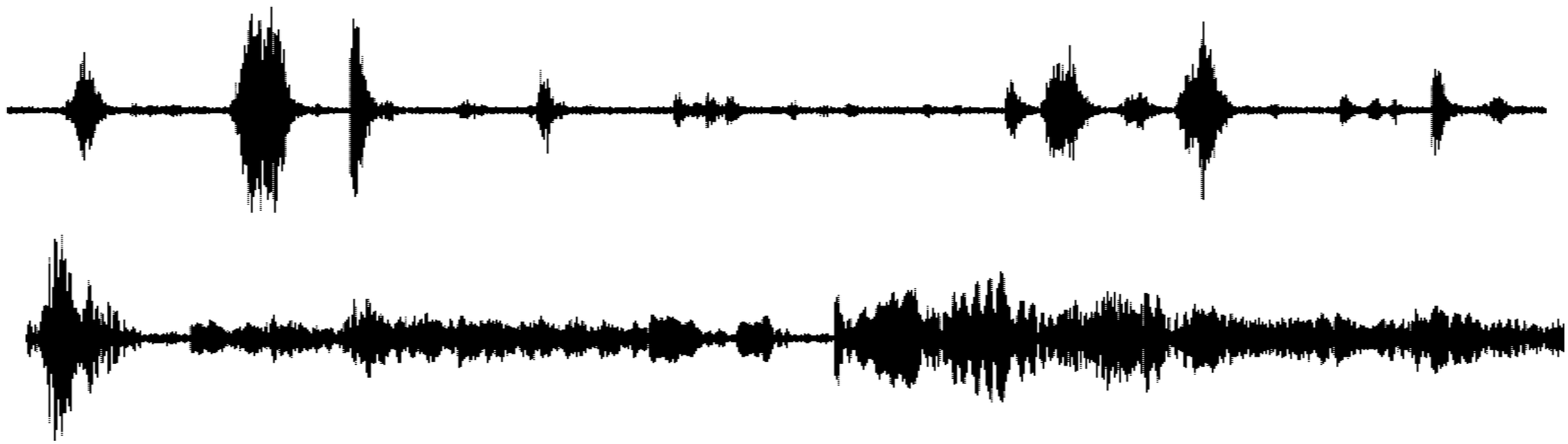
Klassifizierungsproblem



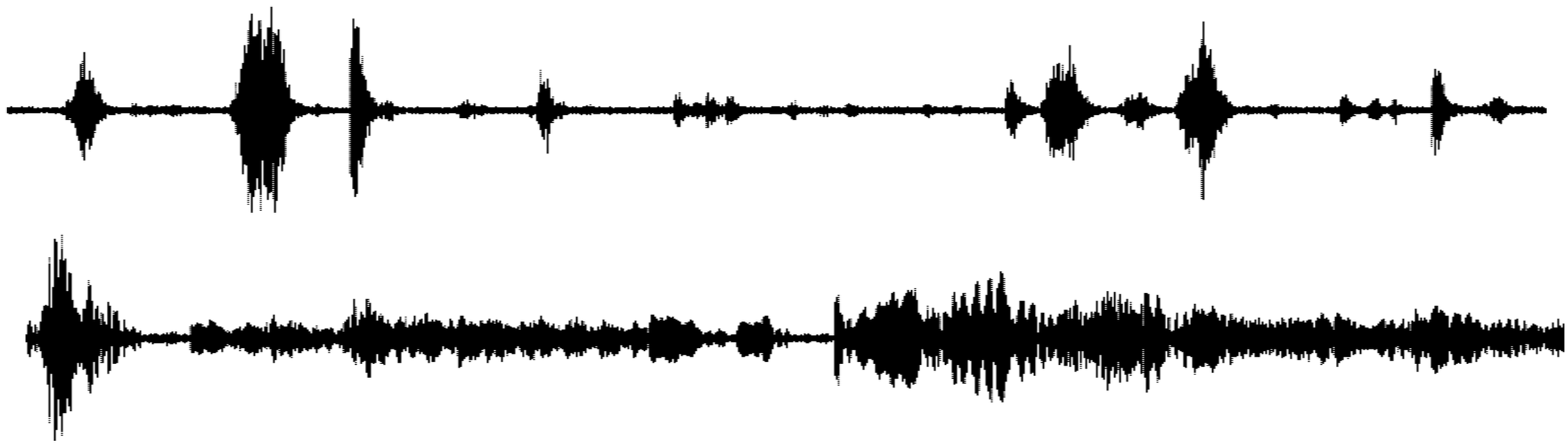
Klassifizierungsproblem



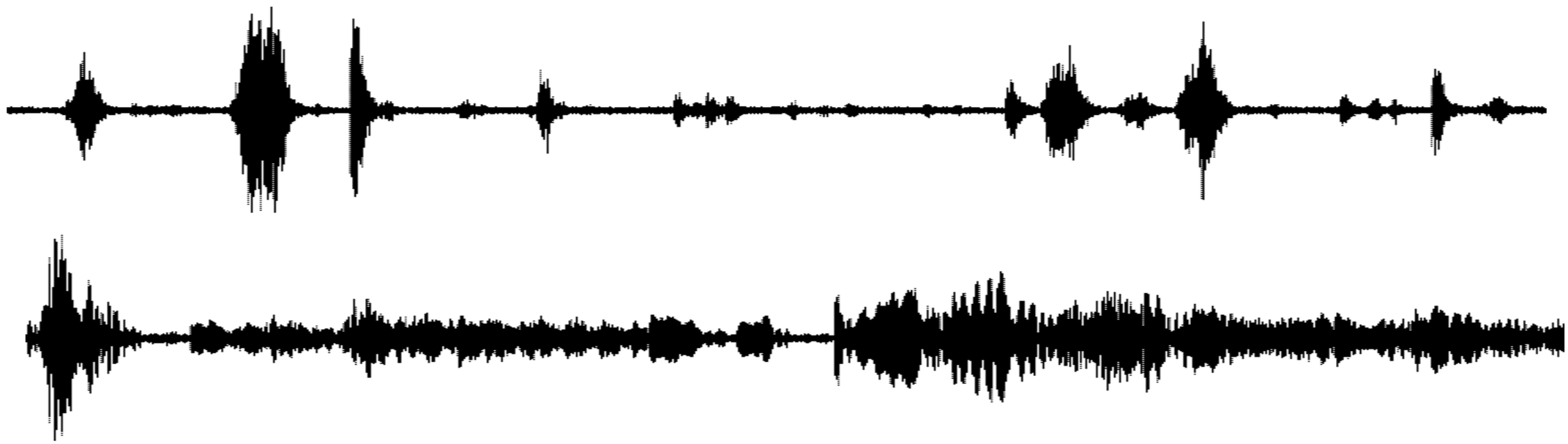
Klassifizierungsproblem



Klassifizierungsproblem



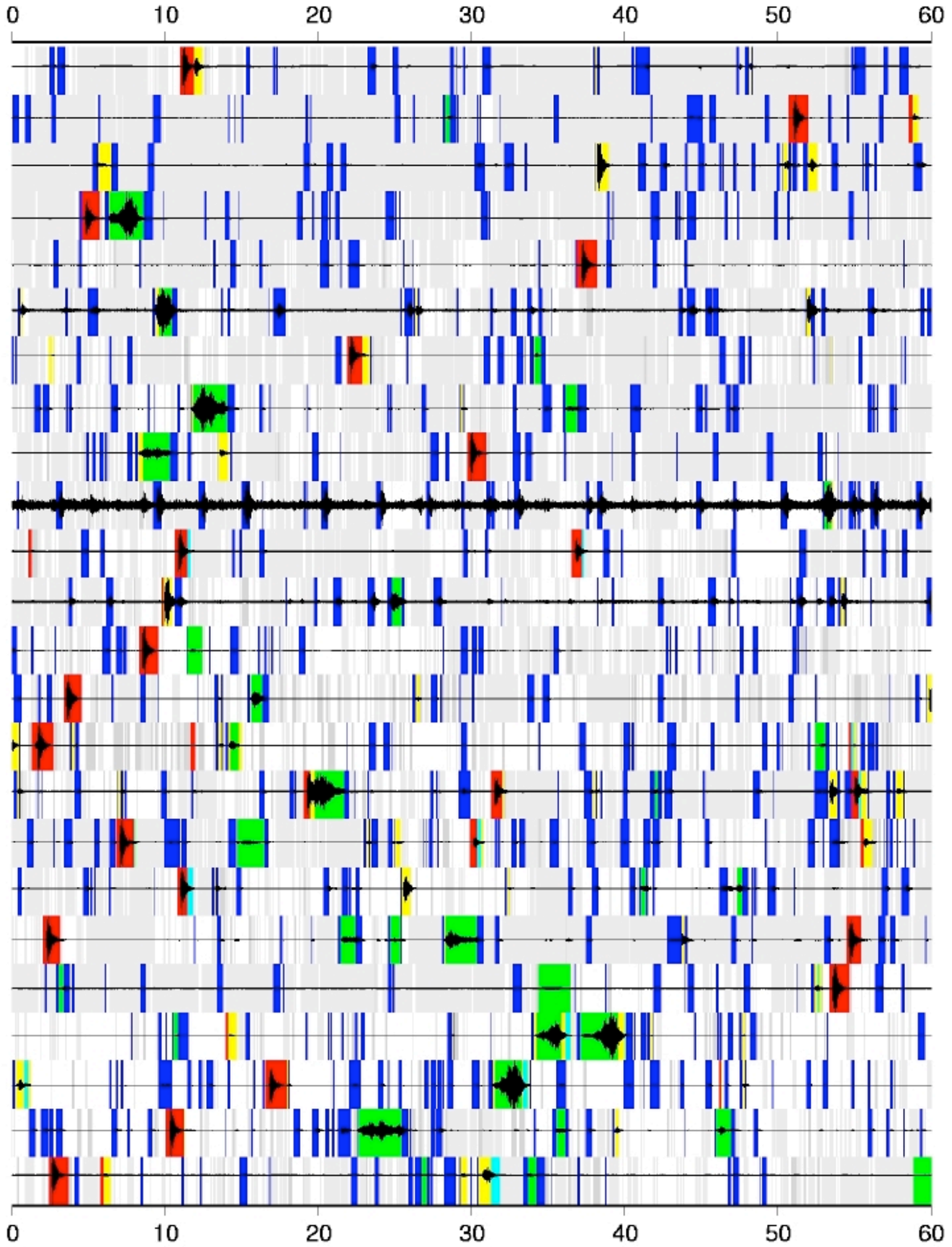
Klassifizierungsproblem



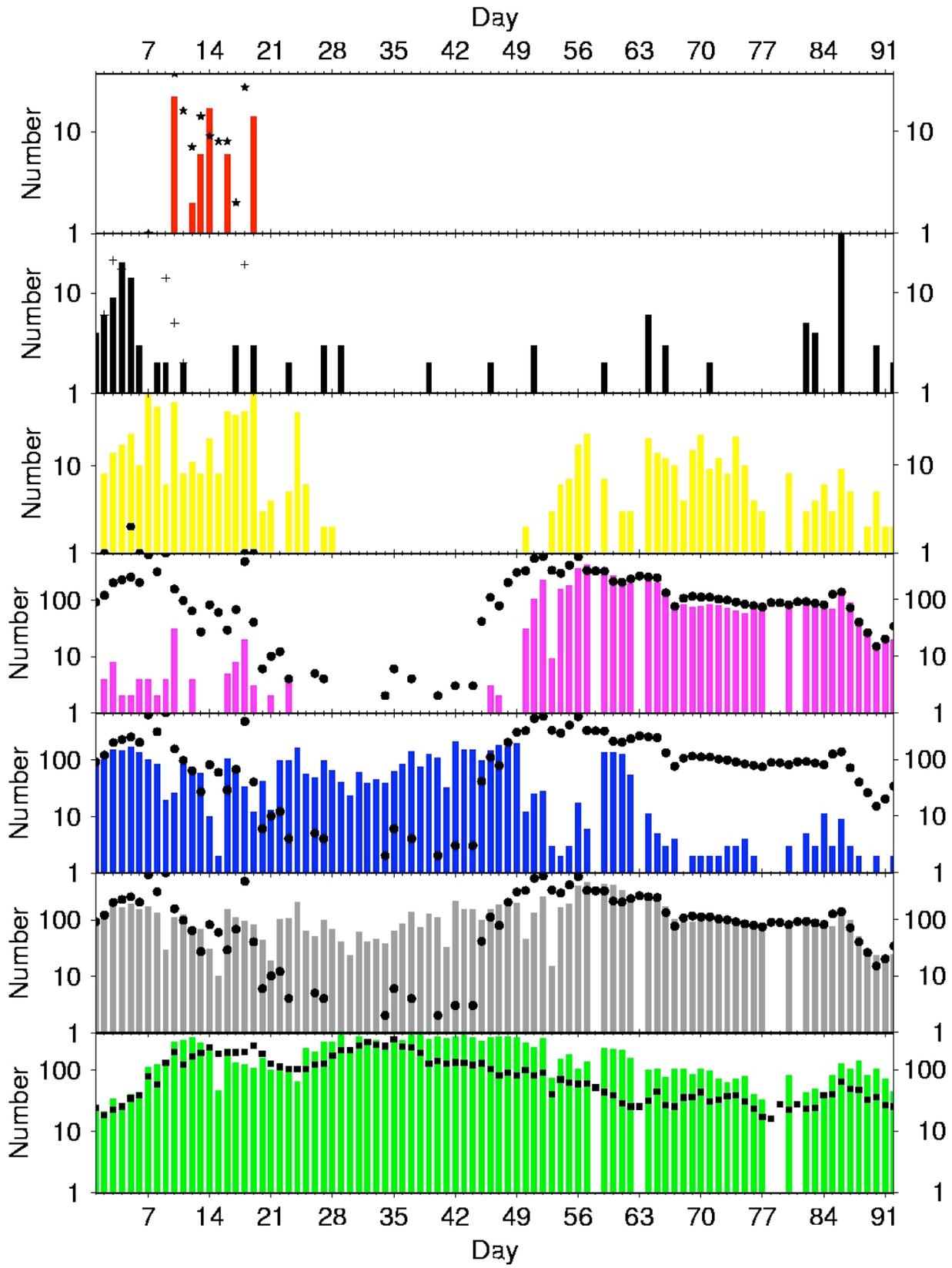
Lösung: “Sprachanalyse”

Automatische Klassifizierung

- MP
- VT-B
- “Unknown”
- Rockfall
- Hybrid



01 July – 30 September 1998



BaF

VT-B

Unknown

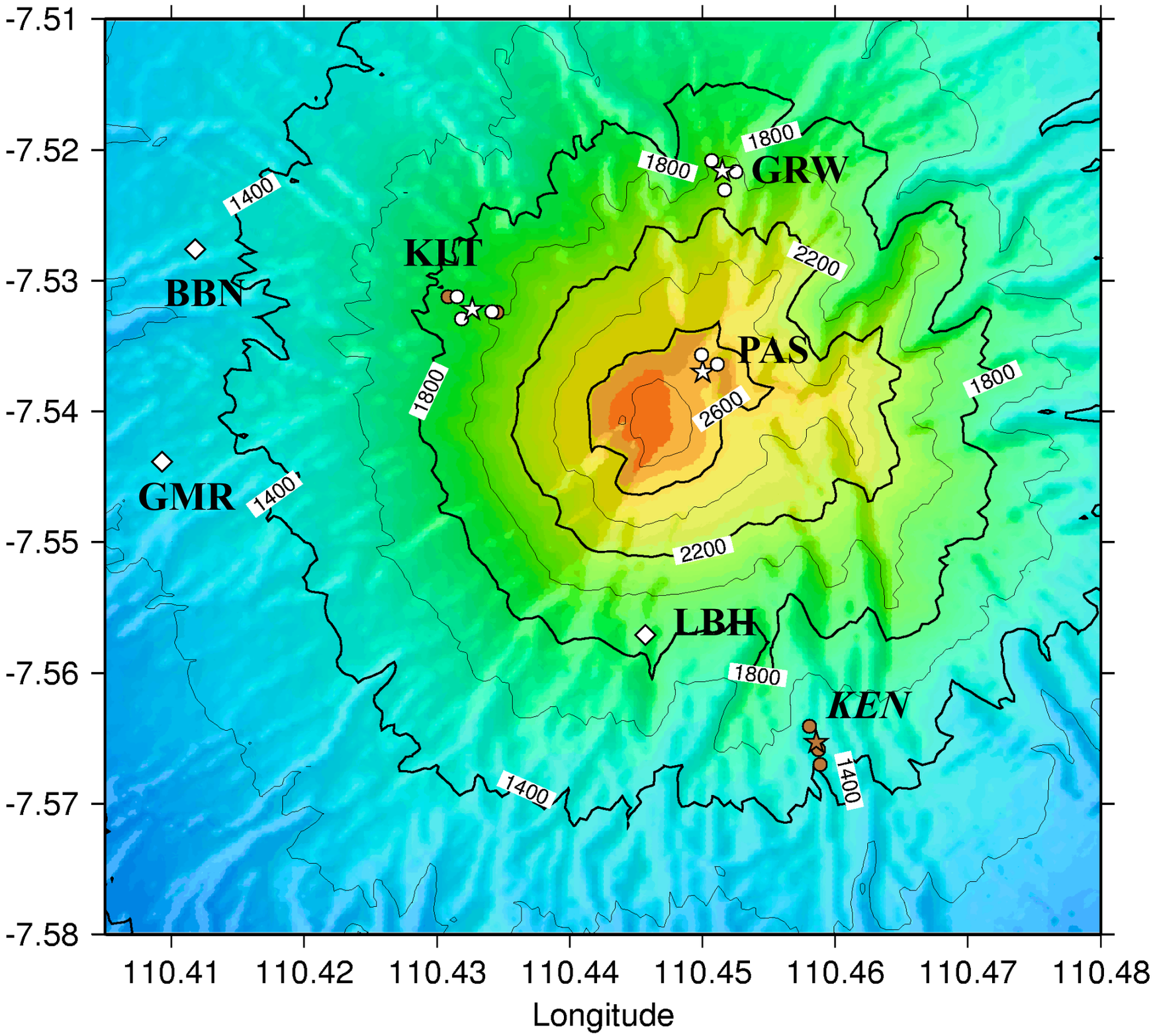
Hybrid

MP

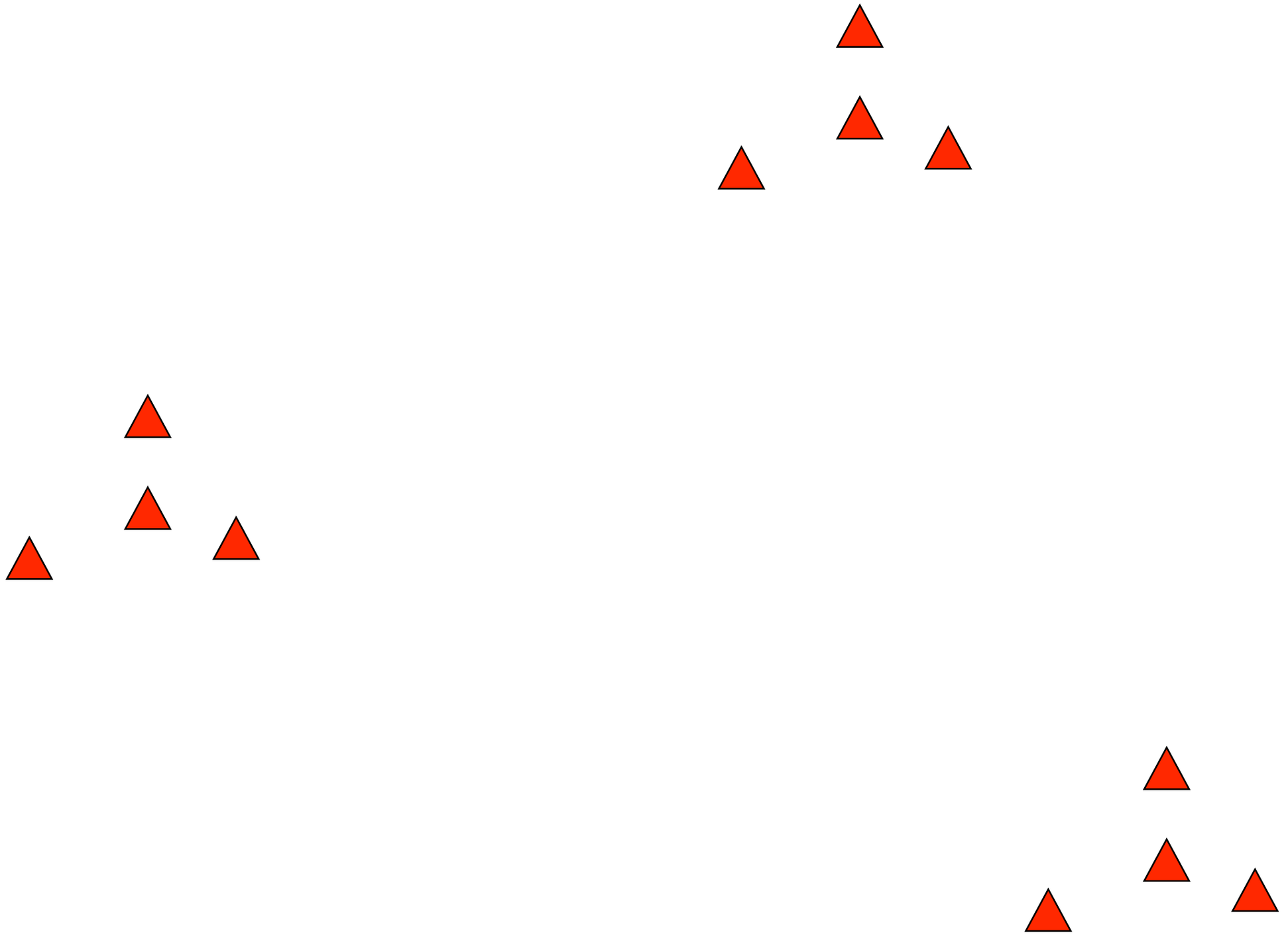
All-MP

Rockfall

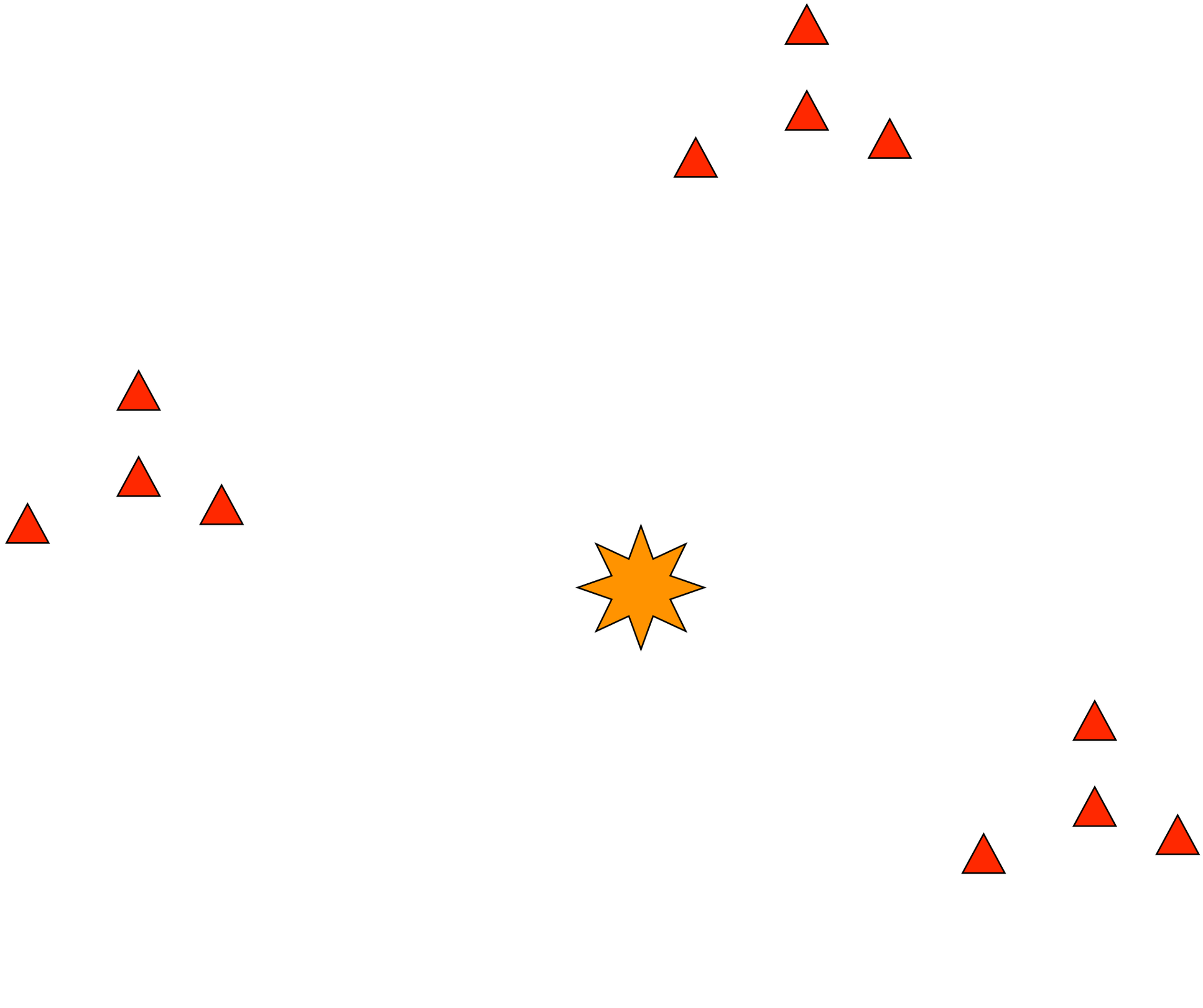
Andere Vorgehensweise:
Seismisches Netz am Vulkan Merapi



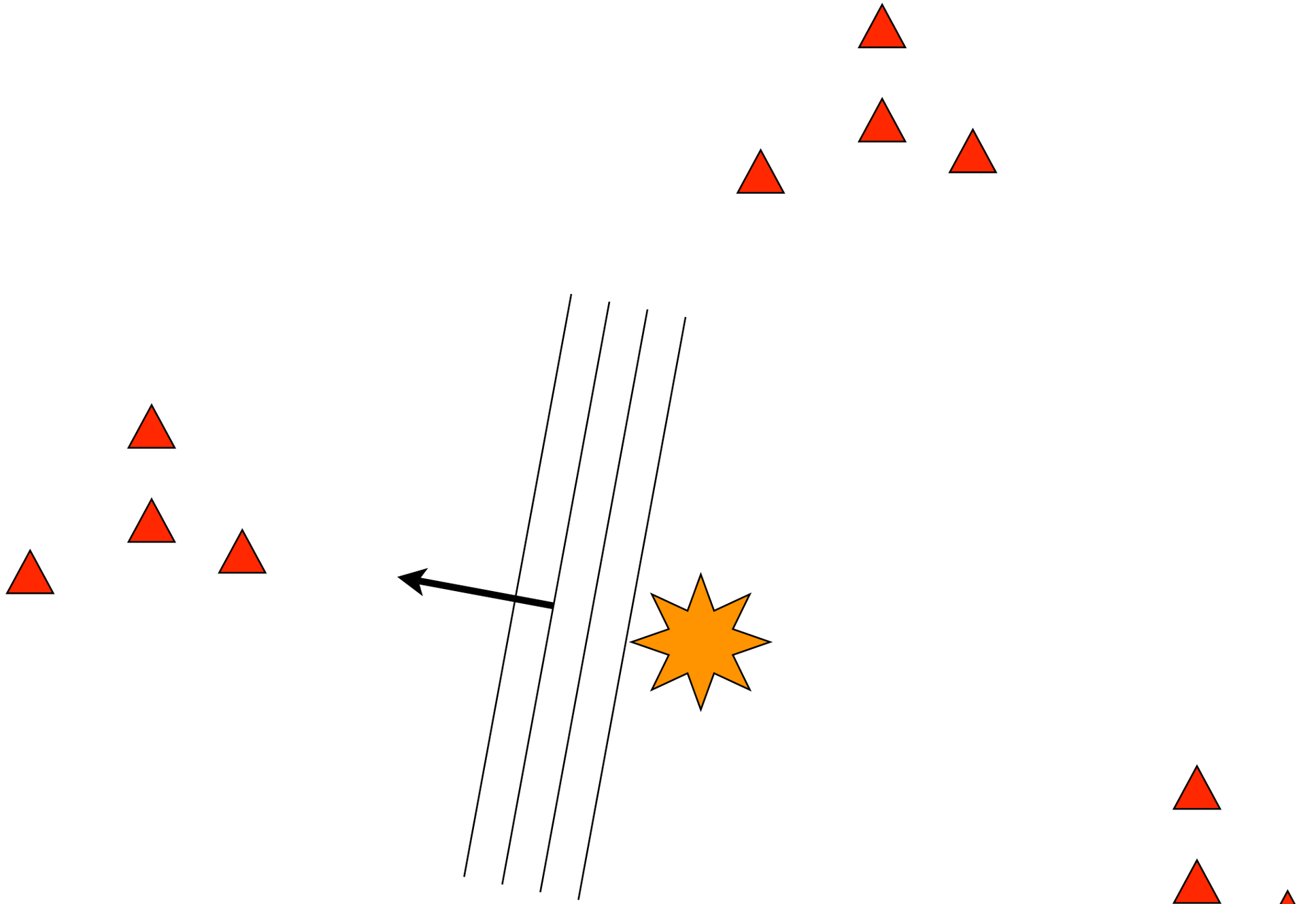
Vorteile seism. Antennen (Arrays)



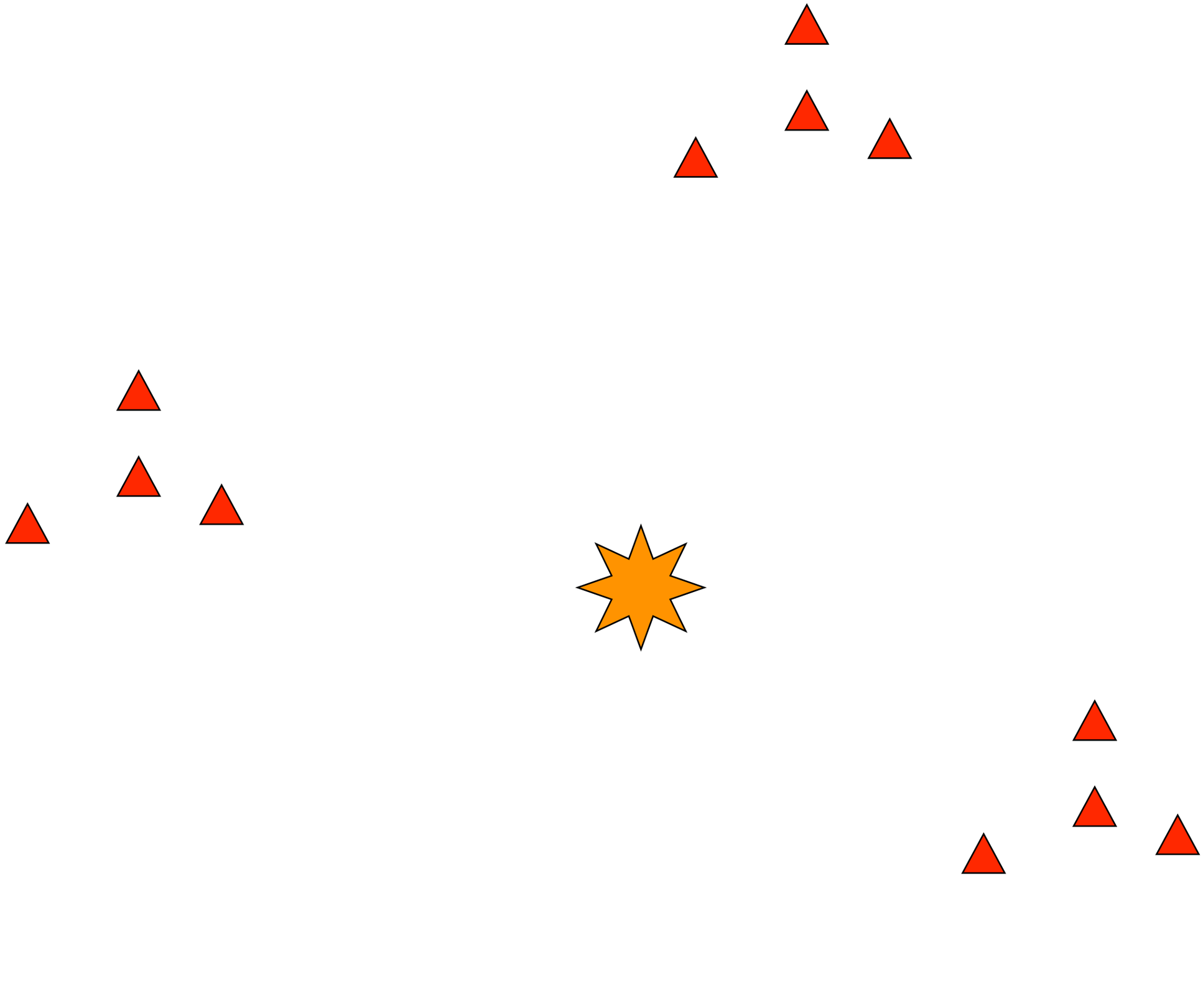
Vorteile seism. Antennen (Arrays)



