

# 3D modelling of the frontal part of the Sveconorwegian orogen, northeast of lake Vänern

Carl-Henric Wahlgren, Phil Curtis & Michael Stephens

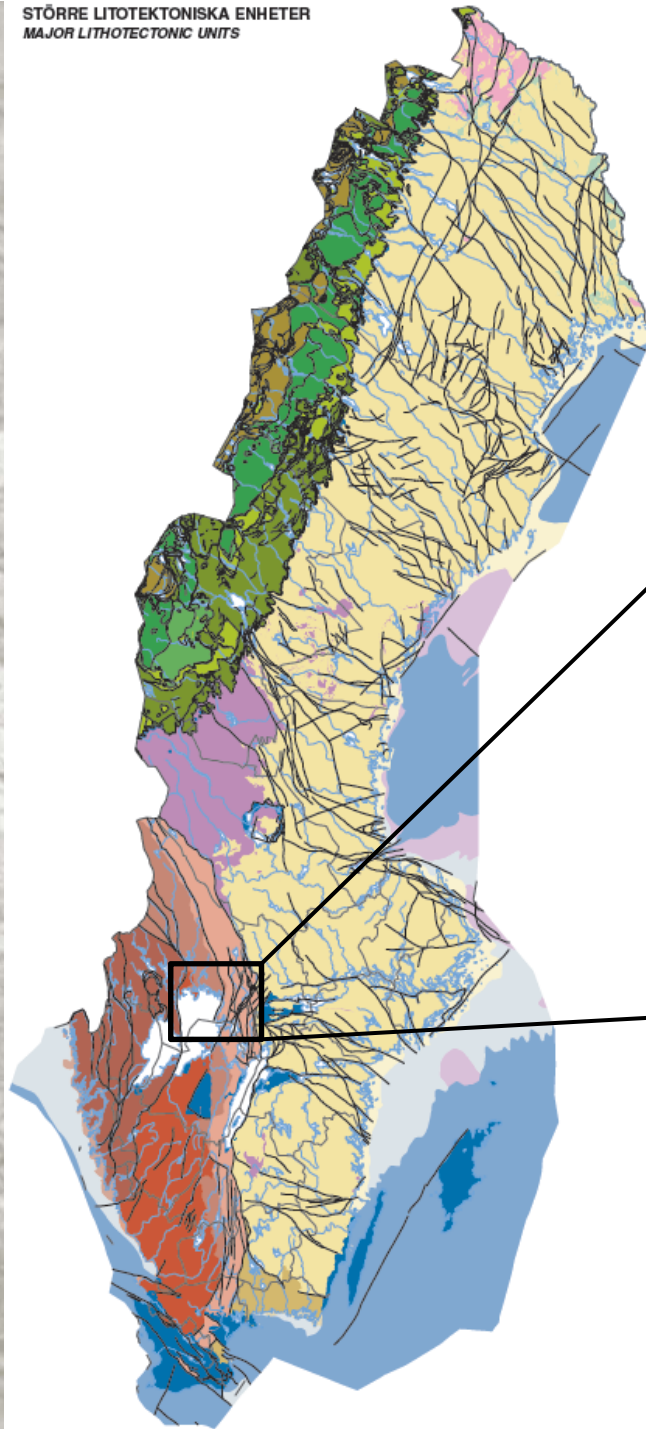
Paradigm™

GOCAD

Mira Geoscience

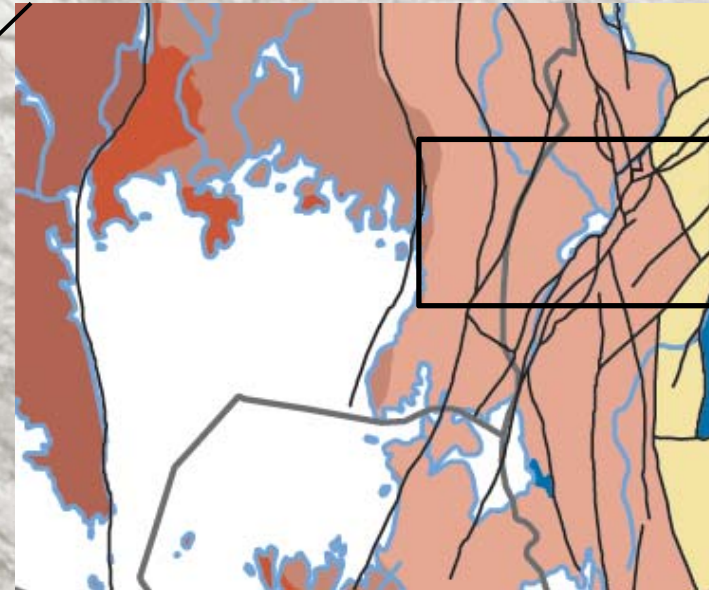


STÖRRE LITOTEKTONISKA ENHETER  
MAJOR LITHOTECTONIC UNITS



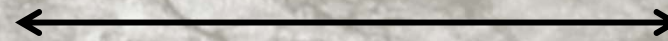
## Major lithotectonic units in the bedrock of Sweden

