Reliability of non-shearing seismic mechanisms solutions for LUMINEOS and VERIS network

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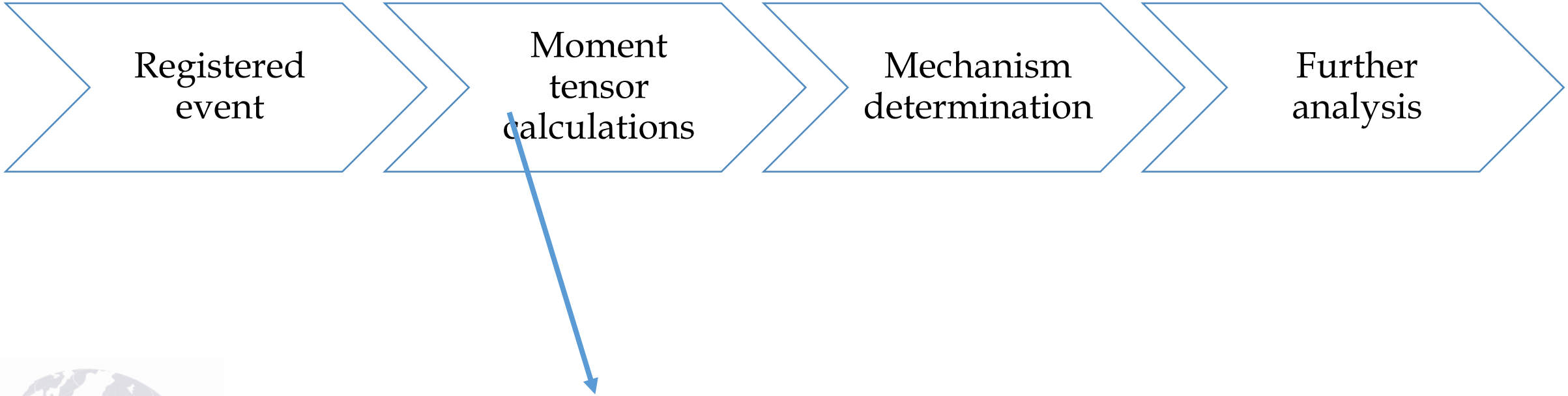
Motivation



How reliable is seismic mechanism calculated for anthropogenic event with high non-DC component? Method: P-wave amplitude inversion

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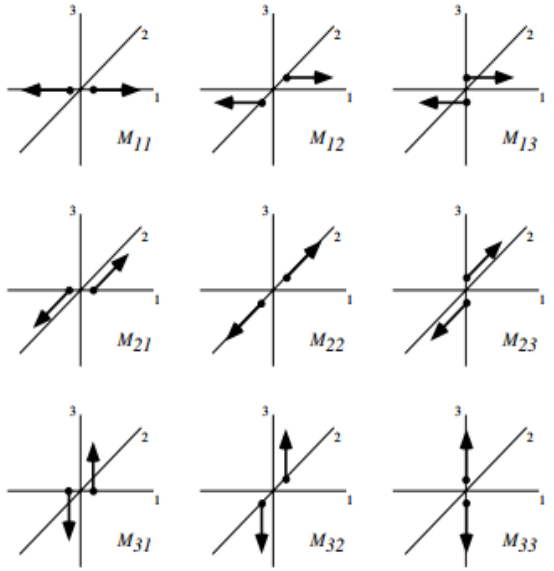
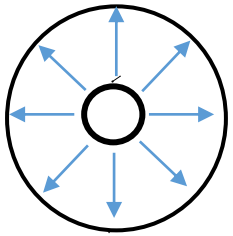
Moment tensor decomposition



$$M_{ij} = \begin{bmatrix} M_{11} & M_{12} & M_{13} \\ M_{21} & M_{22} & M_{23} \\ M_{31} & M_{32} & M_{33} \end{bmatrix}$$

$$\mathbf{U}^P(\mathbf{x},t) = \frac{\boldsymbol{\gamma}\cdot\dot{\mathbf{M}}\left(t-\frac{r}{\alpha}\right)\cdot\boldsymbol{\gamma}}{4\pi\rho\alpha^3 r}\mathbf{l}$$

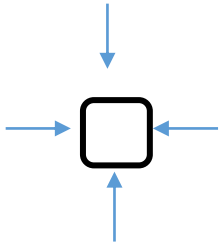
Isotropic part



$$M_{\mathrm{ISO}} = \frac{1}{3}(M_1 + M_2 + M_3)$$

Volume changes

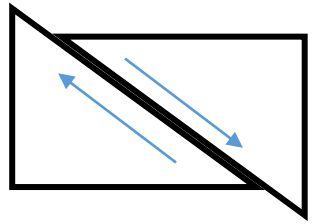
Compensated linear vector dipole



$$M_{\mathrm{CLVD}} = \frac{2}{3}(M_1 + M_3 - 2M_2)$$

One axis tension or compresion

Double couple



$$M_{\mathrm{DC}} = \frac{1}{2}(M_1 - M_3 - |M_1 + M_3 - 2M_2|)$$

Pure shearing

Explosion/implosion

Cavity collapse

Slip on fault

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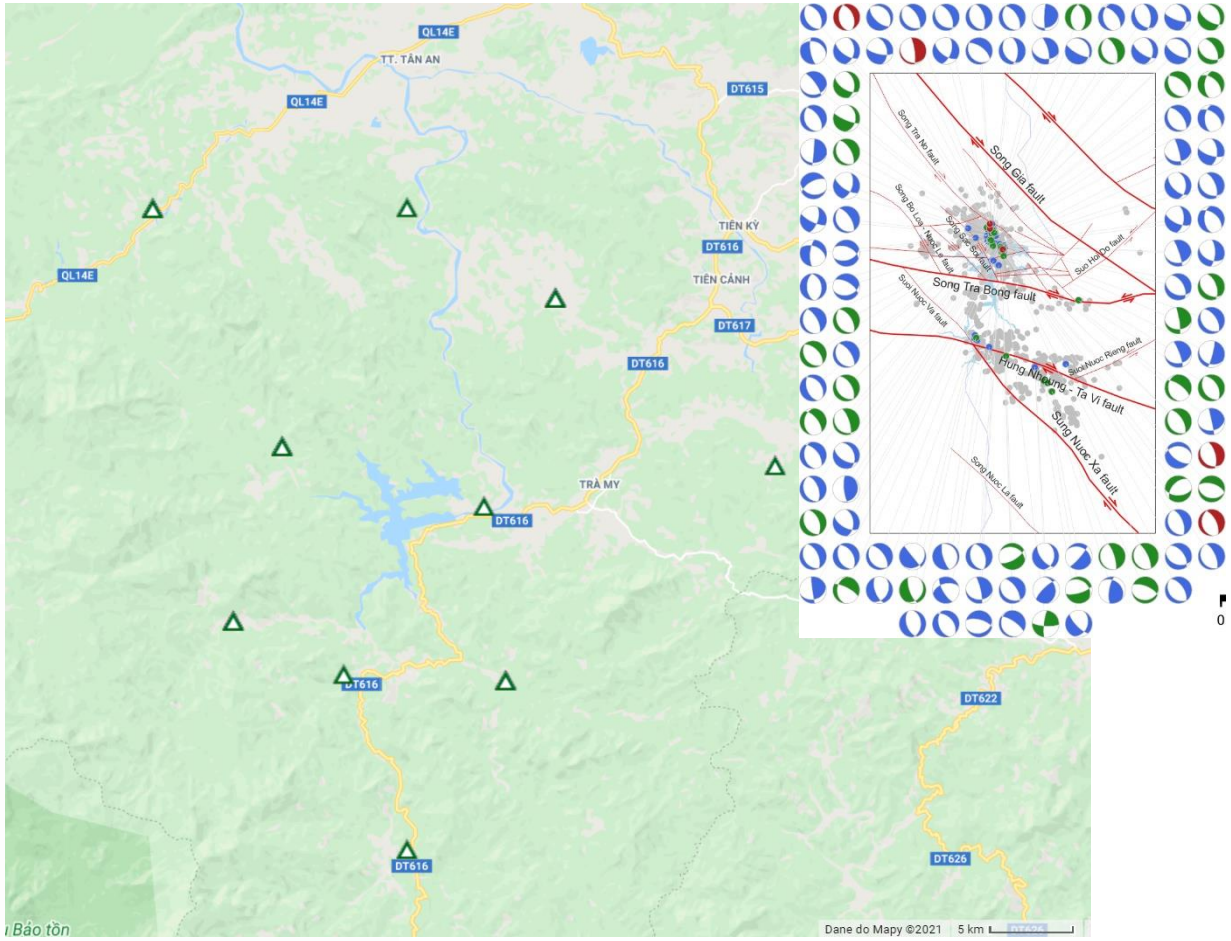
Sites characteristics

