**Sven Schippkus,** D. Zigone, G. Bokelmann, and AlpArray Working Group

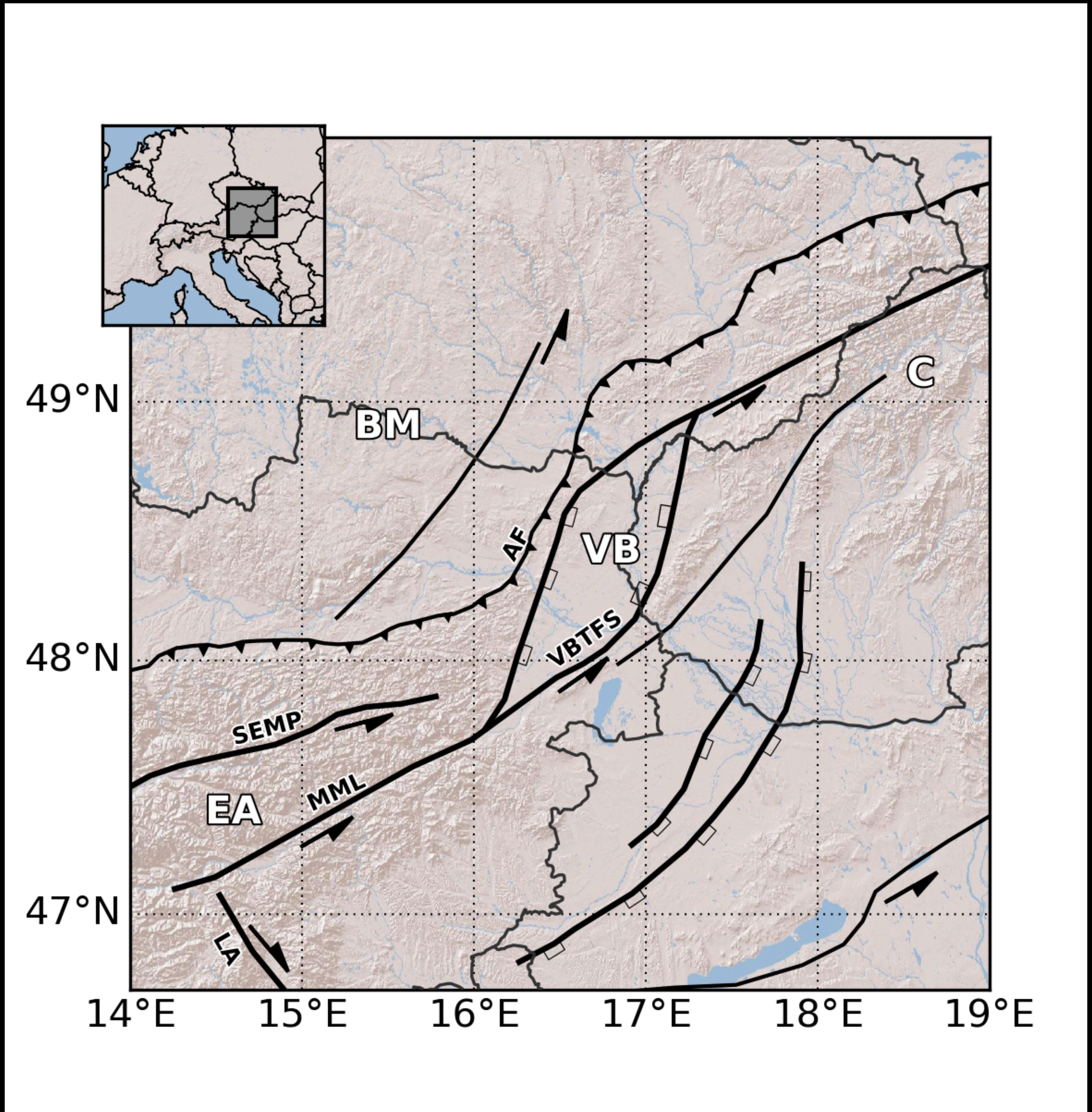
# Stress-field orientation and crustal deformation in the Vienna Basin region (Alpine-Pannonian-Carpathian junction)

## EGU May 2020

# Vienna Basin region

**(Alpine-Pannonian-Carpathian junction)**

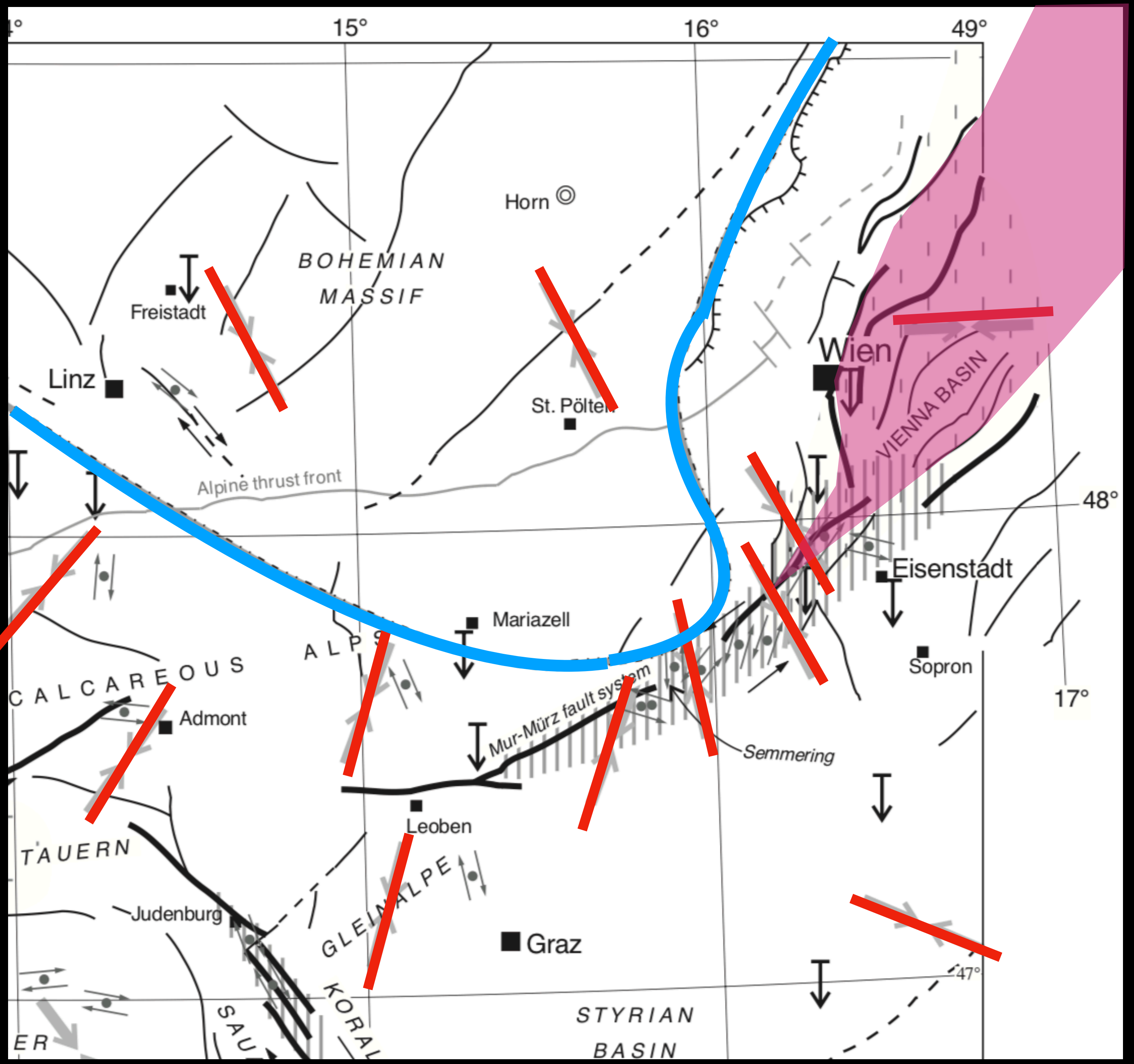
- Complex tectonic region with rich history at the eastern edge of the Alps
- Sinistral strike-slip fault systems (SEMP, MML) accommodate NE-directed lateral extrusion of crustal blocks from the Eastern Alps (EA) in the Miocene. Vienna Basin (VB) formed as pull-apart basin subsequent to extrusion.
- Stress-field orientation today?