Svecokarelian orogen



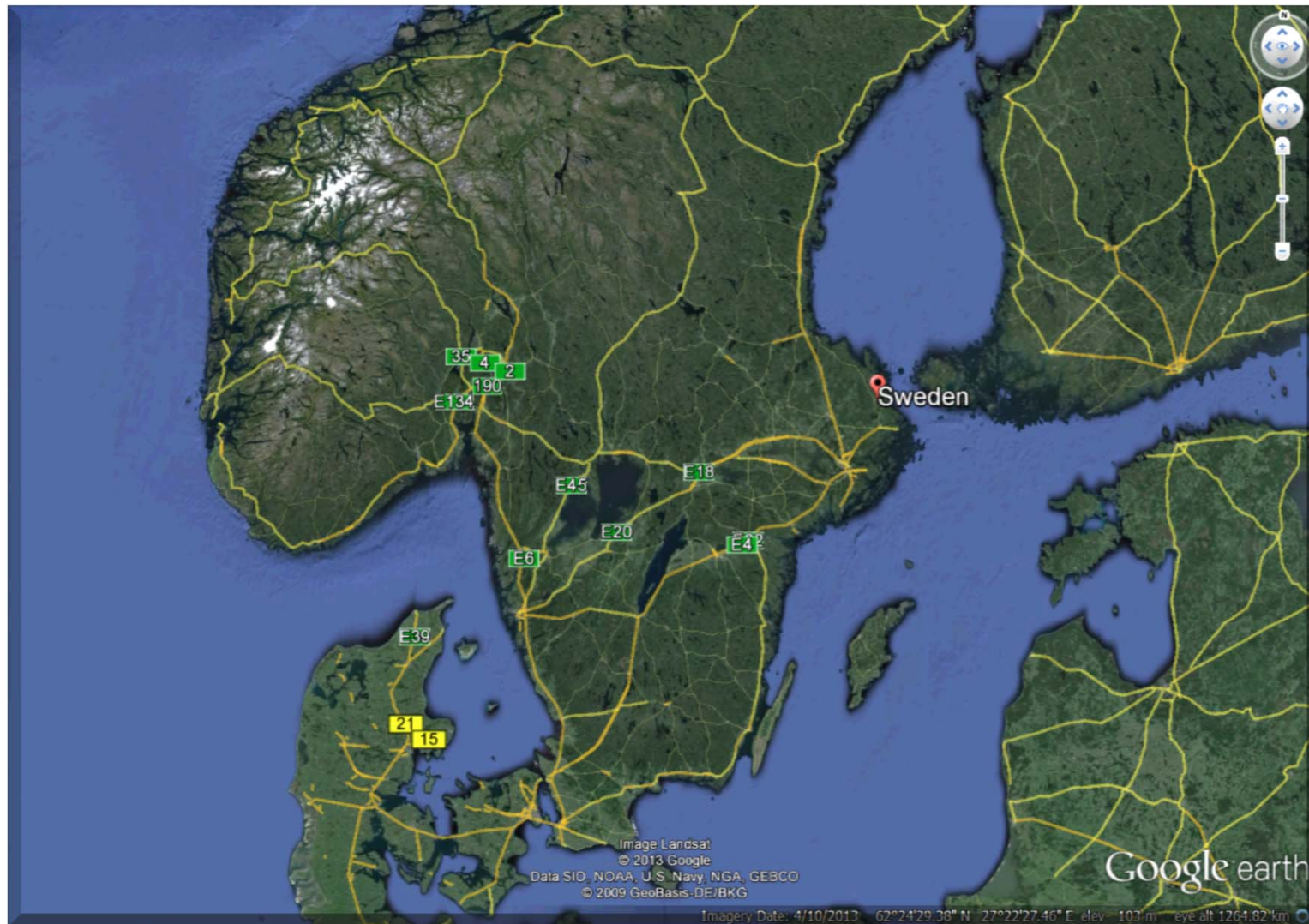
Model  
area