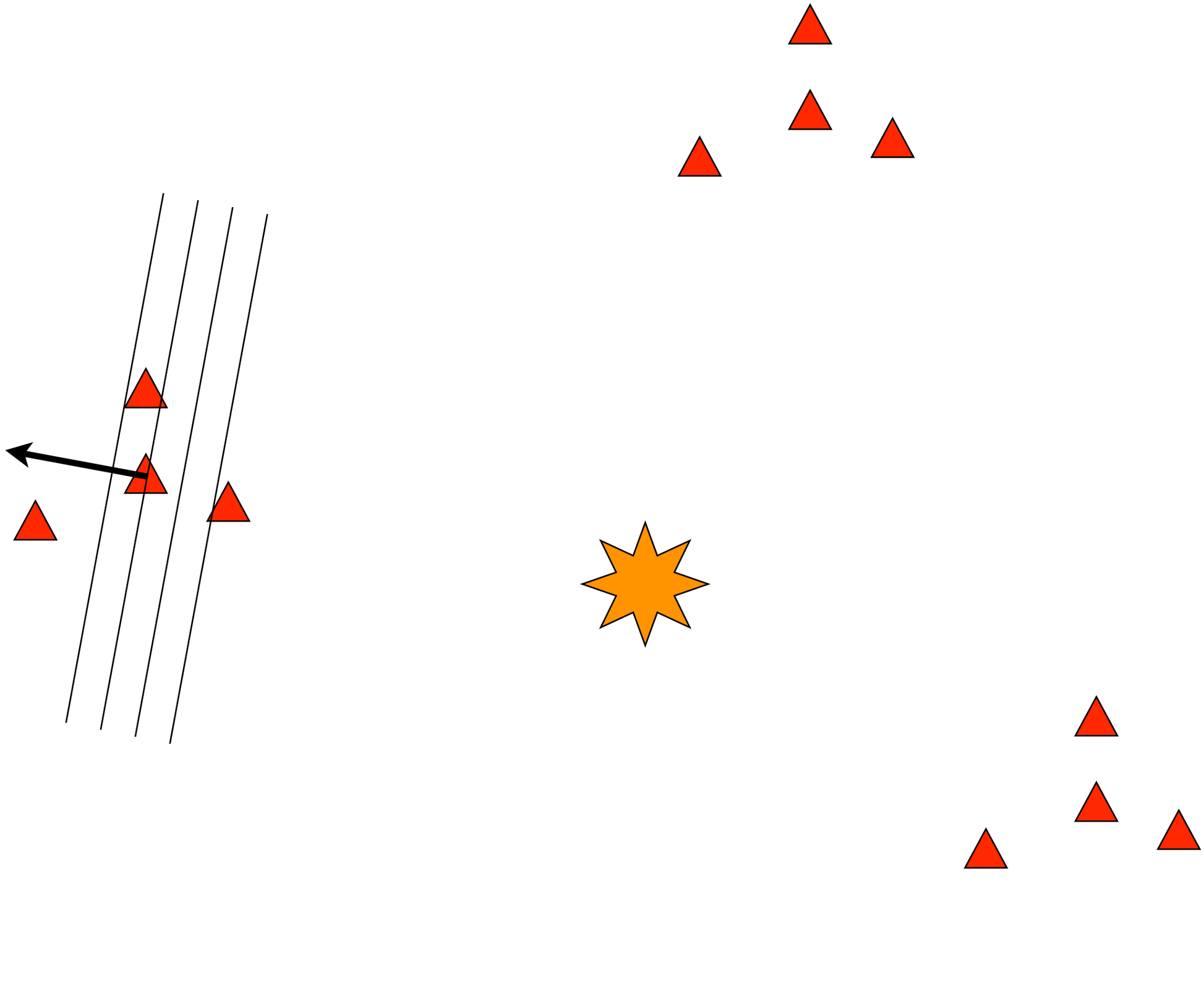
Vorteile seism. Antennen (Arrays)



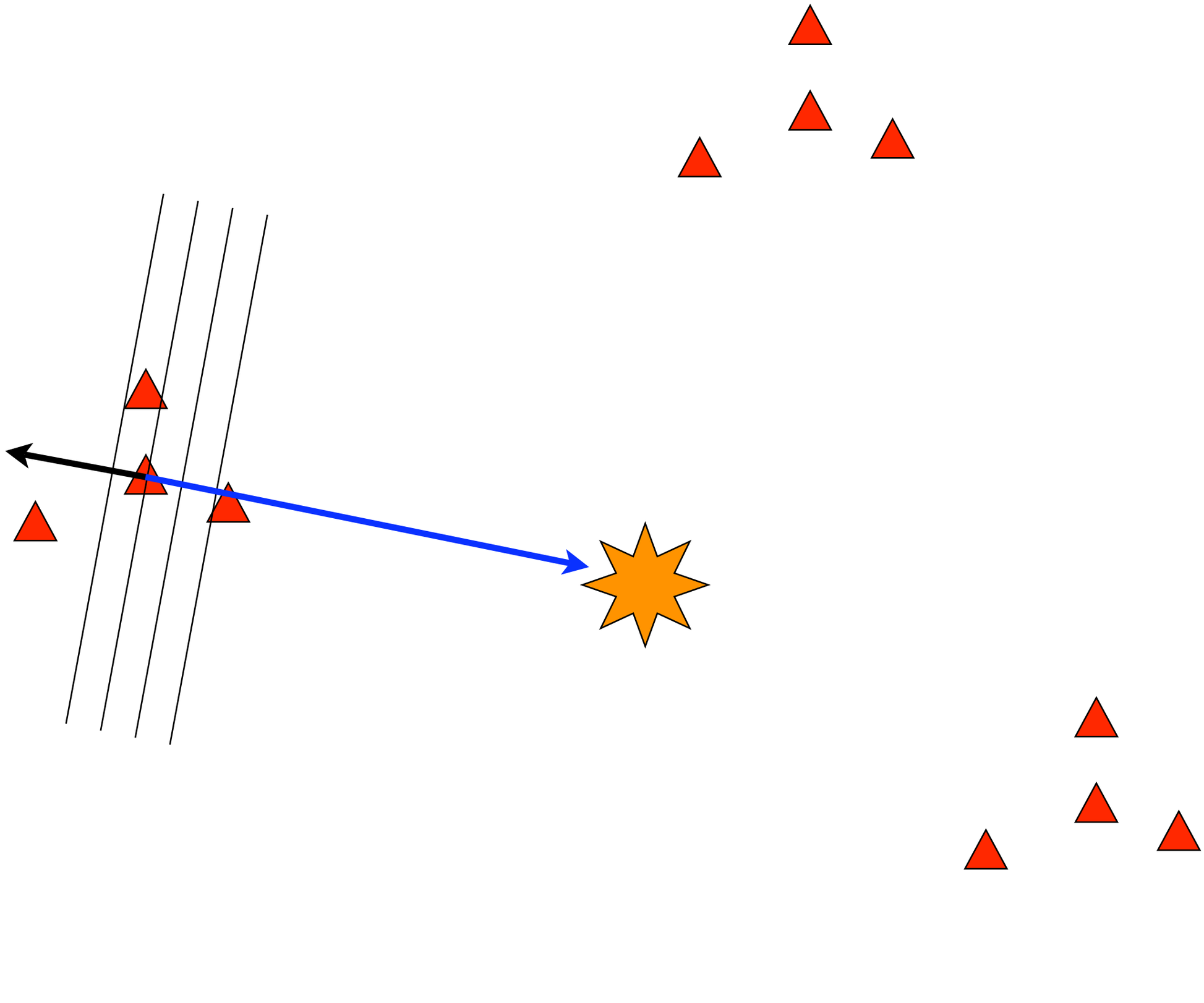
Vorteile seism. Antennen (Arrays)



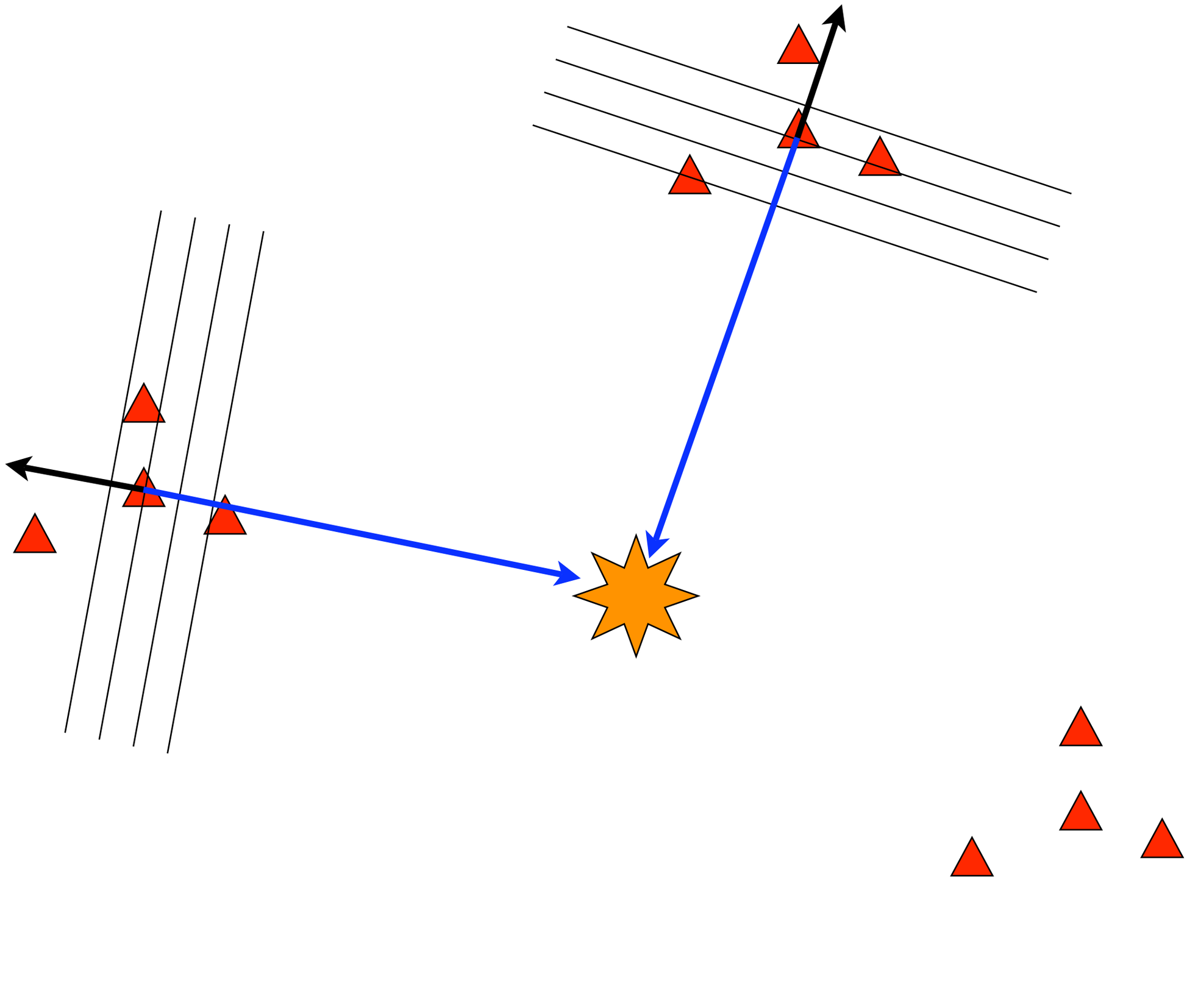
Vorteile seism. Antennen (Arrays)



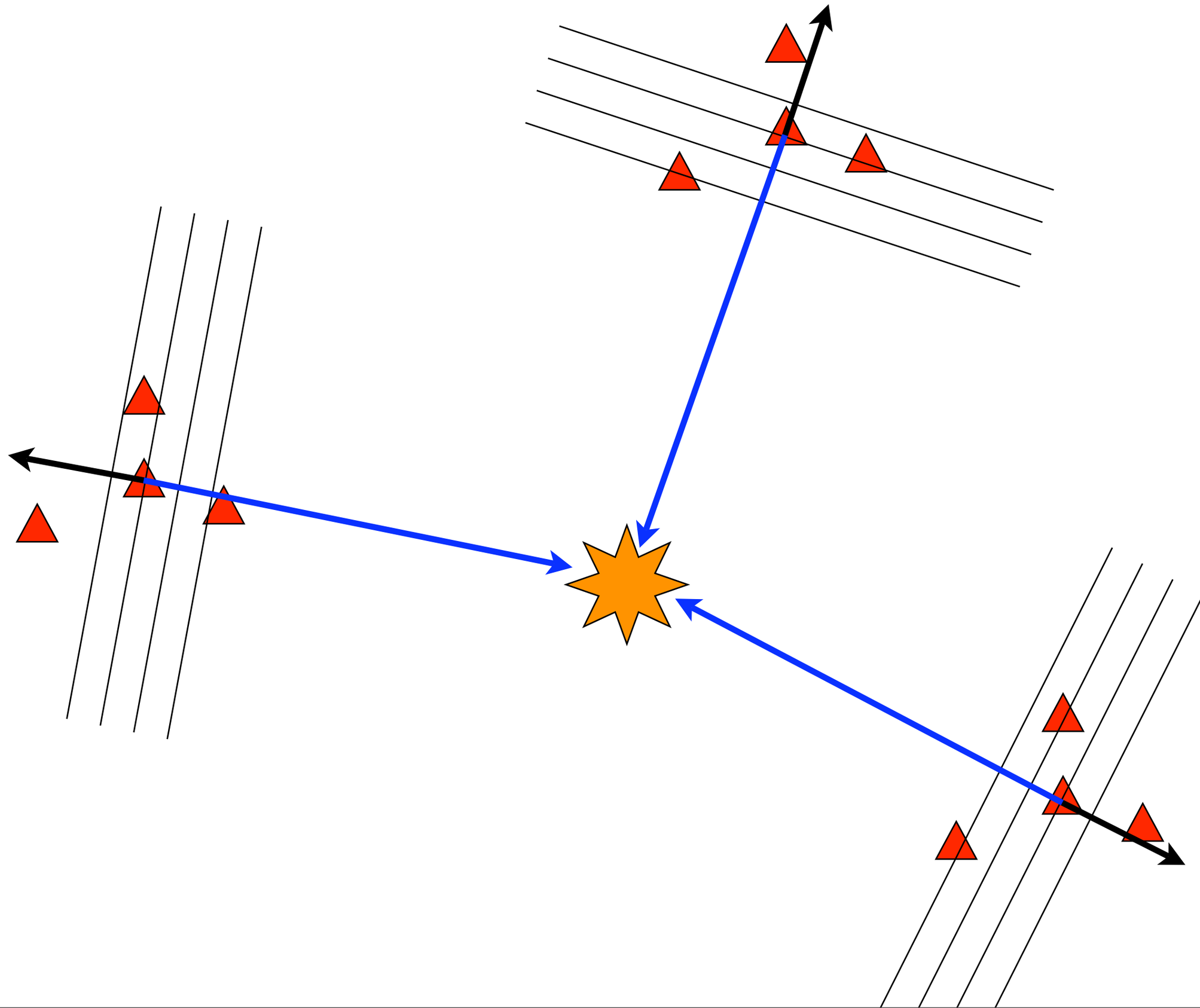
Vorteile seism. Antennen (Arrays)



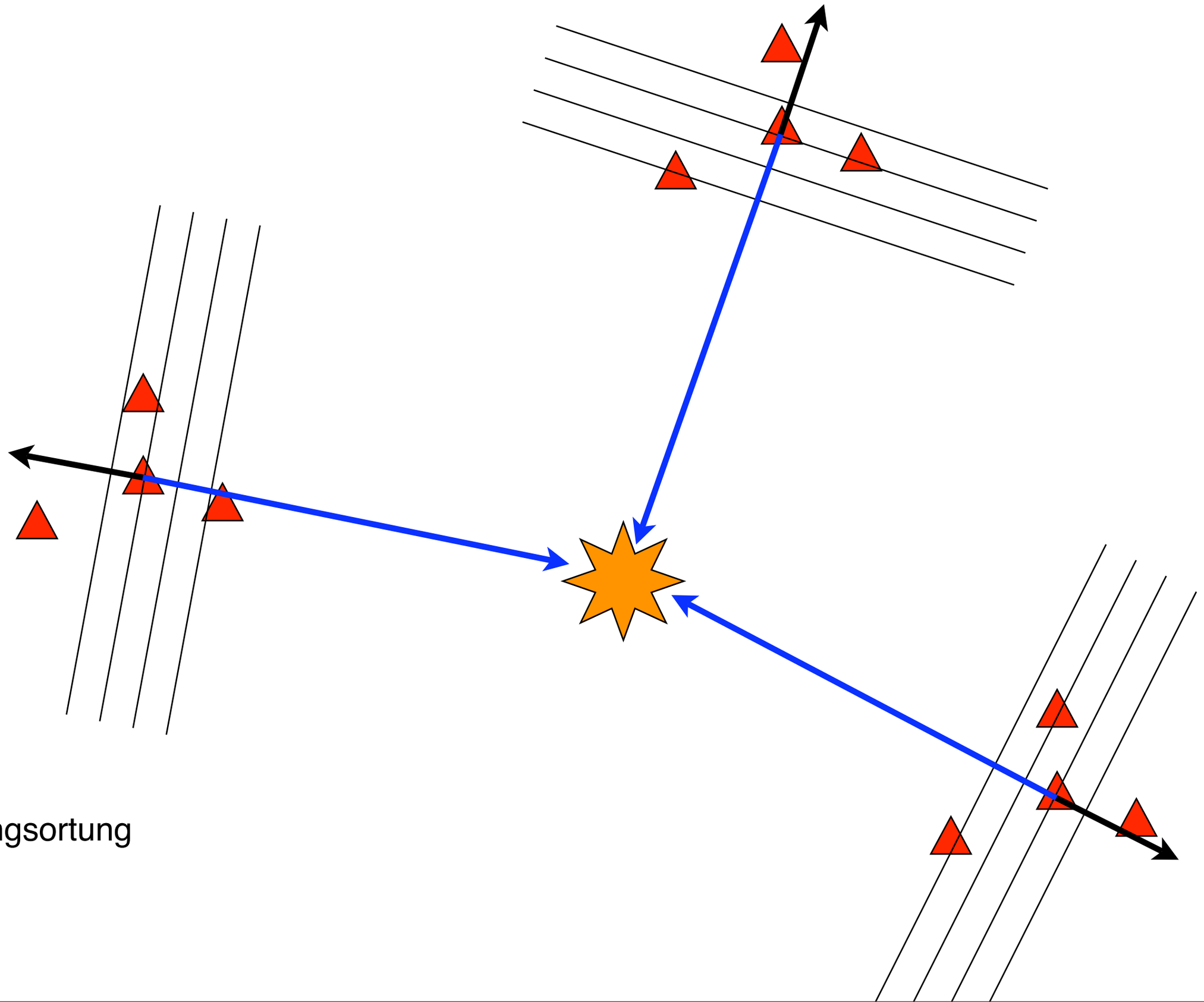
Vorteile seism. Antennen (Arrays)



Vorteile seism. Antennen (Arrays)

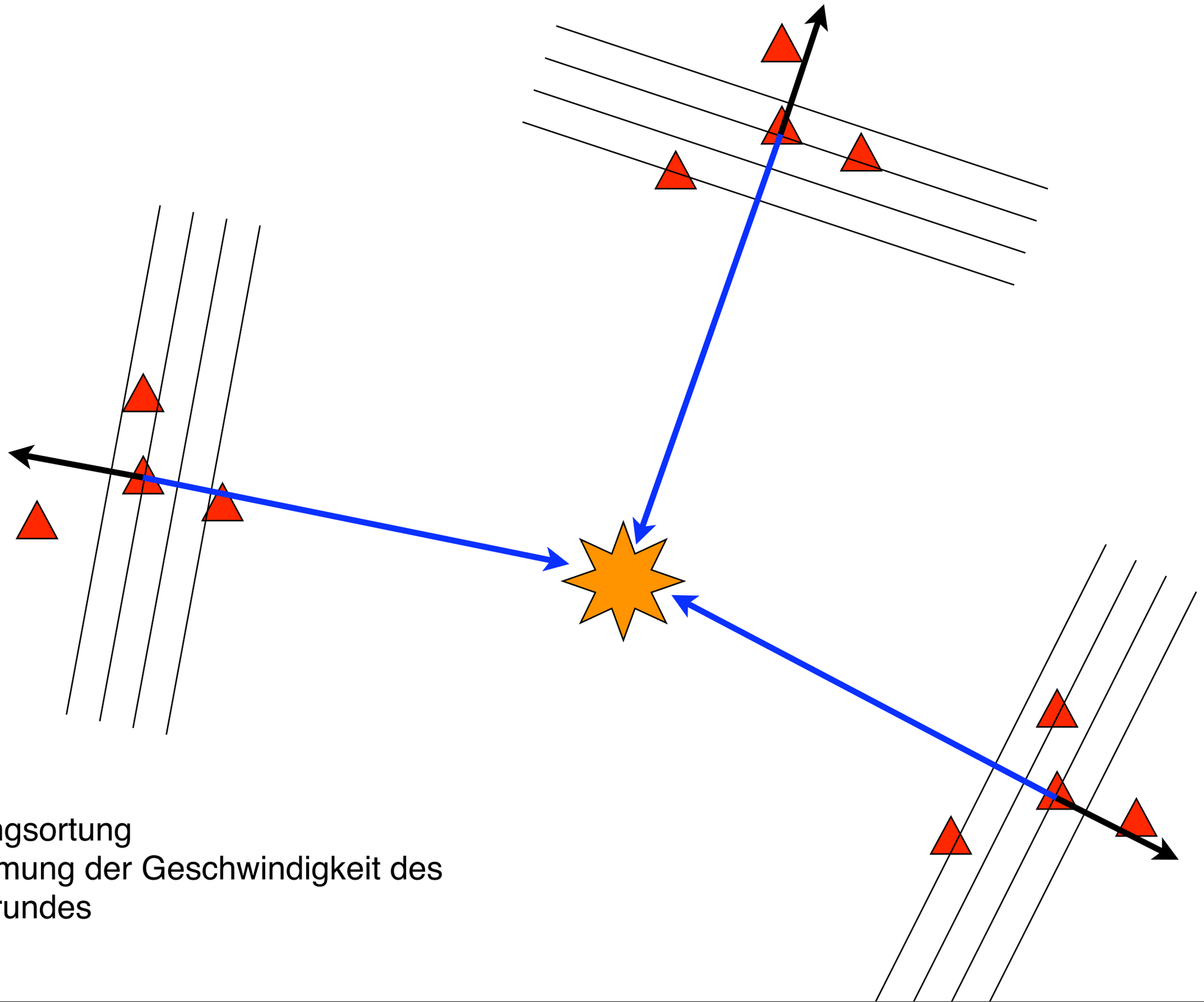


Vorteile seism. Antennen (Arrays)



- Richtungsortung

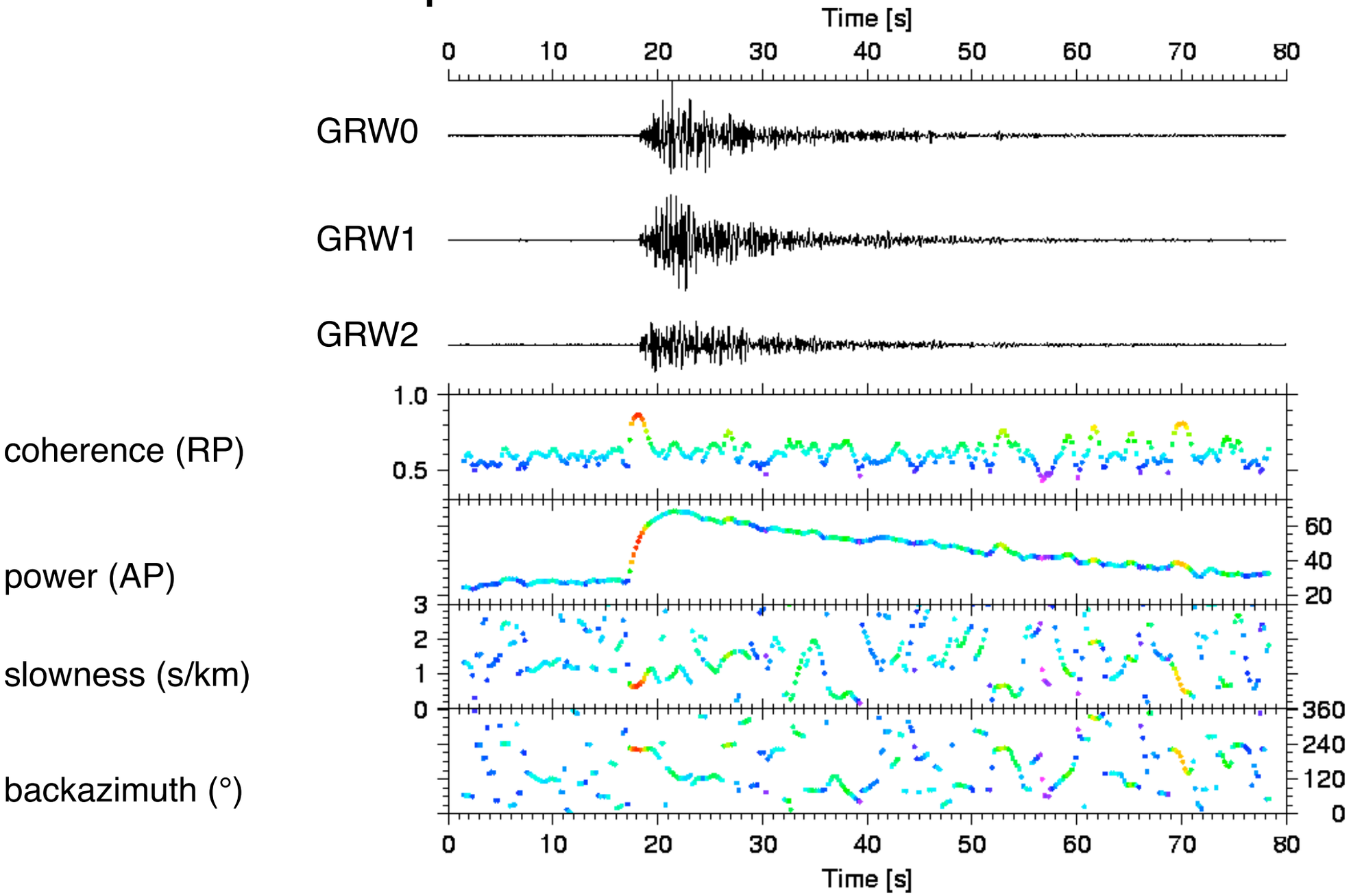
Vorteile seism. Antennen (Arrays)



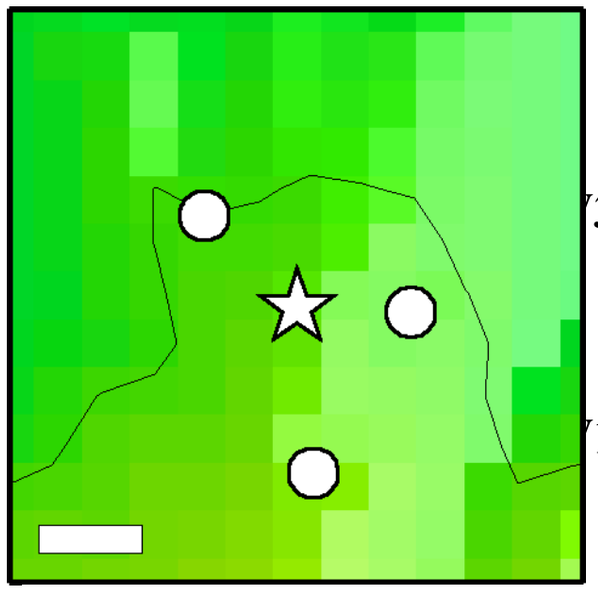
- Richtungsortung
- Bestimmung der Geschwindigkeit des Untergrundes

Vorteile seism. Antennen (Arrays)

Wavefield Properties



Seismische Antennen



☆ Broadband station

○ Short-period station

Digitizer

Opto-
Modem

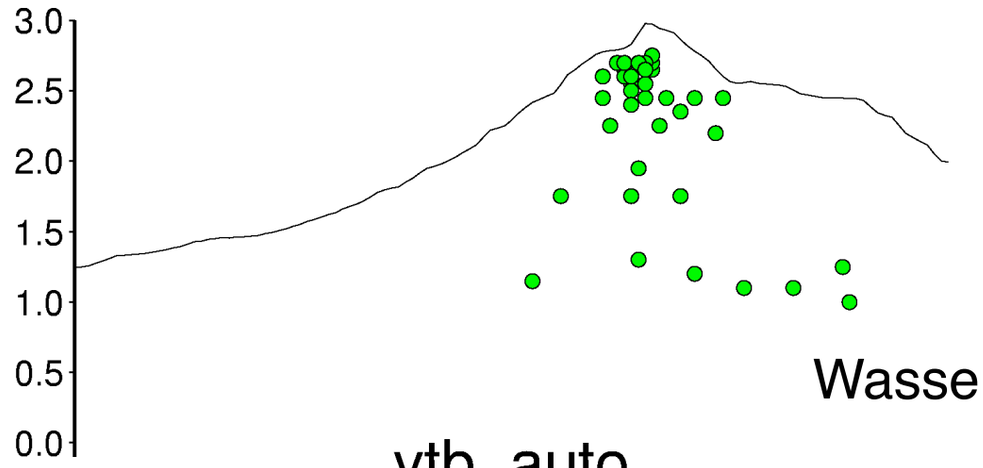
Glas-Fibre

Lightning Protection

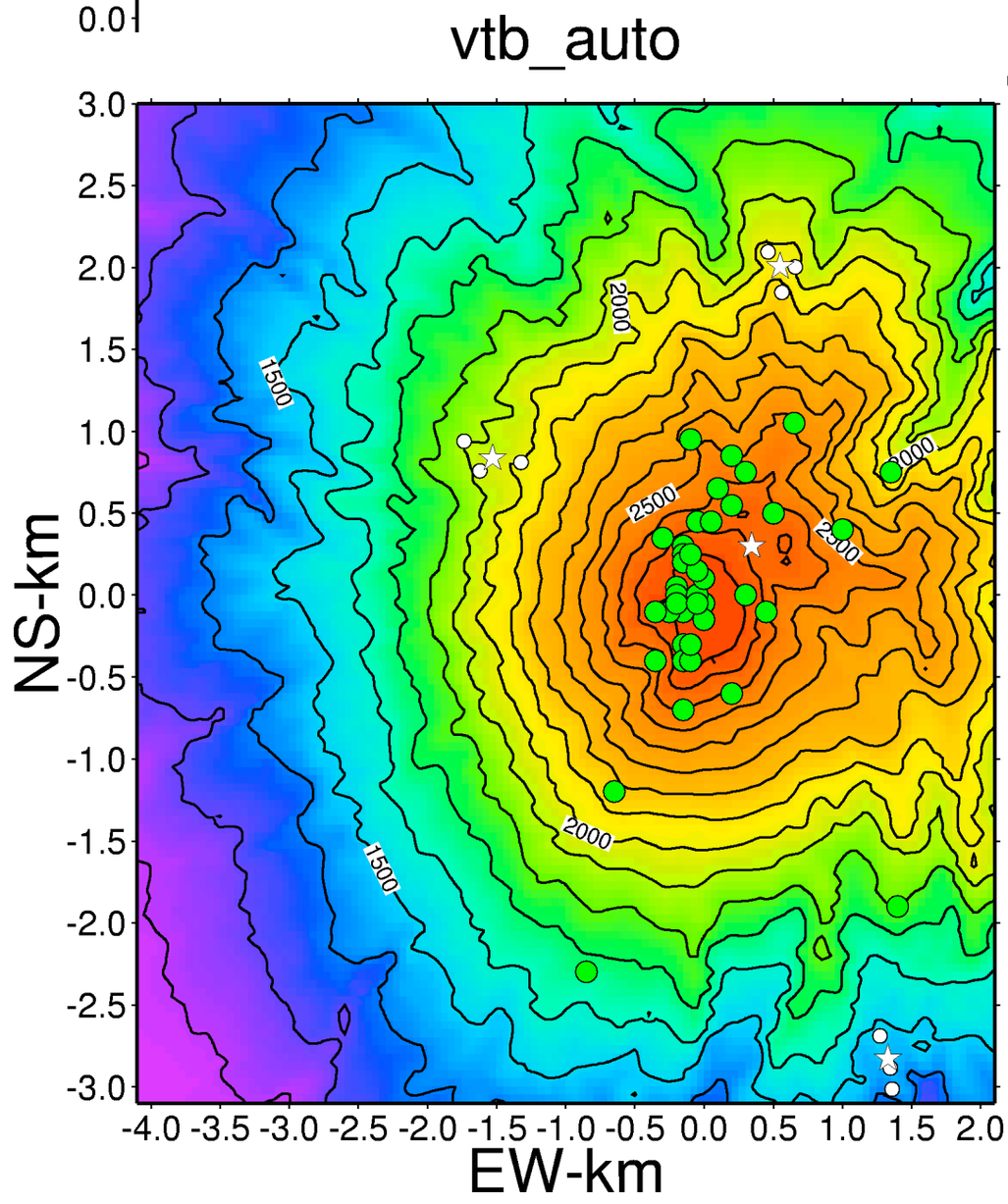
Seismometer

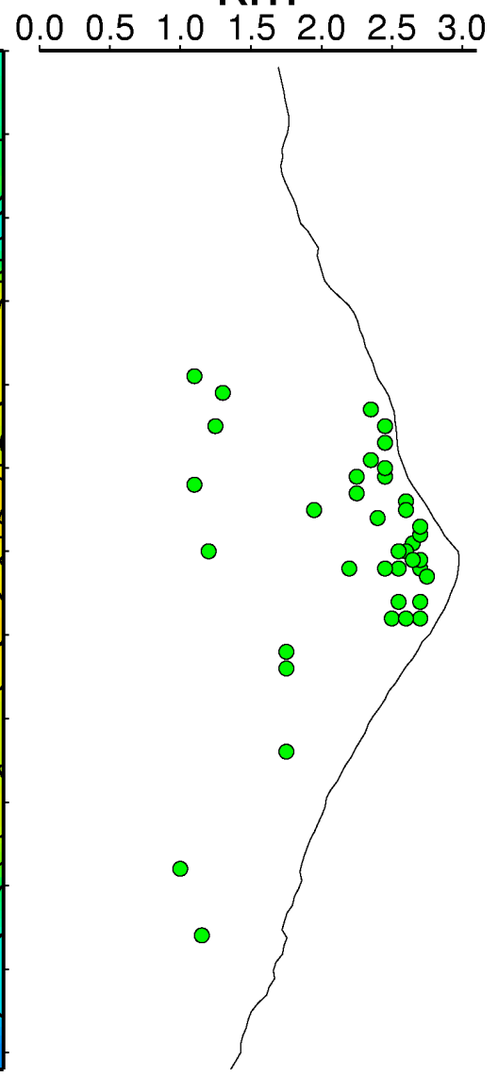
Seismic Array Design

Automatische Lokalisierung (VT-B Typ)