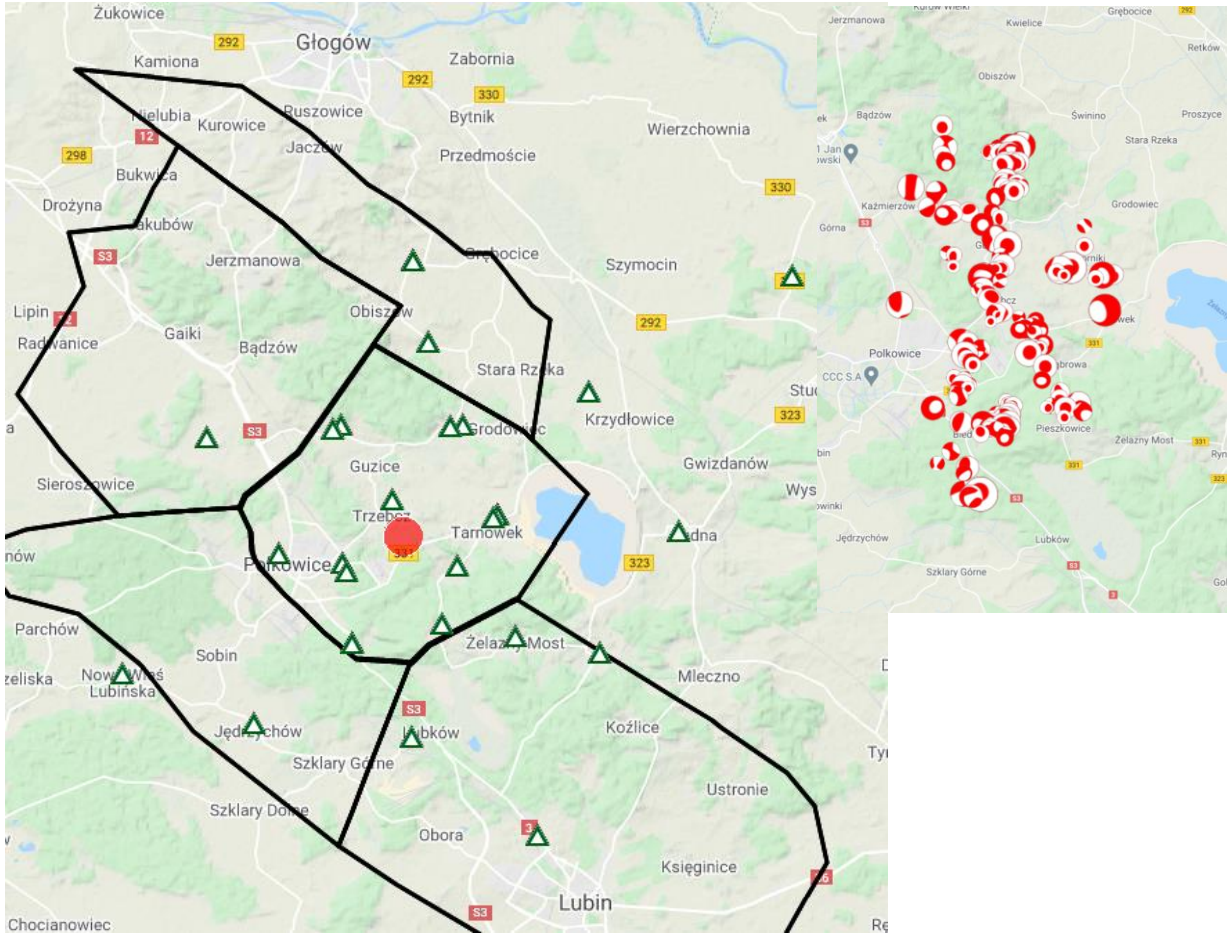
VERIS

VERIS (ViEtnam Reservoir Induced Seismicity) is seismic network aimed in monitoring of the triggered seismic activity in the Song Tranh2 artificial reservoir area. Seismic activity in the region increased significantly after the filling of the reservoir in November 2010 and has continued to the present day. The largest earthquakes in the area were 3 September 2012 M4.2, 22 October 2012 M4.6 and 15 November 2012 M4.7.



LUMINEOS

LUMINEOS (LUbin Mining INduced Earthquake Observation System) is surface seismic network installed for monitoring seismicity in Rudna copper mine. Seismic activity in Rudna copper mine is more than 1000 events with magnitude M>1 per year and strongly depends on mining works and area. The strongest event has magnitude Mw= 3.9 2019 July 5.

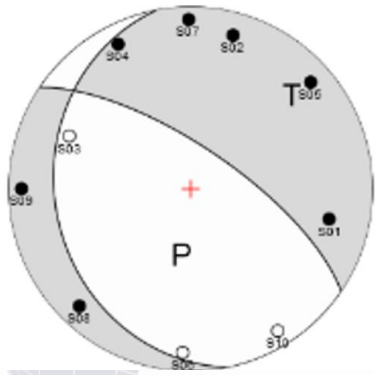


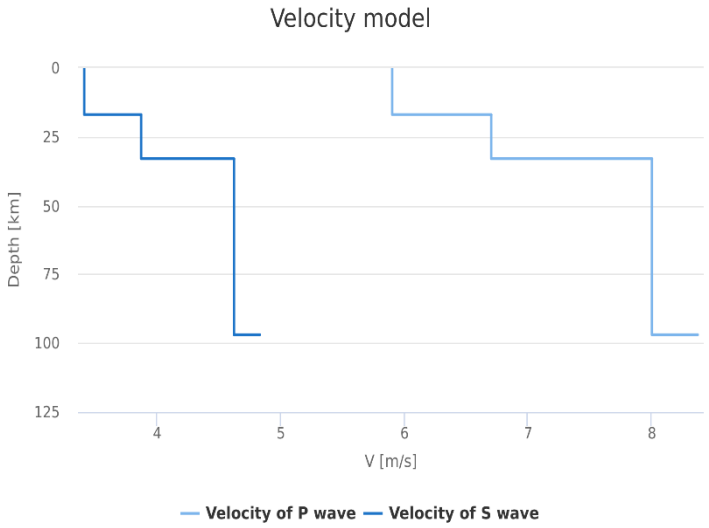
Synthetic data- assumptions

Parameter set was choosen based on characteristic events in catalogs.

VERIS

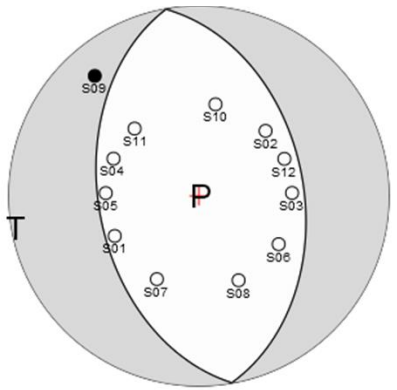
- Mw=3.7
- Depth= 3 km
- Assumed mechanism 304°/71°/±108° (strike/dip/rake)

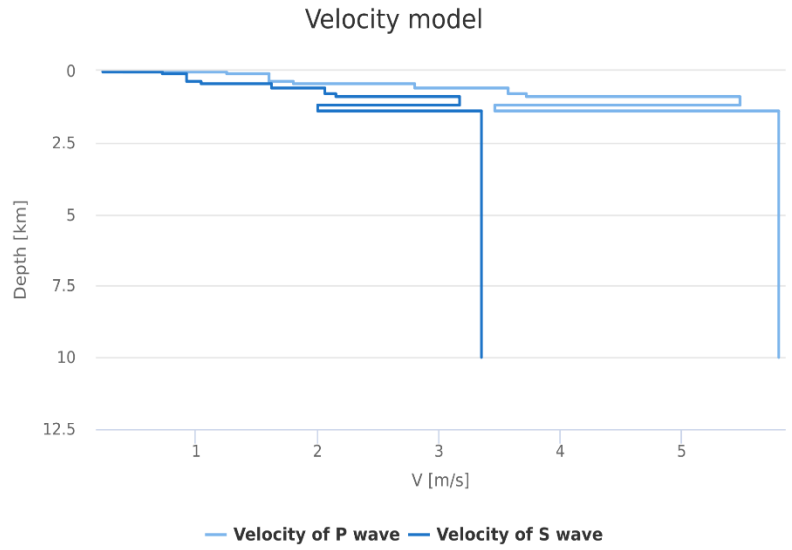




LUMINEOS

- Mw=3.7
- Depth=800 m
- Assumed mechanism 170°/46°/±90° (strike/dip/rake)