Sveconorwegian orogen

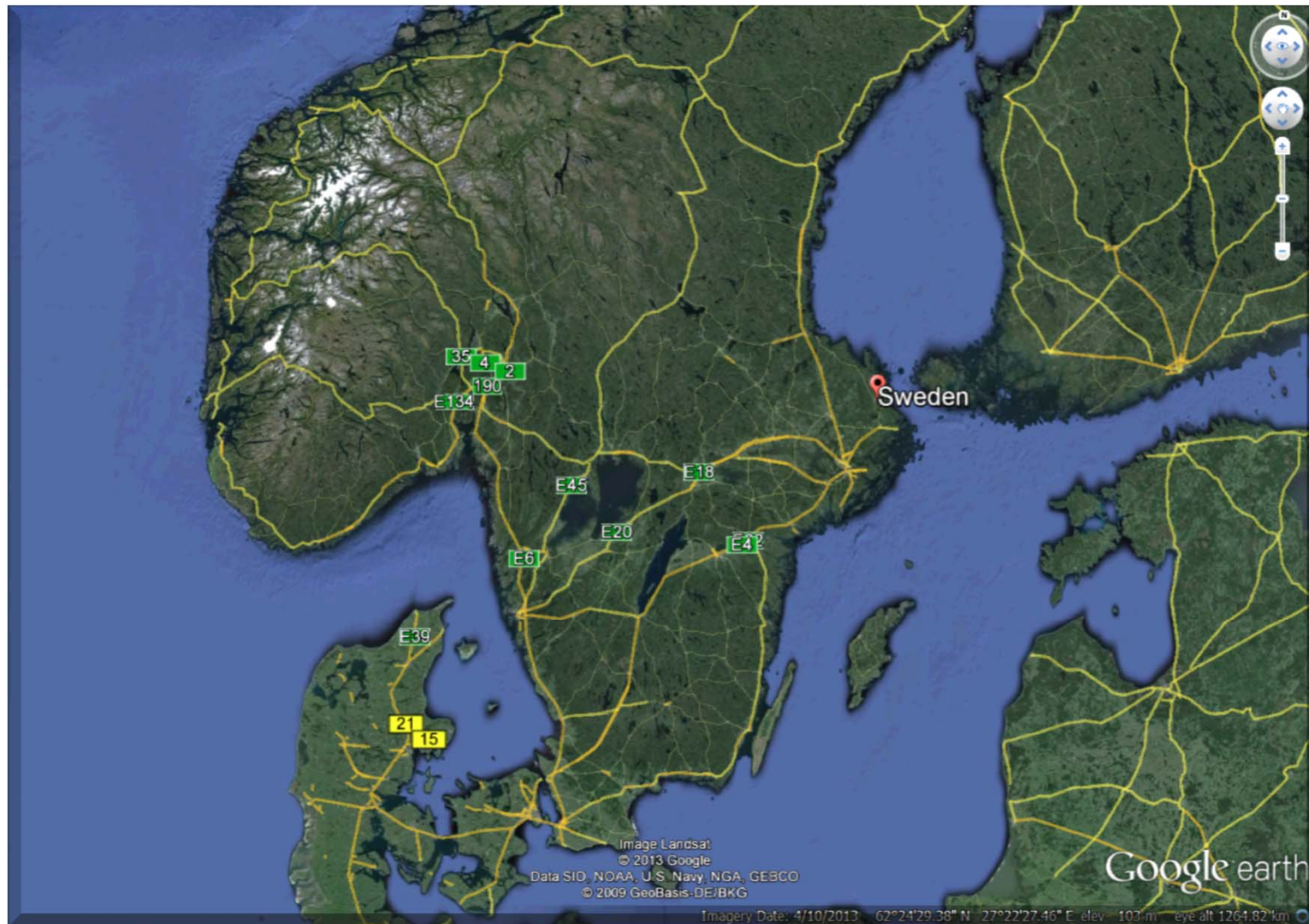


Bergman et al. 2012, (SGU K423)