# Stress-Field ($\sigma_H$)

## Previous Studies

- *Reinecker & Lenhardt 1999* report maximum compressive horizontal stress $\sigma_H$ (–) ~normal to Bohemian Spur (–), based on point-wise measurements (focal mechanisms, borehole breakouts)



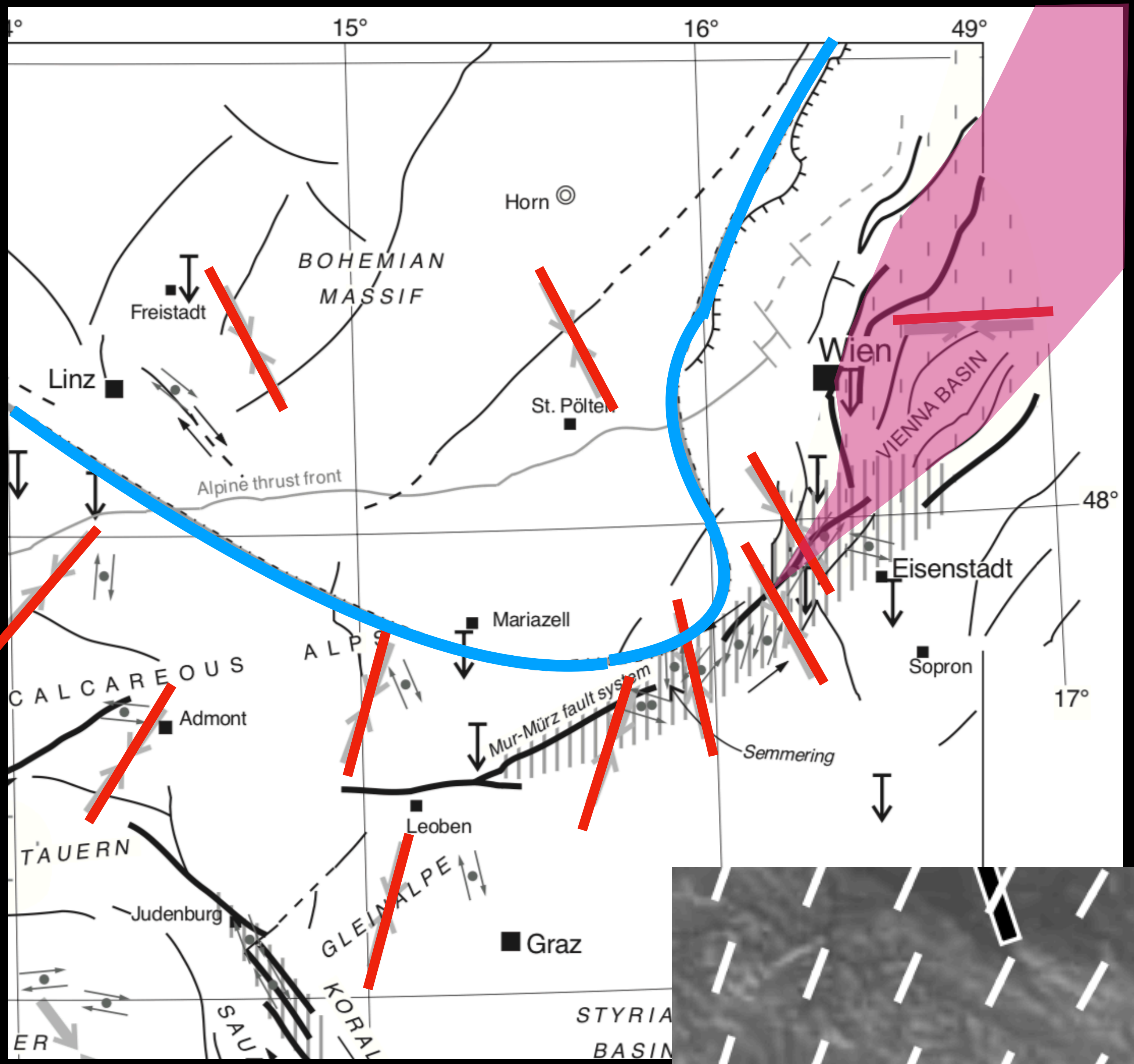

Vienna Basin

Reinecker & Lenhardt 1999

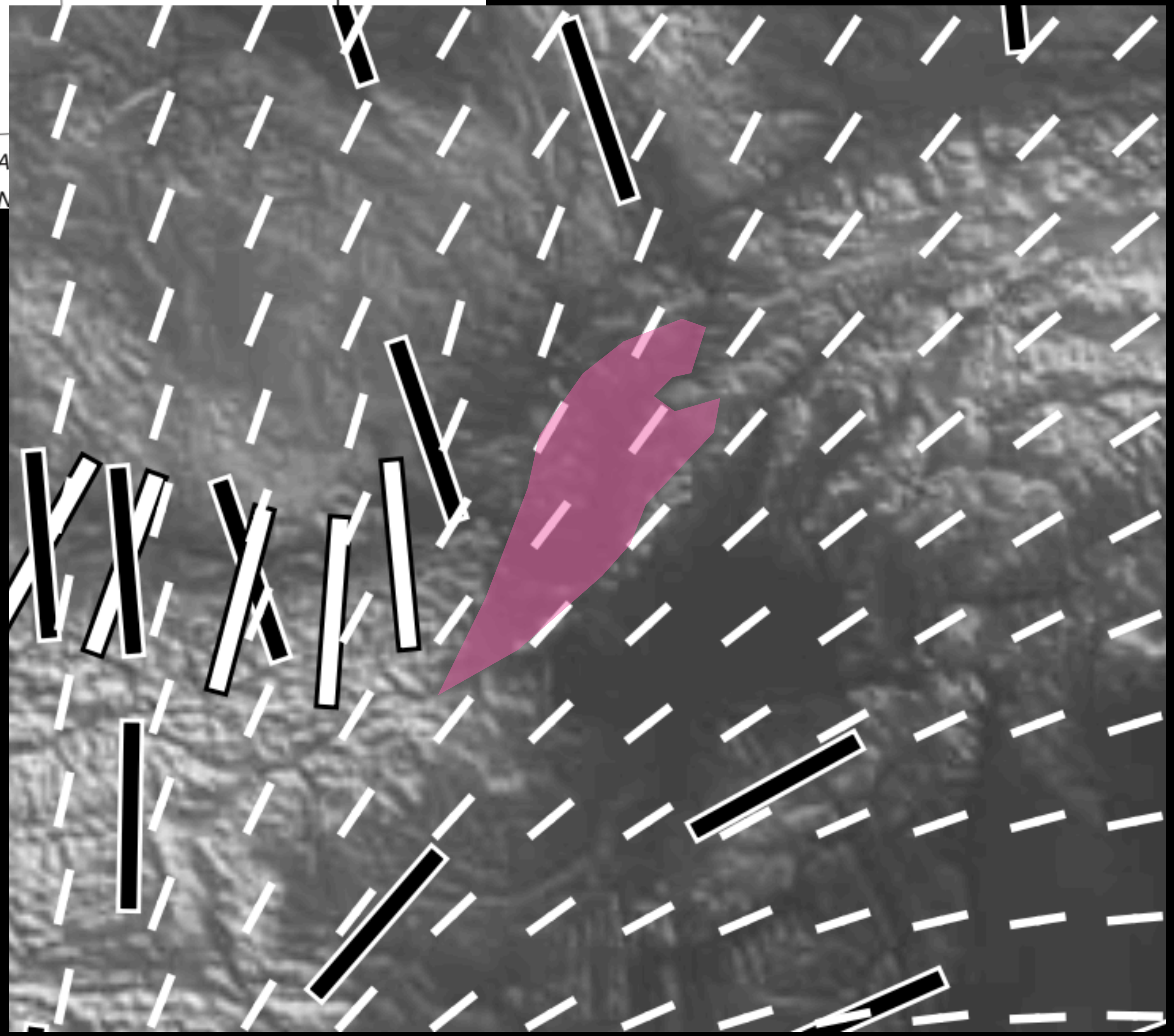
# Stress-Field ($\sigma_H$)

## Previous Studies

- *Reinecker & Lenhardt 1999* report maximum compressive horizontal stress $\sigma_H$ (–) ~normal to Bohemian Spur (–), based on point-wise measurements (focal mechanisms, borehole breakouts)
- *Robl & Stüwe 2005* report $\sigma_H$ (–) oriented NNE to NE, based on viscous thin-sheet modelling of Alpine orogeny
- Can we provide insight using an independent approach?