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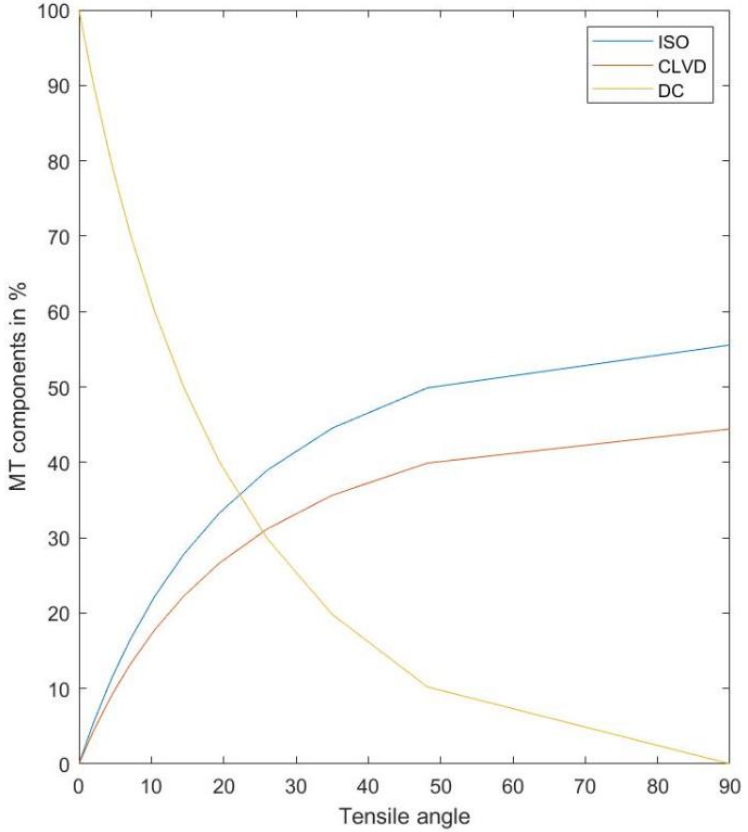
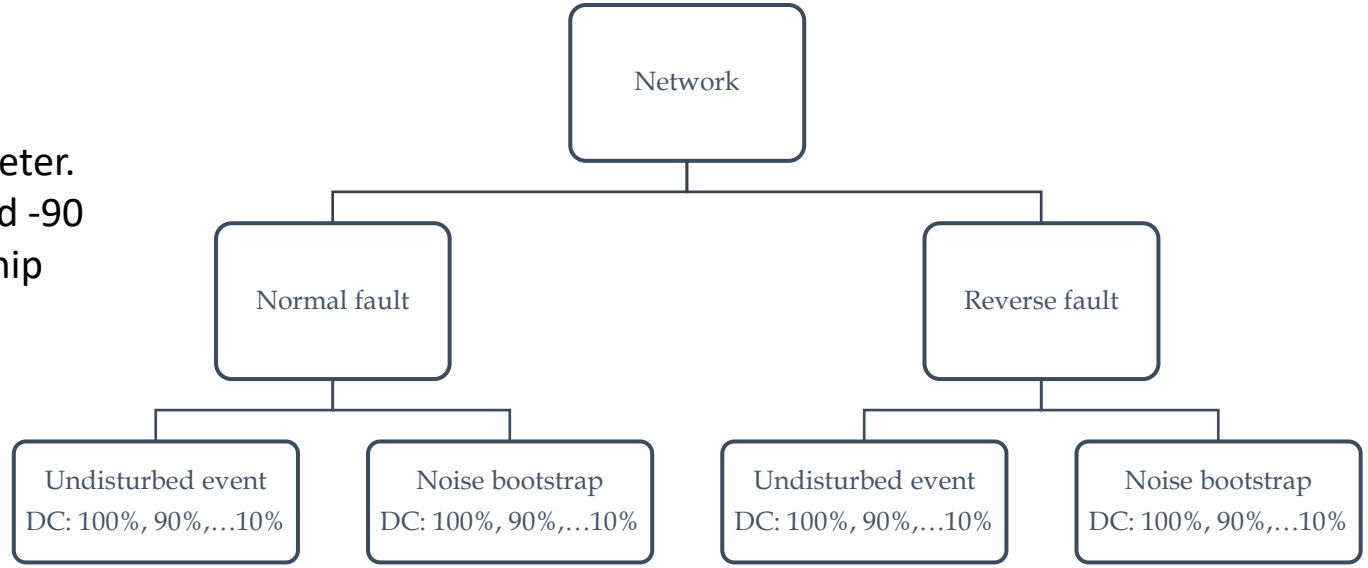
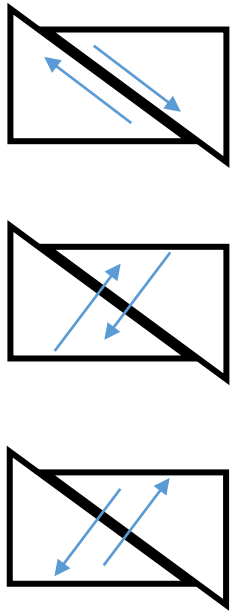
Synthetic data

Changes in mechanism was controlled by tensile angle parameter. Tensile angle equal 0 ° means pure shear mechanism, 90 ° and -90 ° is respectively crack opening and closing. Detailed relationship between MT components and tensile angle is visible on chart below.