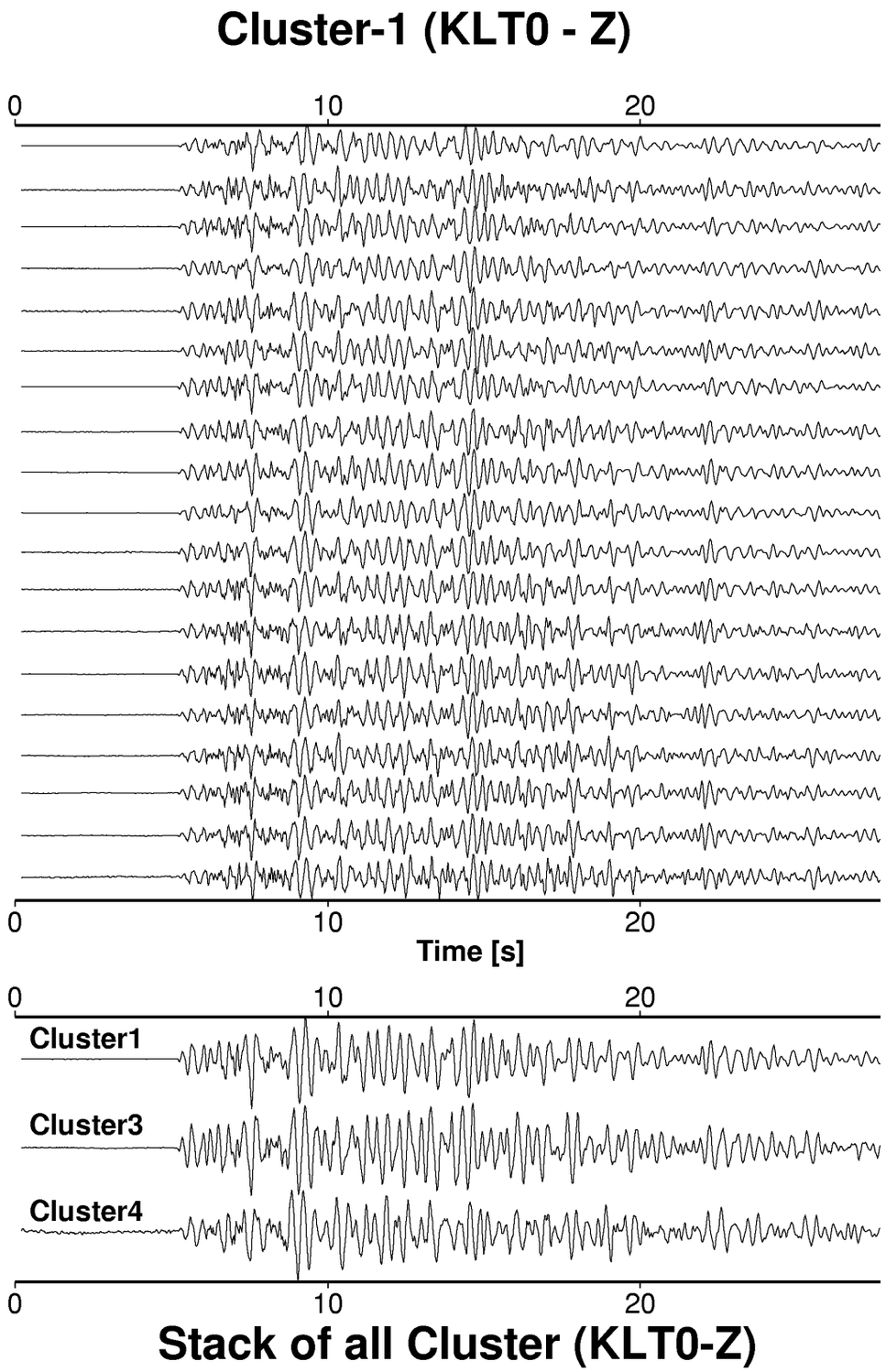


Wassermann and Ohrnberger, JVGR, 2001



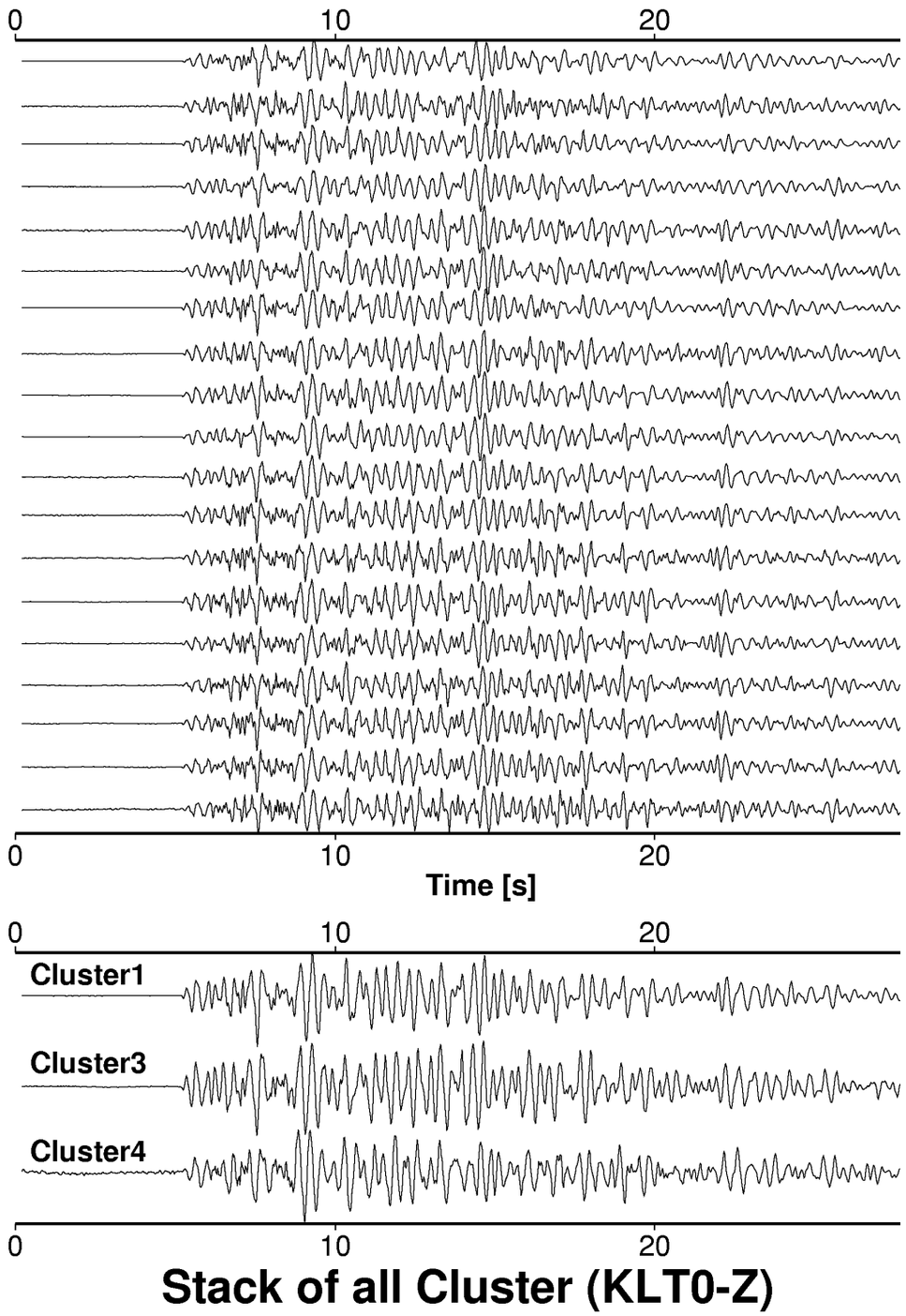


Special Seismic Swarms

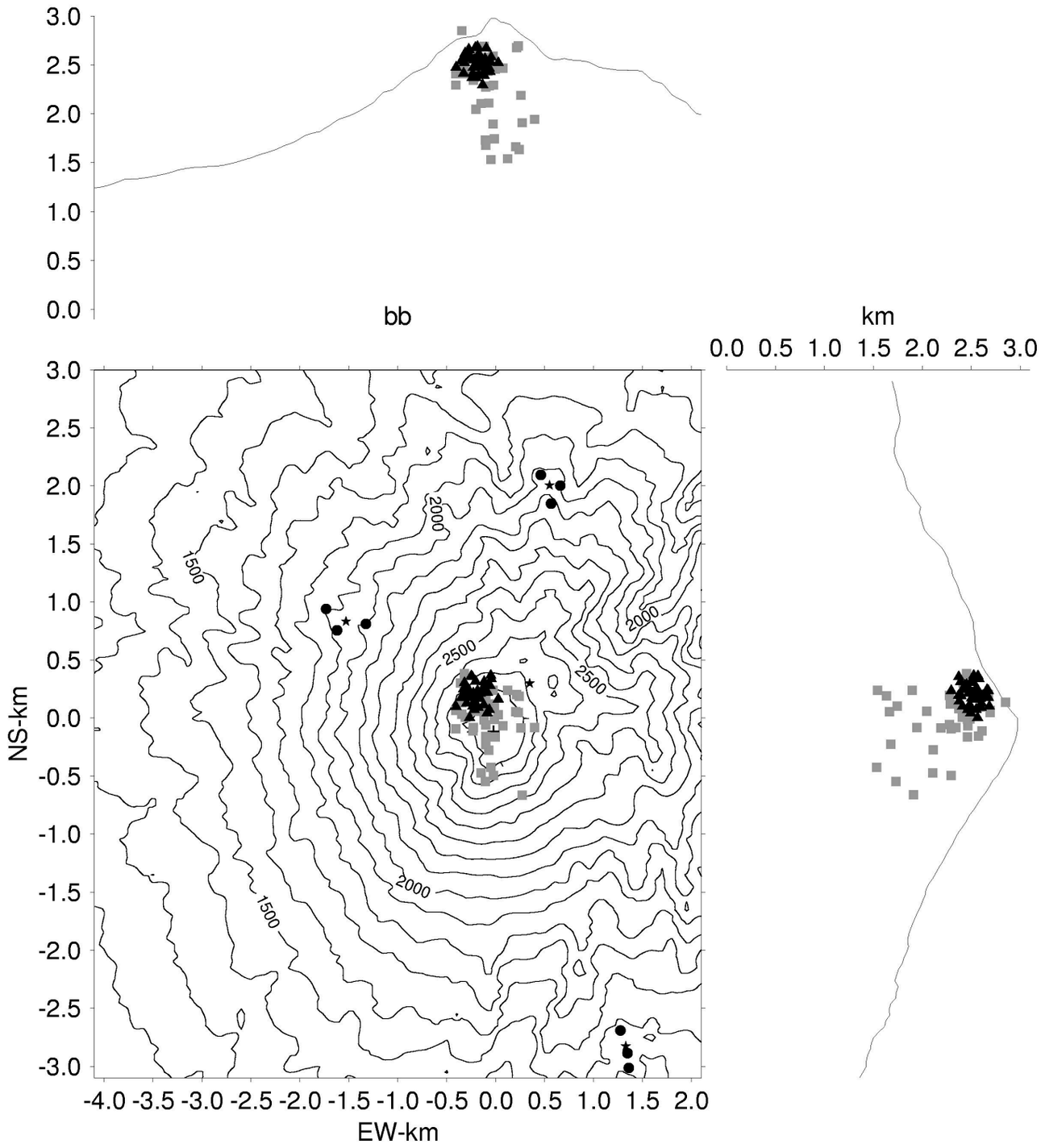


Special Seismic Swarms

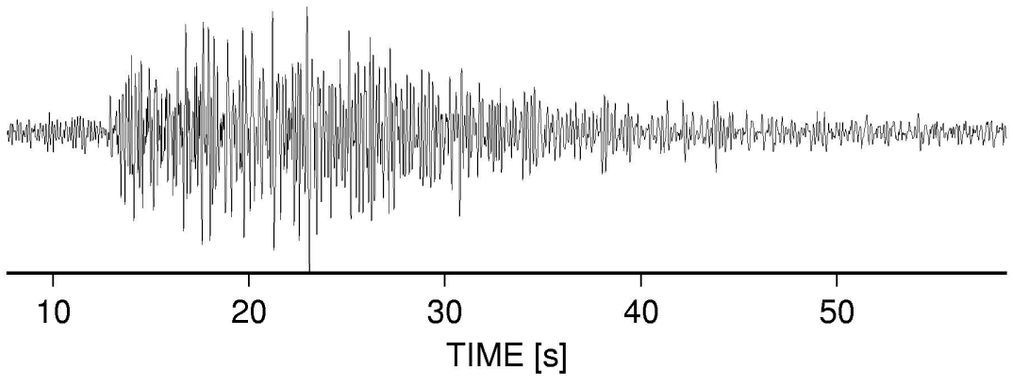
Cluster-1 (KLT0 - Z)

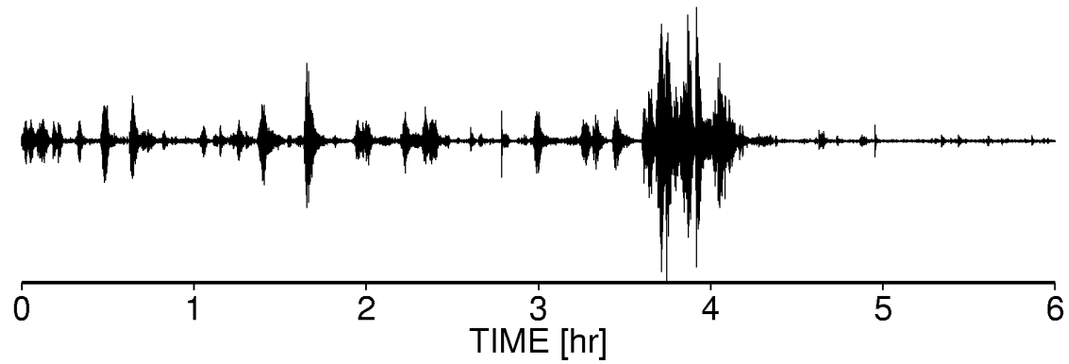


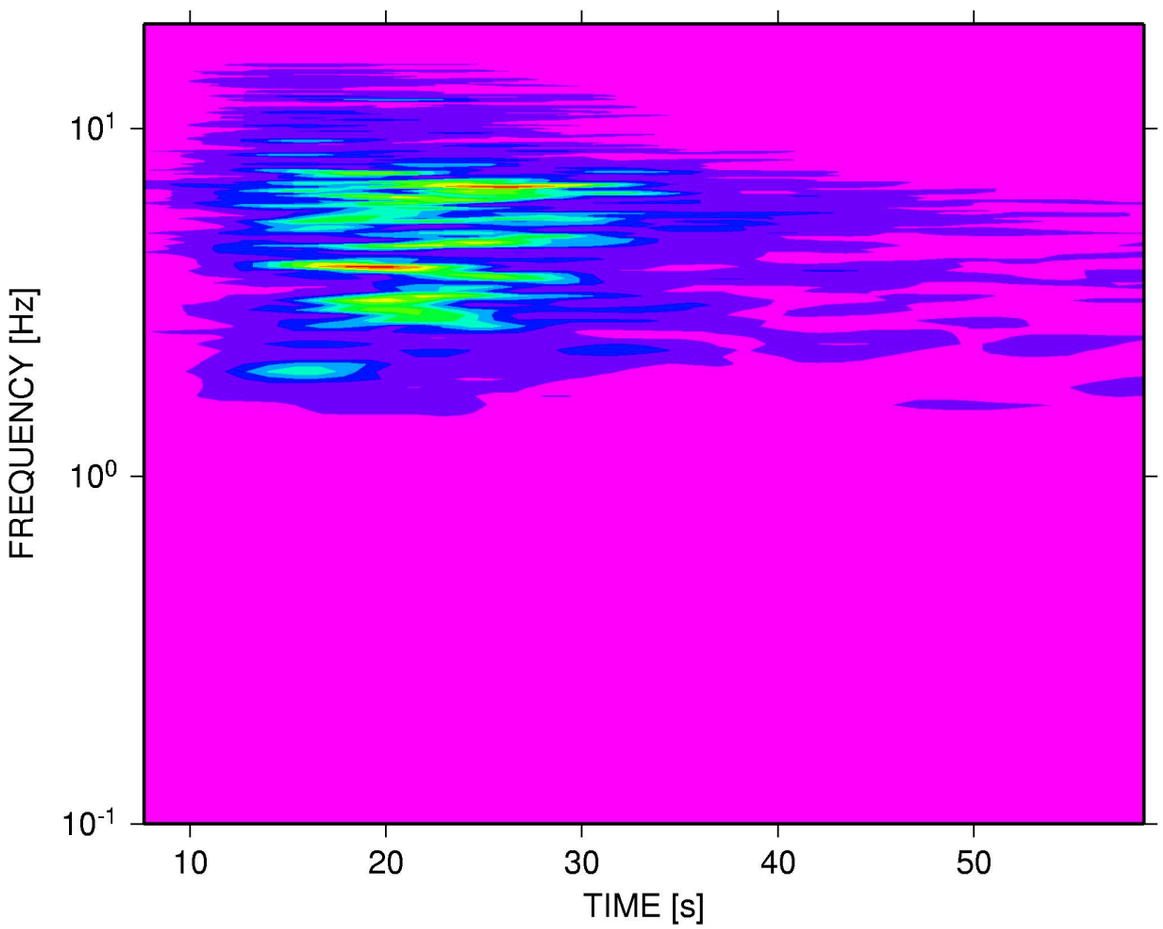
Relocated VT-B

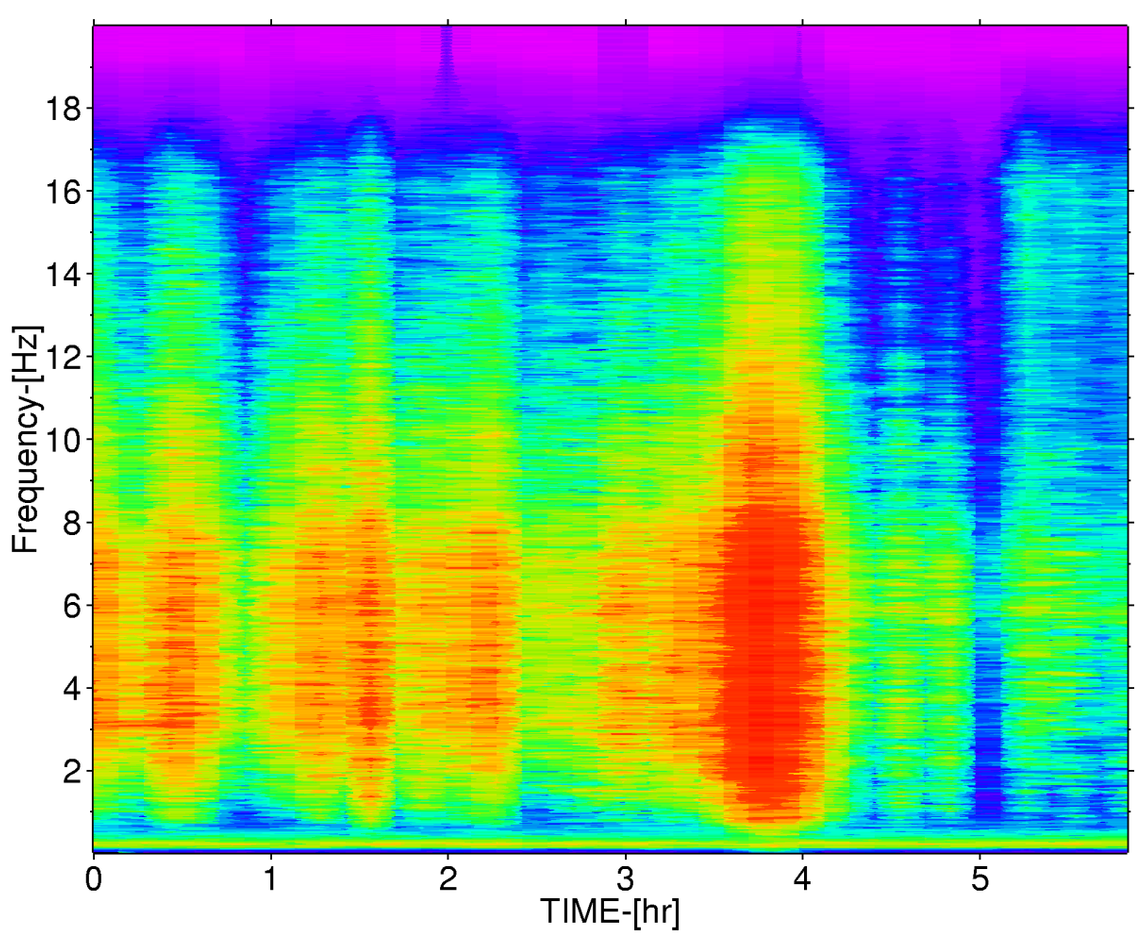


Was ist mit diesen Signalen?

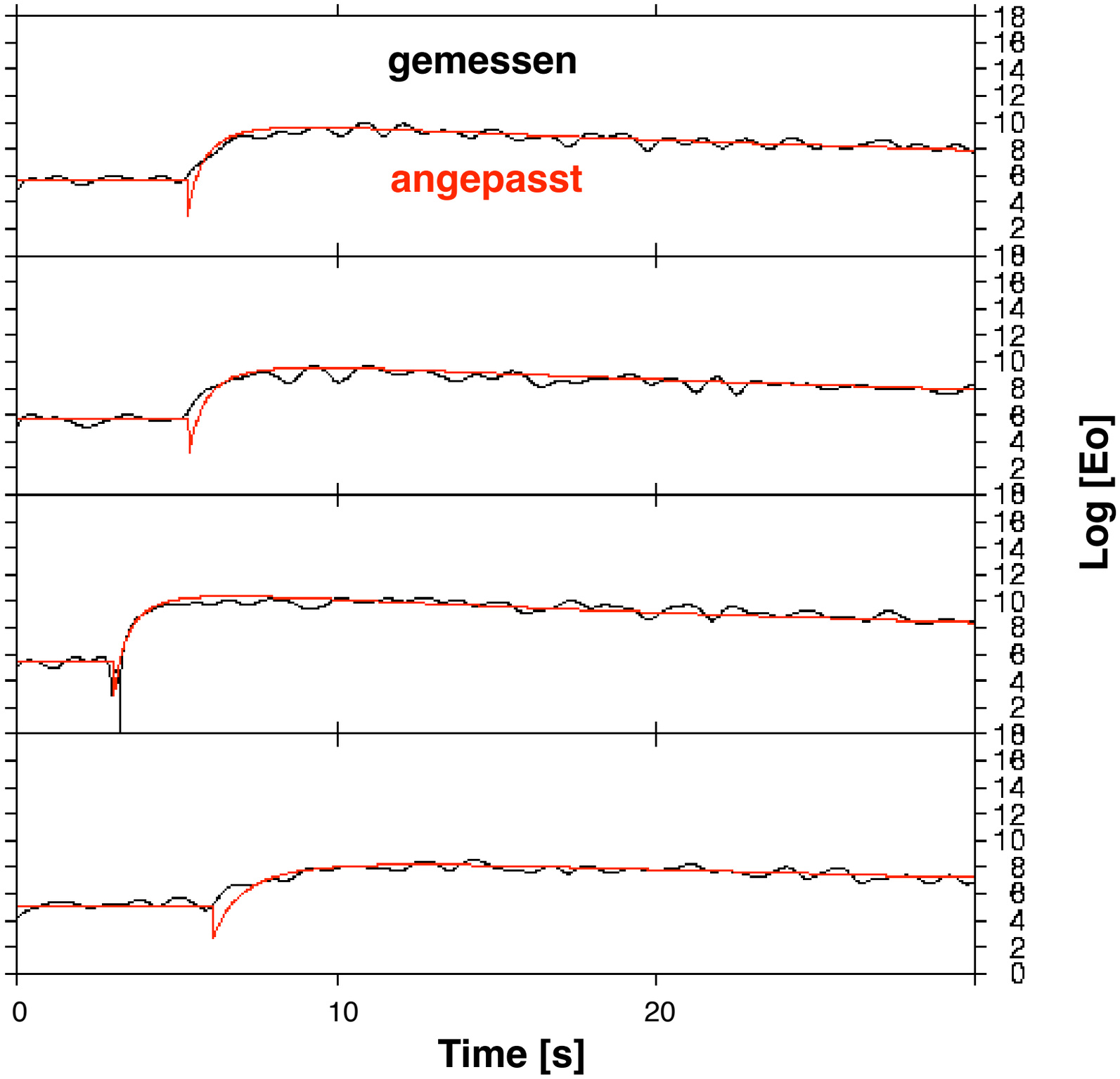




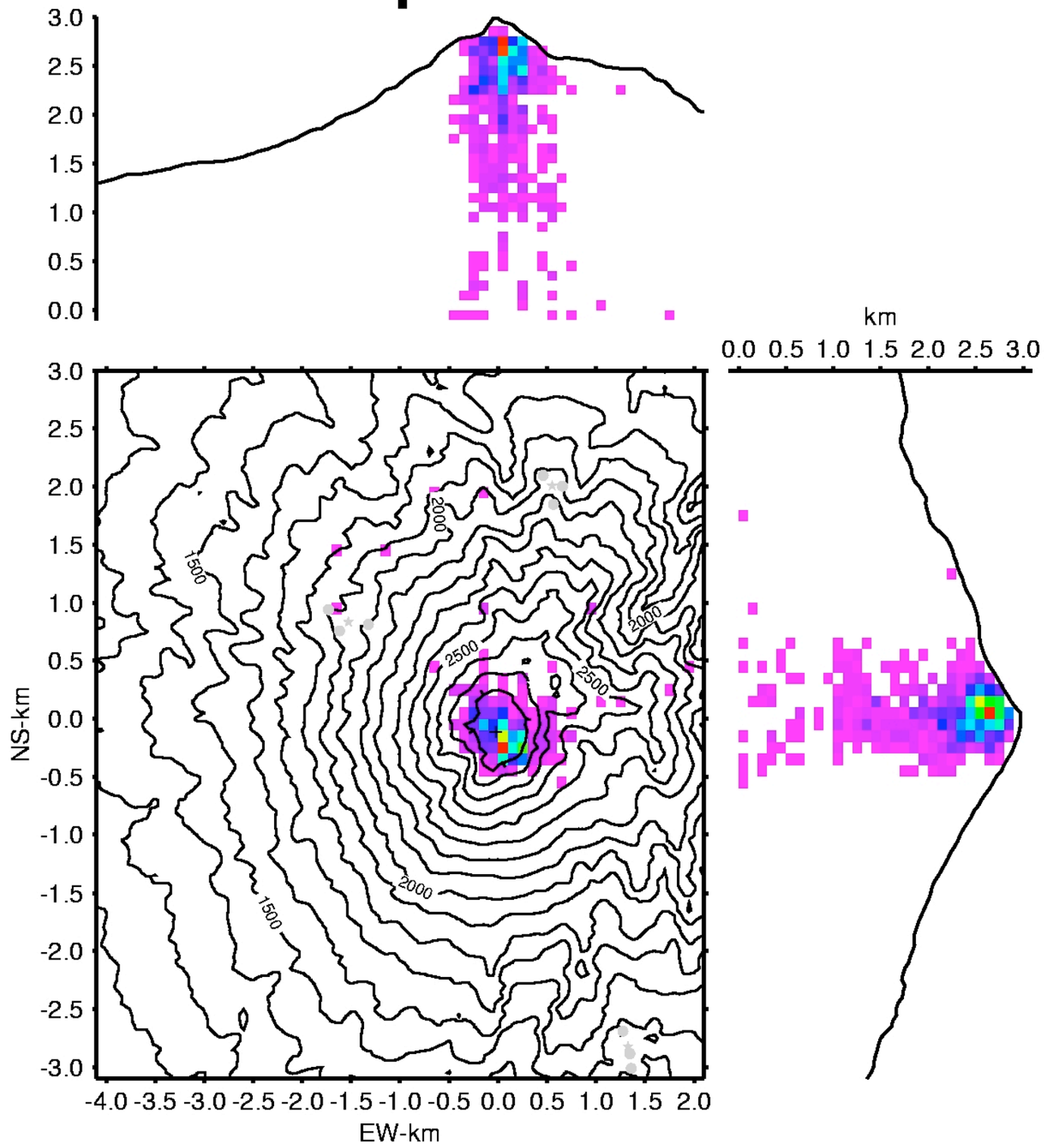




Amplituden-Lokalisierung



MP-Amplituden Lokalisierung



Streuung - anderer Blickwinkel

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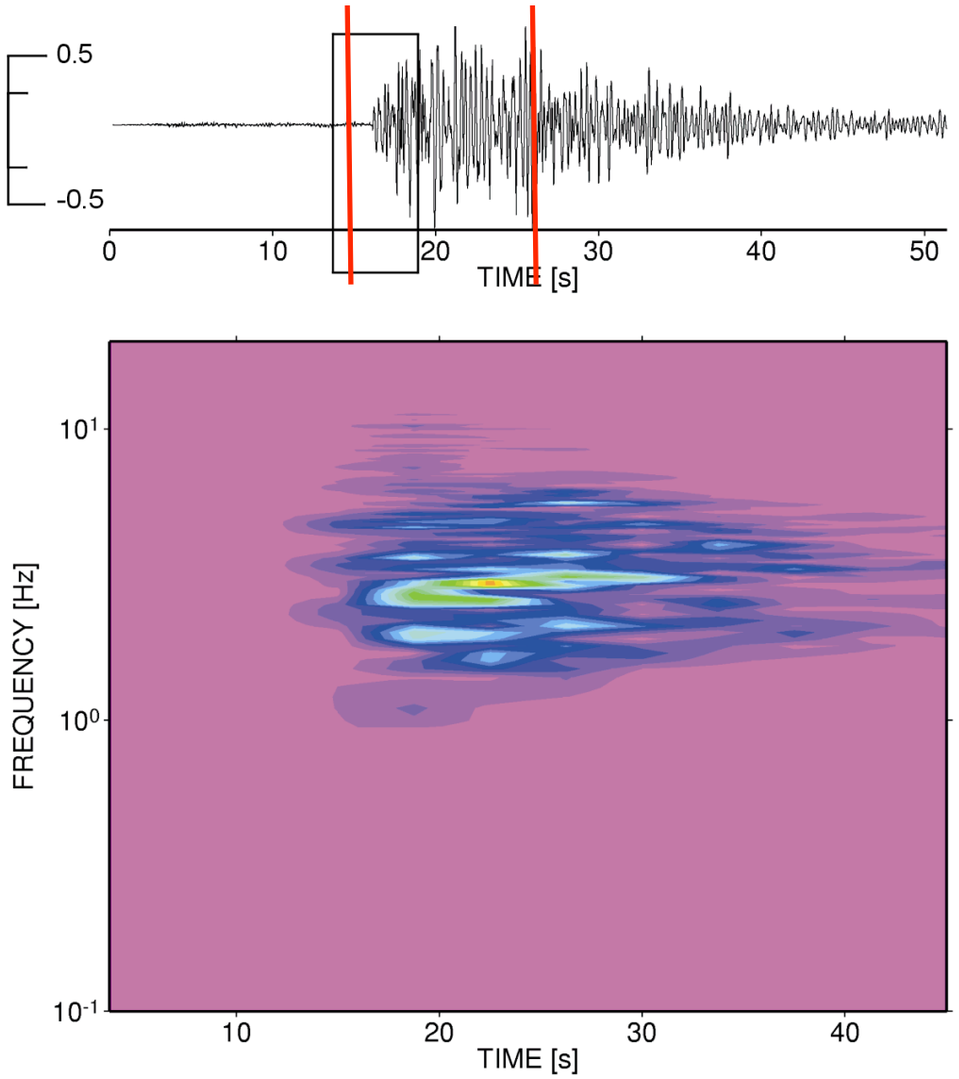