Reinecker & Lenhardt 1999



Robl & Stüwe 2005

Vienna Basin

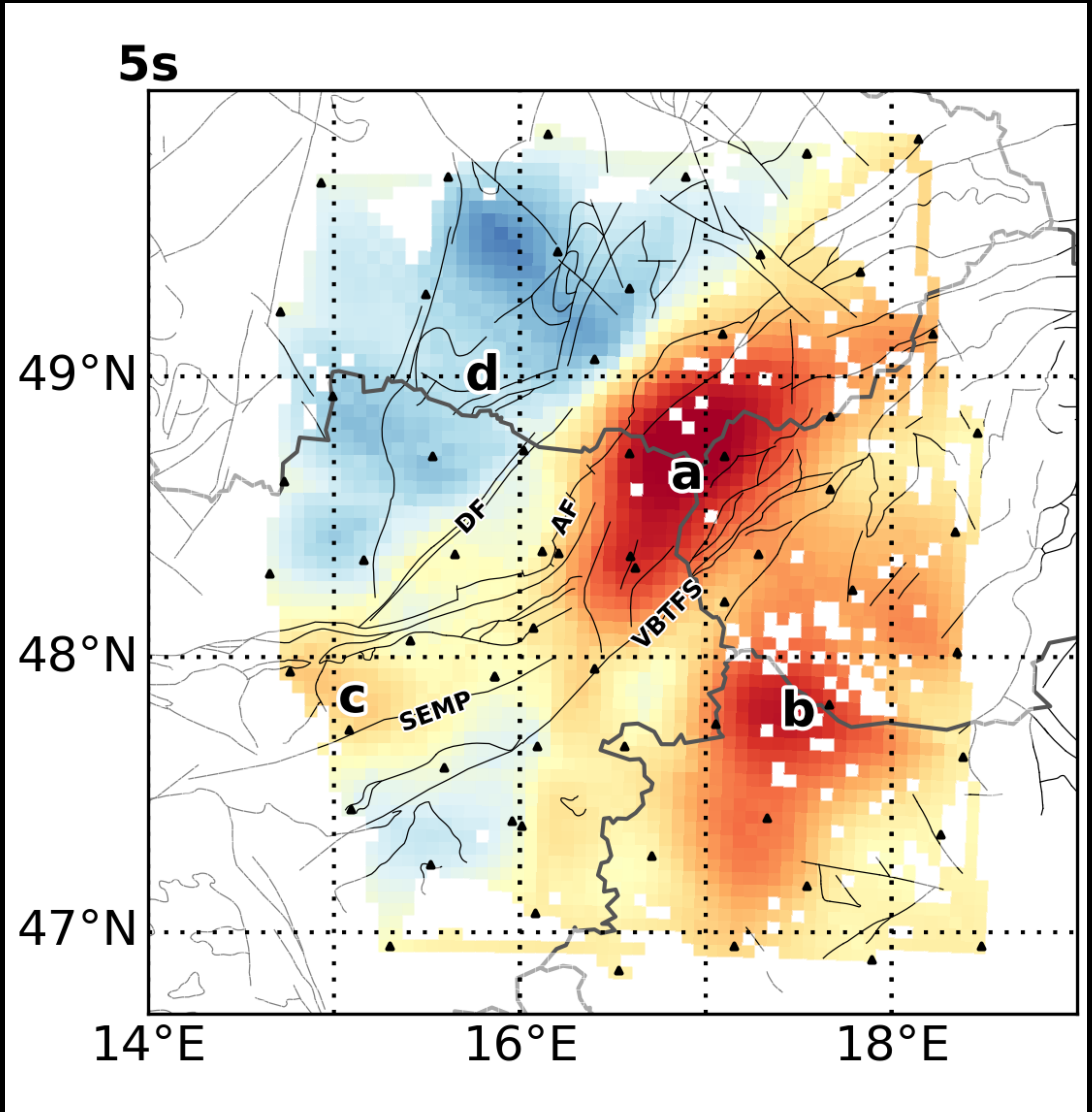
# Our Approach

## 1. Isotropic Inversion → Residuals

- Local group velocity is a combination of isotropic and anisotropic effects:

$$\underbrace{u(\vec{x},\phi)}_{\text{Measured group-velocity}} = \underbrace{u_{iso}(\vec{x})}_{\text{Isotropic model}} + u_{aniso}(\vec{x},\phi)$$

- Ambient-noise-based group velocities are inverted for isotropic group-velocity maps, neglecting anisotropy (*Schippkus et al., 2018*)




Schippkus et al., 2018

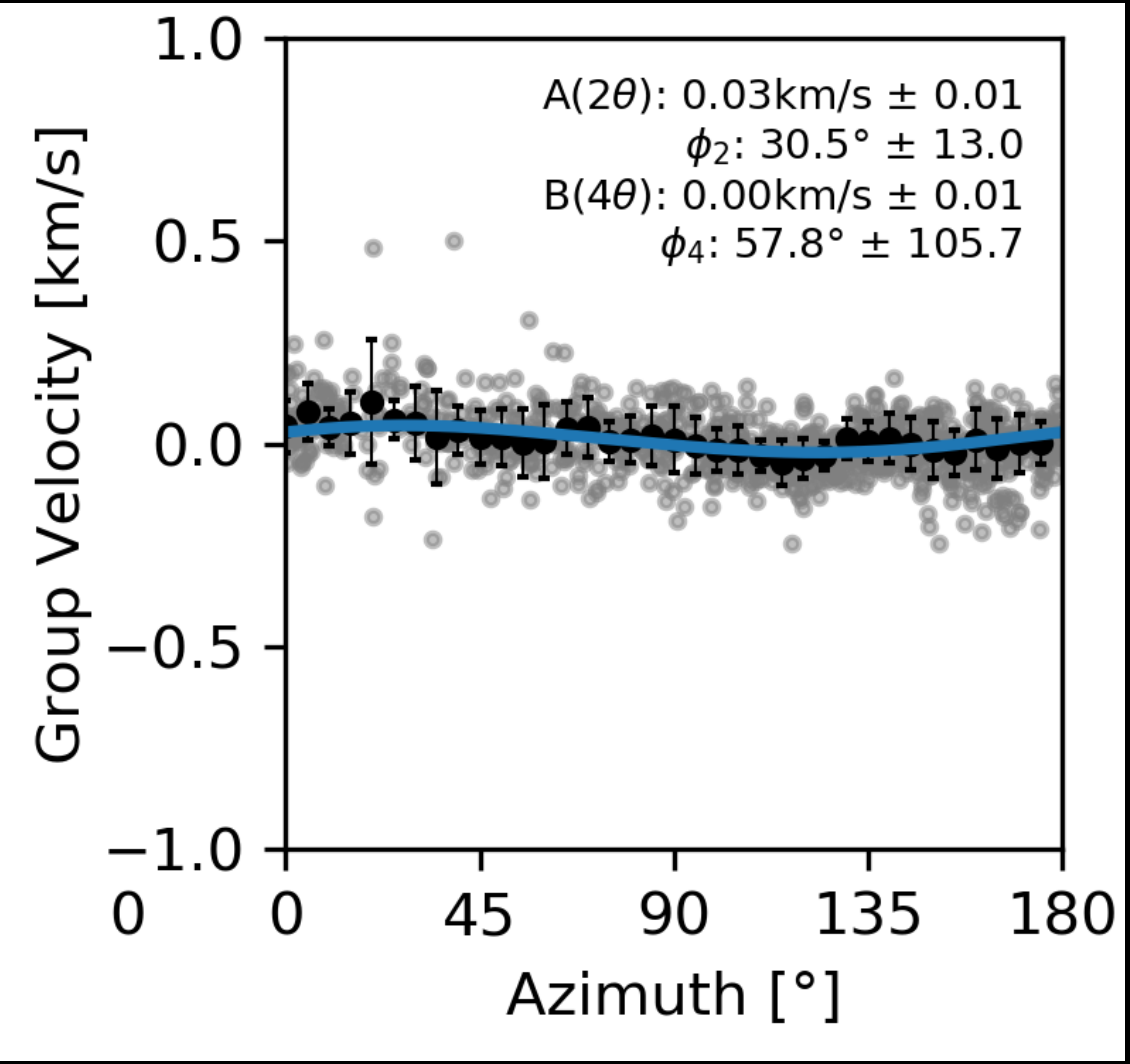
# Our Approach

## 2. Residuals show Anisotropy

- Group-velocity residuals of isotropic inversion contain anisotropic effects:

$$\underbrace{u(\vec{x},\phi)}_{\text{Measured group-velocity}} = \underbrace{u_{iso}(\vec{x})}_{\text{Isotropic model}} + \underbrace{u_{aniso}(\vec{x},\phi)}_{\text{group-velocity residuals}}$$