Scheme of generated data



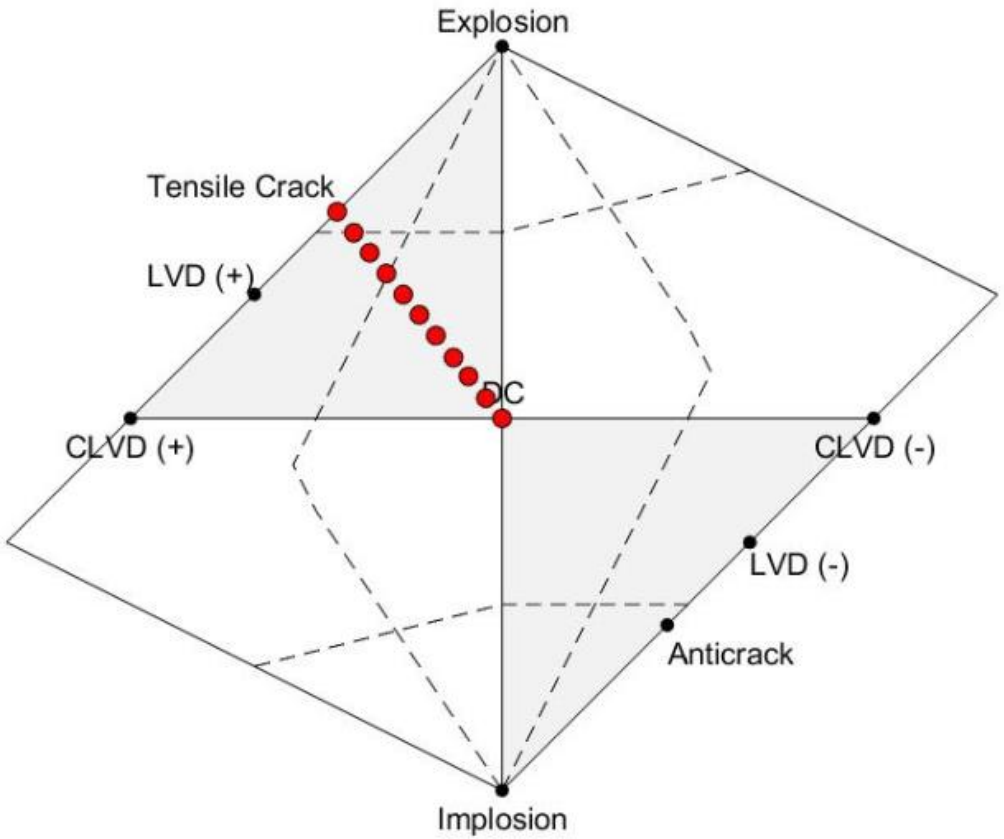


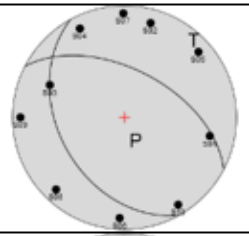
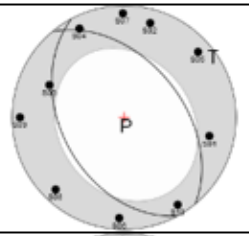
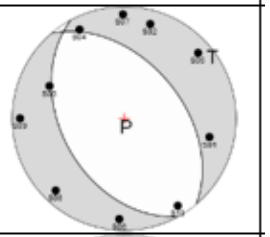
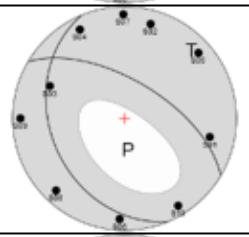
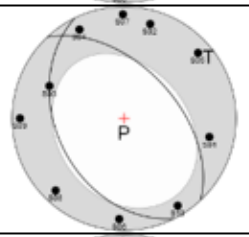
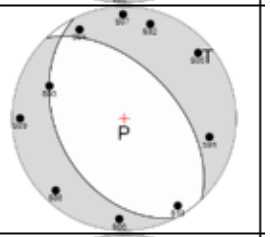
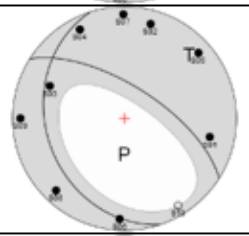
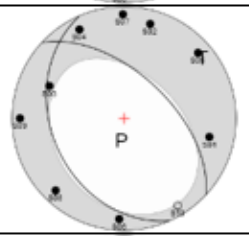
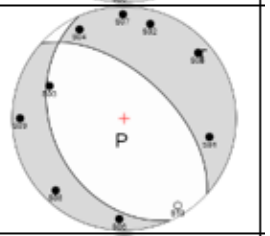
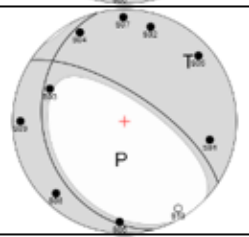
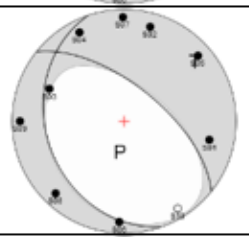
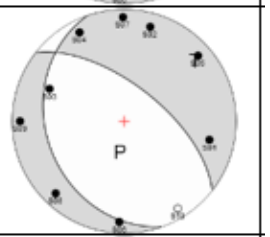
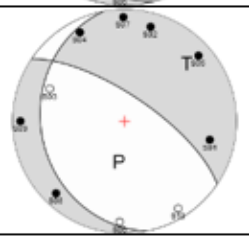
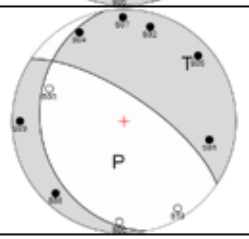
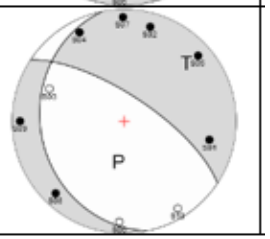
0° pure shear mechanism,

-90° crack closing

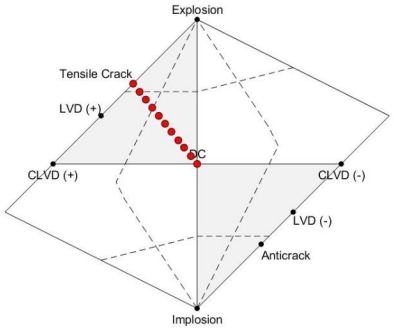
+90° crack opening

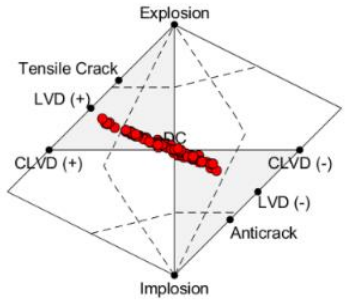
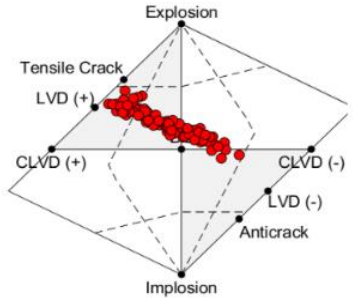
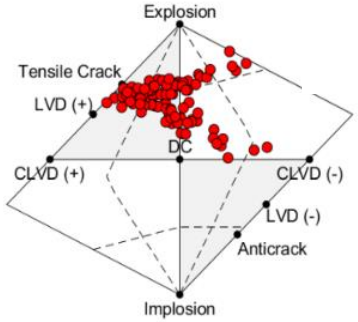
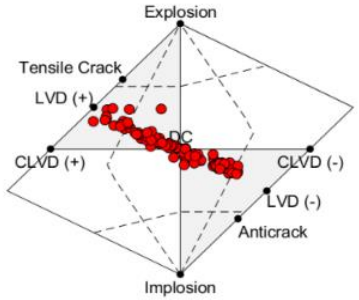
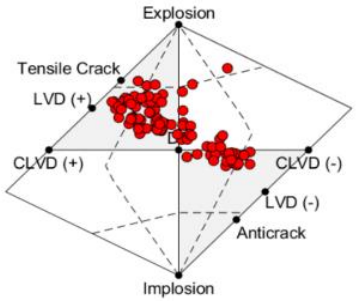
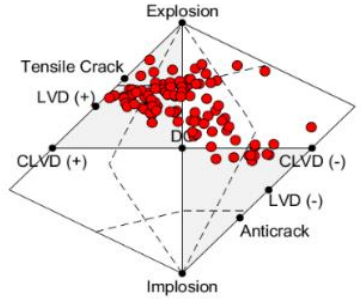
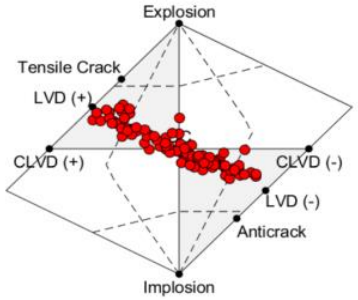
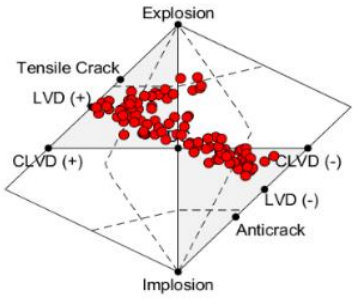
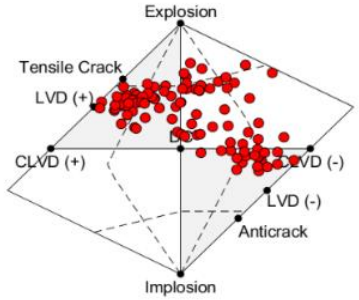
VERIS network- undisturbed data



Assumed mechanism	VERIS- normal fault		
	Full solution	Deviatoric solution	DC solution
20 % DC			
40 % DC			
60 % DC			
80 % DC			
100 % DC			