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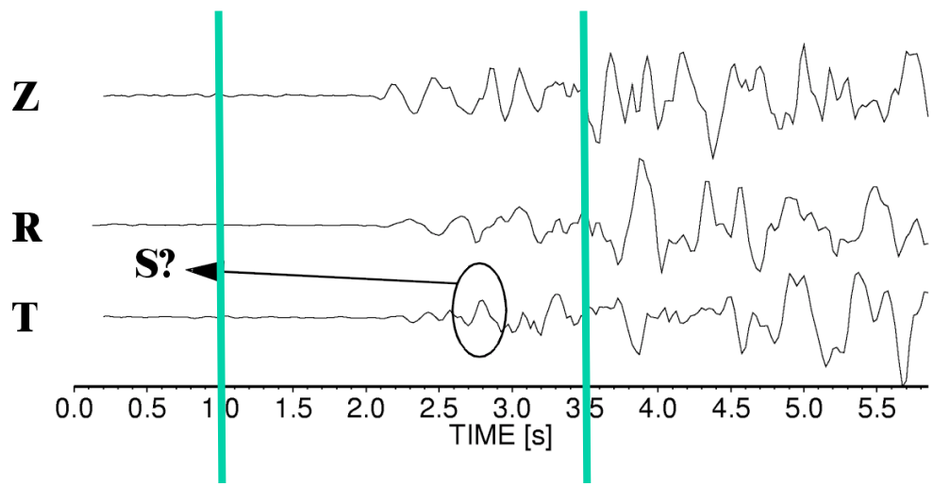
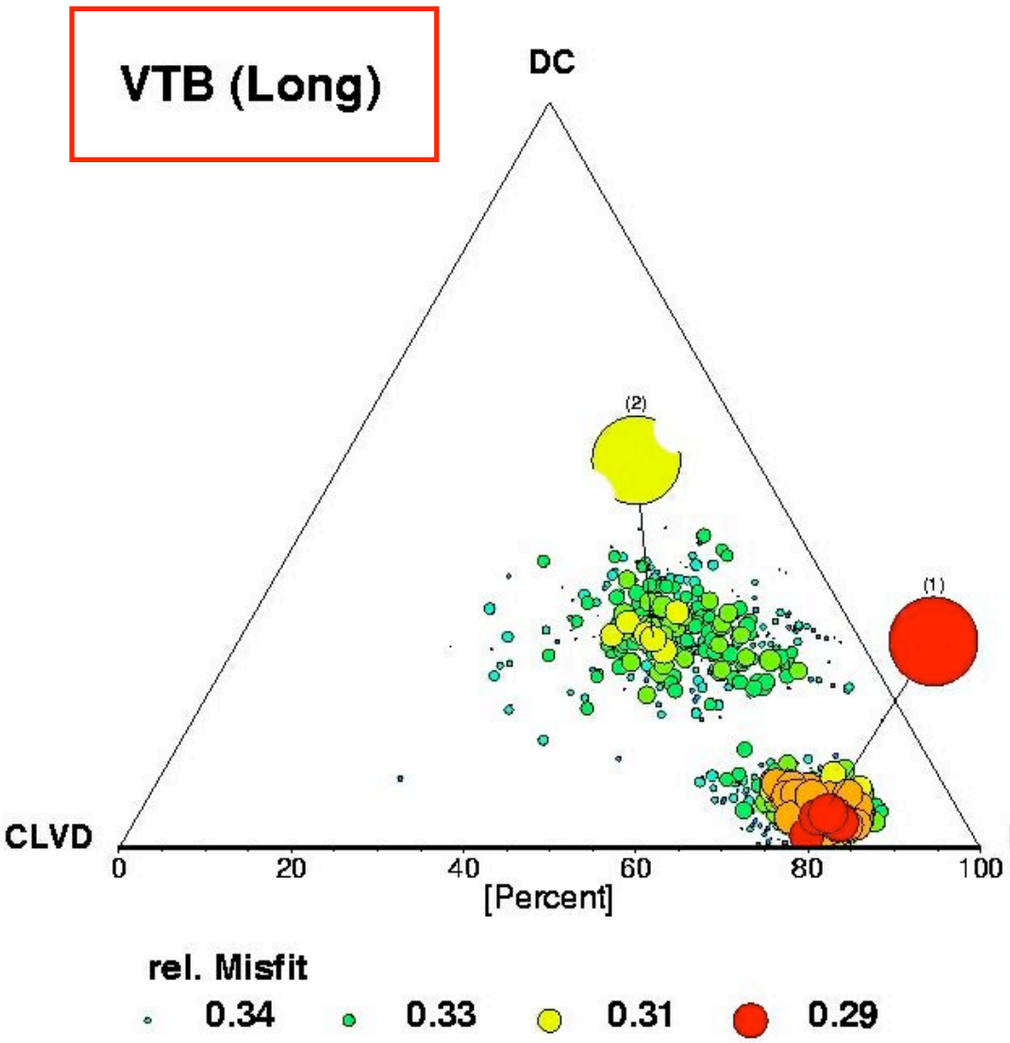
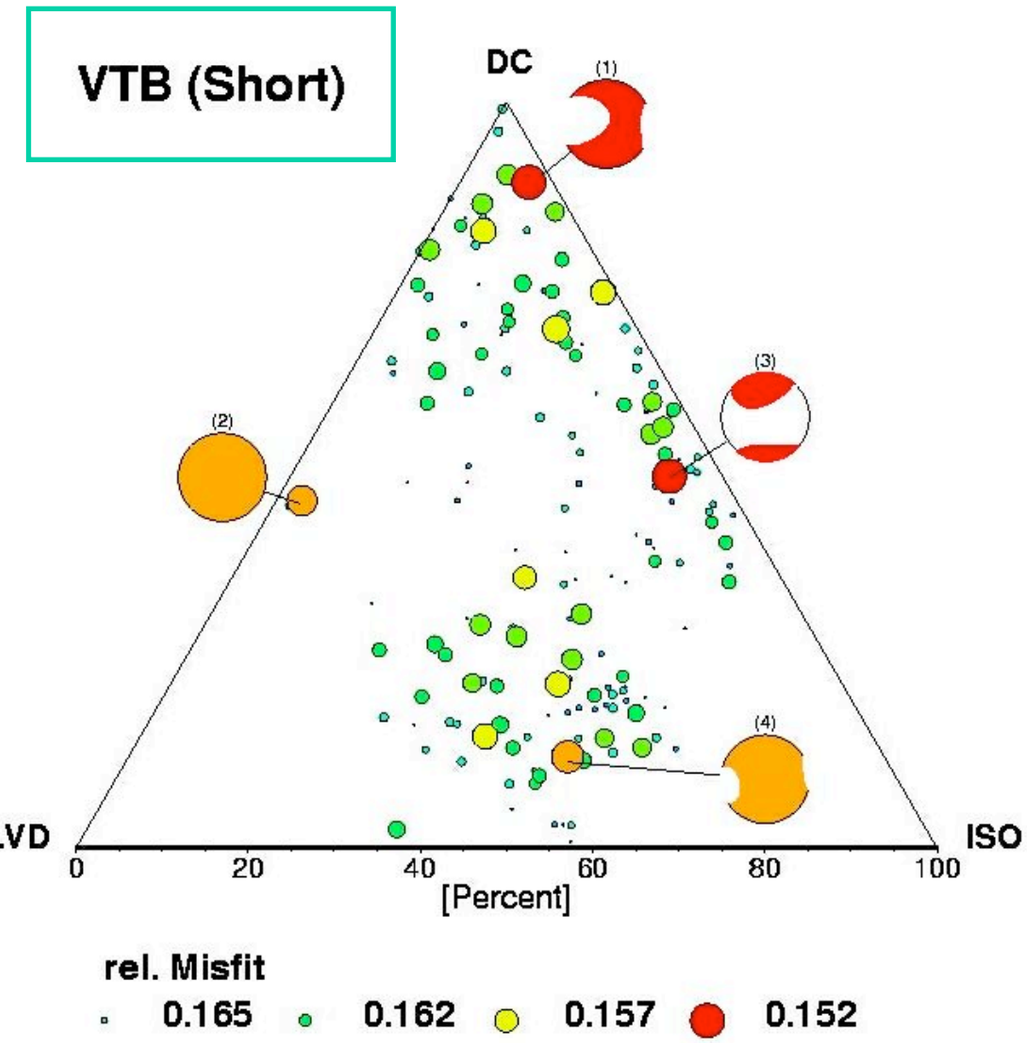


Streuung und Quell-Mechanismus





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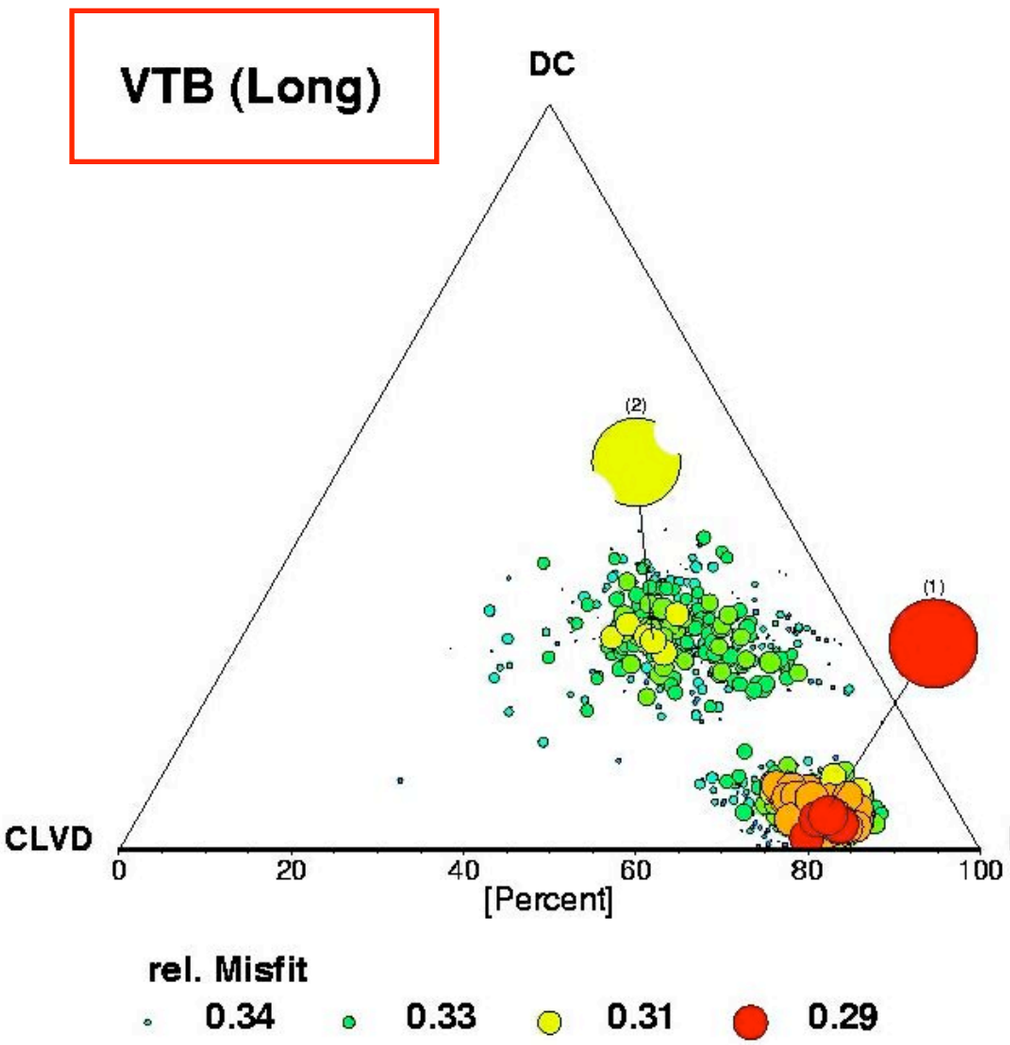
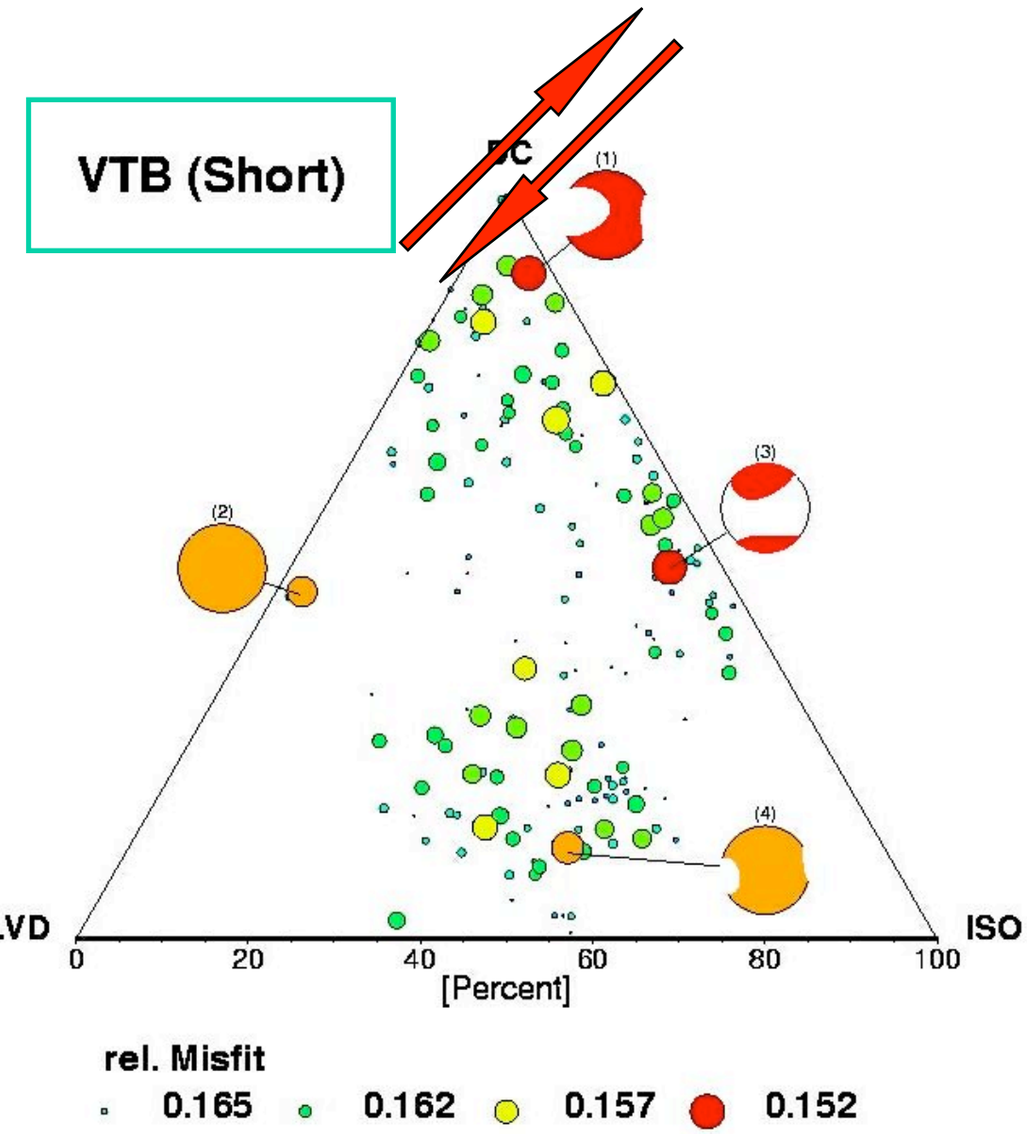
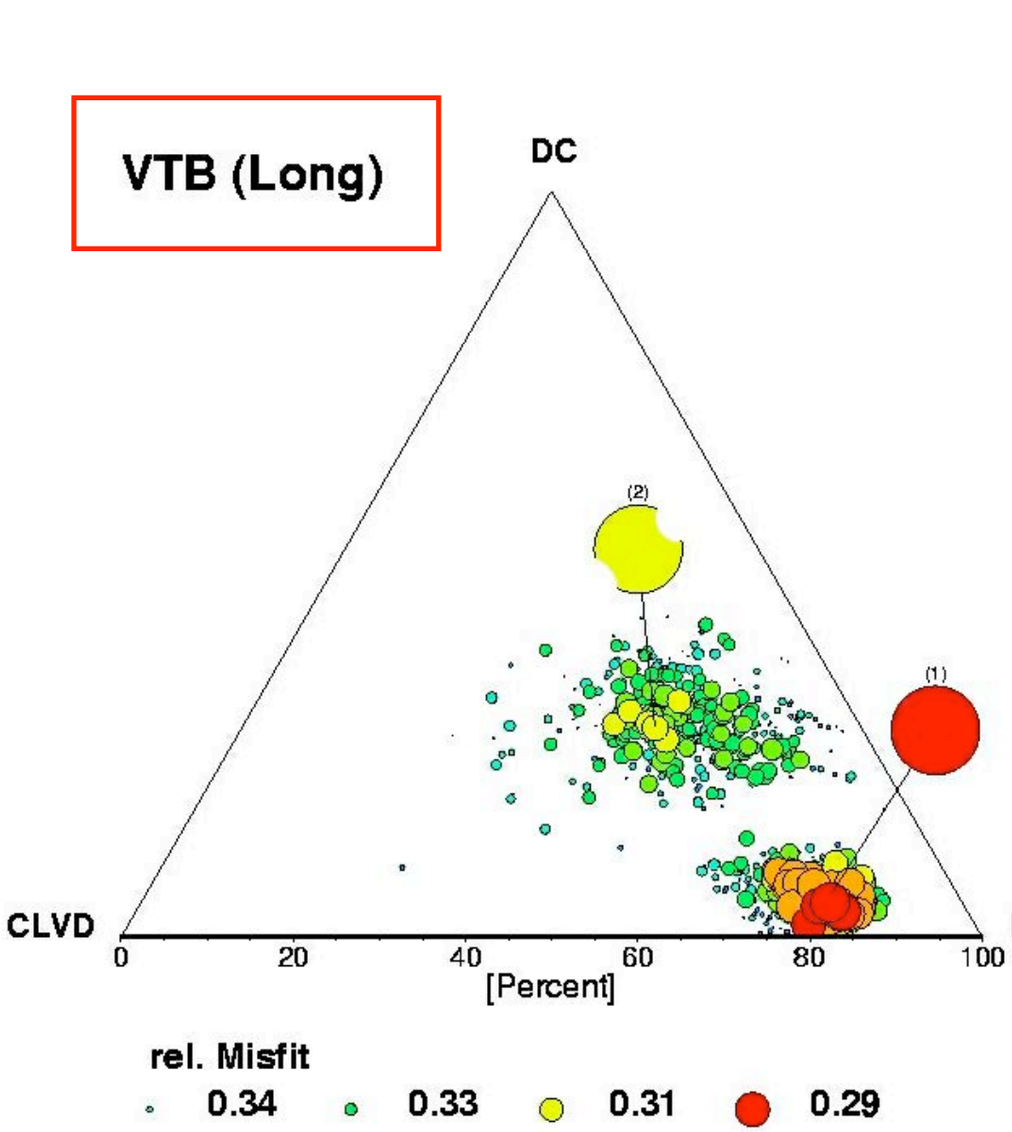
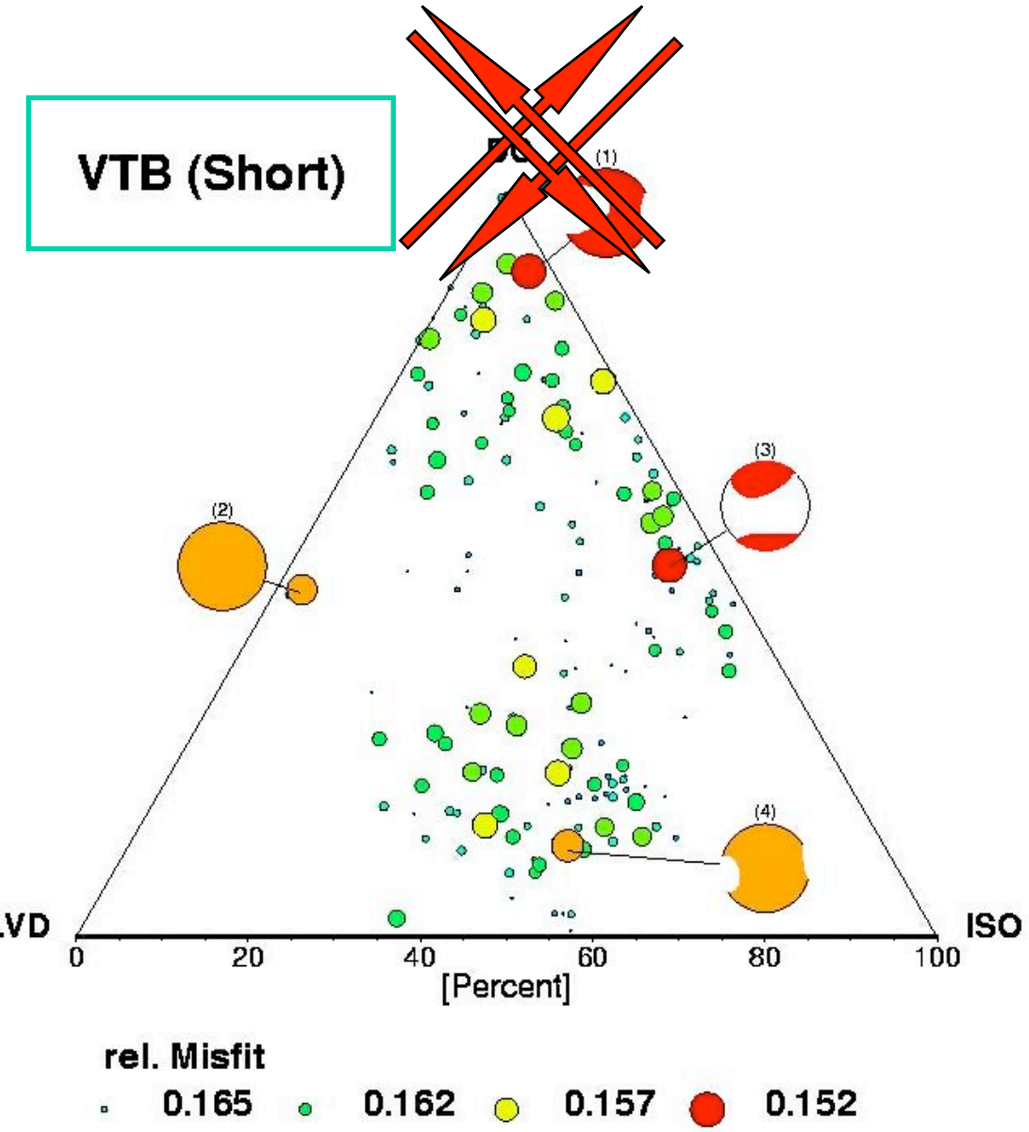


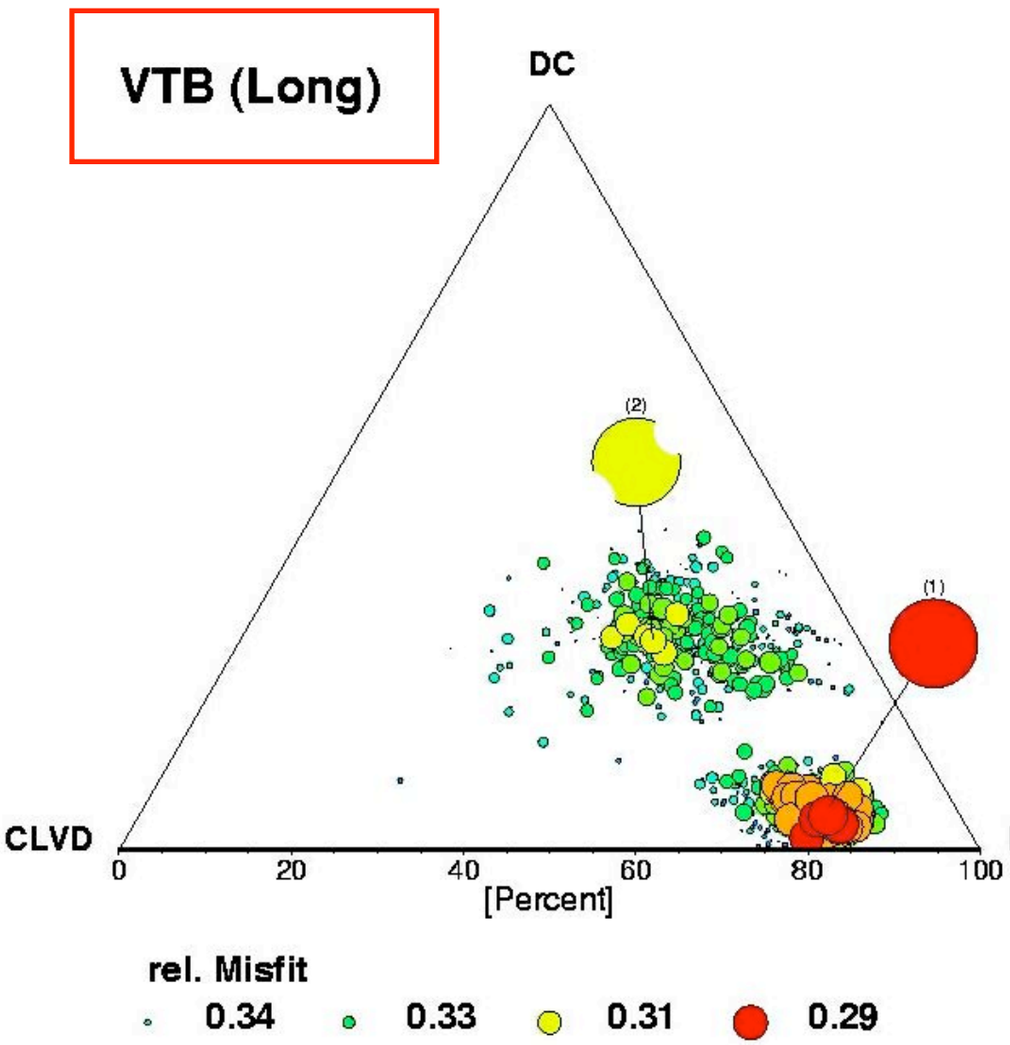


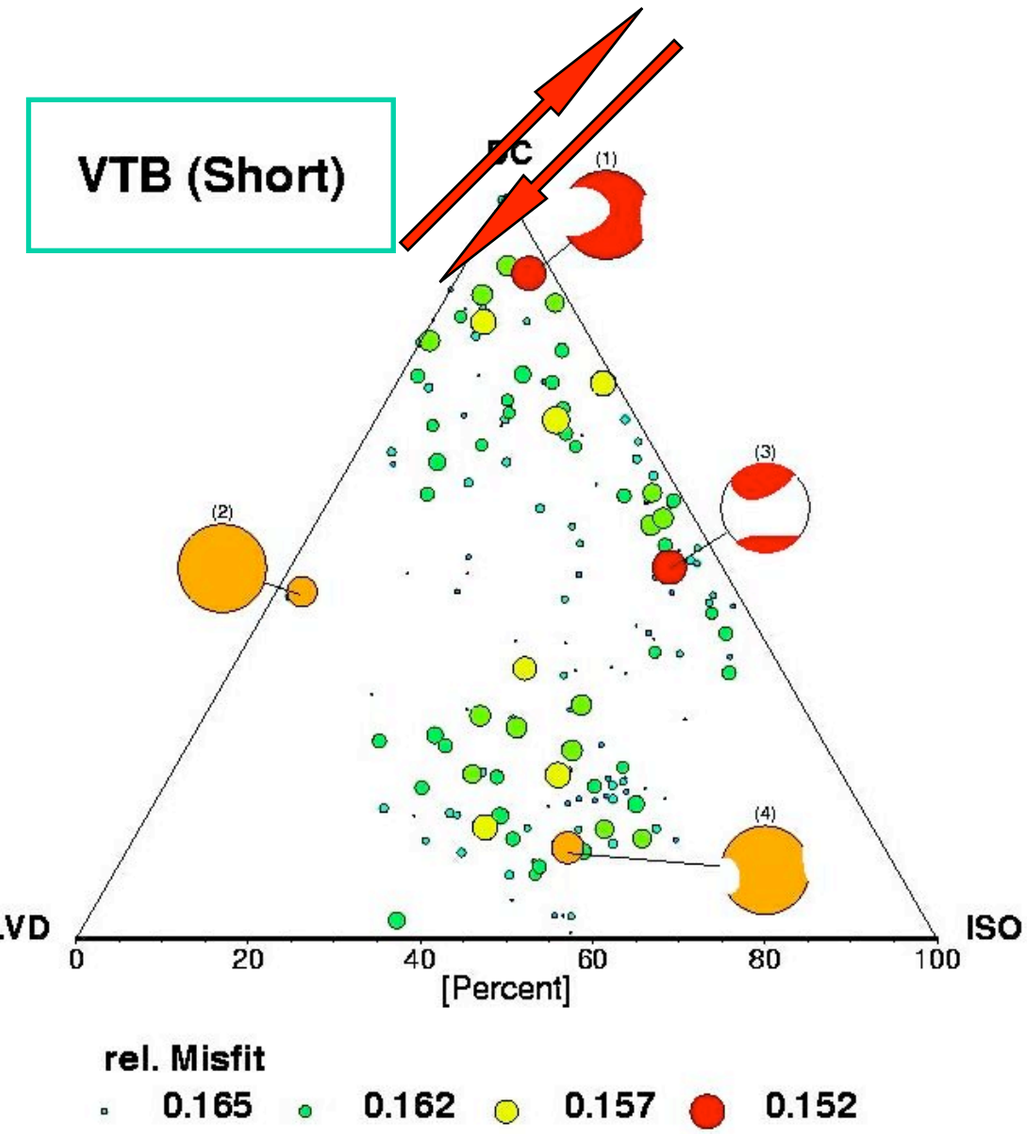
Streuung und Quell-Mechanismus





Streuung und Quell-Mechanismus





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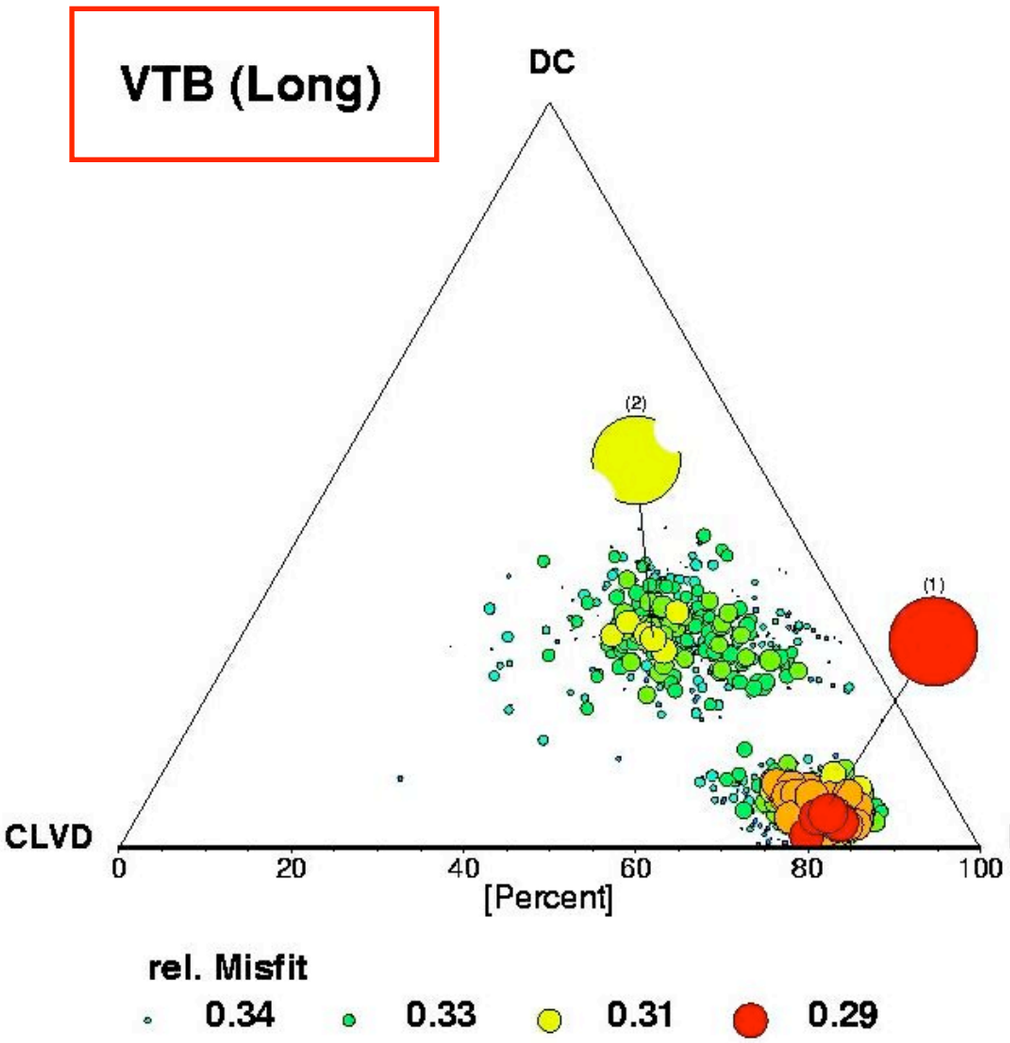
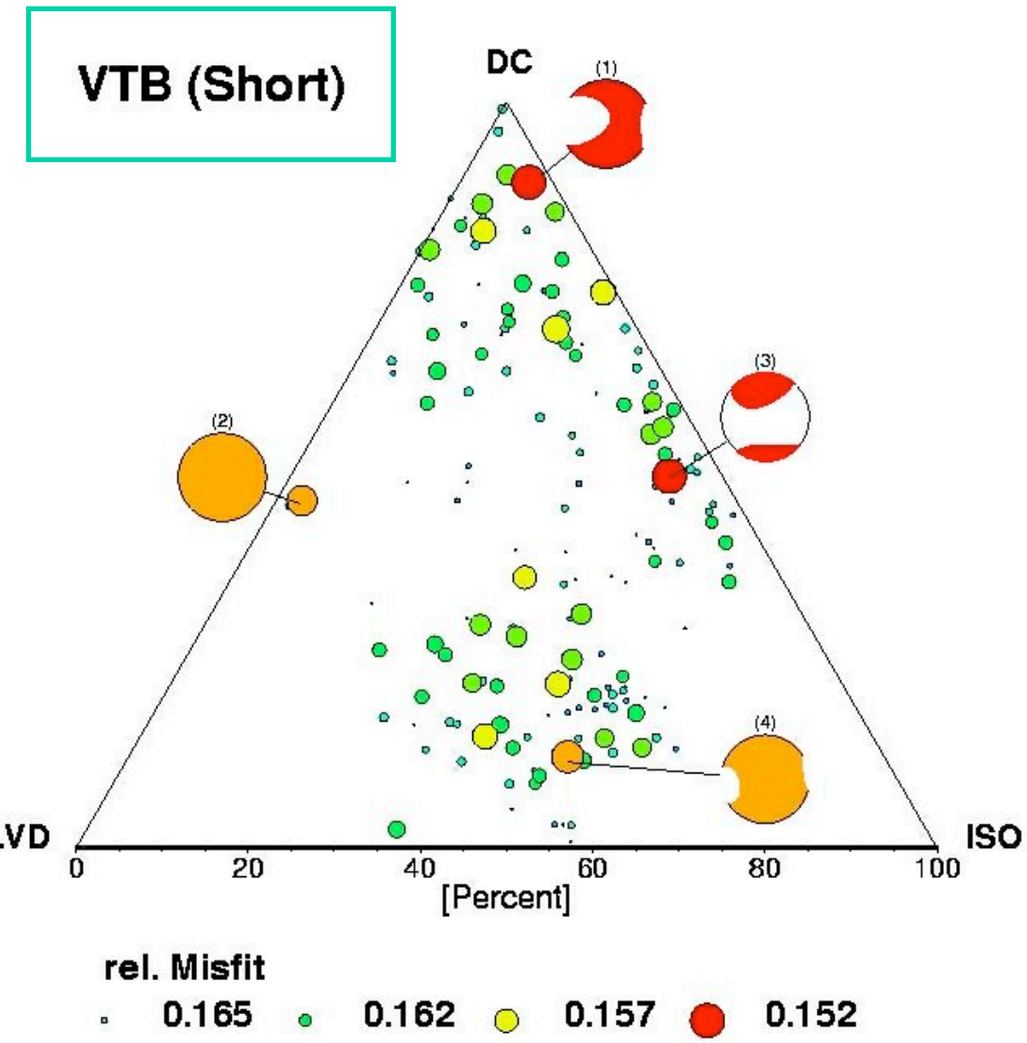
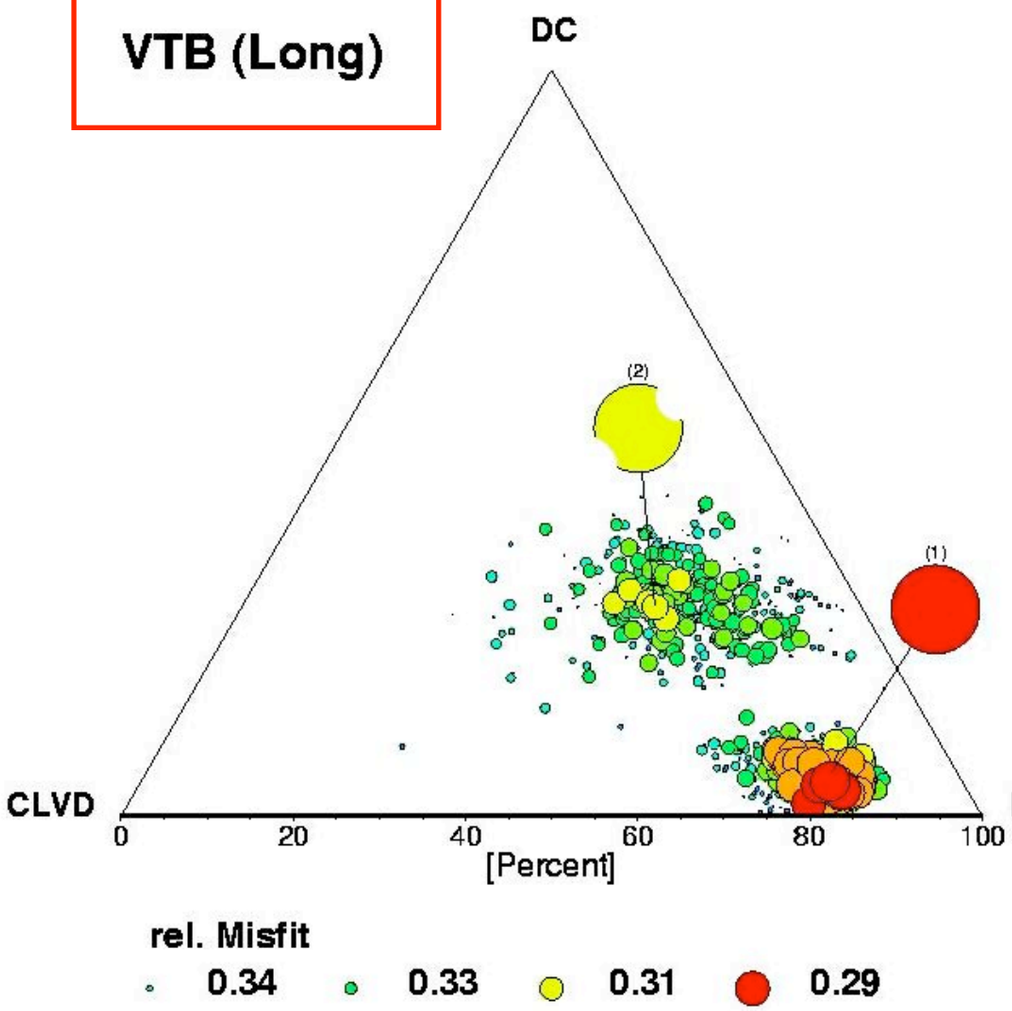