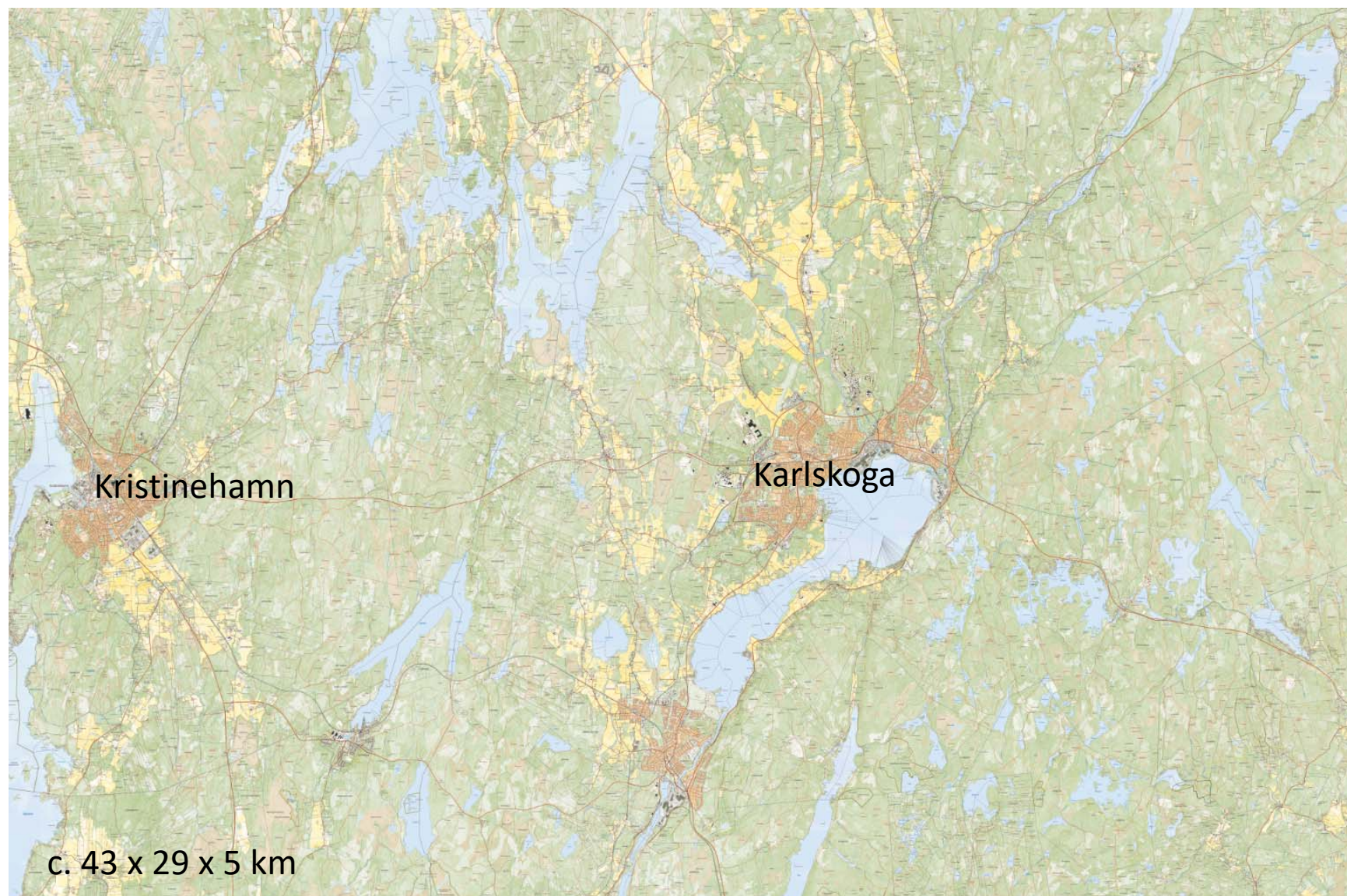


Zoom to model area



Modellområdet





Kristinehamn

Karlskoga

c. 43 x 29 x 5 km



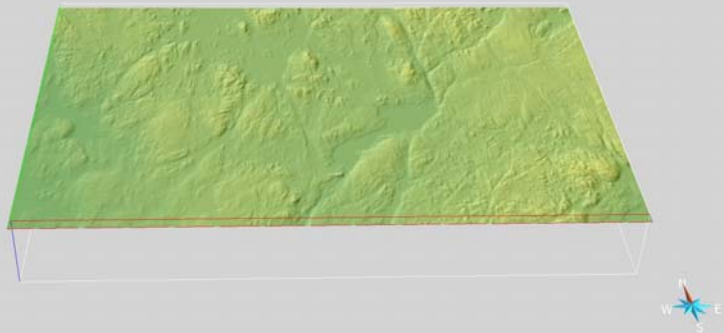