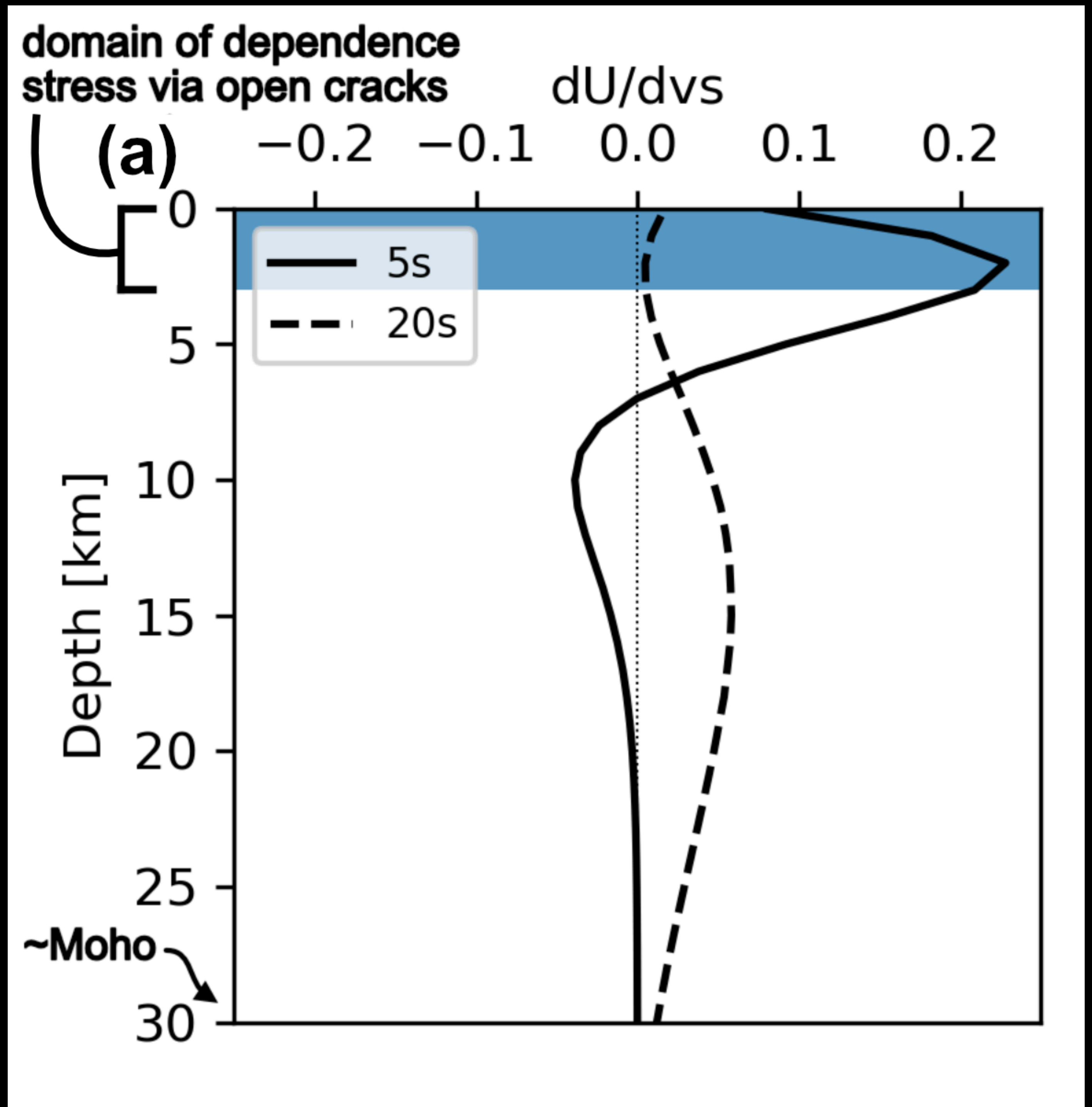
- Measure fast orientation of group-velocity from residuals




Schippkus et al., 2020

# Our Approach
## 3. Anisotropy ≈ Stress-field

- 5s Rayleigh waves are sensitive to top few kilometers of crust (■)