Streuung und Quell-Mechanismus

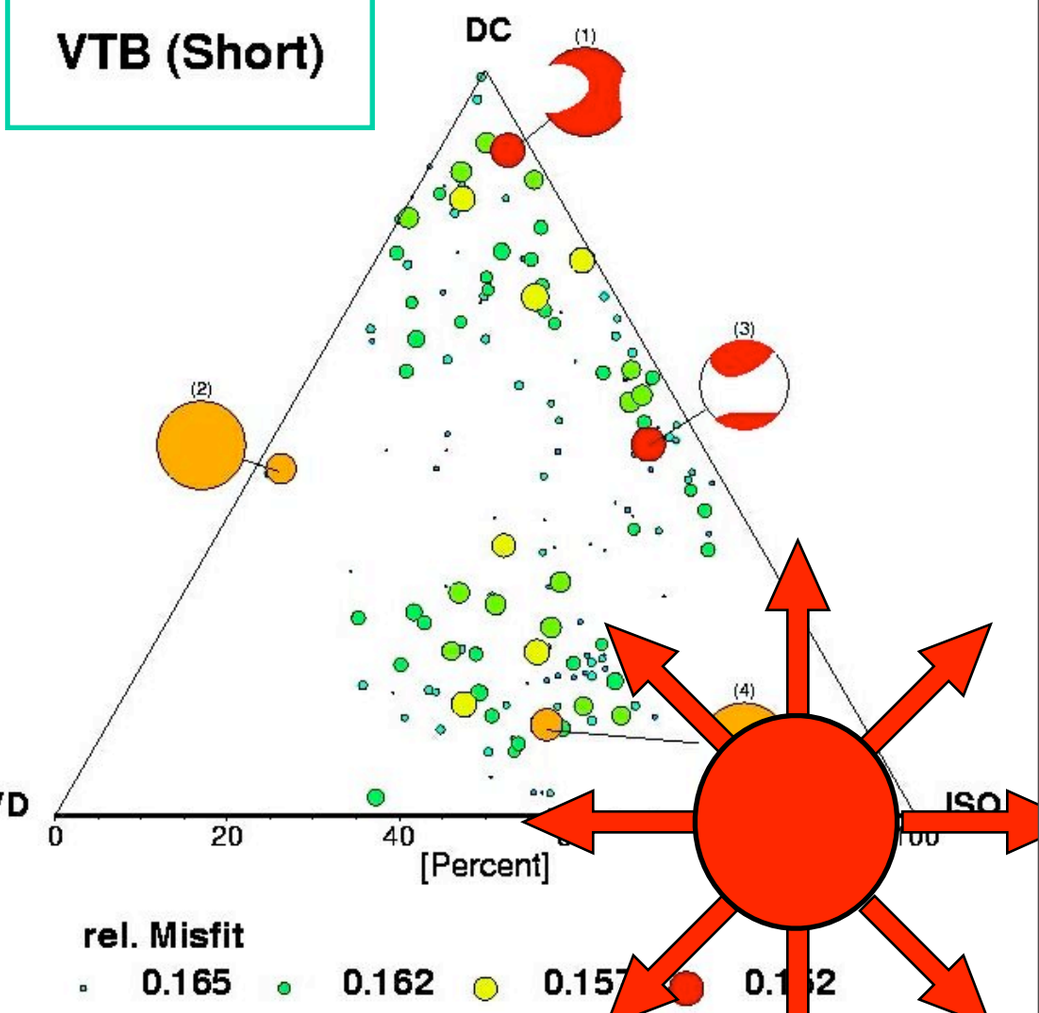
VTB (Long)



rel. Misfit

0.34 0.33 0.31 0.29

VTB (Short)



rel. Misfit

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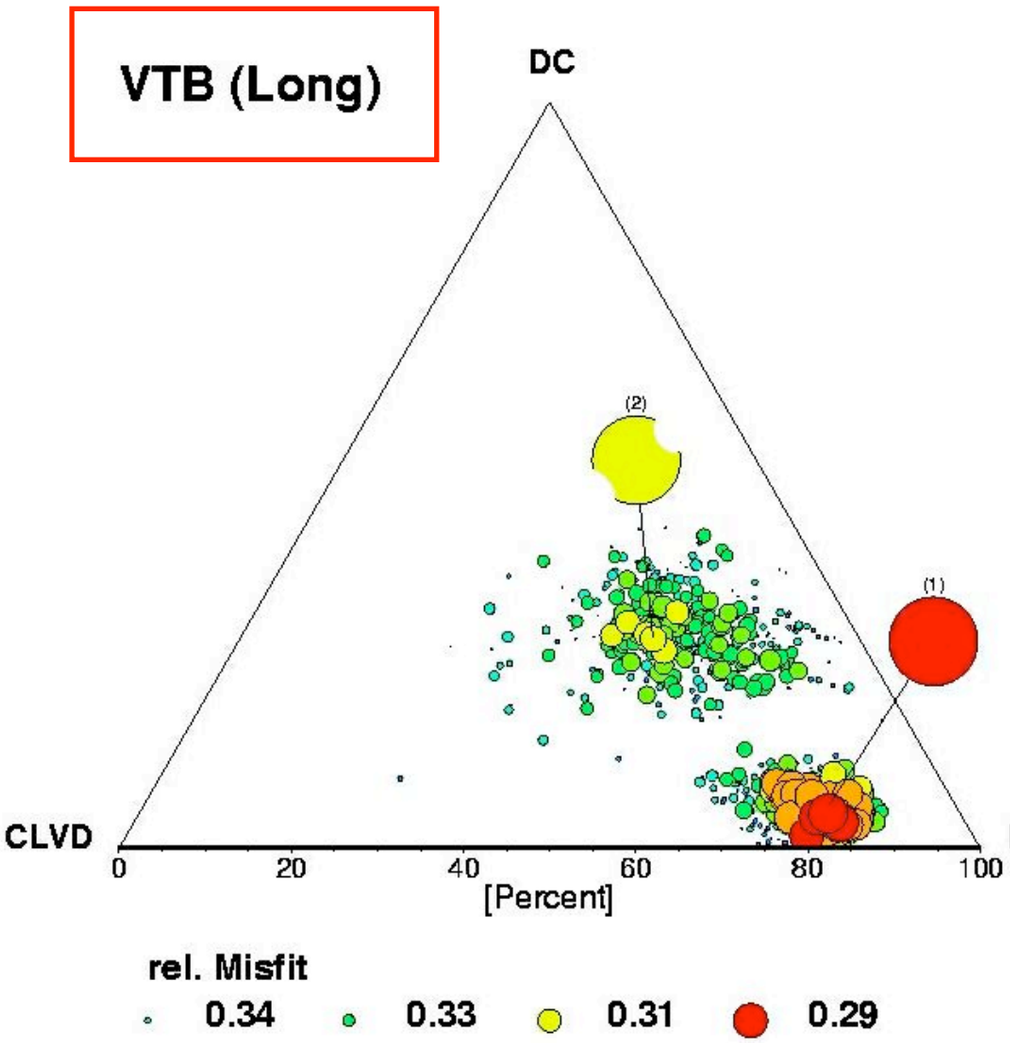
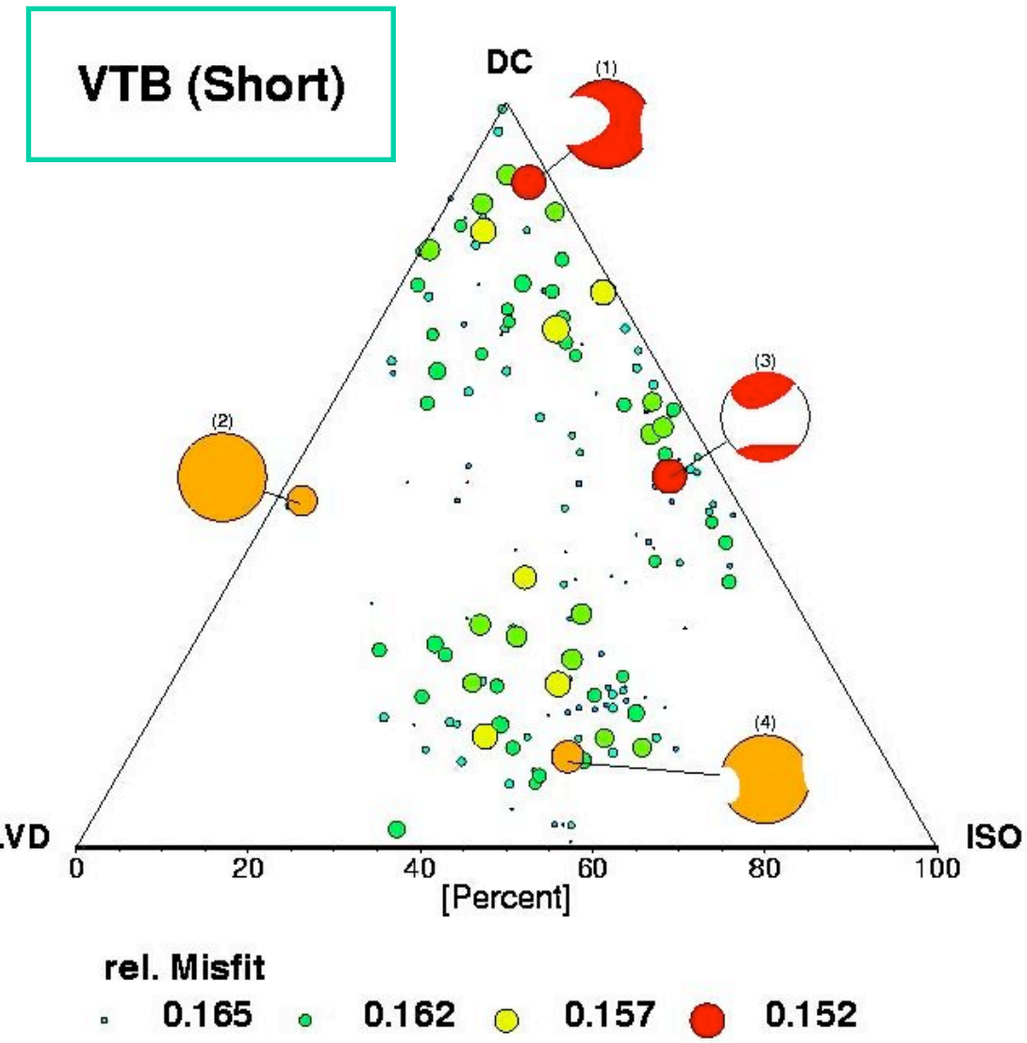
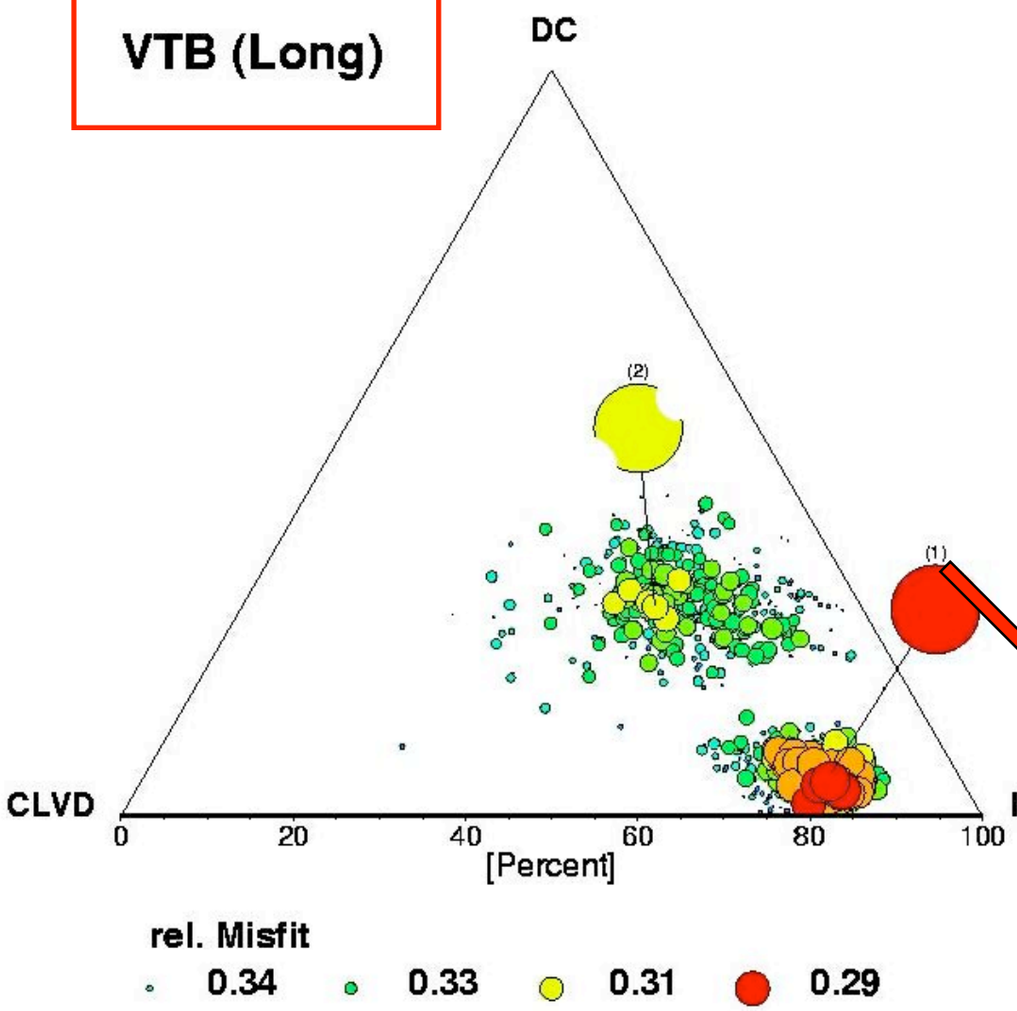
Streuung und Quell-Mechanismus





Streuung und Quell-Mechanismus

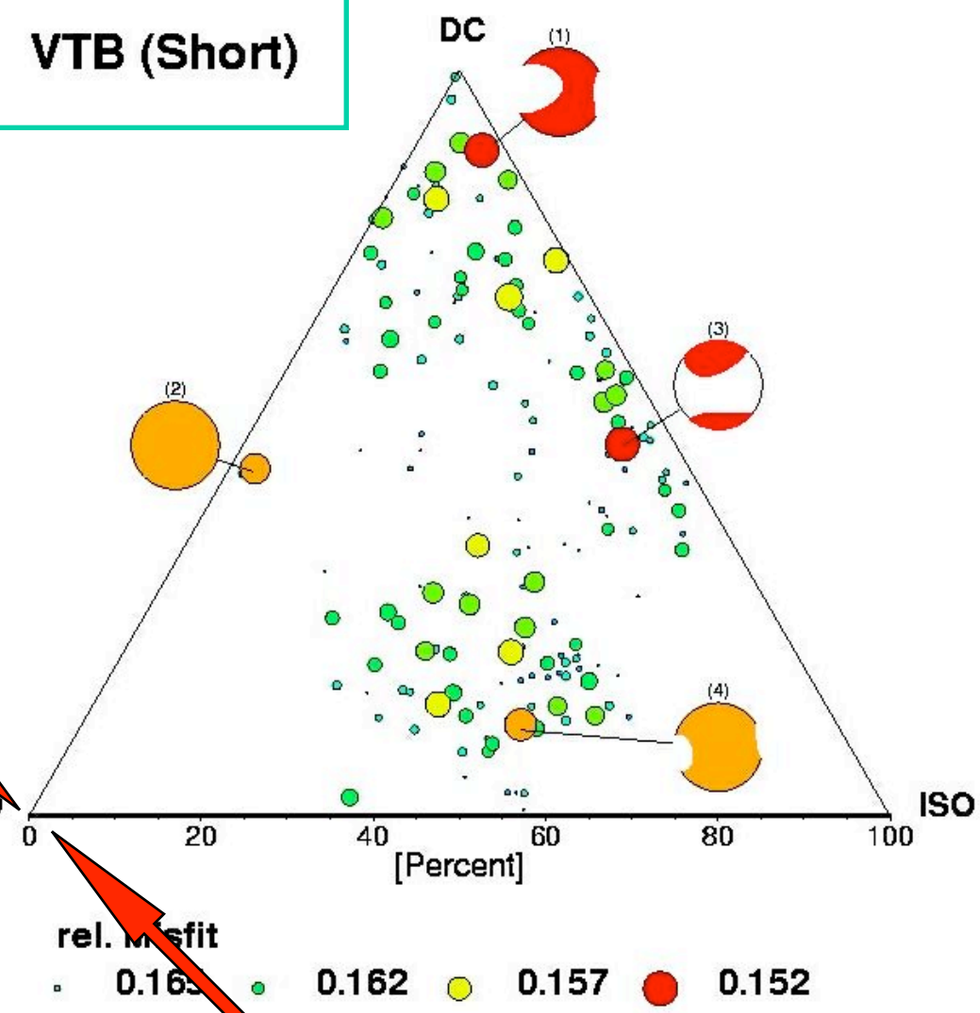
VTB (Long)



rel. Misfit

0.34 0.33 0.31 0.29

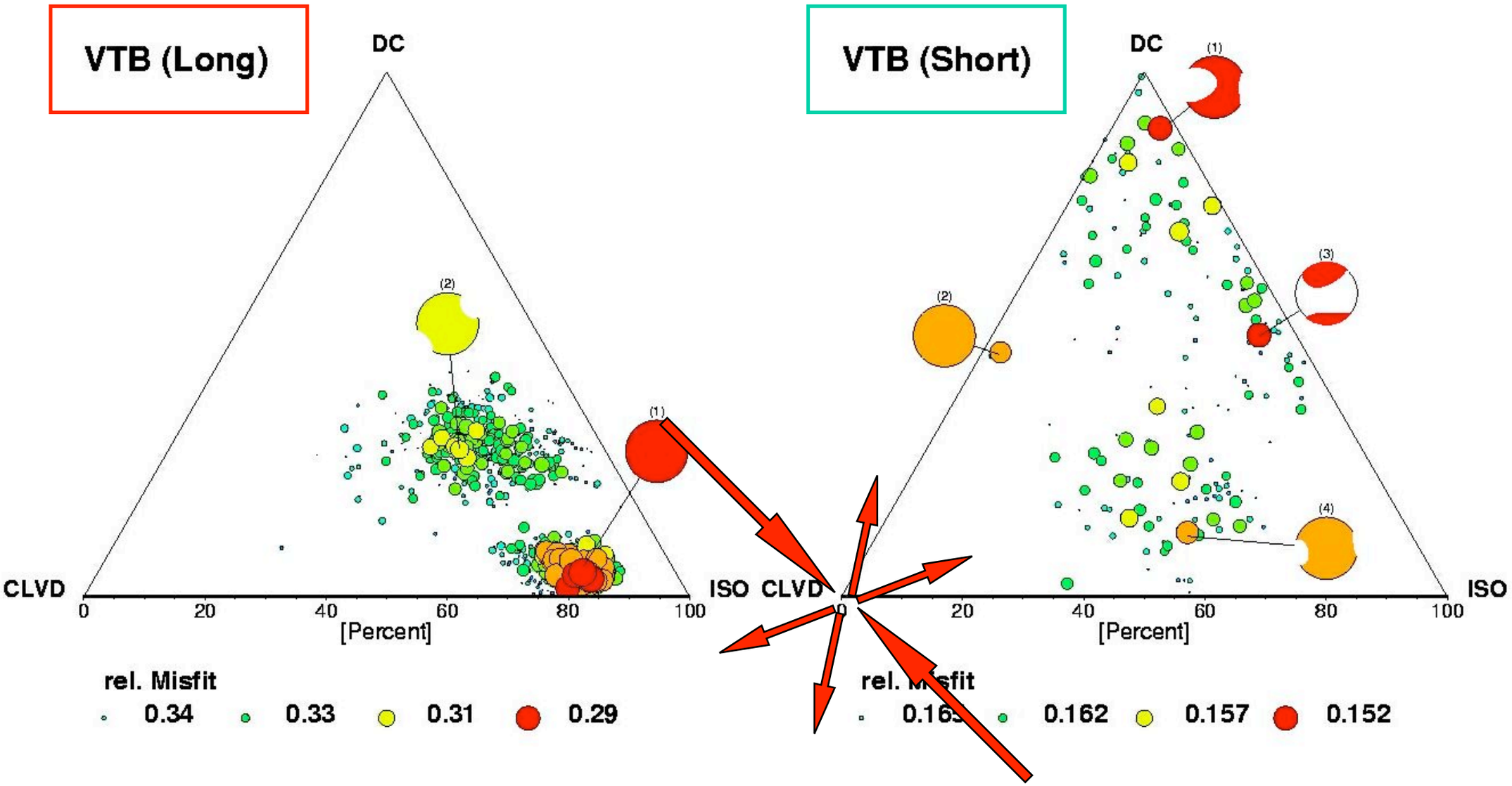
VTB (Short)



rel. Misfit

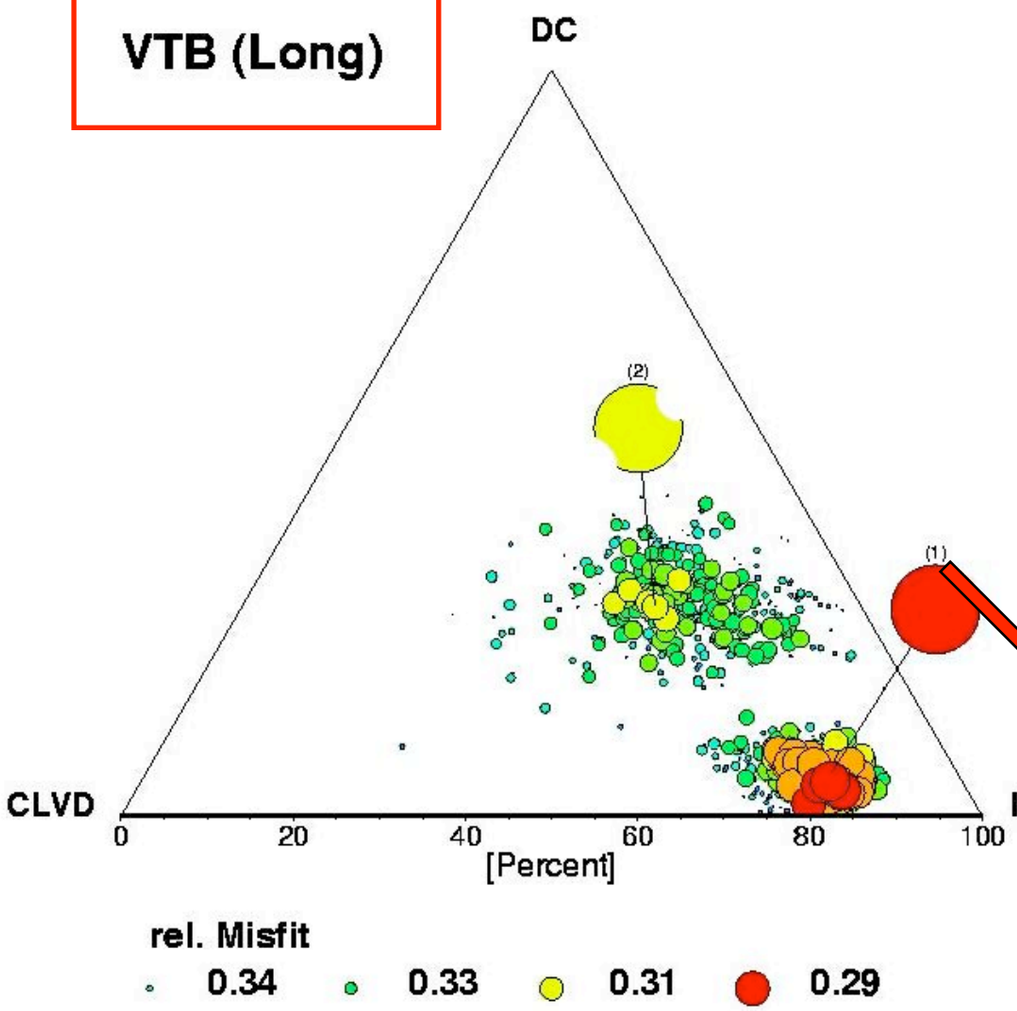
0.163 0.162 0.157 0.152

Streuung und Quell-Mechanismus



Streuung und Quell-Mechanismus

VTB (Long)



rel. Misfit

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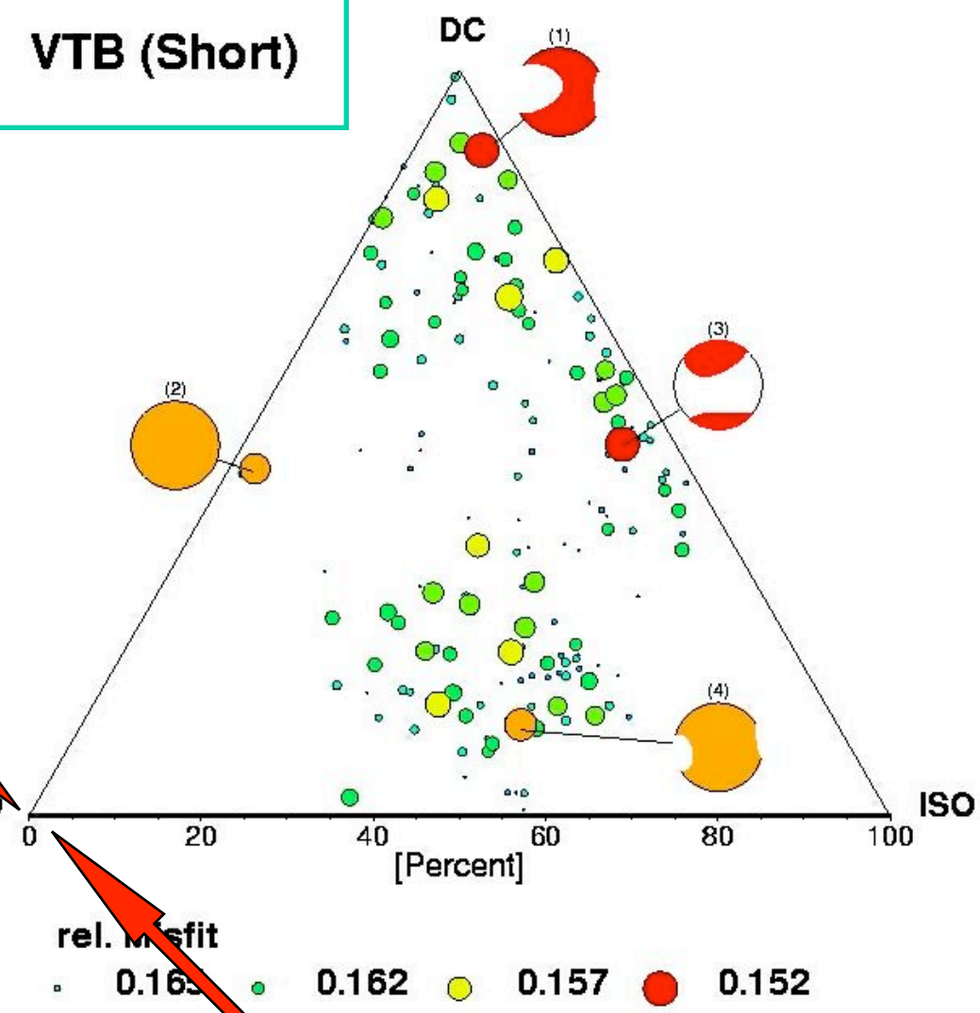
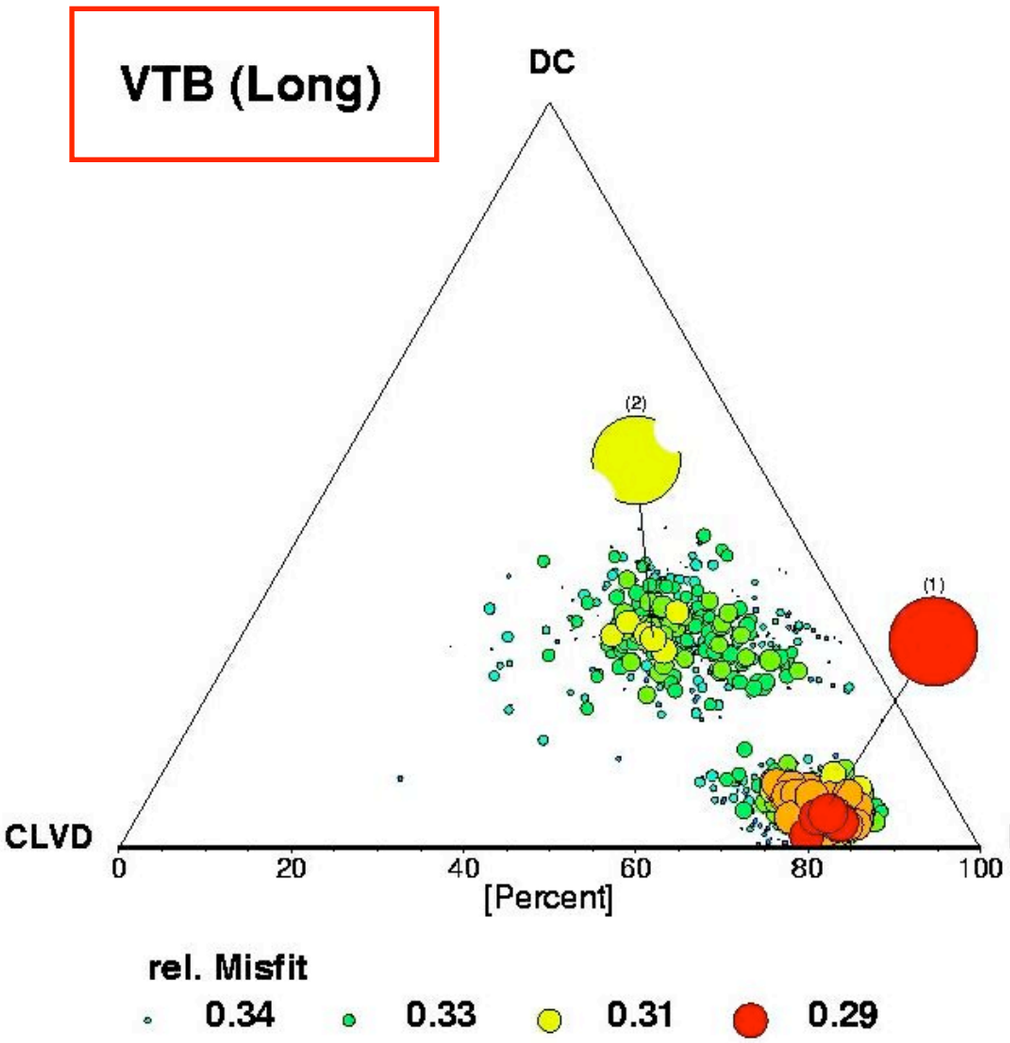
VTB (Short)