VERIS network- noise bootstrap



	100% DC	60% DC	20% DC
Noise up to 20 %			
Noise up to 40 %			
Noise up to 60 %			

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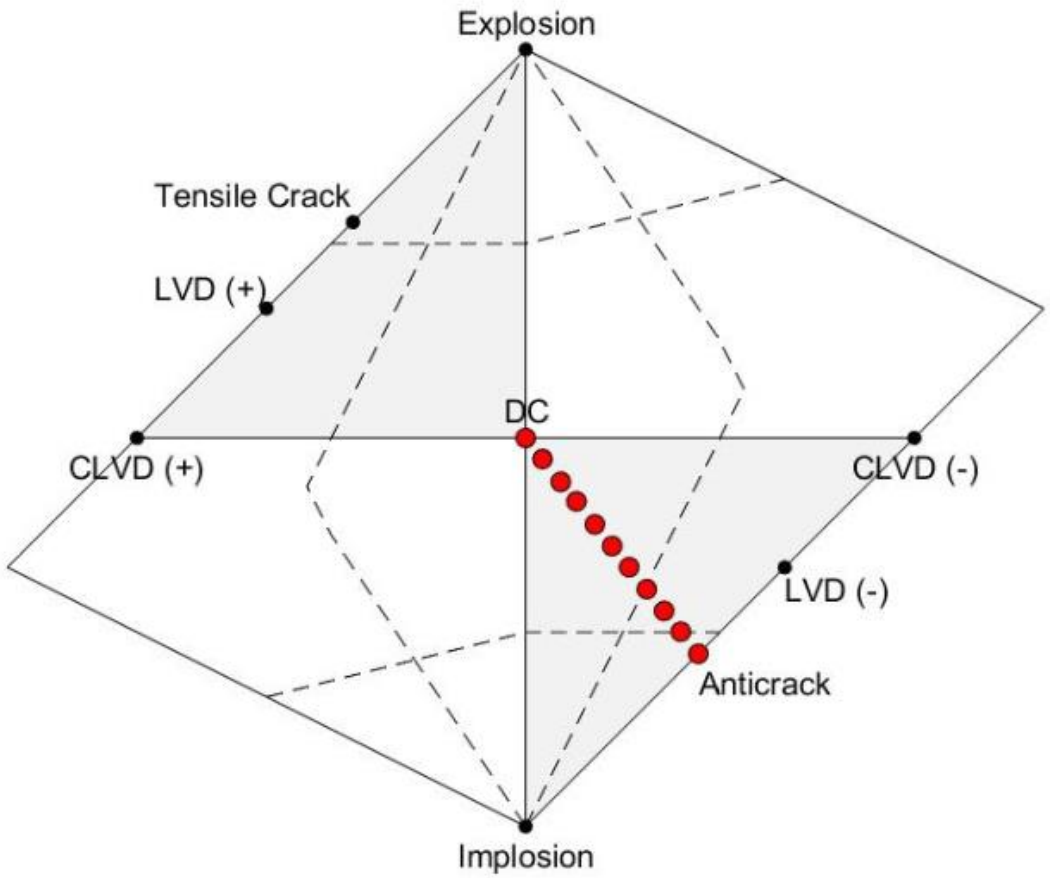
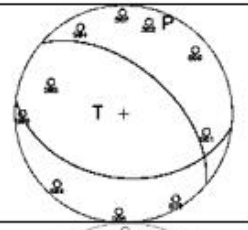
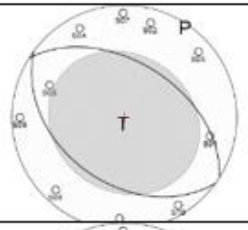
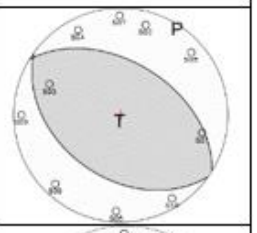
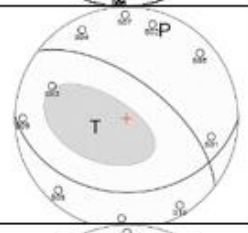
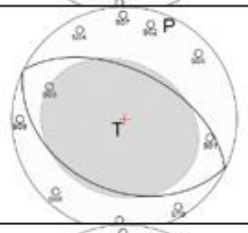
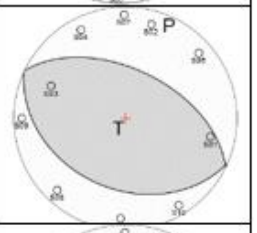
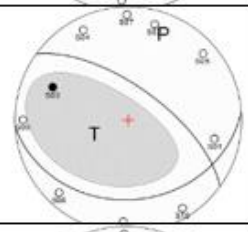
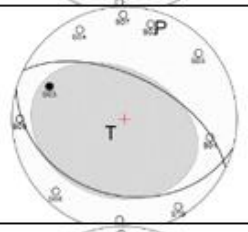
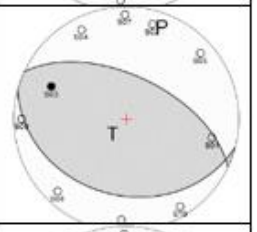
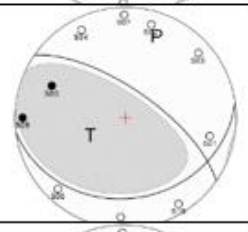
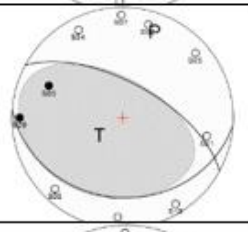
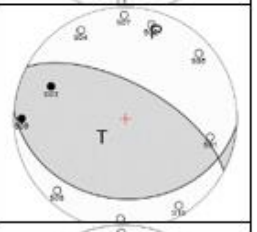
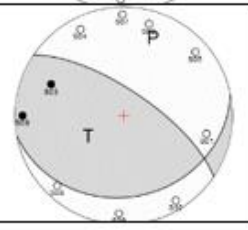
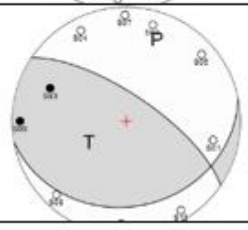
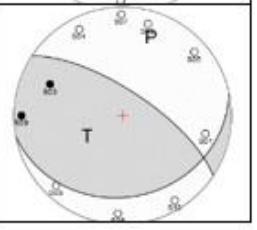
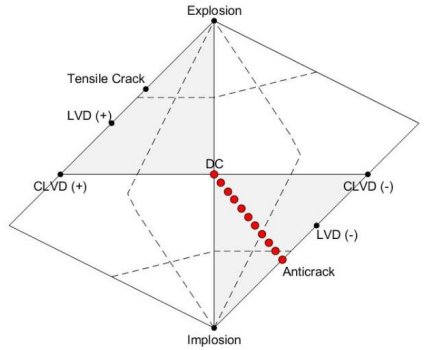
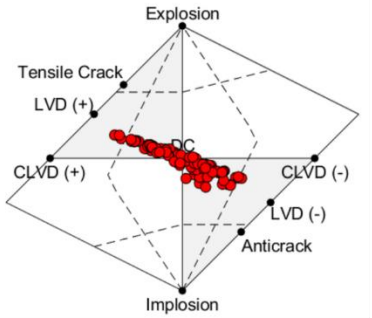
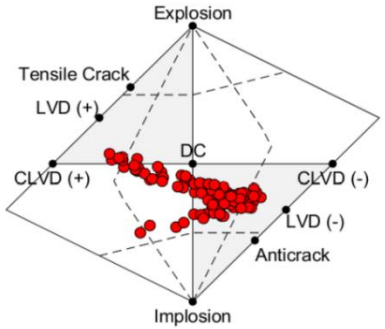
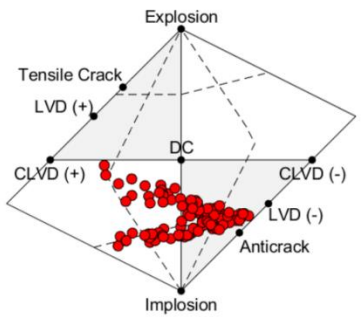
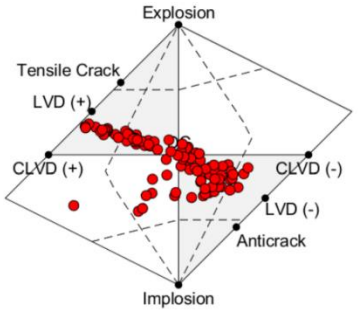
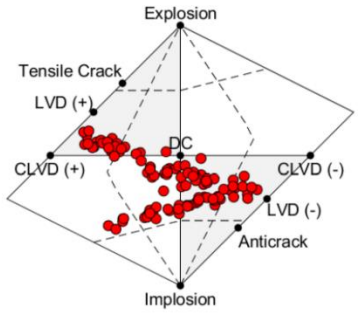
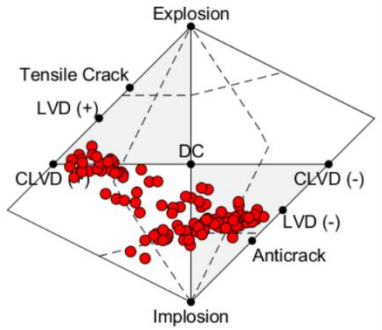
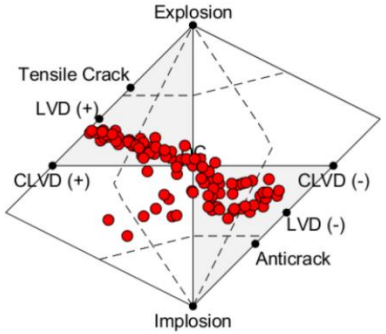
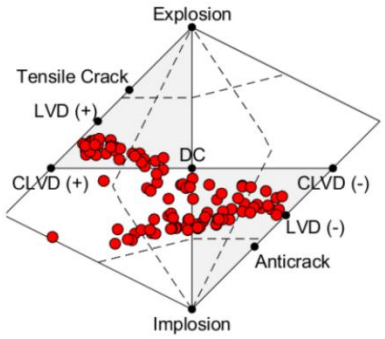
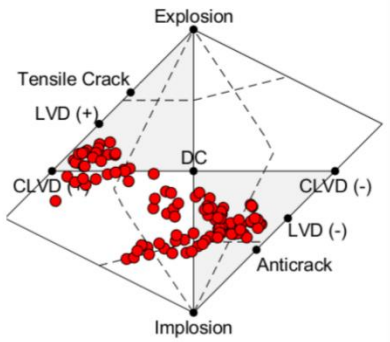
VERIS network- undisturbed data



Assumed mechanism	VERIS- reversed fault		
	Full solution	Deviatoric solution	DC solution
20 % DC			
40 % DC			
60 % DC			
80 % DC			
100 % DC			