Bedrock



Bedrock cross-sections



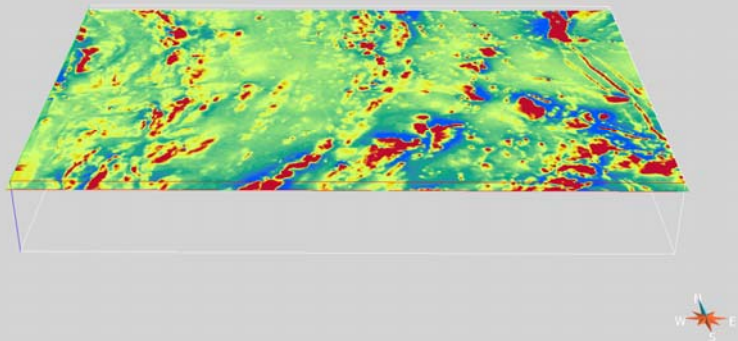
DEM



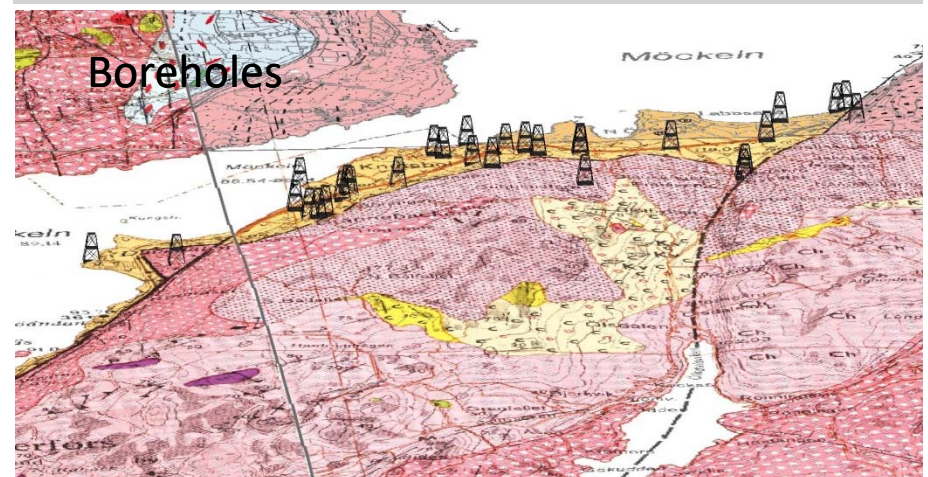
Seismic reflection