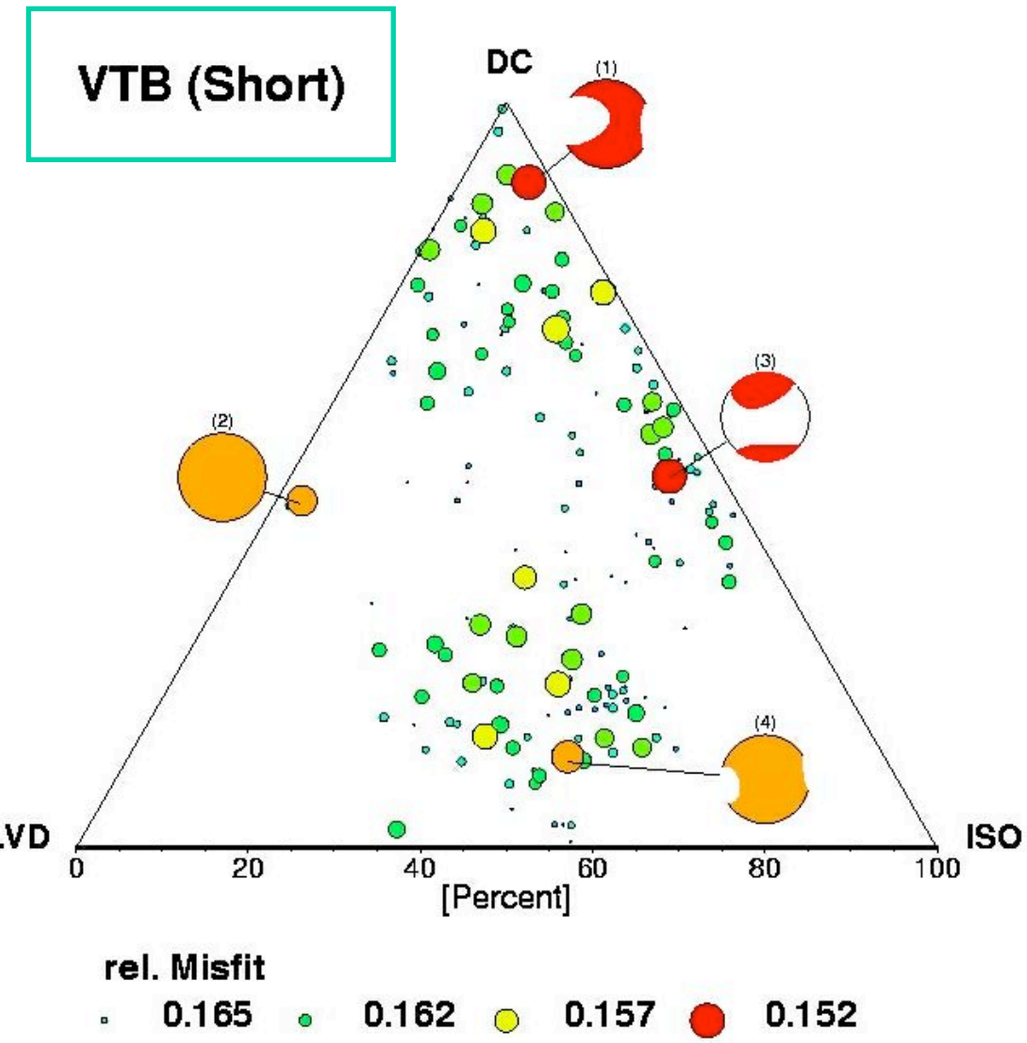


rel. Misfit

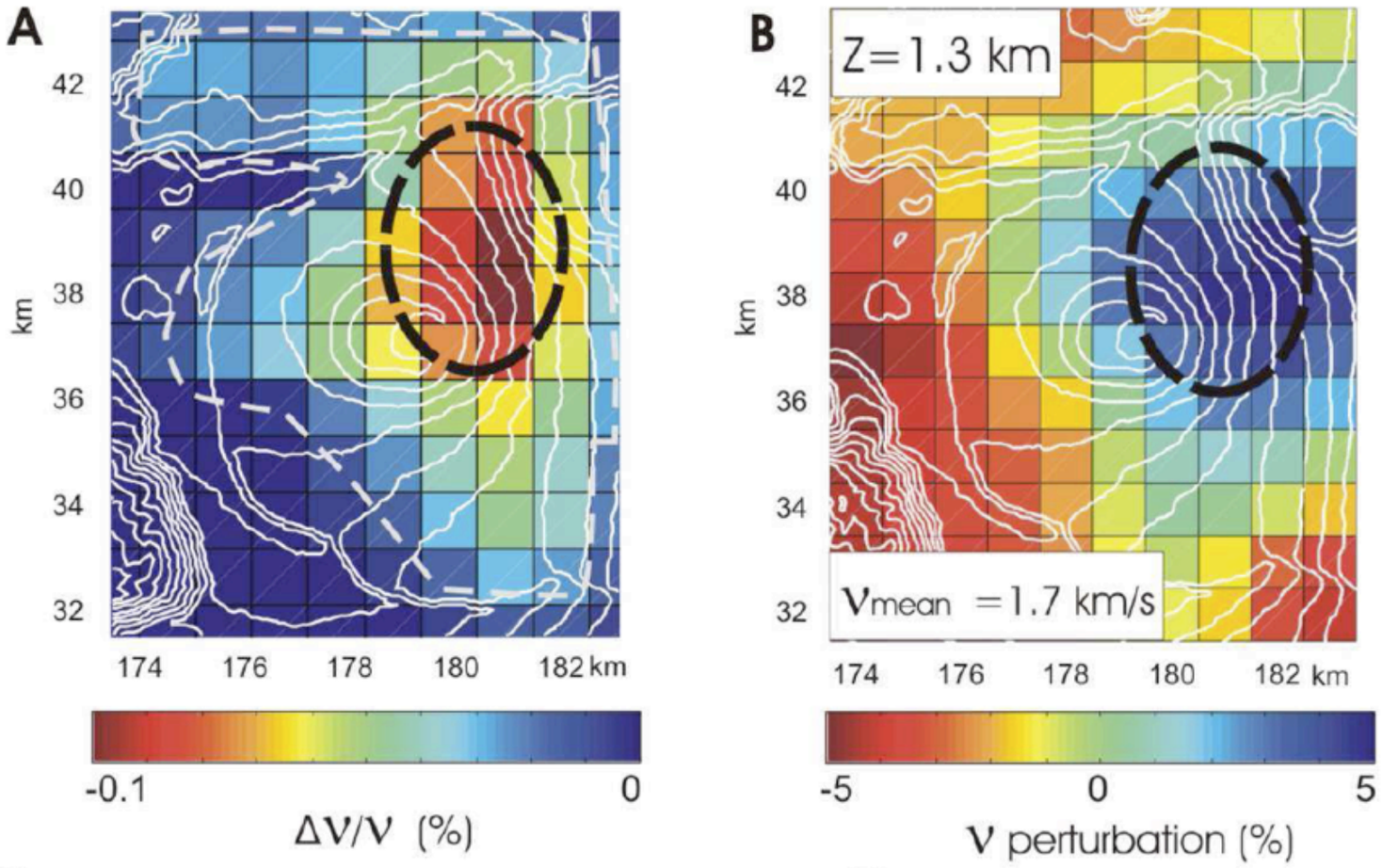
0.163 0.162 0.157 0.152

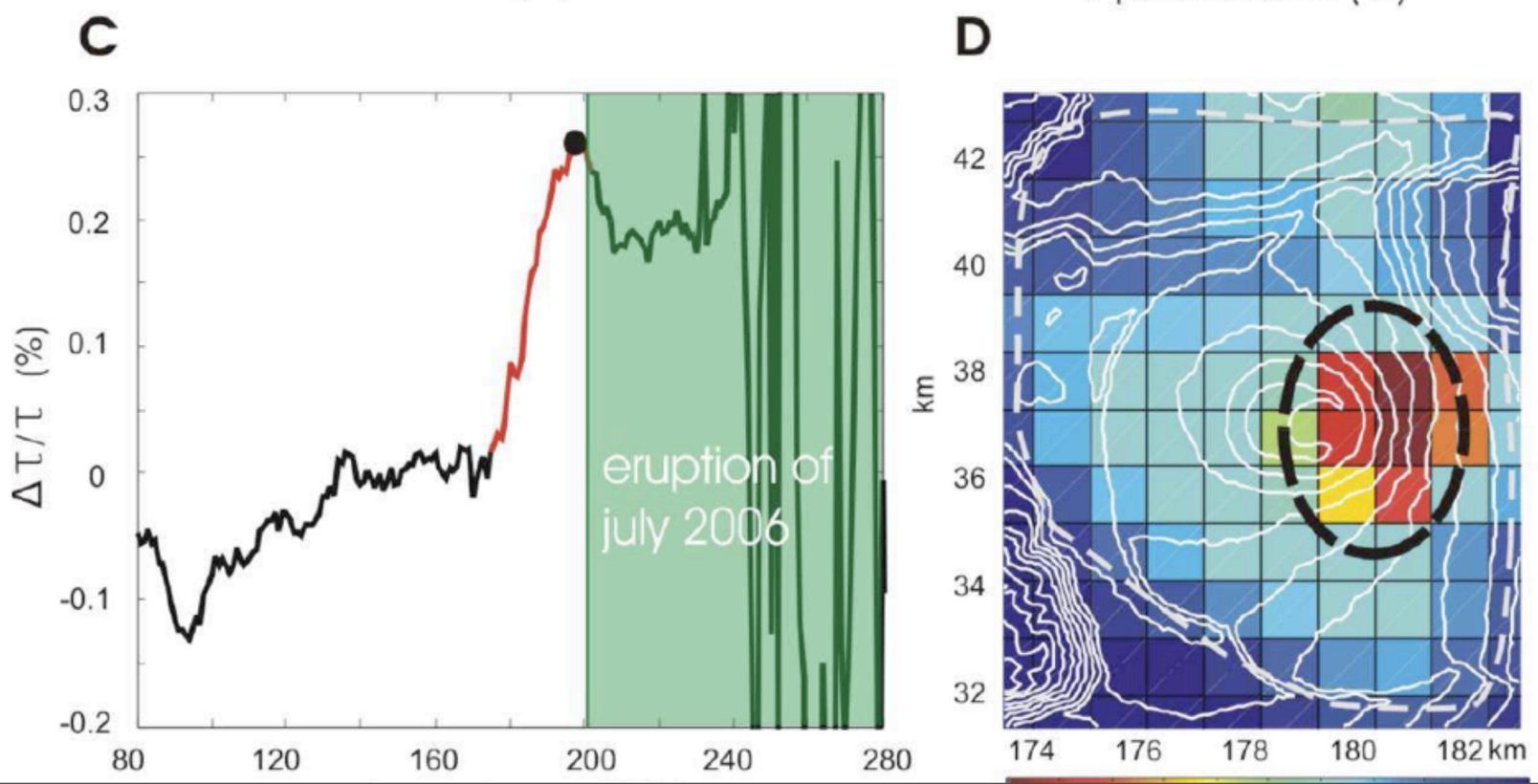
Streuung und Quell-Mechanismus



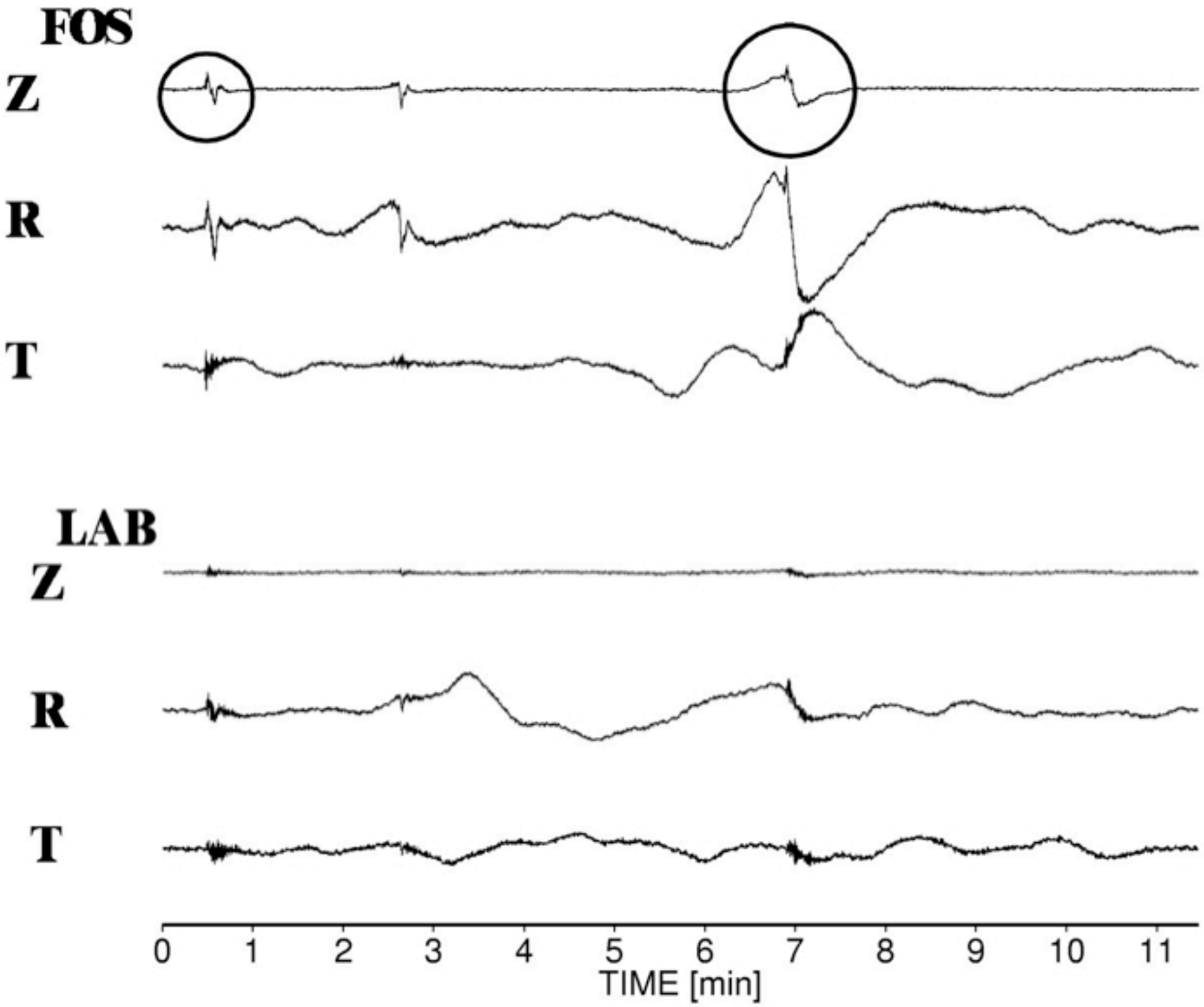


Streuung und seismisches Rauschen

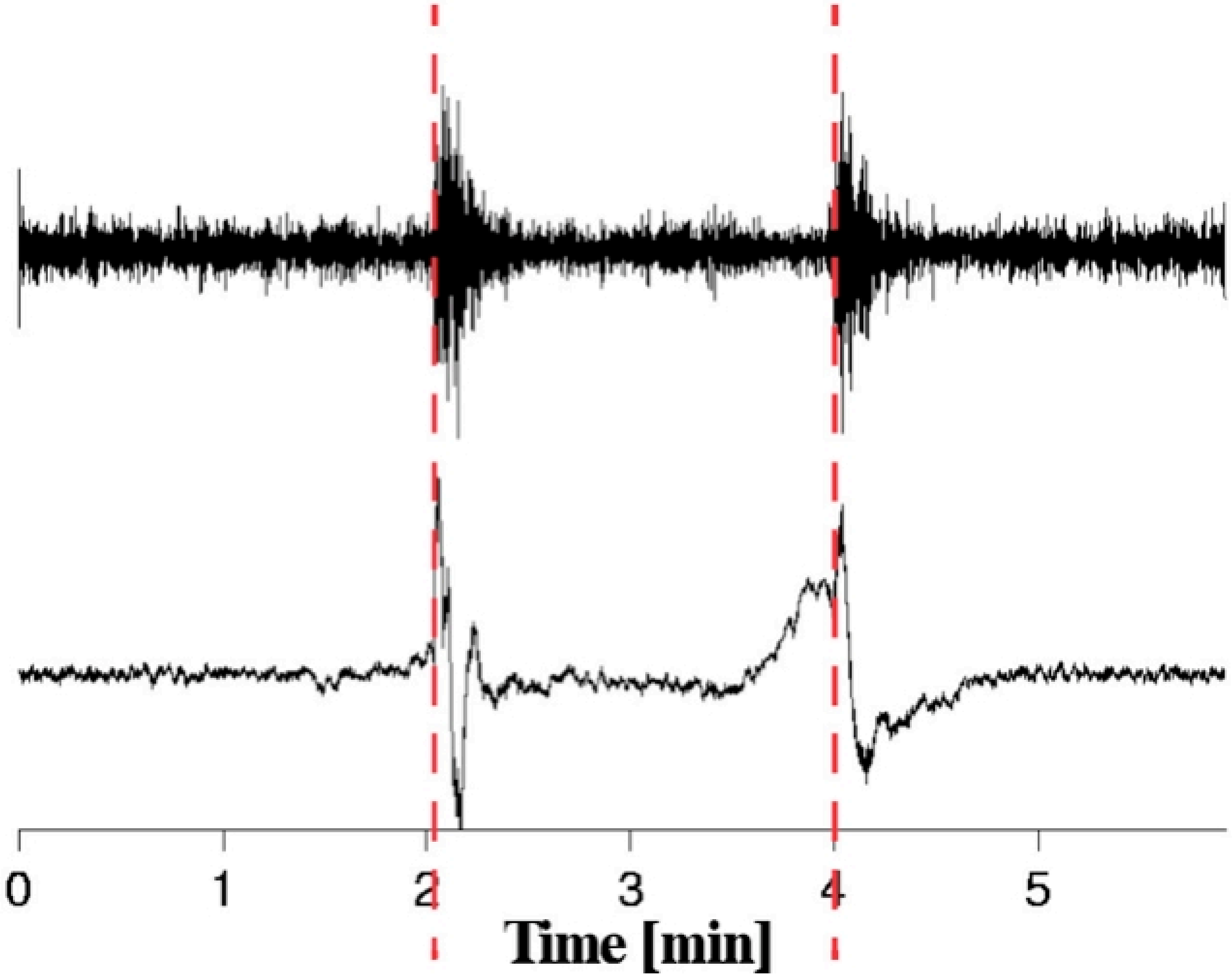




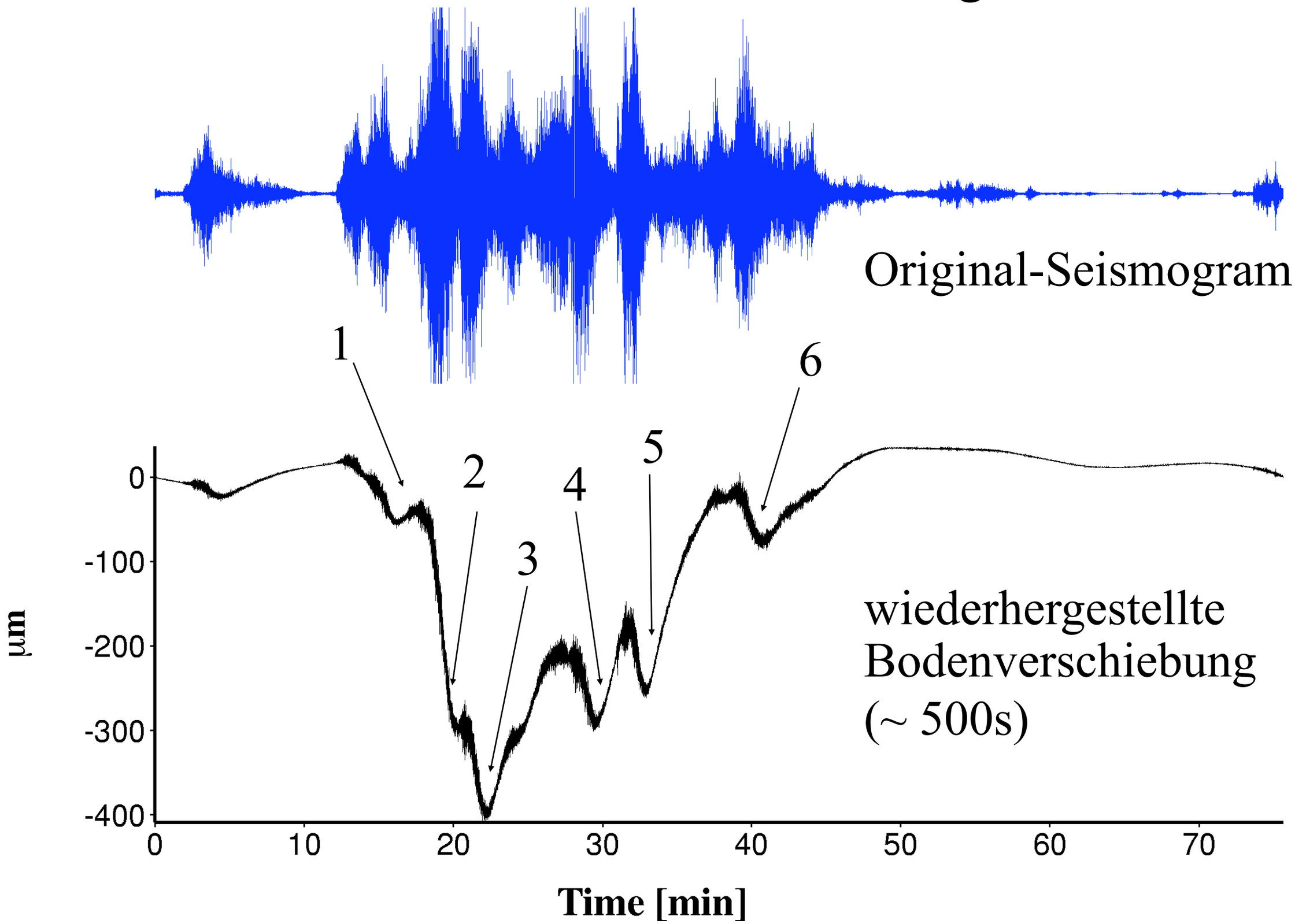
“Breitband” Signale (VLP/ULP)



“Breitband” Signale (VLP/ULP)



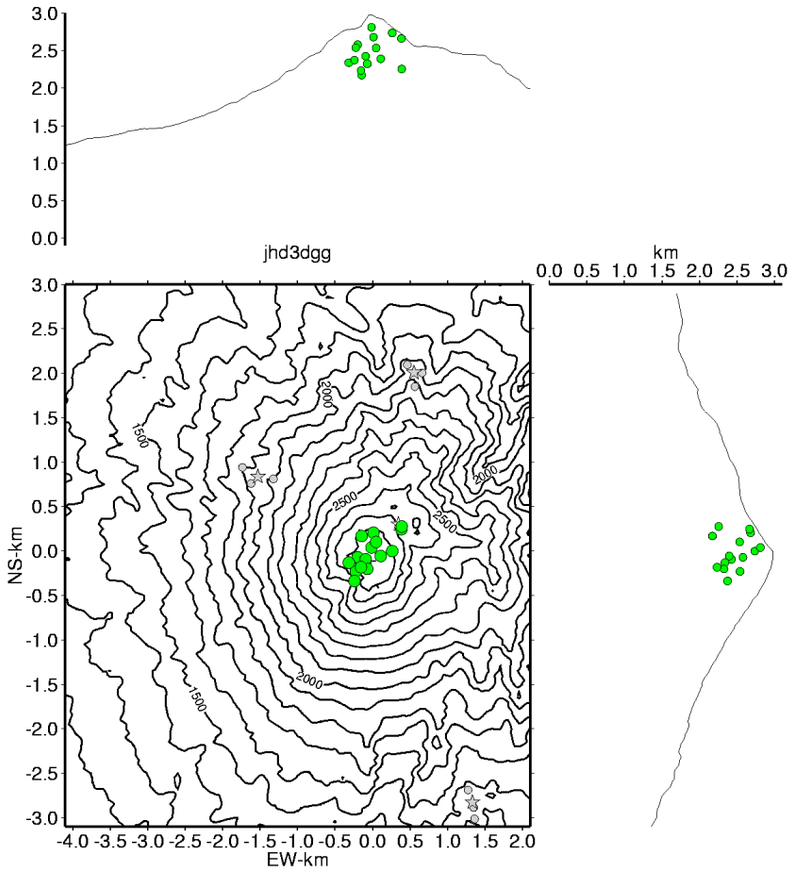
“Block and Ash Flow” Signale



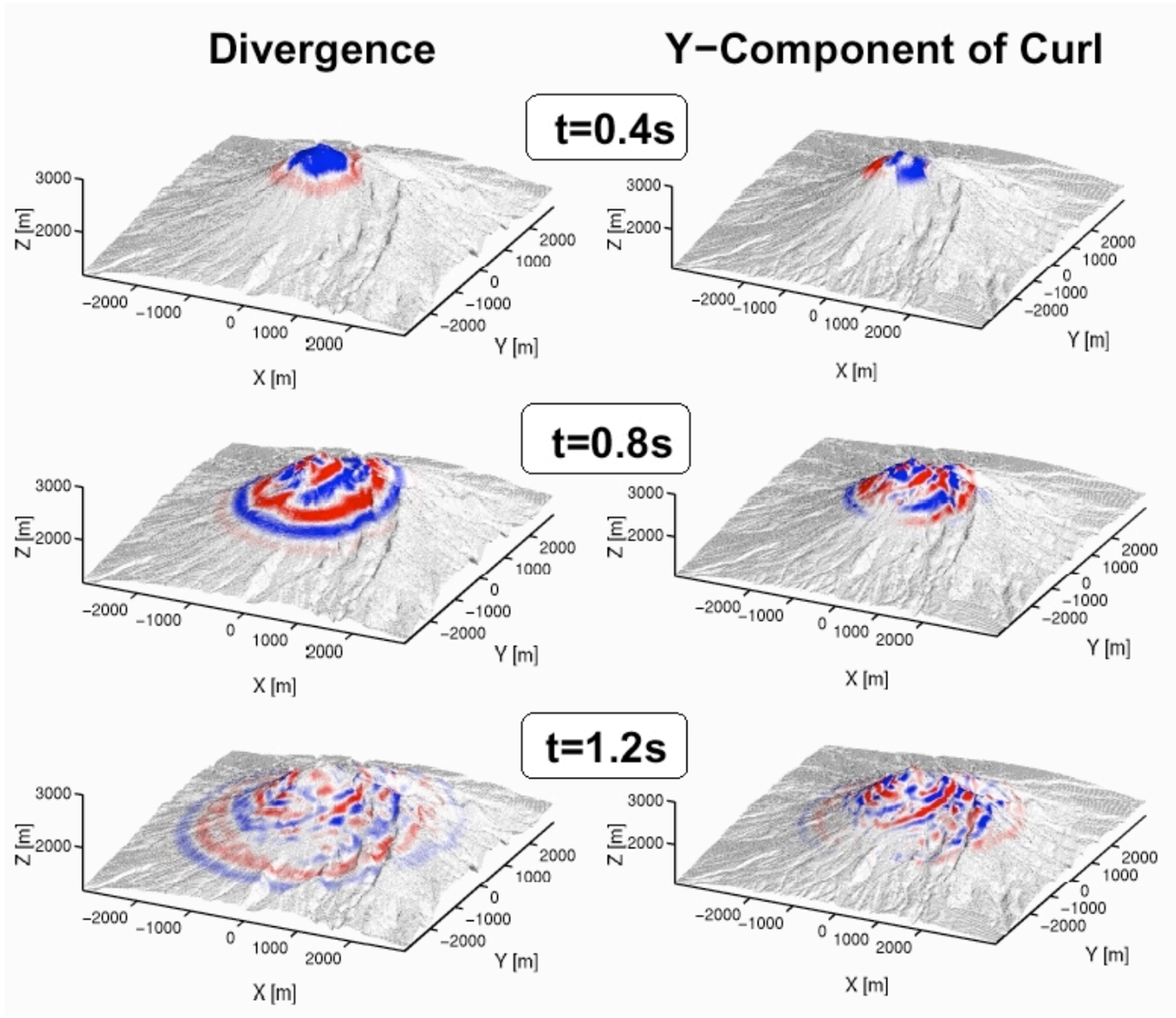
Was müsste weiter getan werden?