VERIS network- noise bootstrap



	100% DC	60% DC	20% DC
Noise up to 20 %			
Noise up to 40 %			
Noise up to 60 %			

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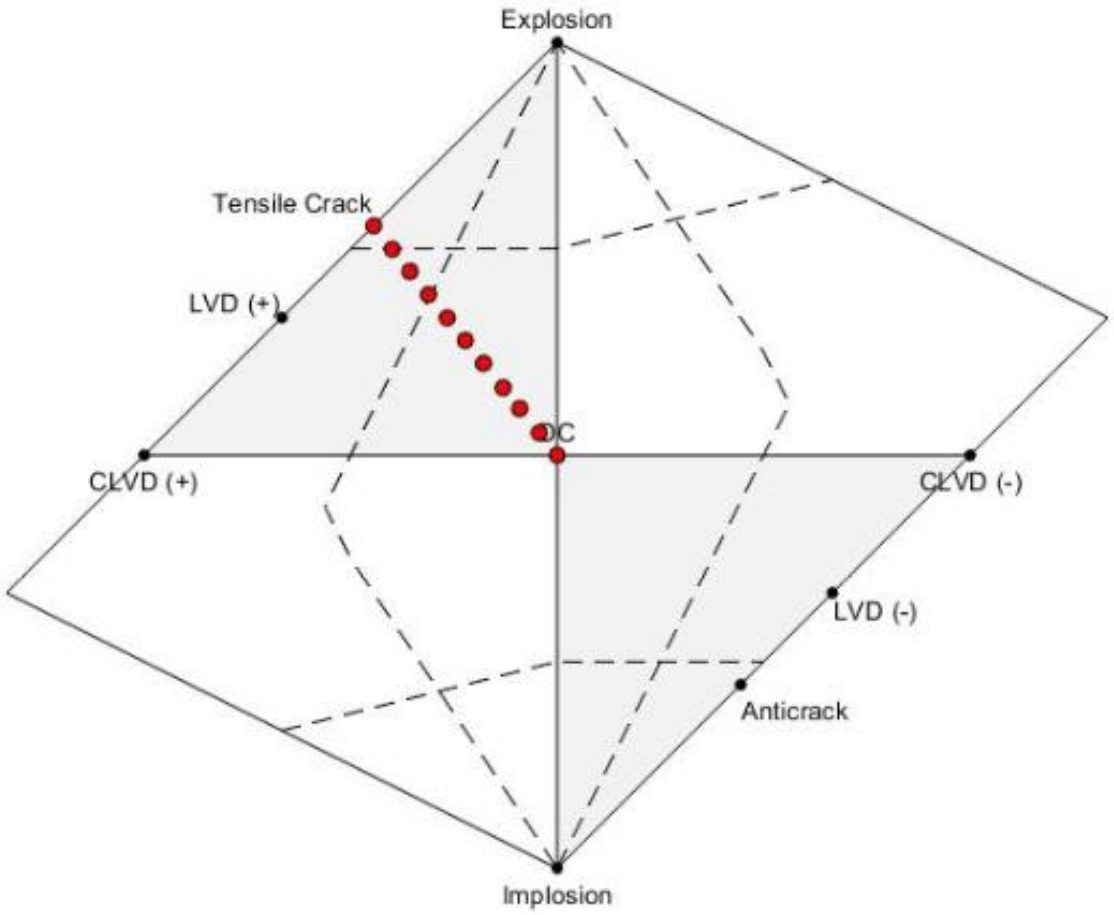
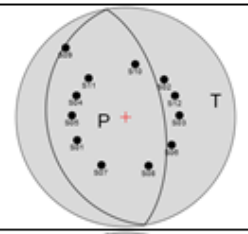
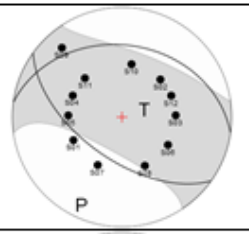
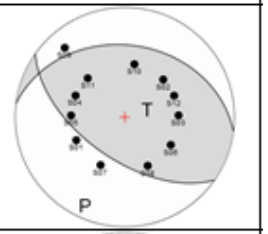
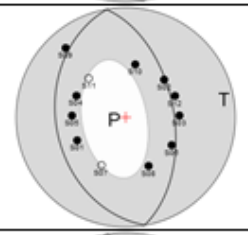
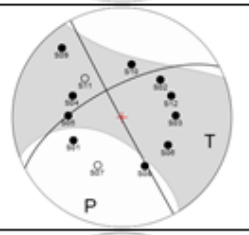
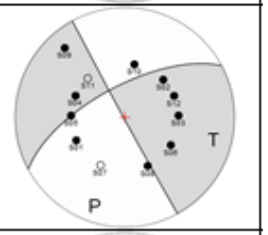
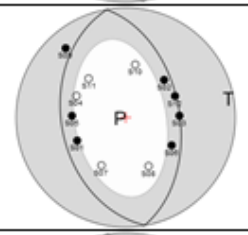
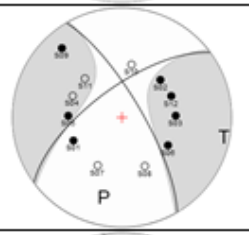
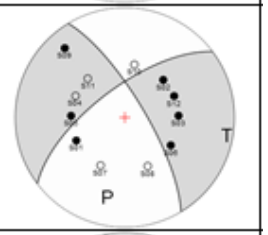
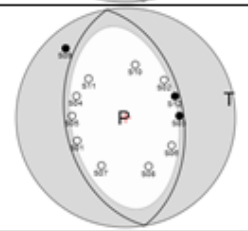
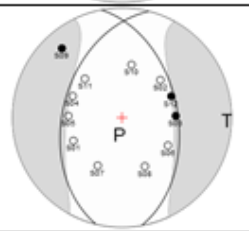
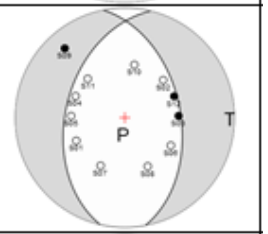
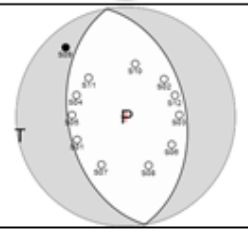
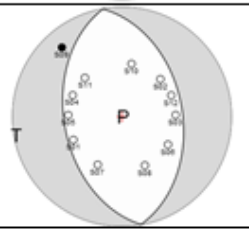
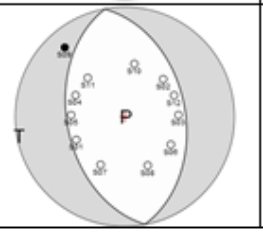
LUMINEOS network- undisturbed data



Assumed mechanism	LUMINEOS- normal fault		
	Full solution	Deviatoric solution	DC solution
20 % DC			
40 % DC			
60 % DC			
80 % DC			
100 % DC			