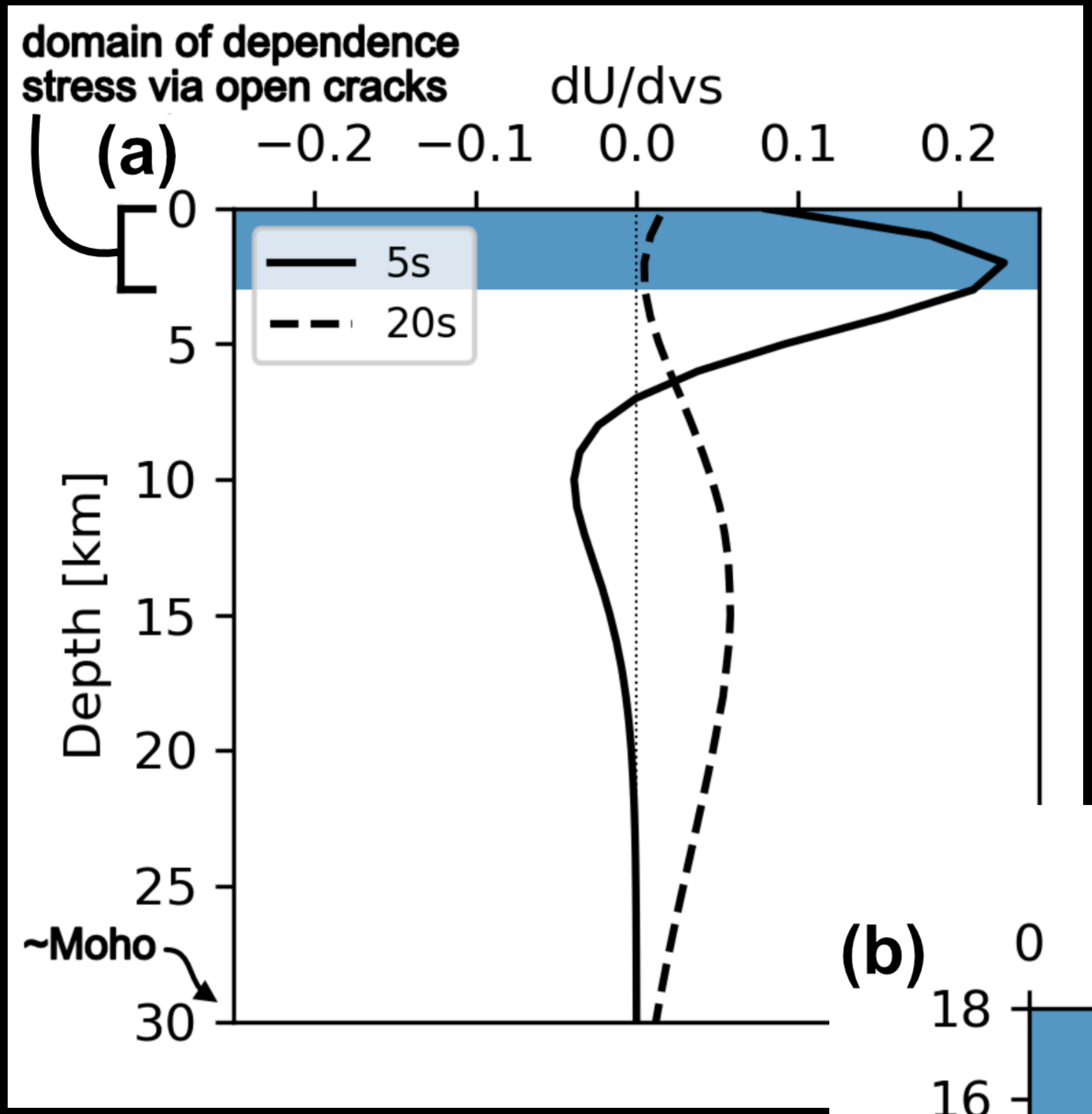



Schippkus et al., 2020

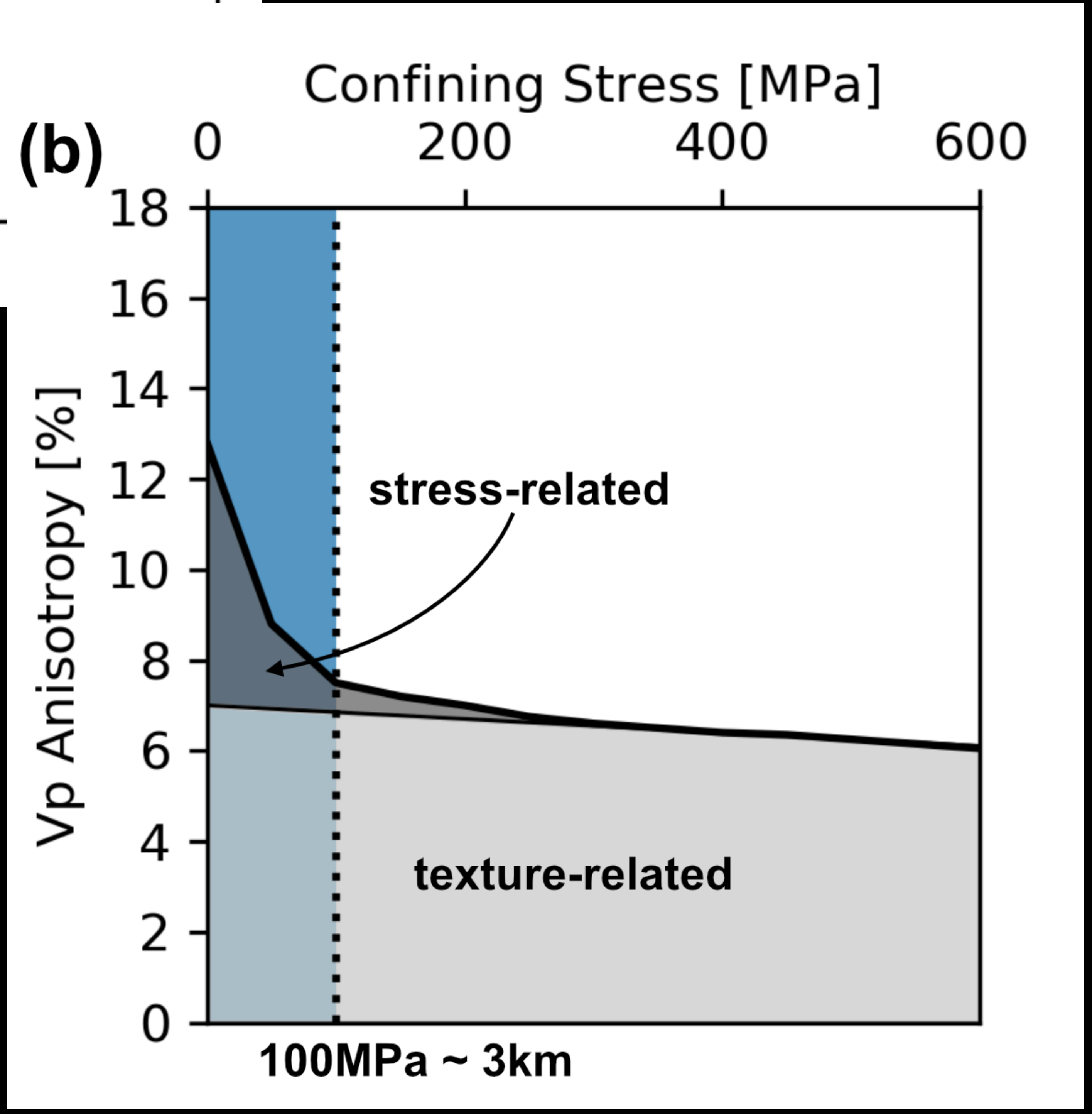
# Our Approach

## 3. Anisotropy ≈ Stress-field

- 5s Rayleigh waves are sensitive to top few kilometers of crust (■)
- There (■), microscopic cracks open along the stress-field ($\sigma_H$), inducing (stress-related) anisotropy in addition to texture-related anisotropy (e.g., aligned crystals)
- Thus, Rayleigh waves travel faster along $\sigma_H$, and group-velocity residuals allow to measure this effect




Schippkus et al., 2020

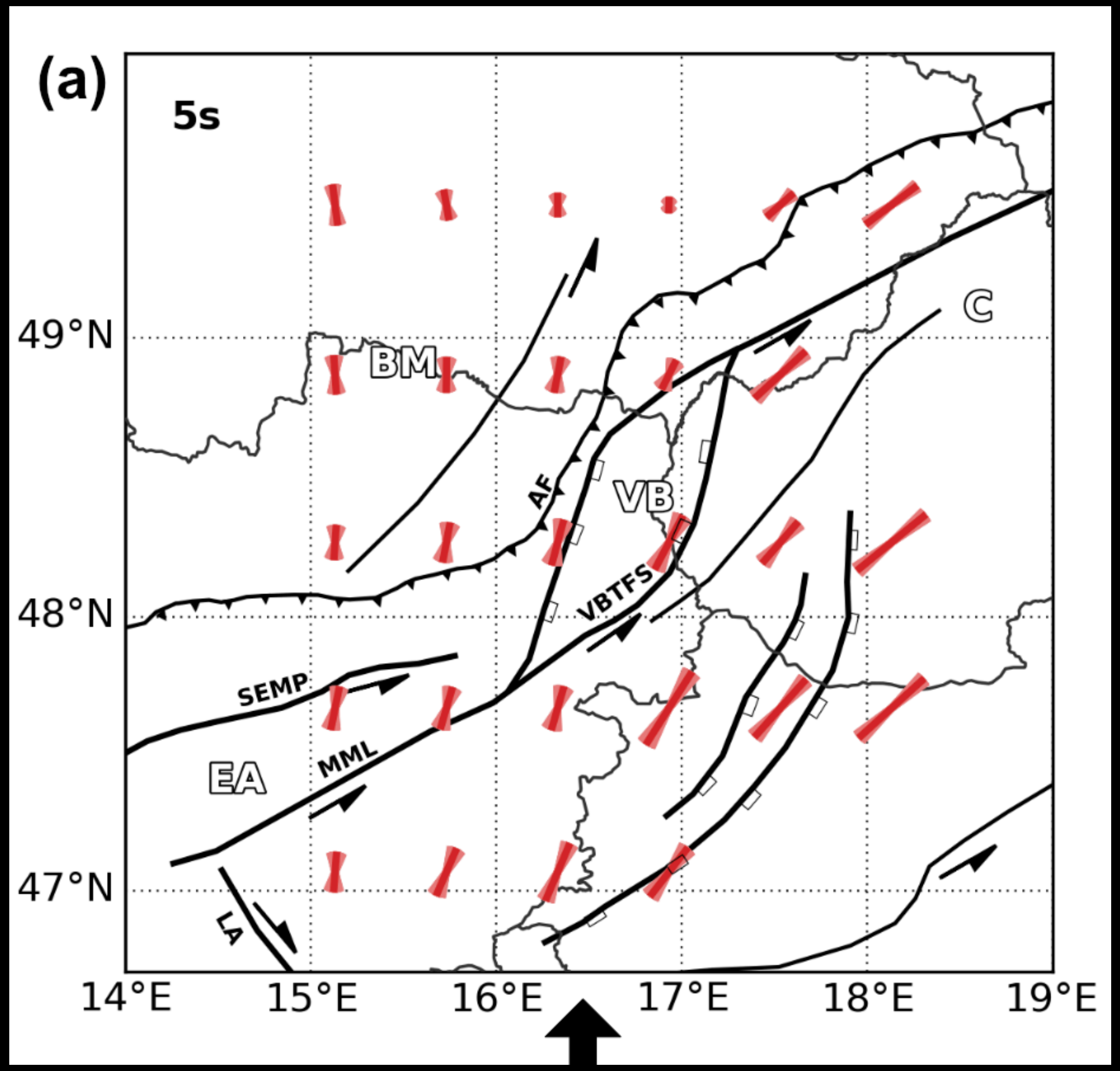



after Kern, 1990

# Results

## Stress-field orientation

- $\sigma_H$ ~N/S in the West, rotating to ~NE/SW in the East.