⇨ Modellierung der Wellenfeldeffekte in 3D

Simulation der Ausbreitung seismischer Wellen



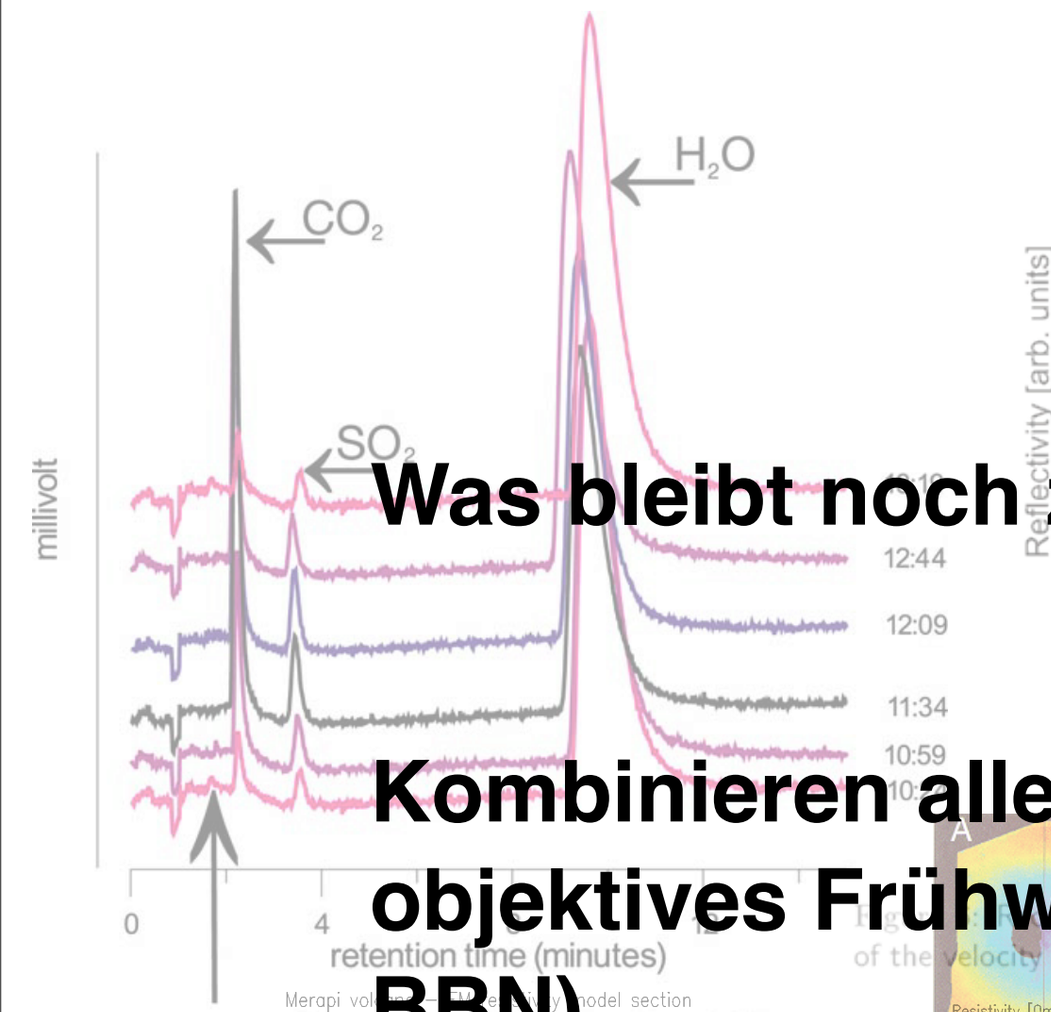
From: Wassermann

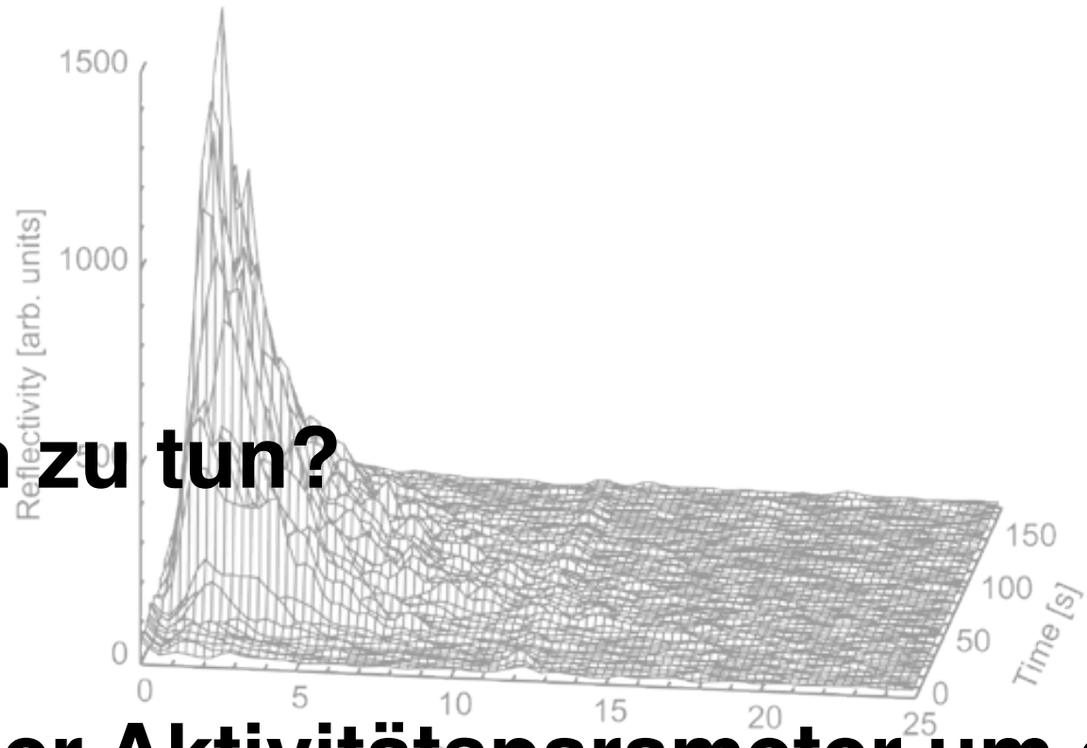


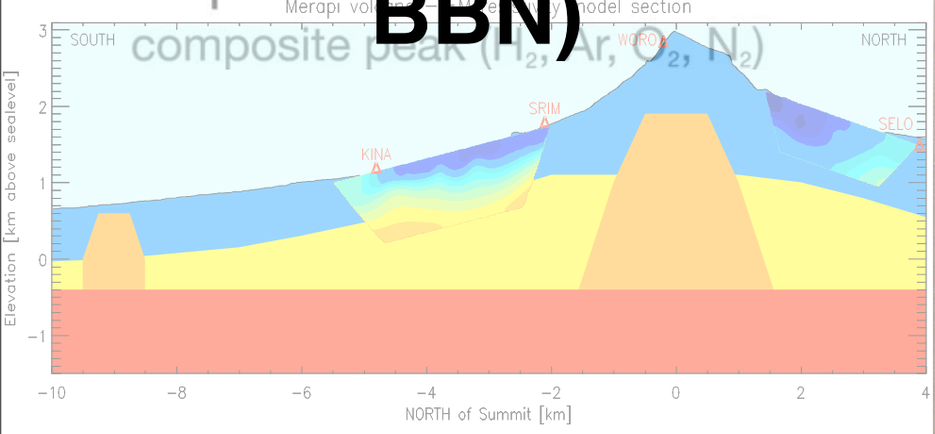
Ripperger et al., 2003

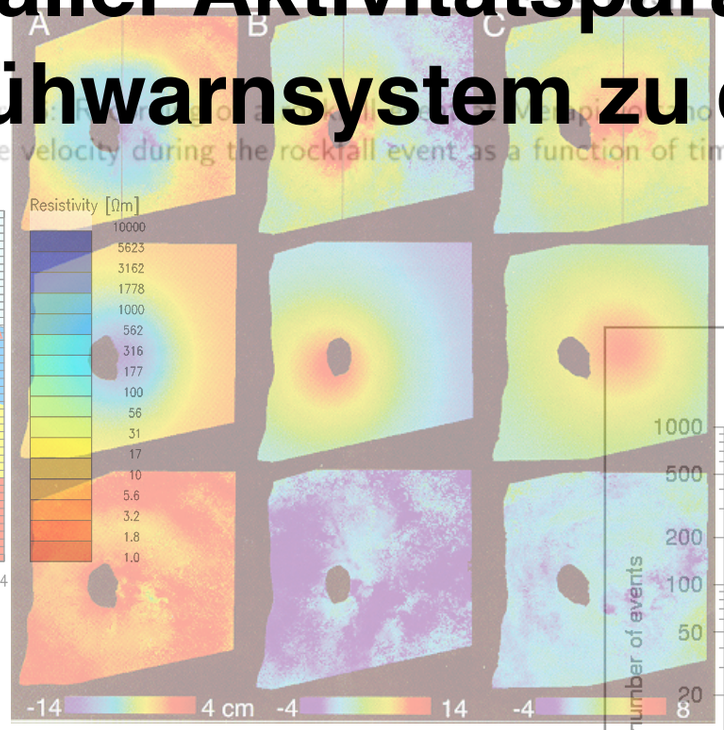
Was bleibt noch zu tun?

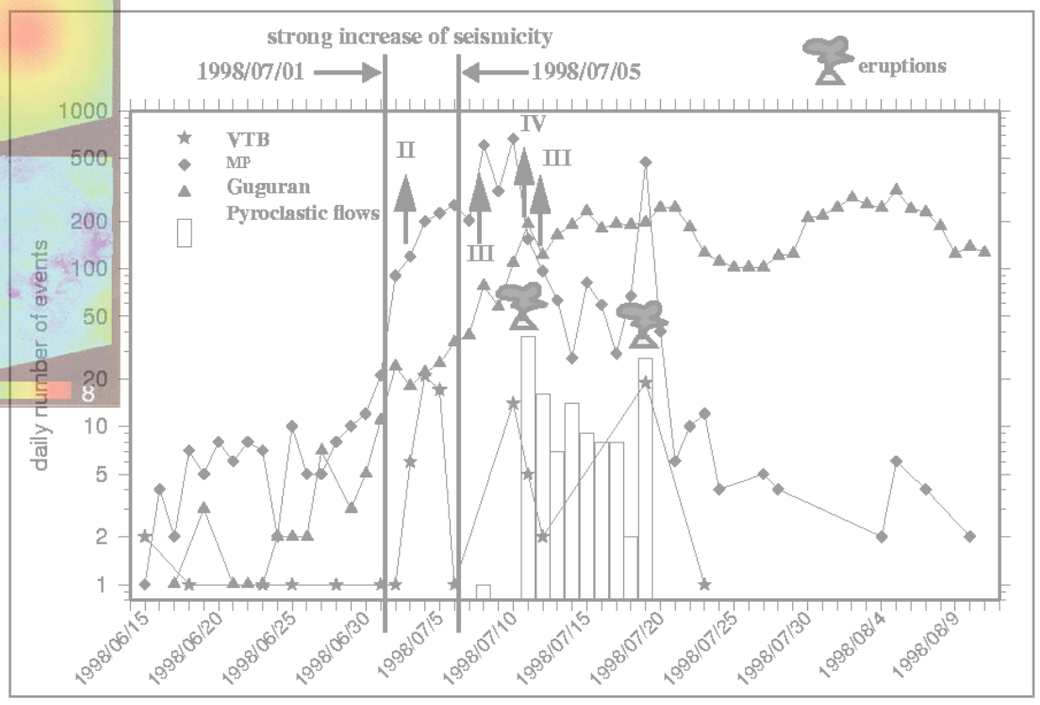
Kombinieren aller Aktivitätsparameter um ein objektives Frühwarnsystem zu erhalten (KI & HMM/ BBN)



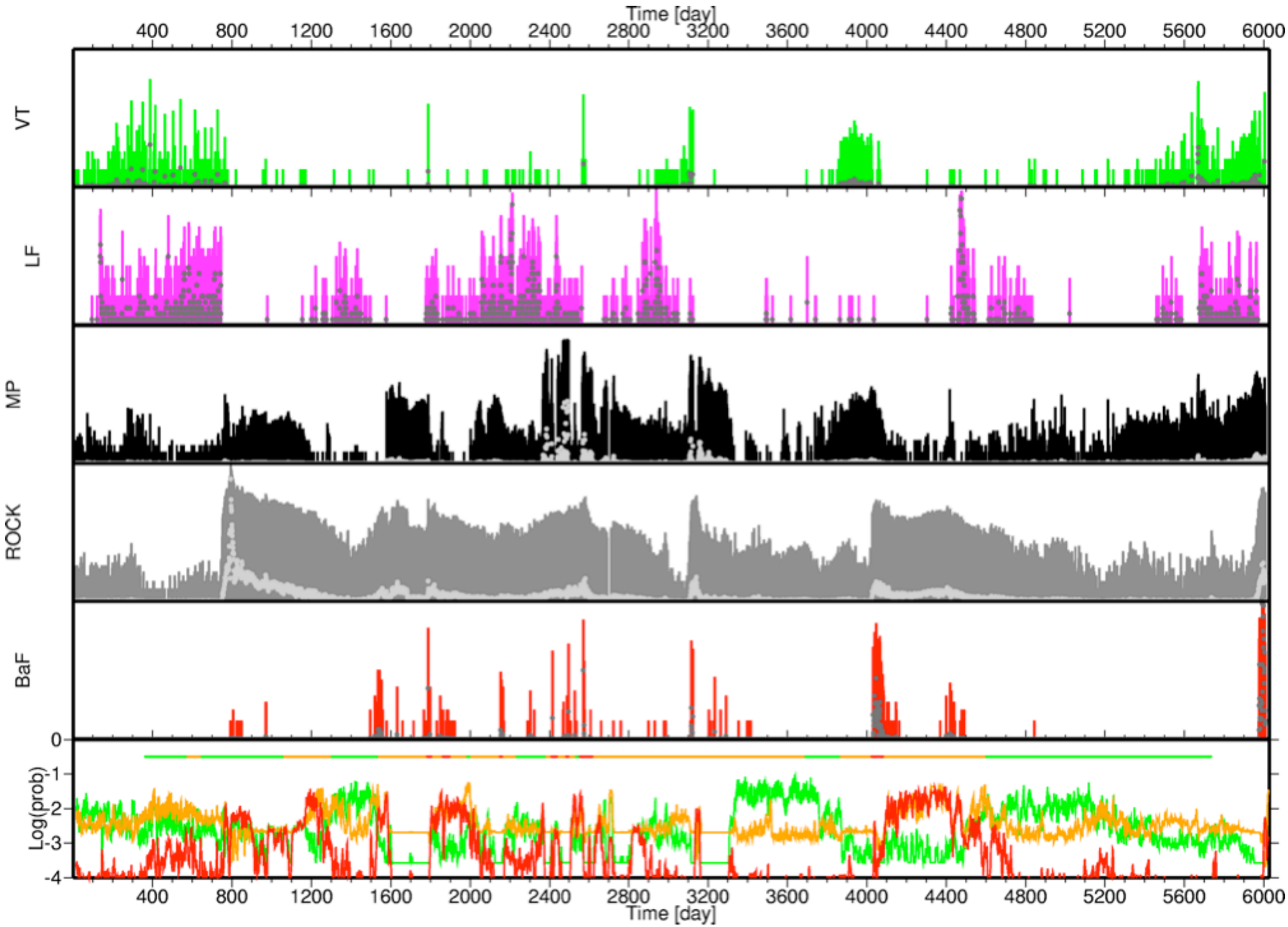




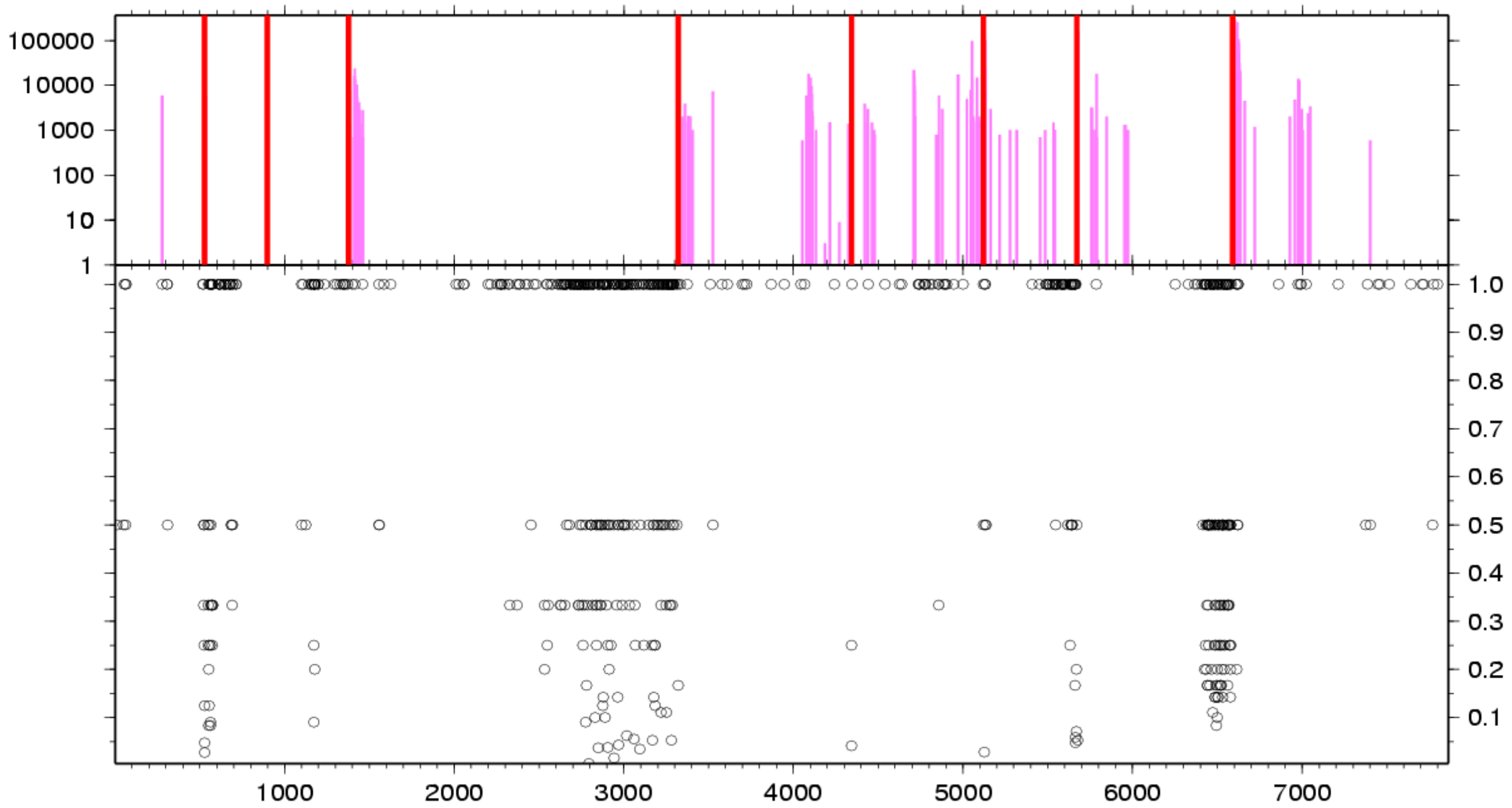




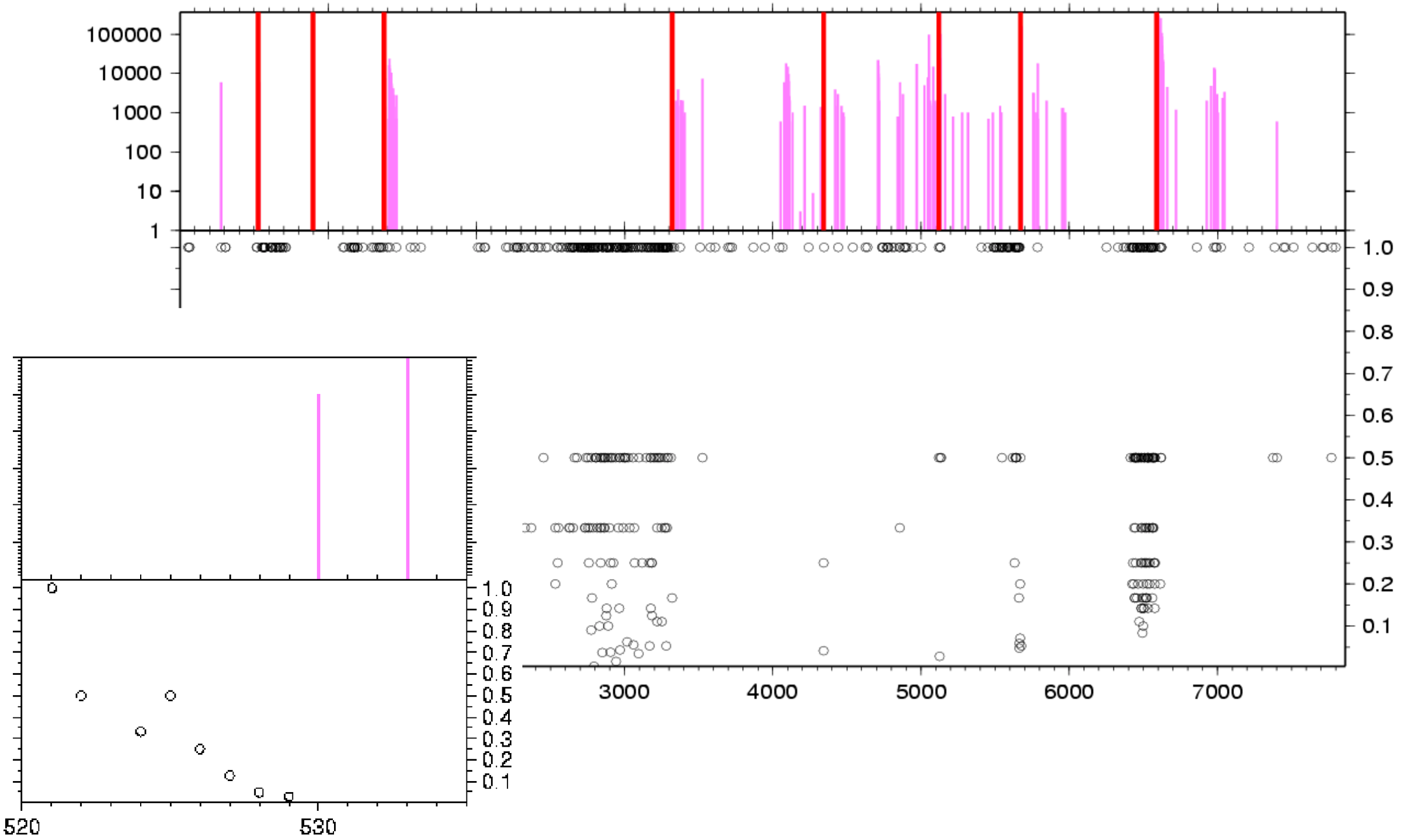
Frühwarnung mit Sprachanalyse?



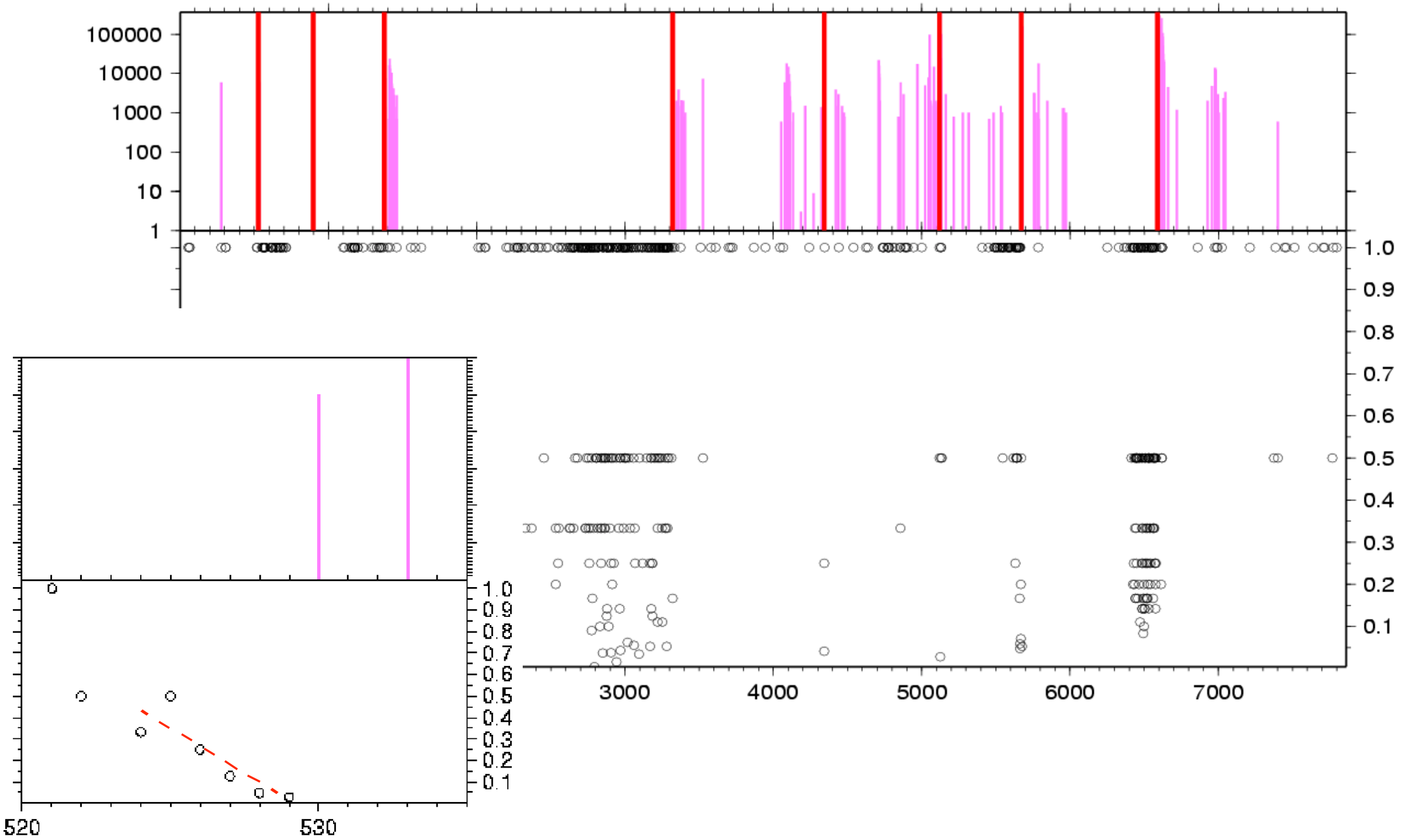
Frühwarnung unter Zuhilfenahme der Materialwissenschaften



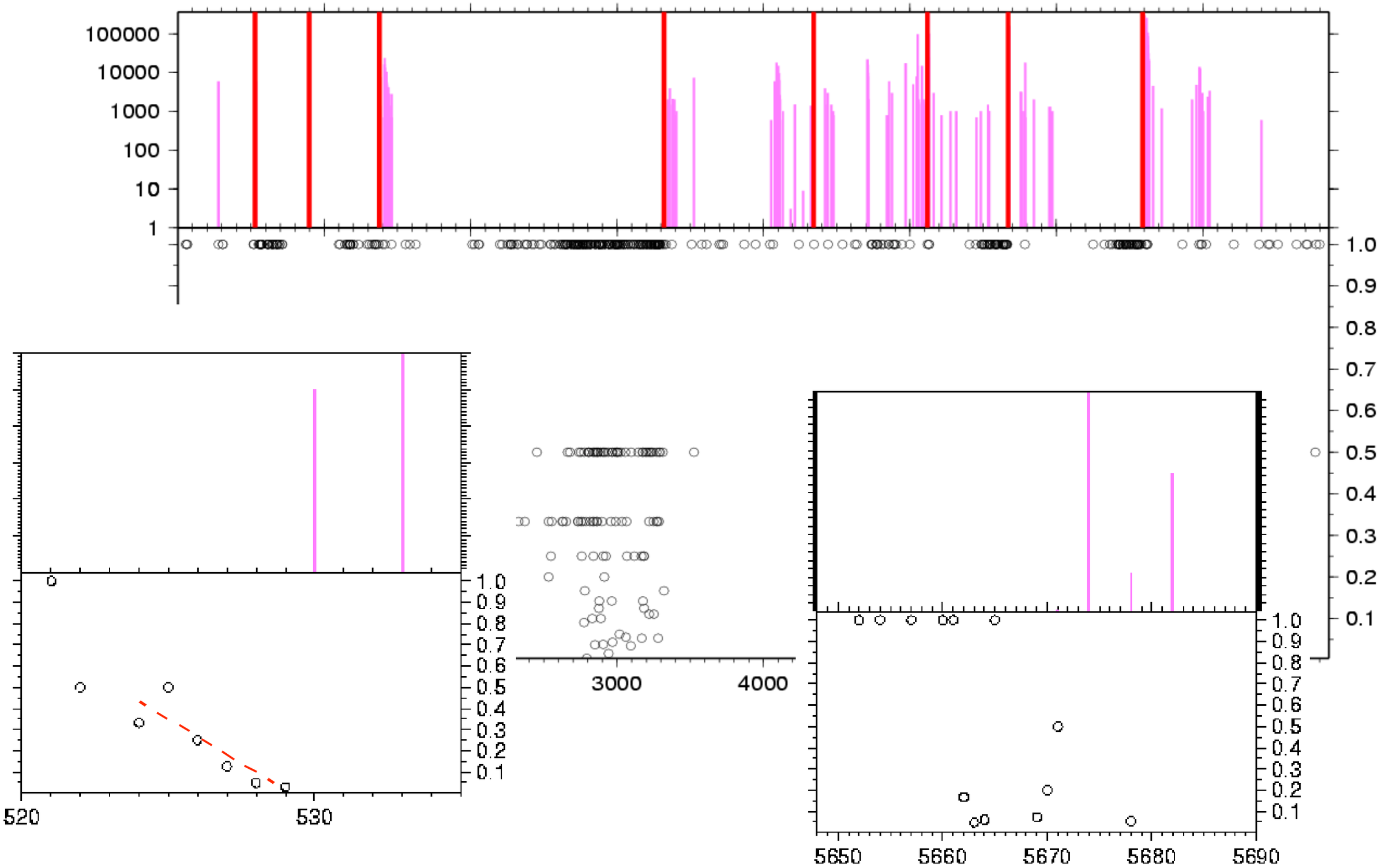
Frühwarnung unter Zuhilfenahme der Materialwissenschaften



Frühwarnung unter Zuhilfenahme der Materialwissenschaften



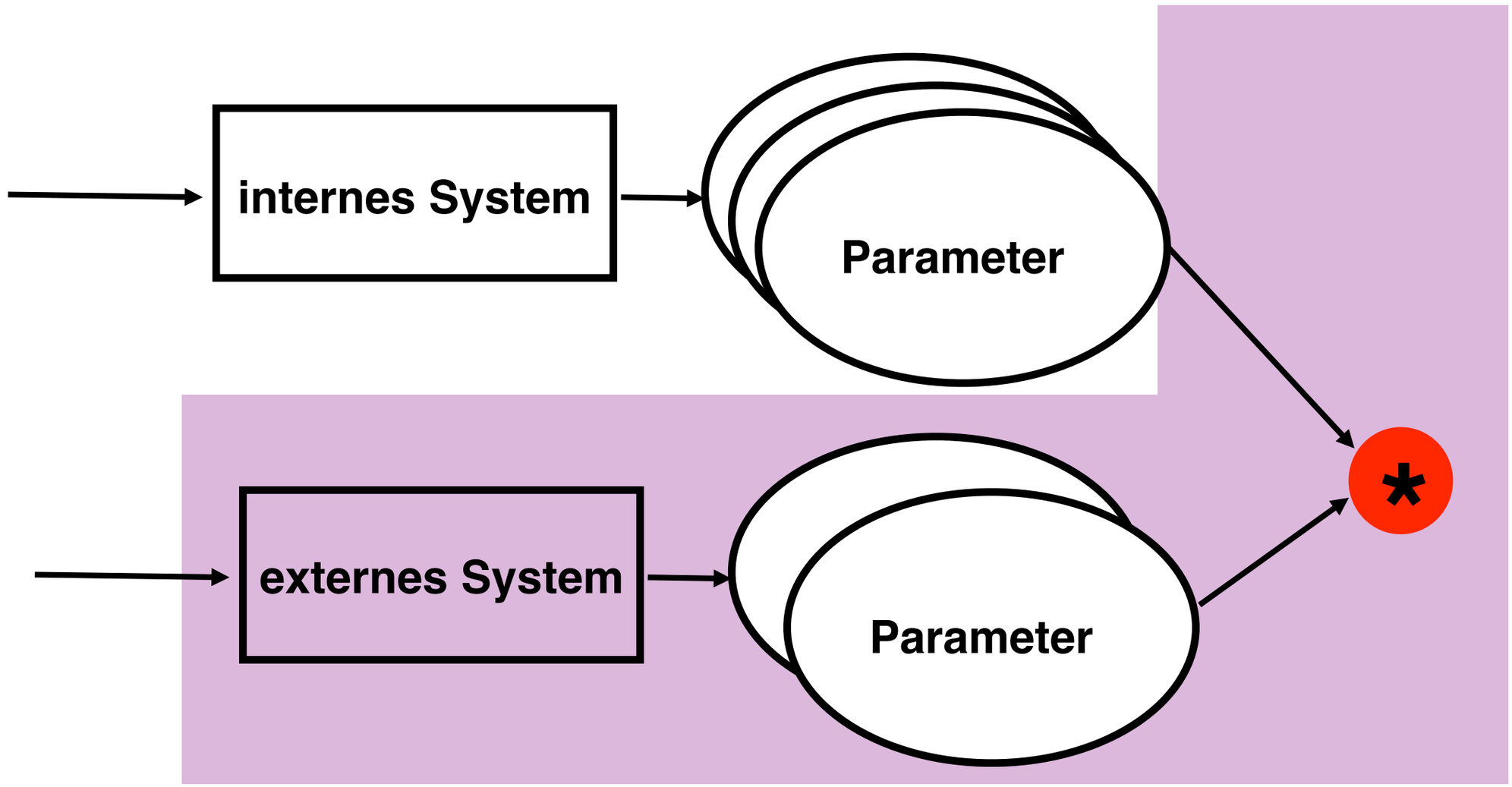
Frühwarnung unter Zuhilfenahme der Materialwissenschaften



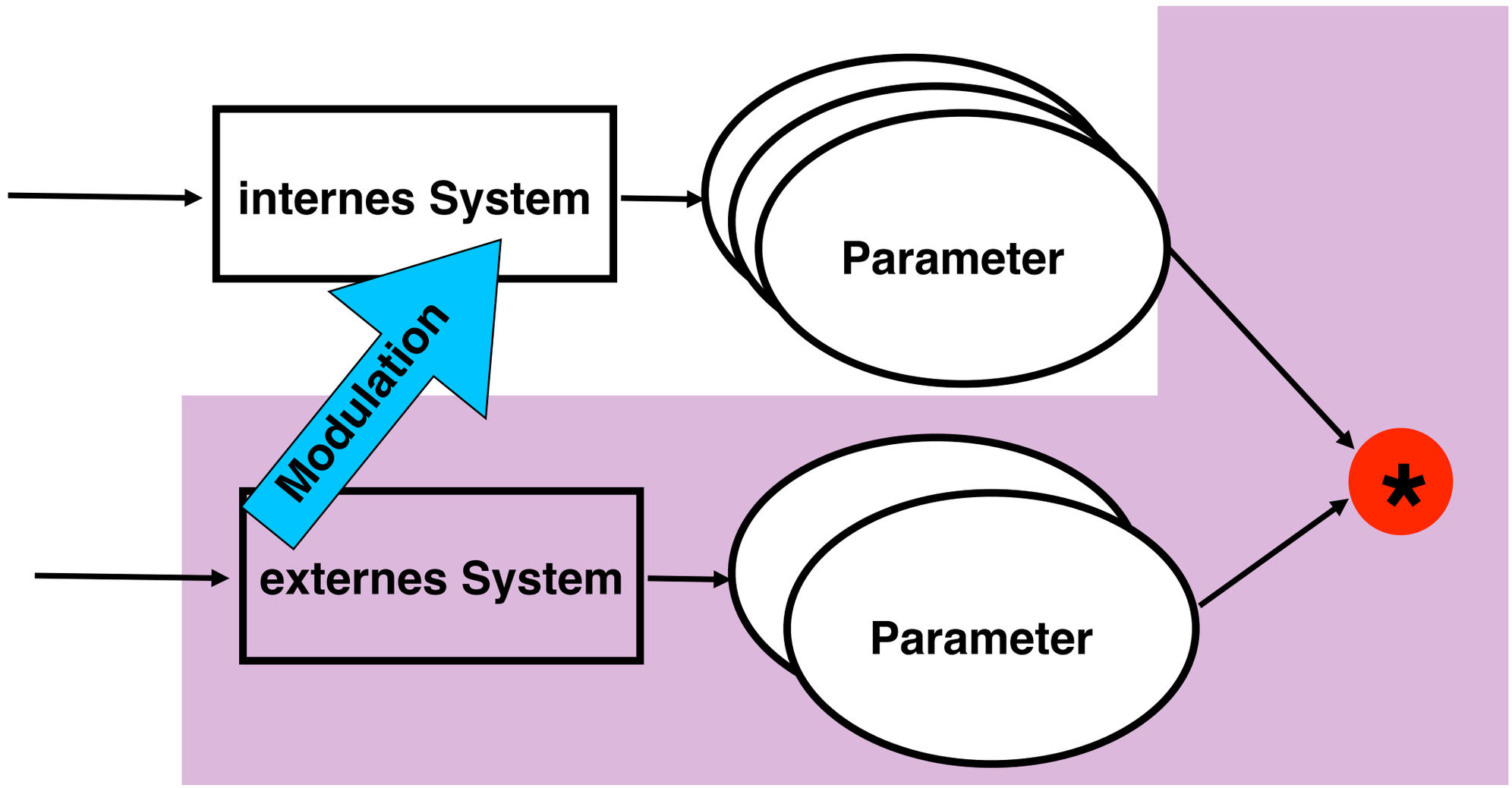
Noch was?