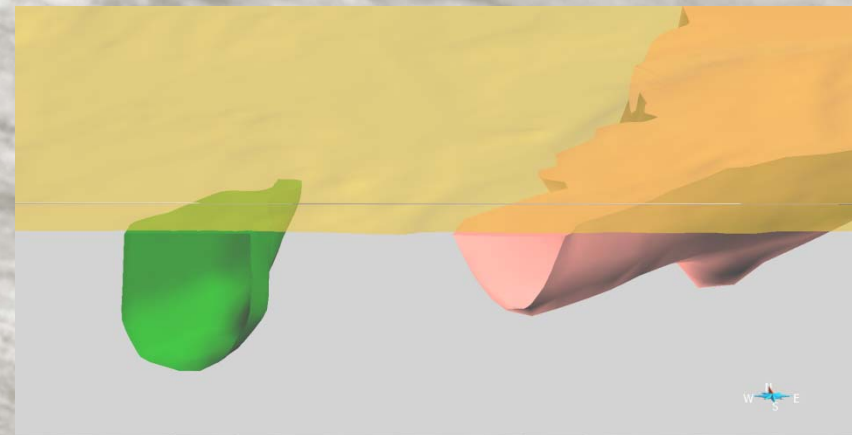
Magnetic total field



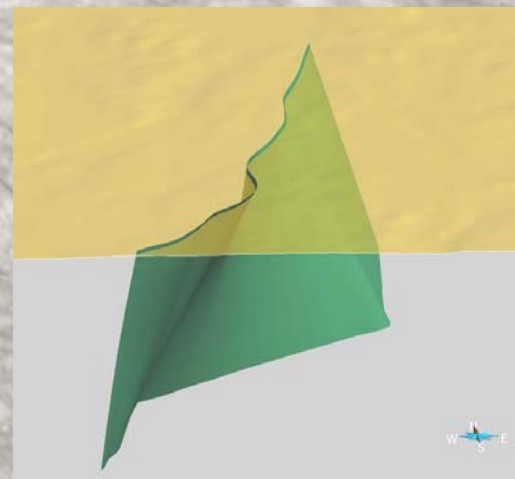
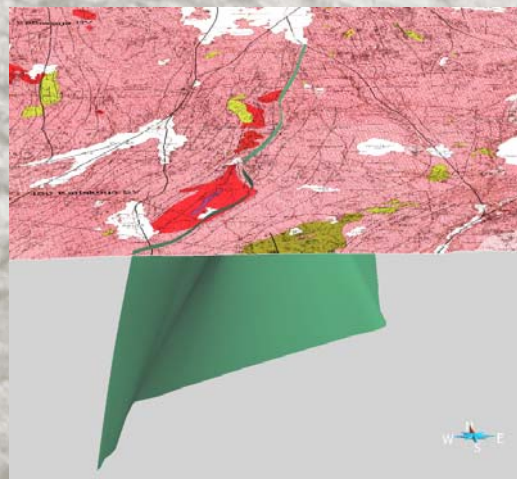
Boreholes