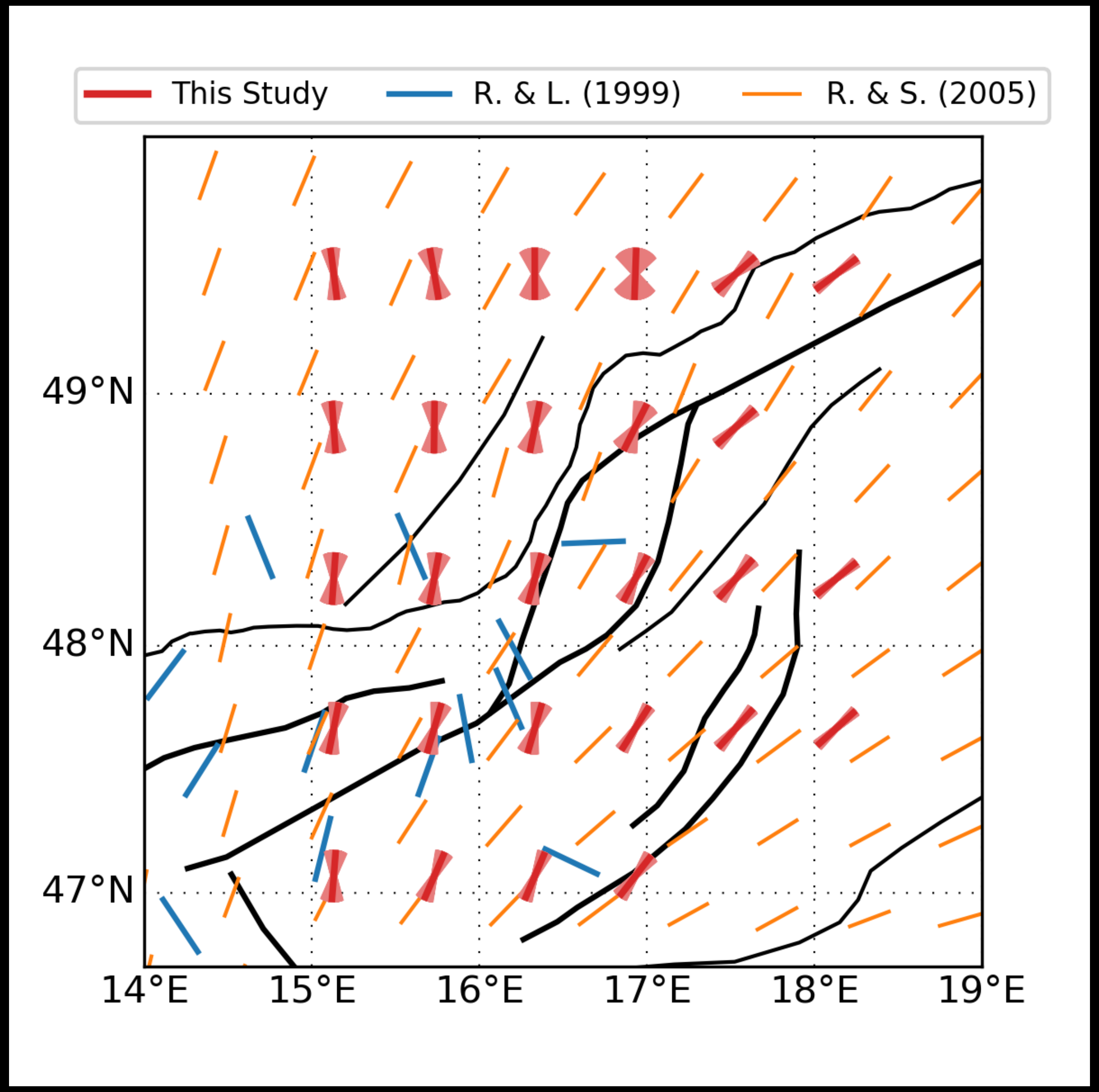


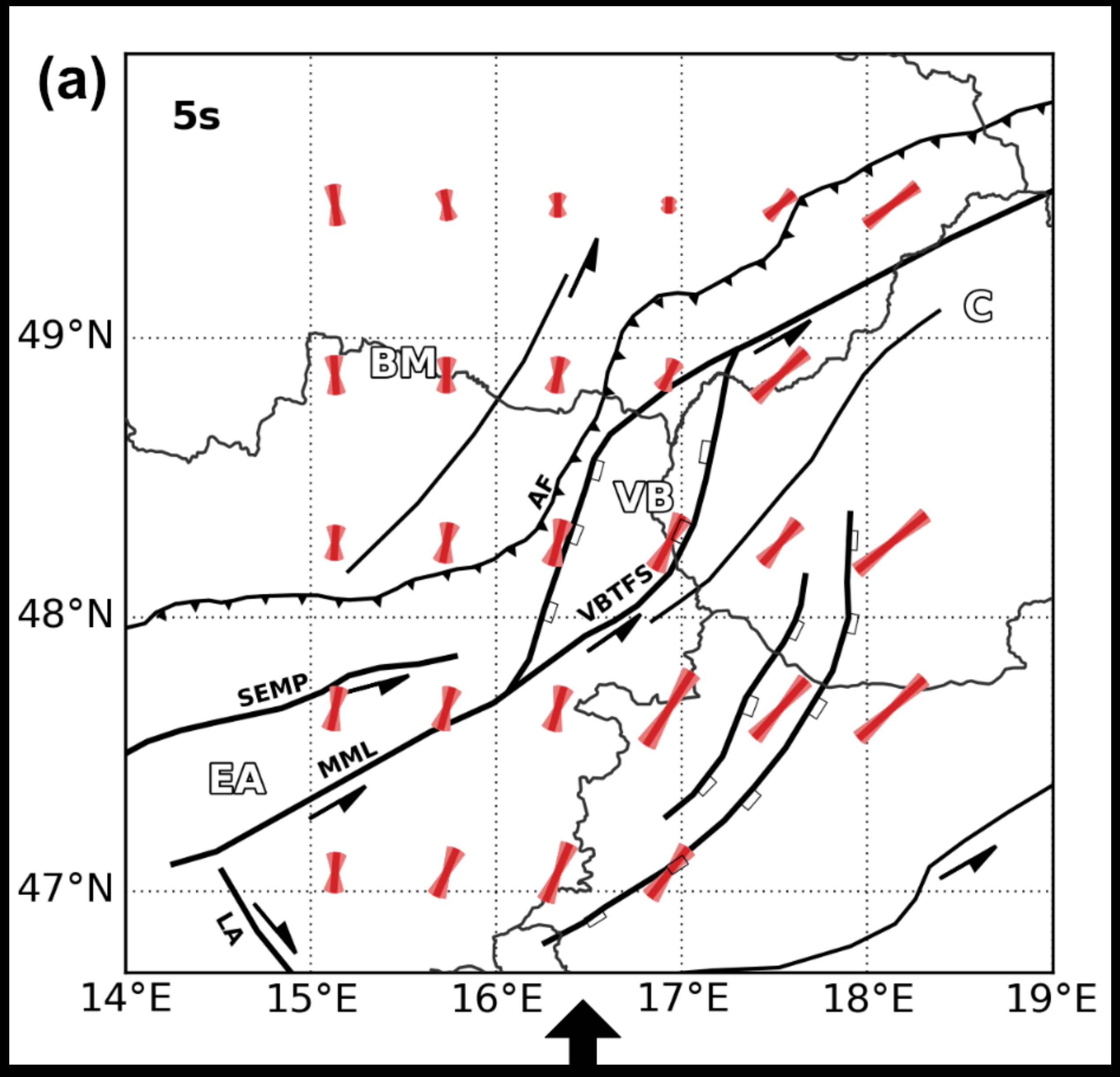

Schippkus et al., 2020

# Results

## Stress-field orientation

- $\sigma_H$ ~N/S in the West, rotating to ~NE/SW in the East.
- Remarkable agreement w/ modelling results of *Robl & Stüwe 2005*, disagreement w/ *Reinecker & Lenhardt 1999*