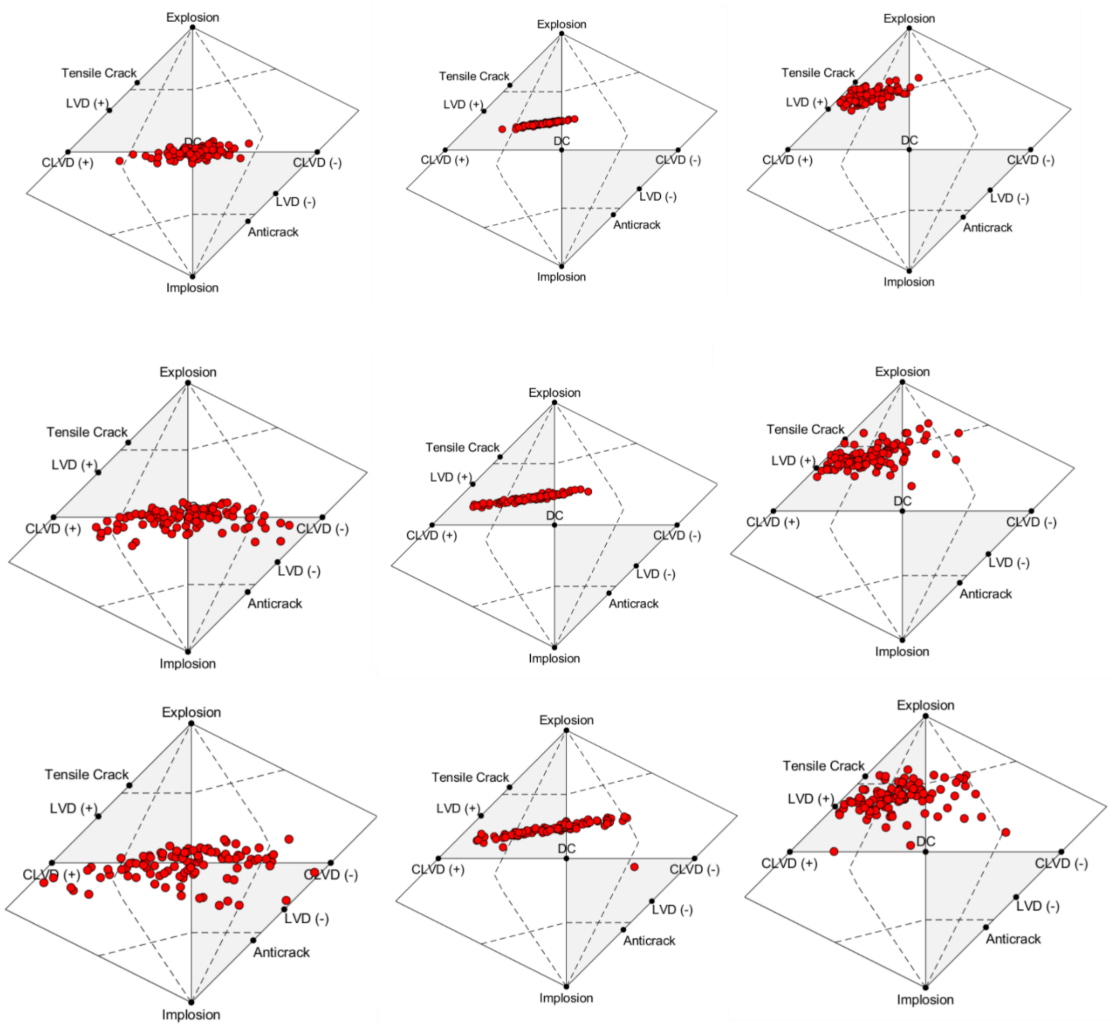
LUMINEOS network- noise bootstrap

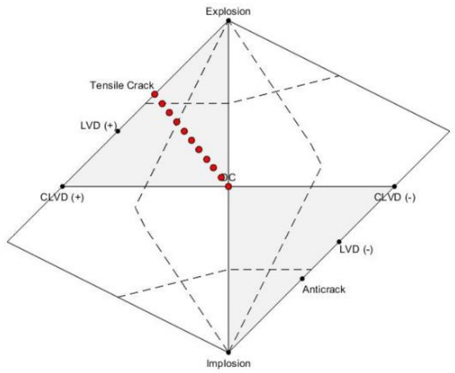
100% DC | 60% DC | 20% DC

Noise up to 20 %

Noise up to 40 %

Noise up to 60 %





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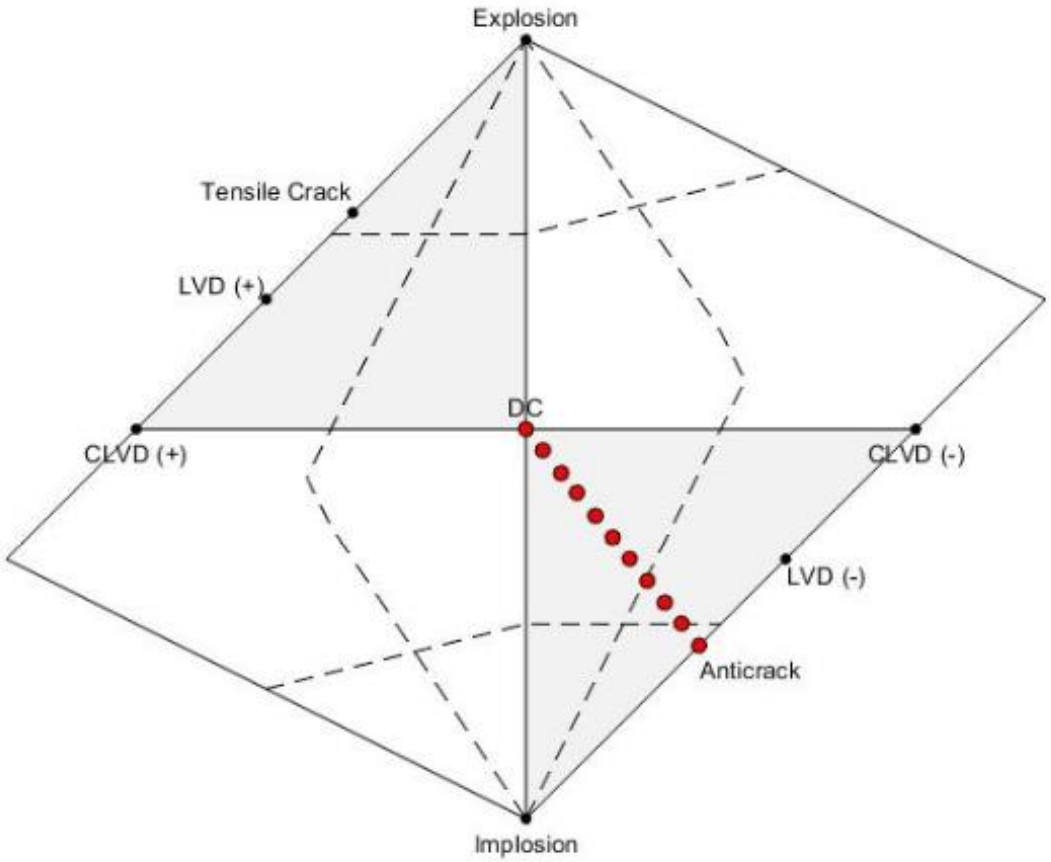
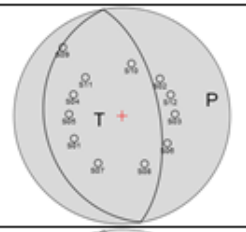
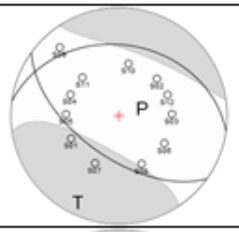
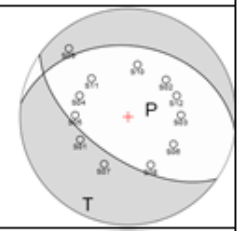
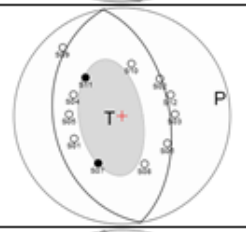
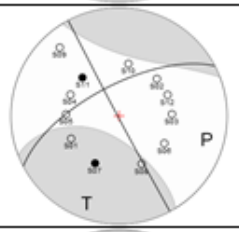
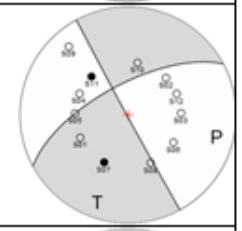
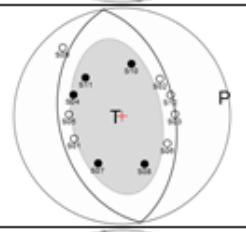
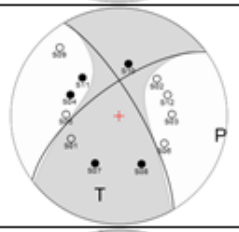
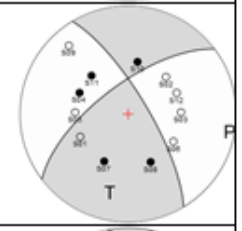
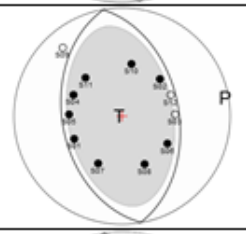
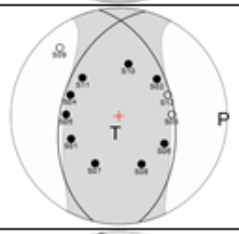
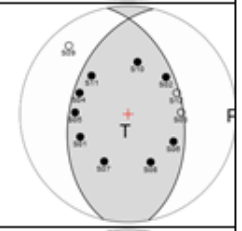
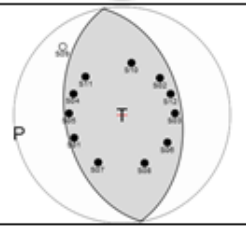
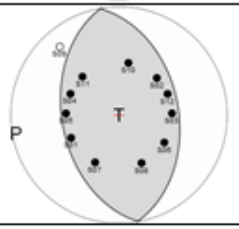
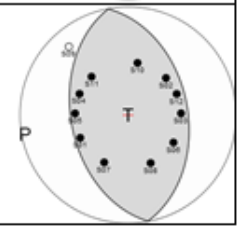
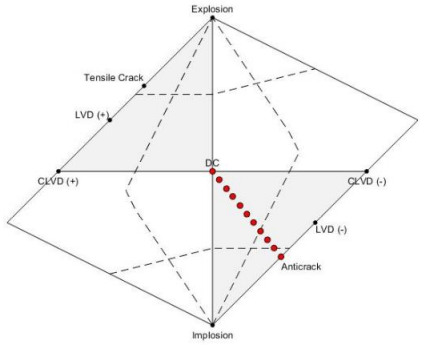
LUMINEOS network- undisturbed data



Assumed mechanism	LUMINEOS- reverse fault		
	Full solution	Deviatoric solution	DC solution
20 % DC			
40 % DC			
60 % DC			
80 % DC			
100 % DC			