Forschung in Richtung der Beeinflussung vulkan. Aktivität durch externe Faktoren

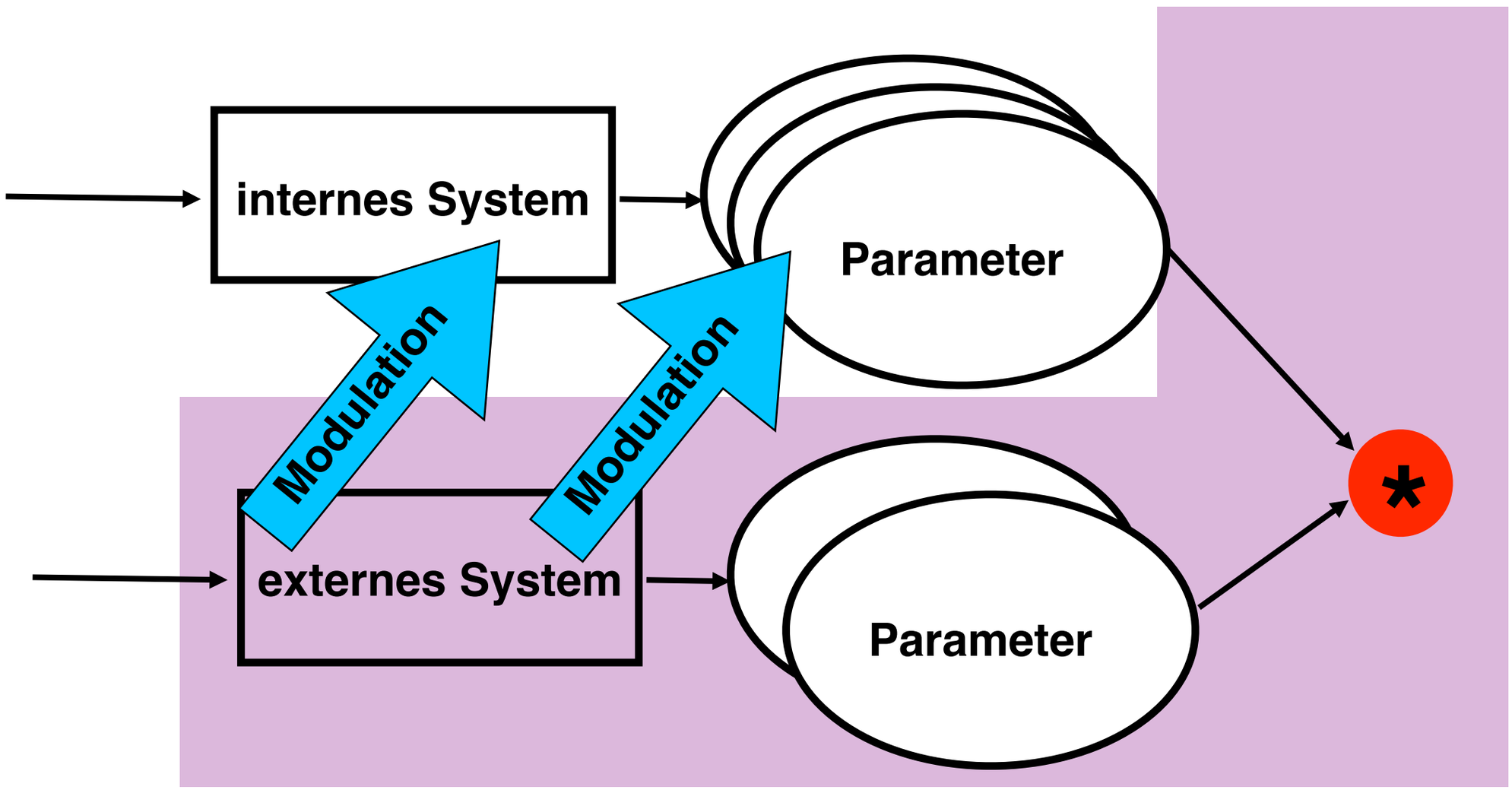
Modulation vulkanischer Aktivitätsparameter durch externe Einflüsse

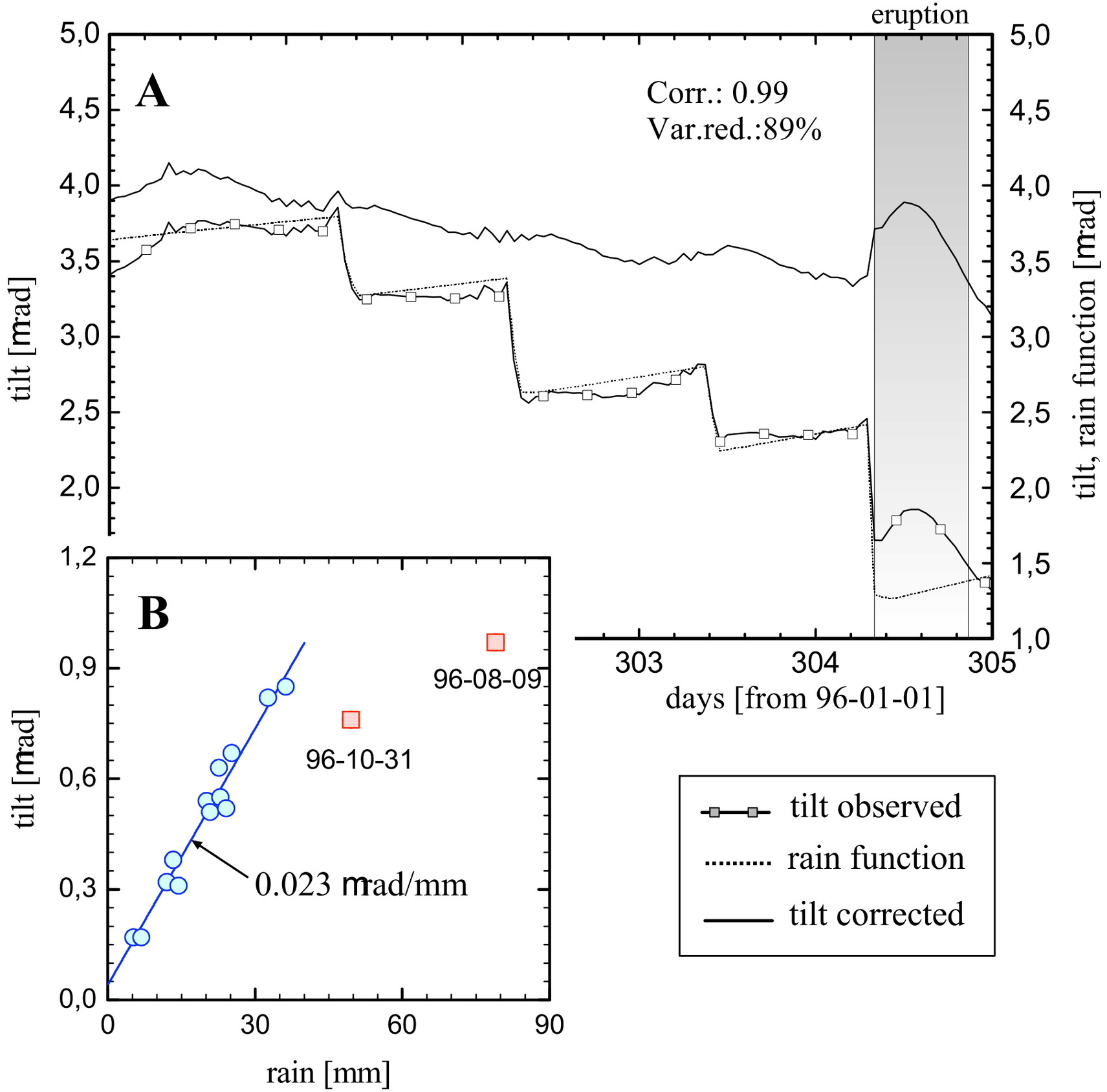


Modulation vulkanischer Aktivitätsparameter durch externe Einflüsse



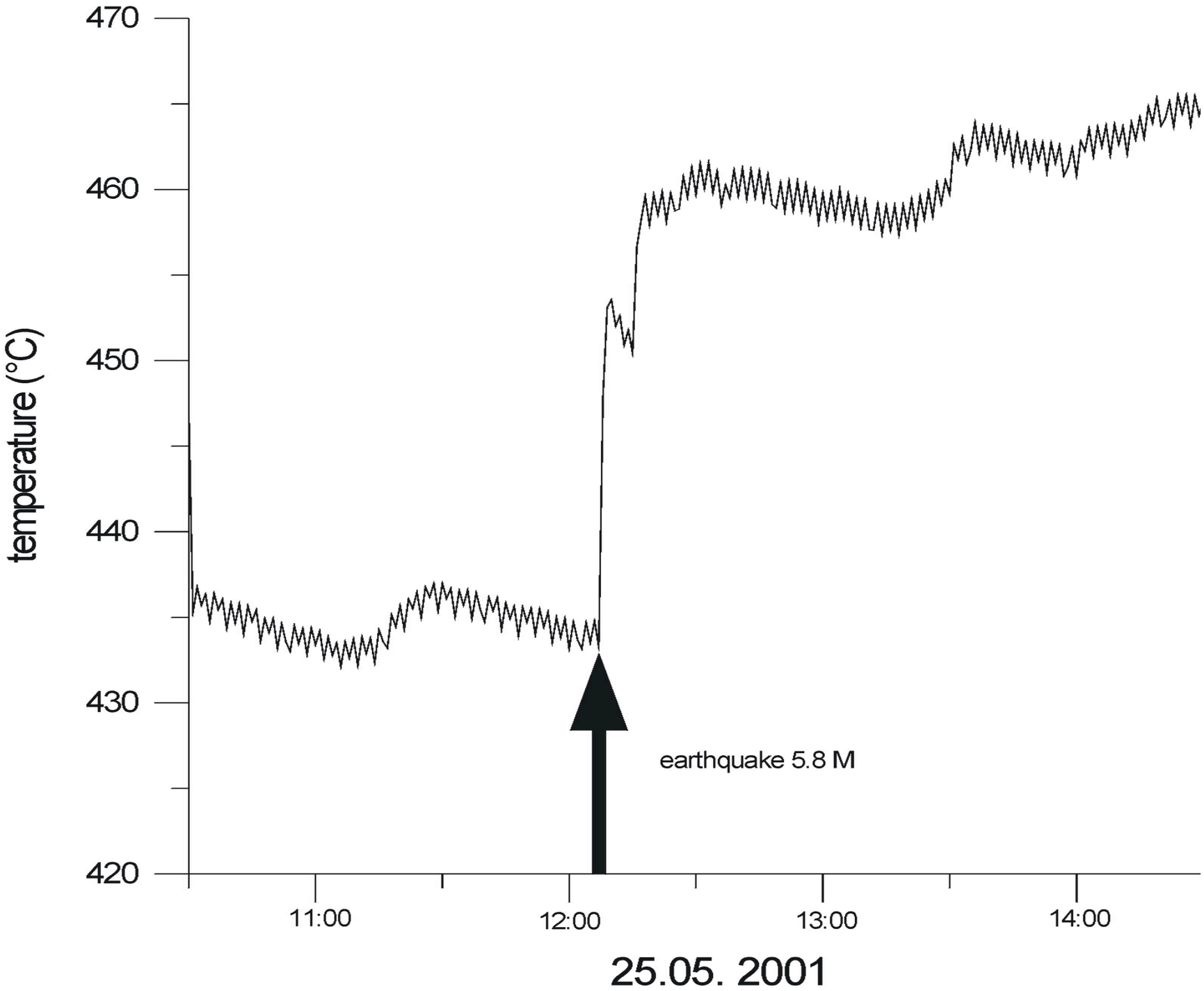
Modulation vulkanischer Aktivitätsparameter durch externe Einflüsse





M.Westerhaus, 2002

Ko-seismischer Sprung der Fumarolentemp.



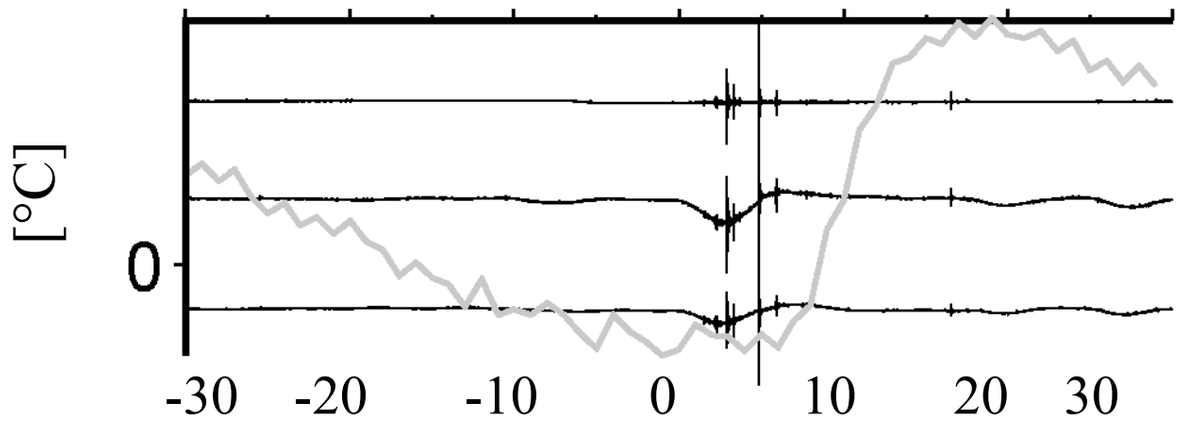
courtesy M. Zimmer

Correlation: Gas + Seismic?

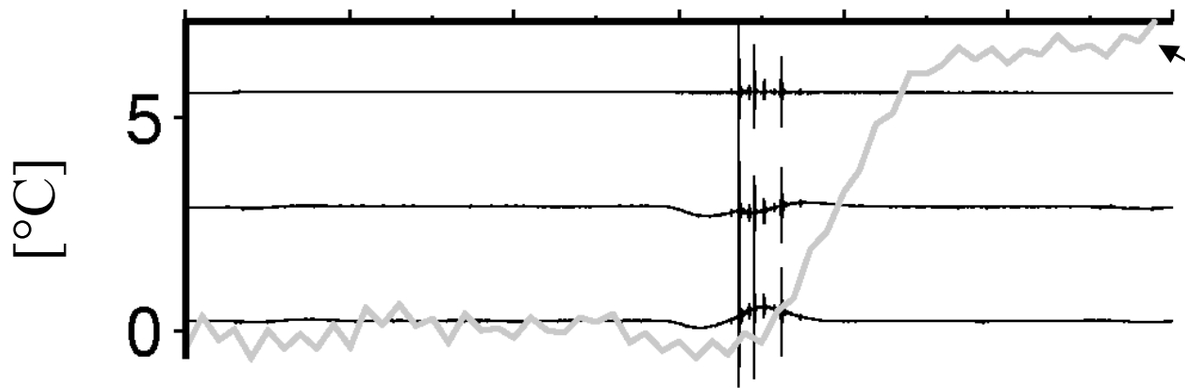
Min

2000

20. Sep. 10:06

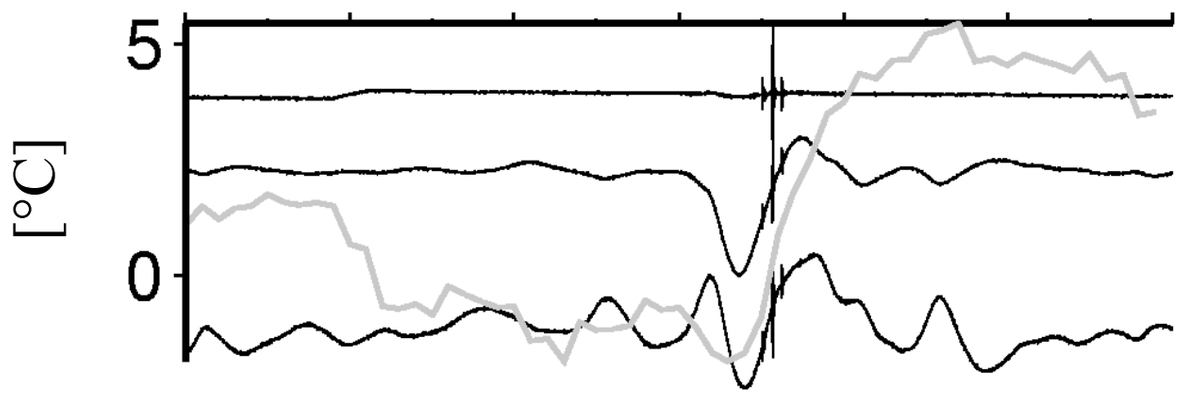


9. Oct. 1:27



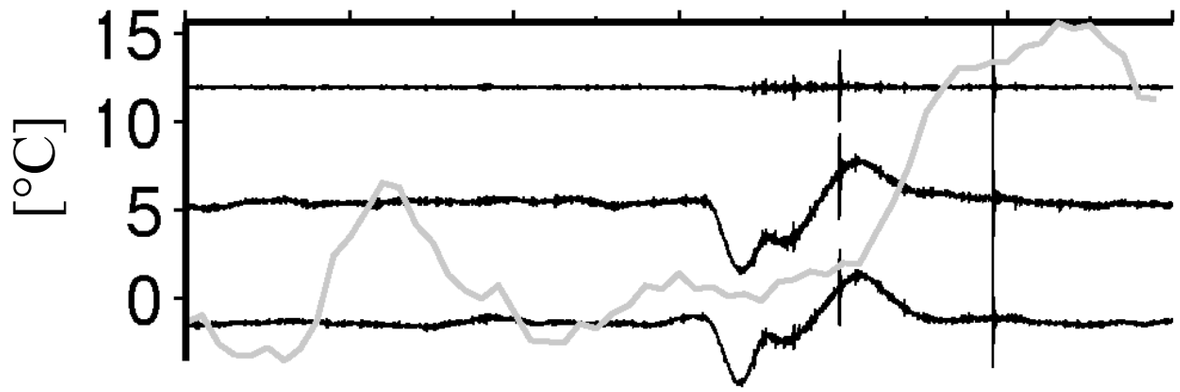
Temperature

4. Nov. 2:21



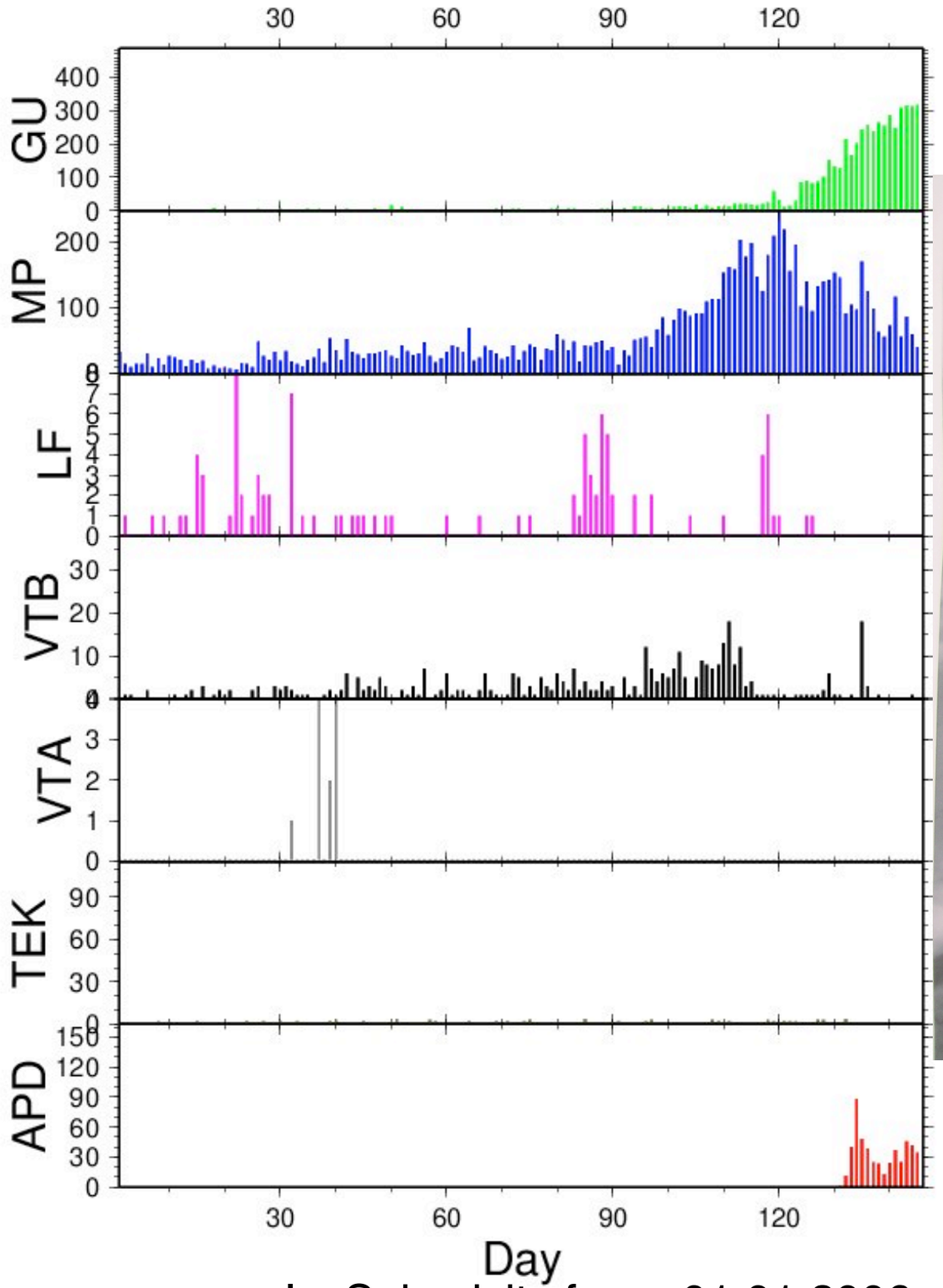
PAS0
(restituted to 500 s)

3. Dec. 20:44



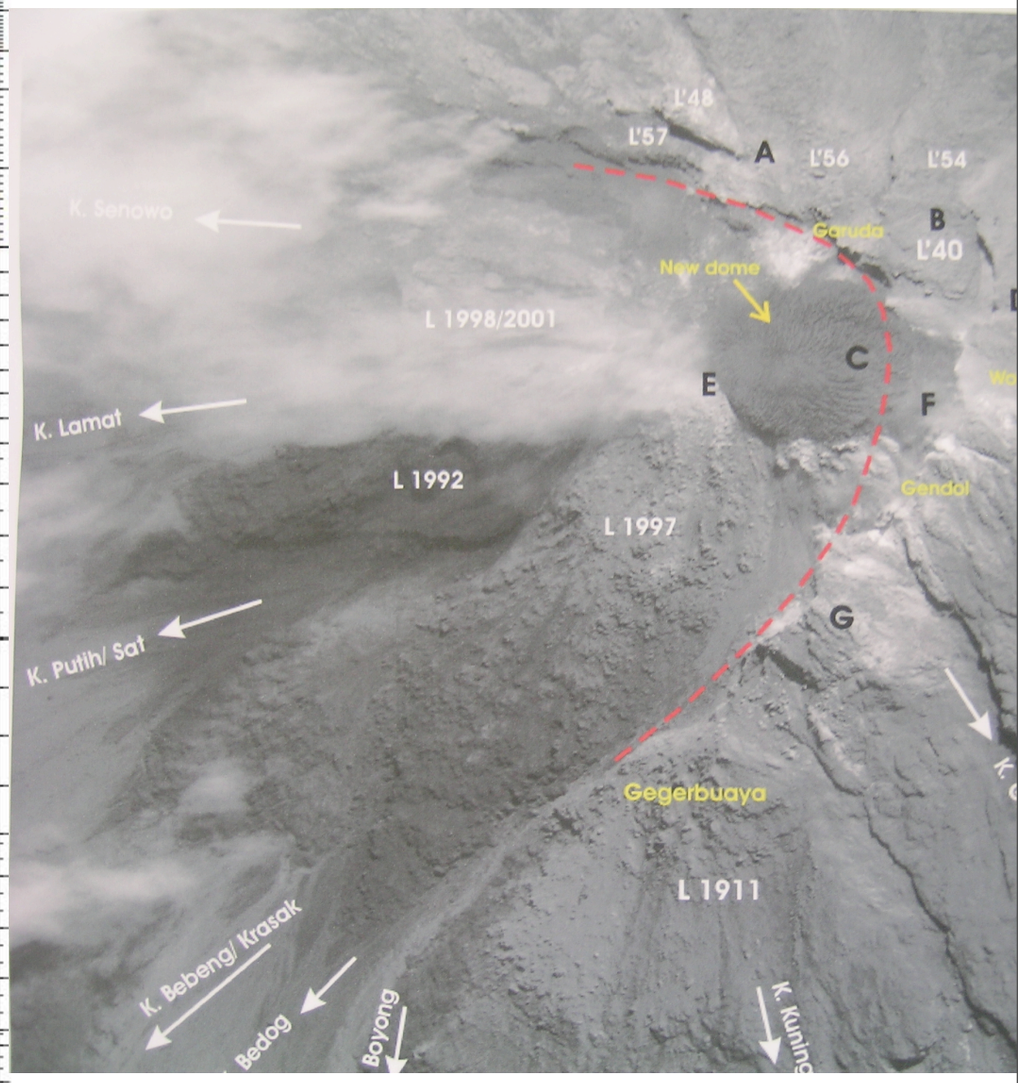
Courtesy G. Richter

Weiteres Beispiel für externe Einflüsse

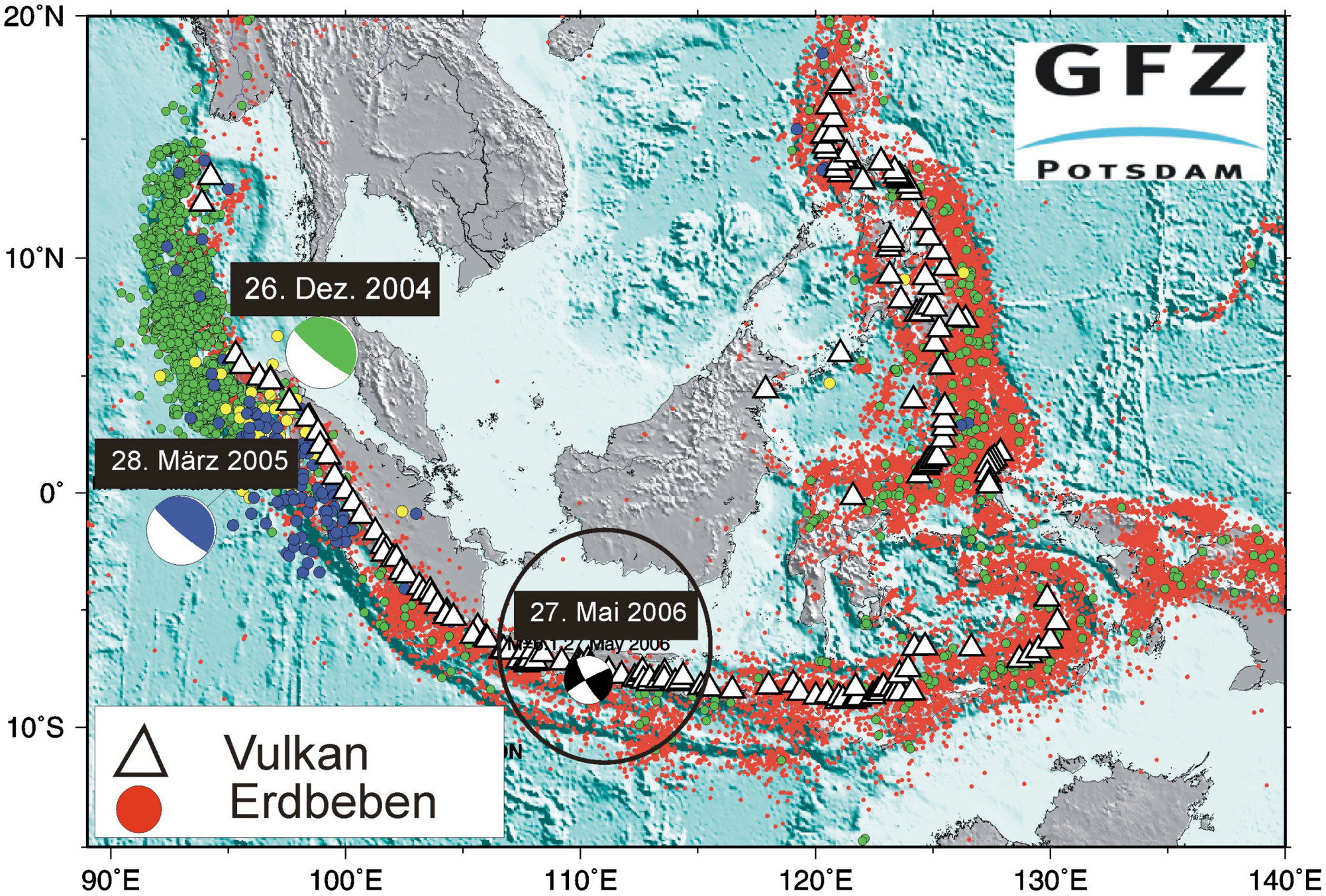


volc. Seismicity from 01.01.2006

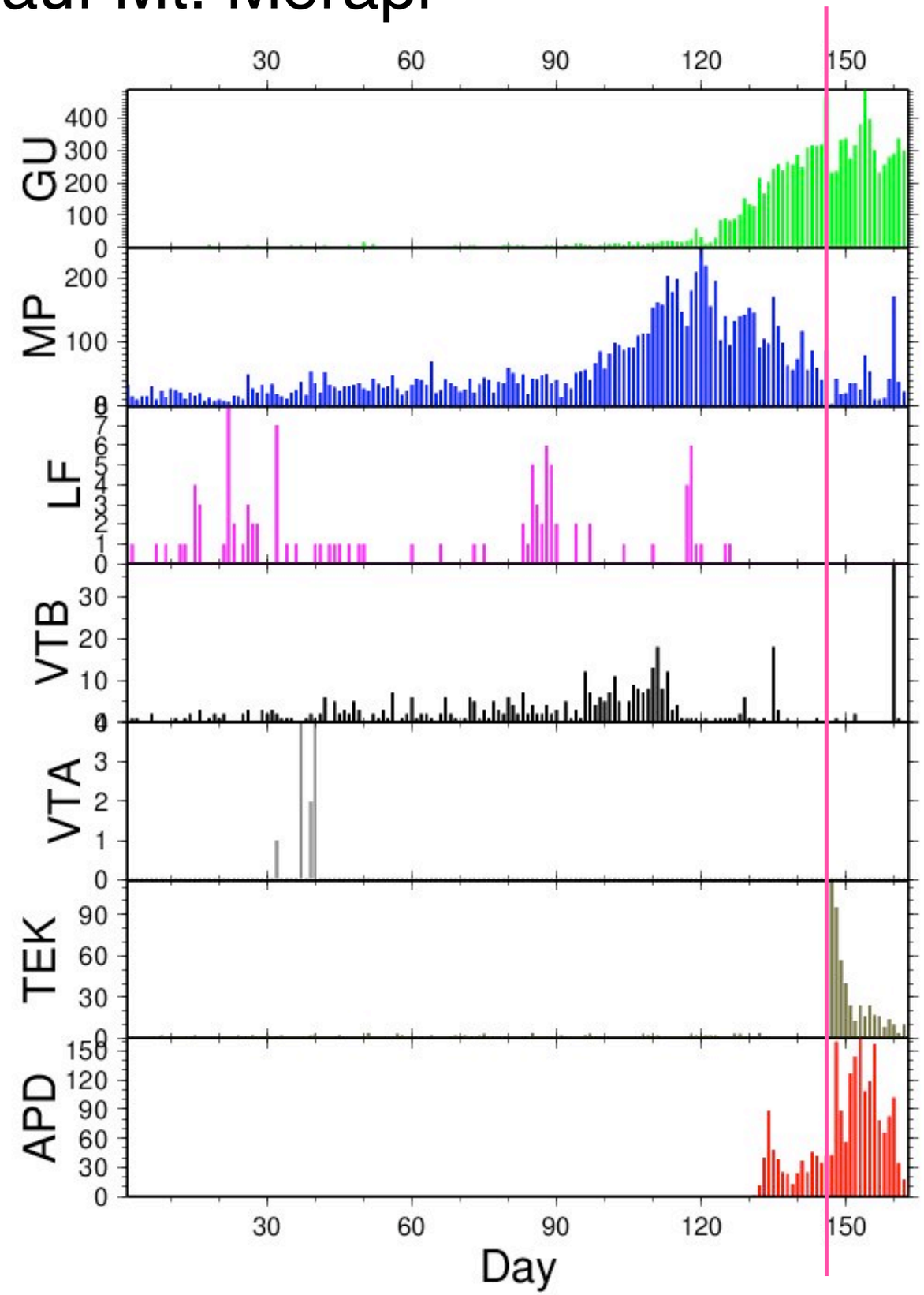
Ikonos: 10.05.2006



Java-Erdbeben: 26.05.2006 22:54:02 UTC

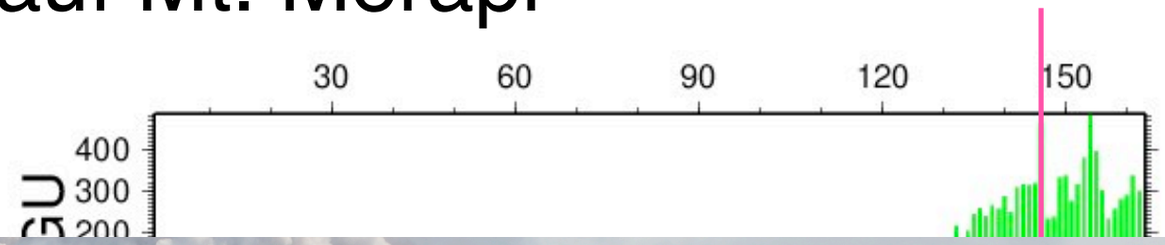


Auswirkungen auf Mt. Merapi



Auswirkungen auf Mt. Merapi

Auswirkungen auf Mt. Merapi



Danke !