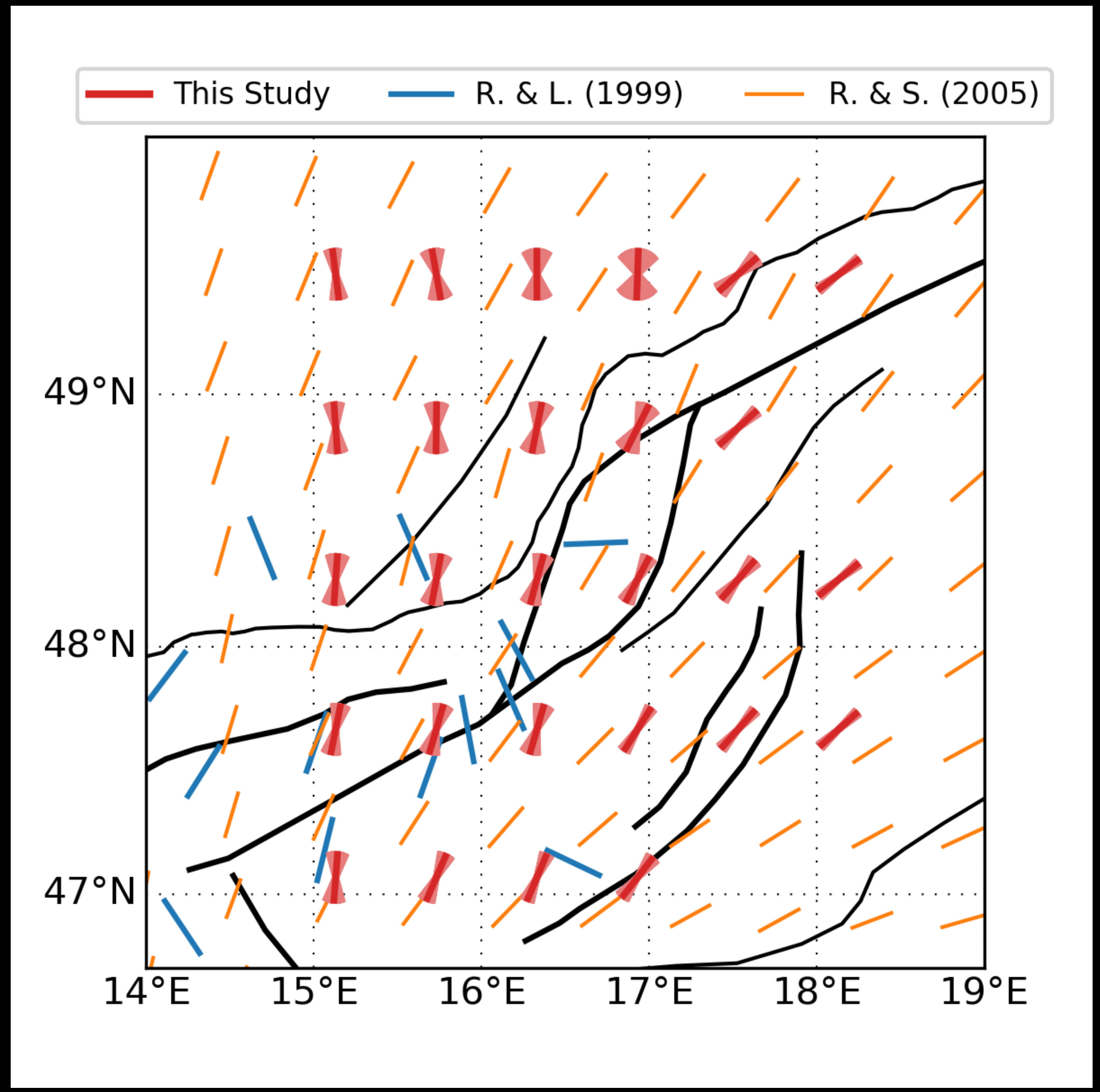



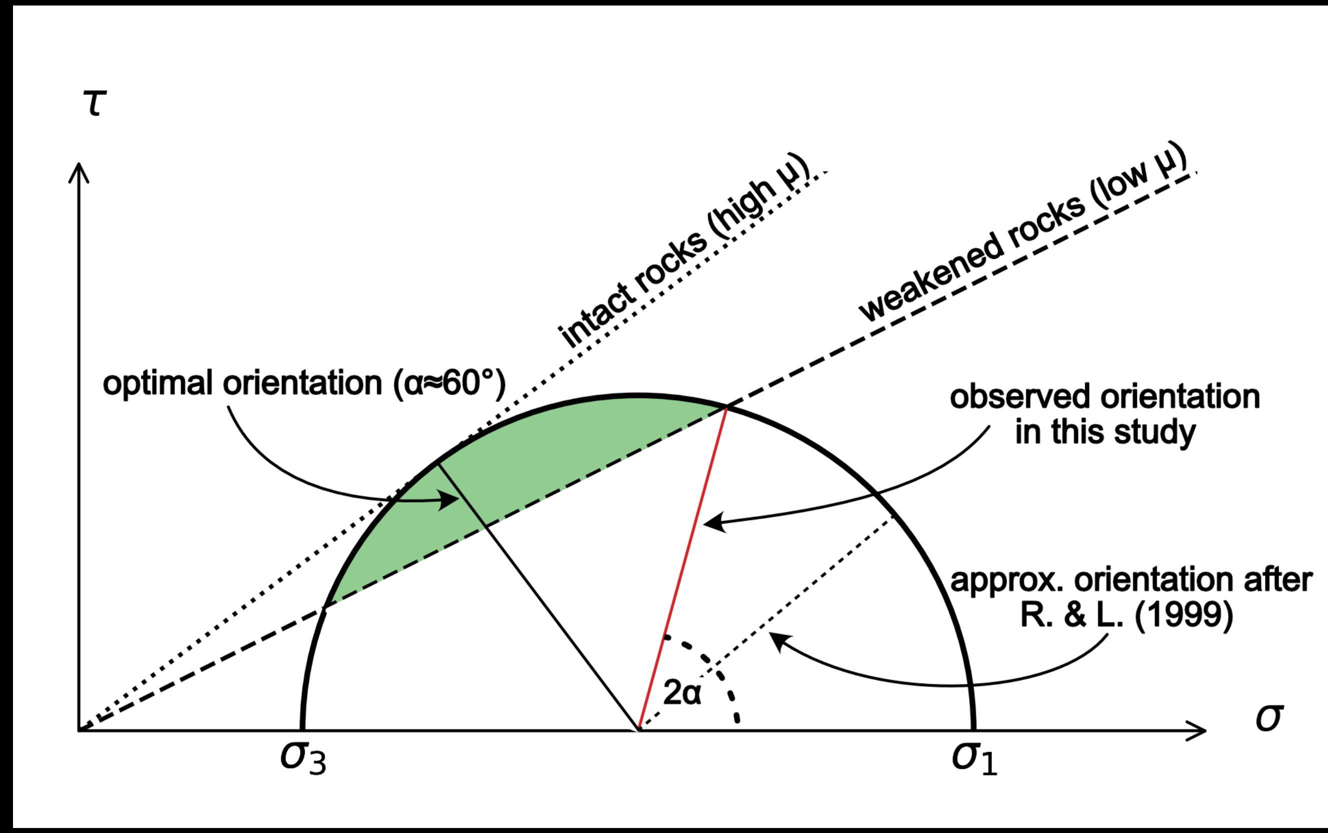

Schippkus et al., 2020

# Results

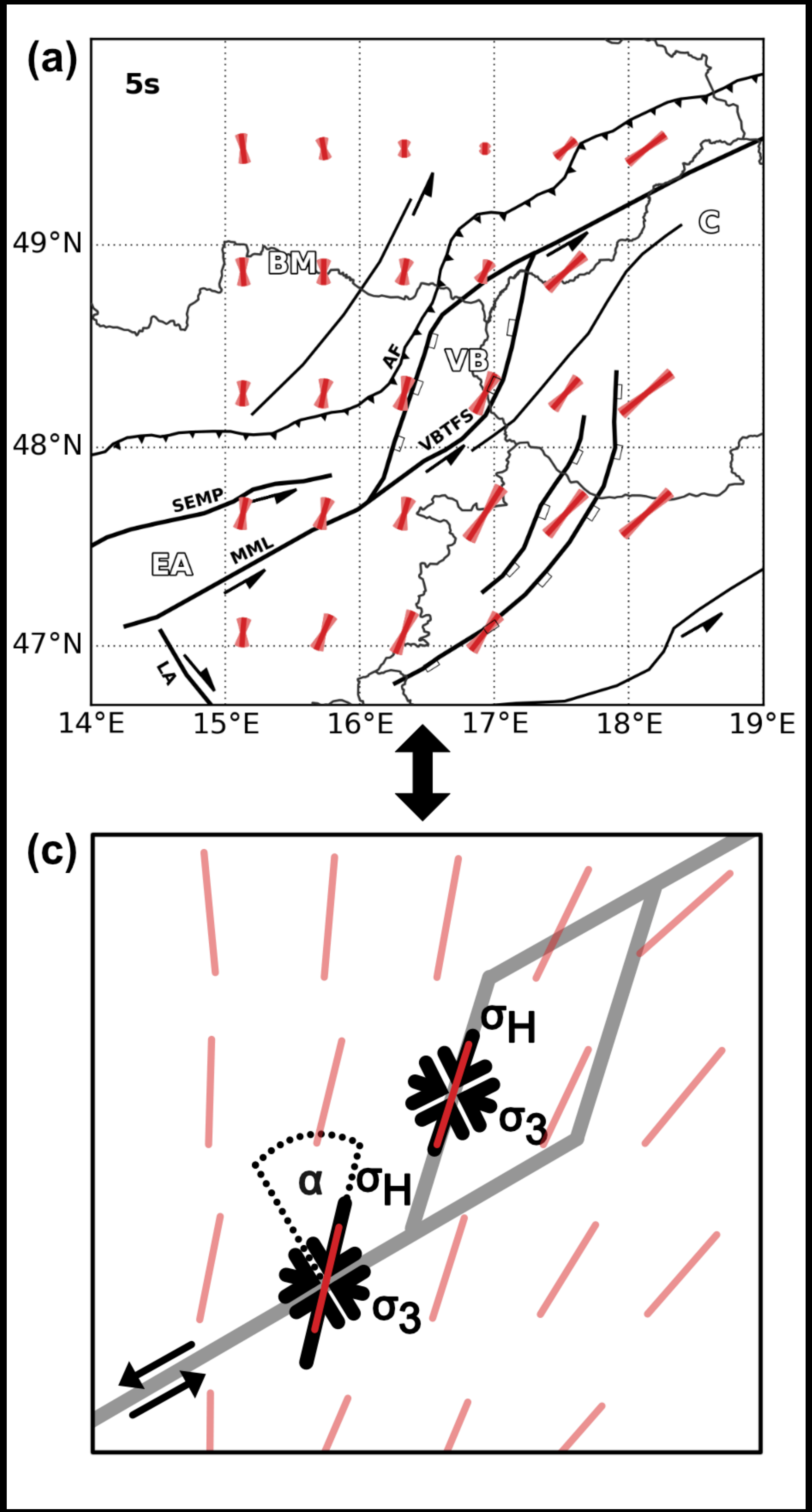
## Stress-field orientation

- $\sigma_H$ ~N/S in the West, rotating to ~NE/SW in the East.
- Remarkable agreement w/ modelling results of *Robl & Stüwe 2005*, disagreement w/ *Reinecker & Lenhardt 1999*
- $\sigma_H$ compatible with tectonic regimes of fault systems. Regimes change over few tens of kilometers with similar $\sigma_H$.




Schematic Mohr's circle: seismicity along MML compatible with $\sigma_H$

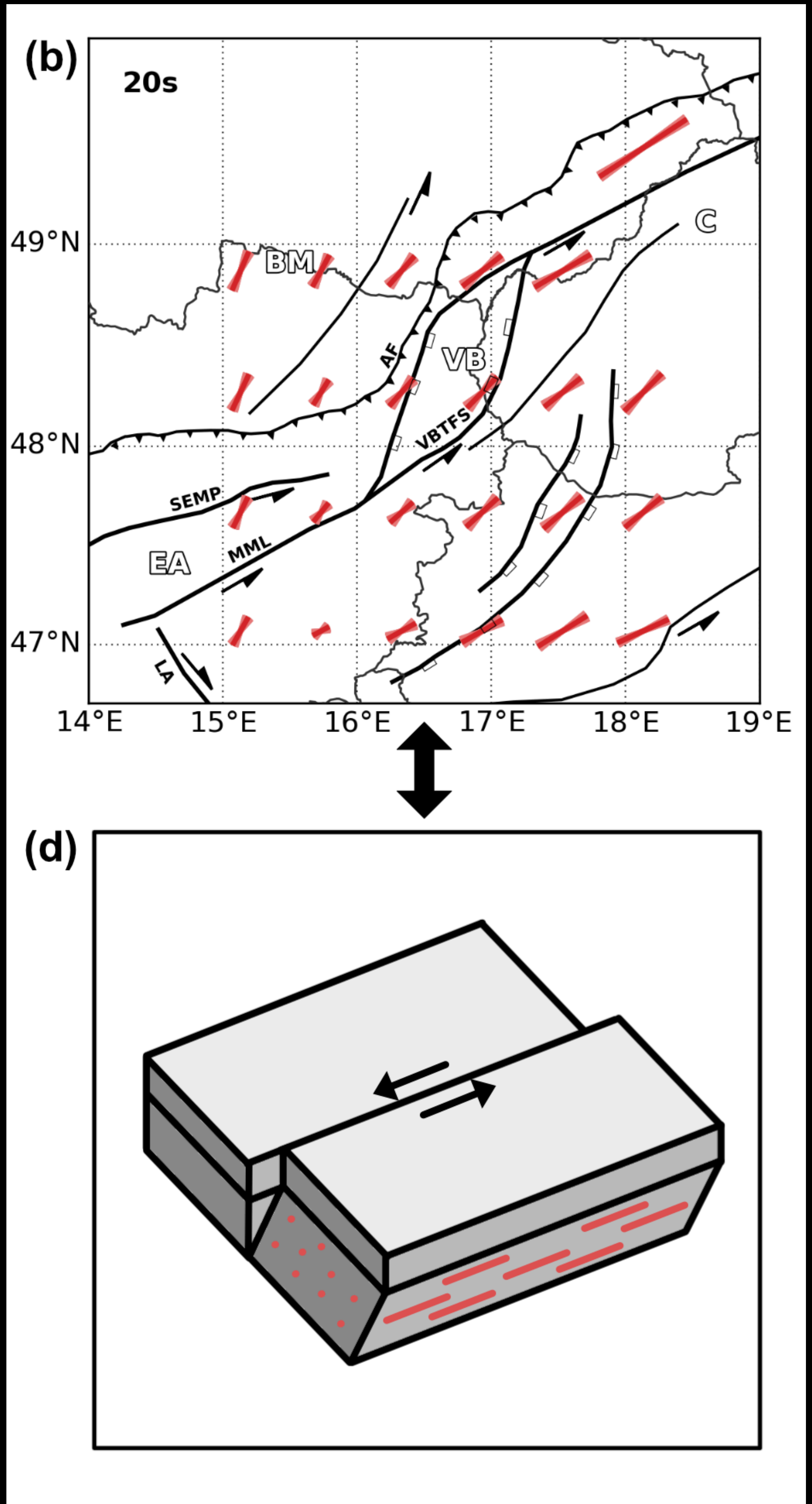



Schippkus et al., 2020

# Results

## Crustal deformation

- 20s Rayleigh waves sensitive to mid-crustal depths.
- Cracks closed, only texture-related anisotropy. Not sensitive to stress-field.
- Fast orientations rotate towards NE to ENE orientations, ~parallel to strike-slip fault systems.
- Likely an image of alignment of crystals due to continued lateral extrusion of blocks.




Schippkus et al., 2020

## Conclusions

- New sequential approach to determine the orientation of $\sigma_H$. Based on ambient-noise-derived Rayleigh waves, using group-velocity residuals after isotropic inversion.