LUMINEOS network- noise bootstrap

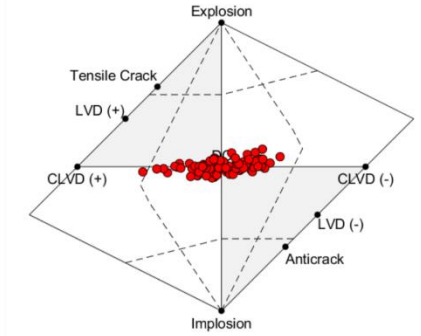


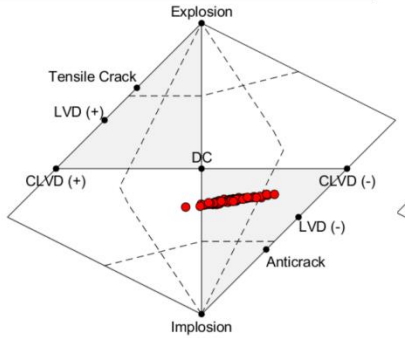
100% DC

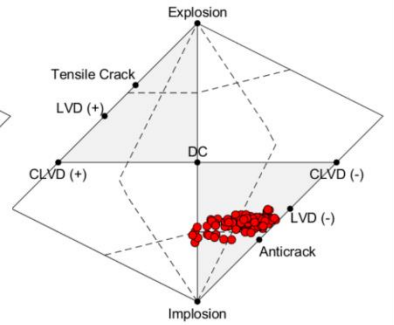
60% DC

20% DC

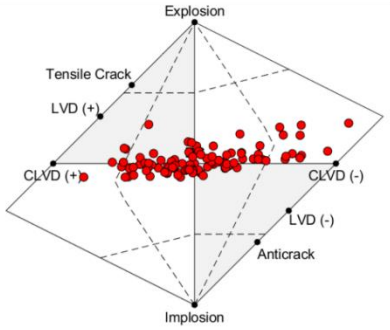
Noise up to 20 %

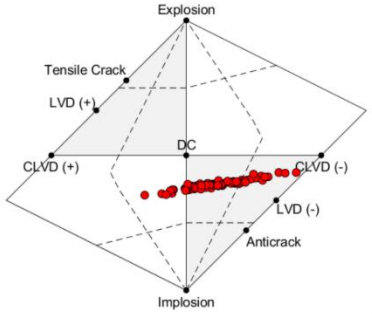


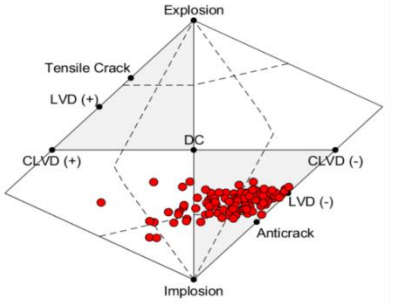




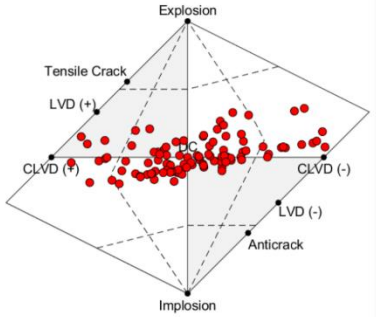
Noise up to 40 %

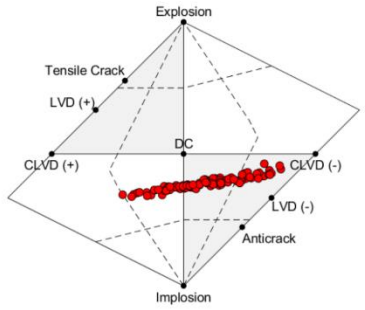


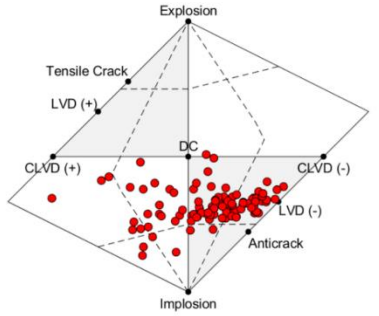




Noise up to 60 %







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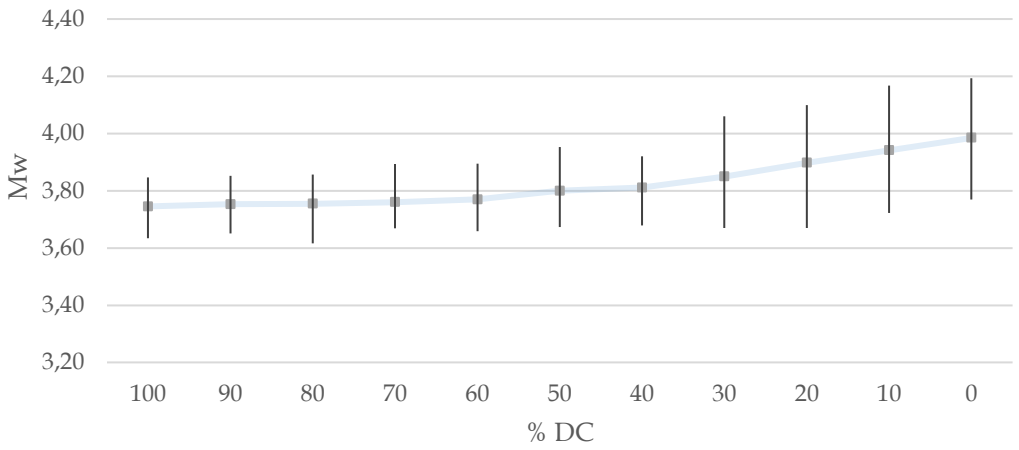
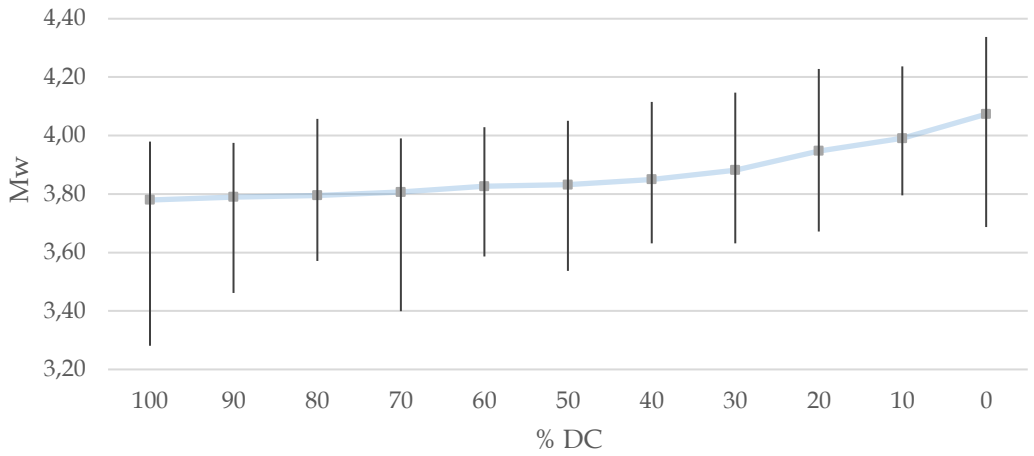
Magnitude changes

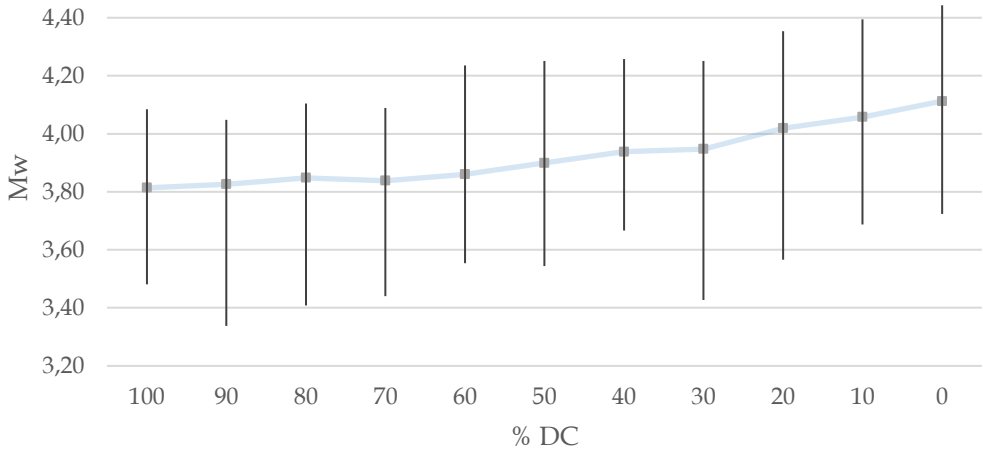
Magnitude changes for 20% noise contamination
VERIS reversed fault



Magnitude changes for 40% noise contamination
VERIS reversed fault



Magnitude changes for 60% noise contamination
VERIS reversed fault



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Conclusions

- Non-physical solutions are more often for high non-DC components in generated events.
- Calculated magnitude increase with decreasing DC component.

- MT solutions obtained with VERIS network are reliable, but should be carefully interpreted, if the high non-DC components occur.
  - VERIS network focal coverage allow for stable and reliable MT solutions for all undisturbed focal mechanisms.
  - For VERIS network spurious non-DC components are usually small if the noise is not bigger than 40% of the initial amplitude. The fault plane orientations are stable and solved well in the majority of cases even when up to 60% of noise contamination is introduced.

- LUMINEOS data for MT inversion can be used as additional data source after careful check of the MT solution quality or together with in-mine network data for proper focal mechanism interpretation. It is not recomended as part of routine data analysis.
  - LUMINEOS network gives stable solutions only for events with more than 60% DC for undisturbed data.
  - Nodal planes in solutions for LUMINEOS network are unstable for even 20% seismic noise level if event is not pure shearing type.