- In the Vienna Basin region, results agree with previous modelling results. Provides an independent and spatially broad measurement of $\sigma_H$-orientation in the region.

- For more details, see Schippkus et al. 2020: https://doi.org/10.1093/gji/ggz565

# References


- Kern, H. (1990). Laboratory seismic measurements: an aid in the interpretation of seismic field data. Terra Nova, 2(6), 617–628.

- Reinecker, J., & Lenhardt, W. A. (1999). Present-day stress field and deformation in eastern Austria. International Journal of Earth Sciences, 88(3), 532–550. http://doi.org/10.1007/s005310050283

- Robl, J., & Stüwe, K. (2005). Continental collision with finite indenter strength: 2. European Eastern Alps. Tectonics, 24(4), TC4014. http://doi.org/10.1029/2004TC001741

- Schippkus, S., Zigone, D., Bokelmann, G., the AlpArray Working Group. (2018). Ambient-noise tomography of the wider Vienna Basin region. Geophysical Journal International, 215(1), 102–117. http://doi.org/10.1093/gji/ggy259

- Schippkus, S., Zigone, D., AlpArray Working Group. (2020). Azimuthal anisotropy in the wider Vienna basin region: a proxy for the present-day stress field and deformation. Geophysical Journal International, 220(3), 2056–2067. http://doi.org/10.1093/gji/ggz565