## Rock domains (lithological units)



## Deformation zones





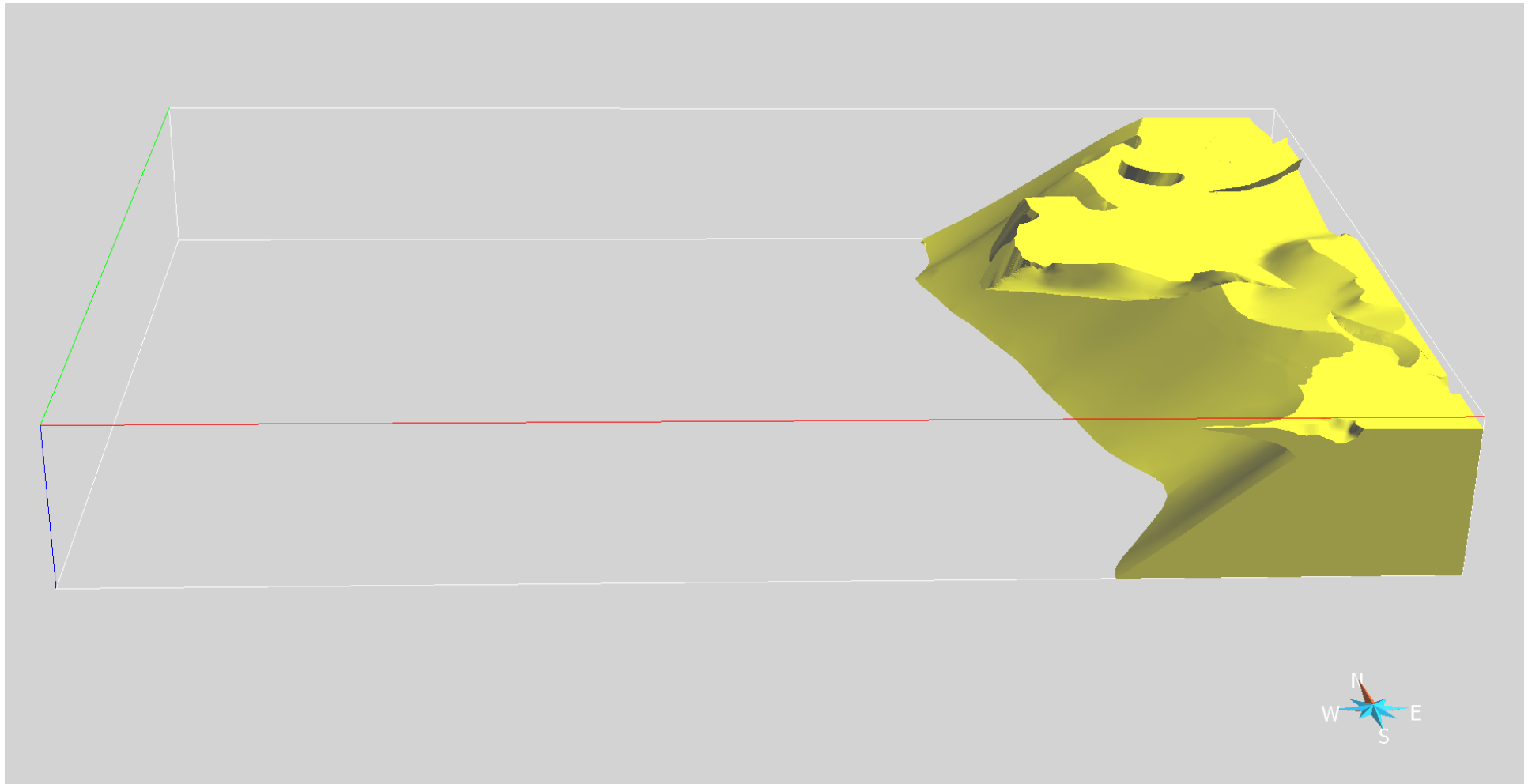
# Sequential presentation of the major rock domains from 1.9 Ga to 0.7 Ga



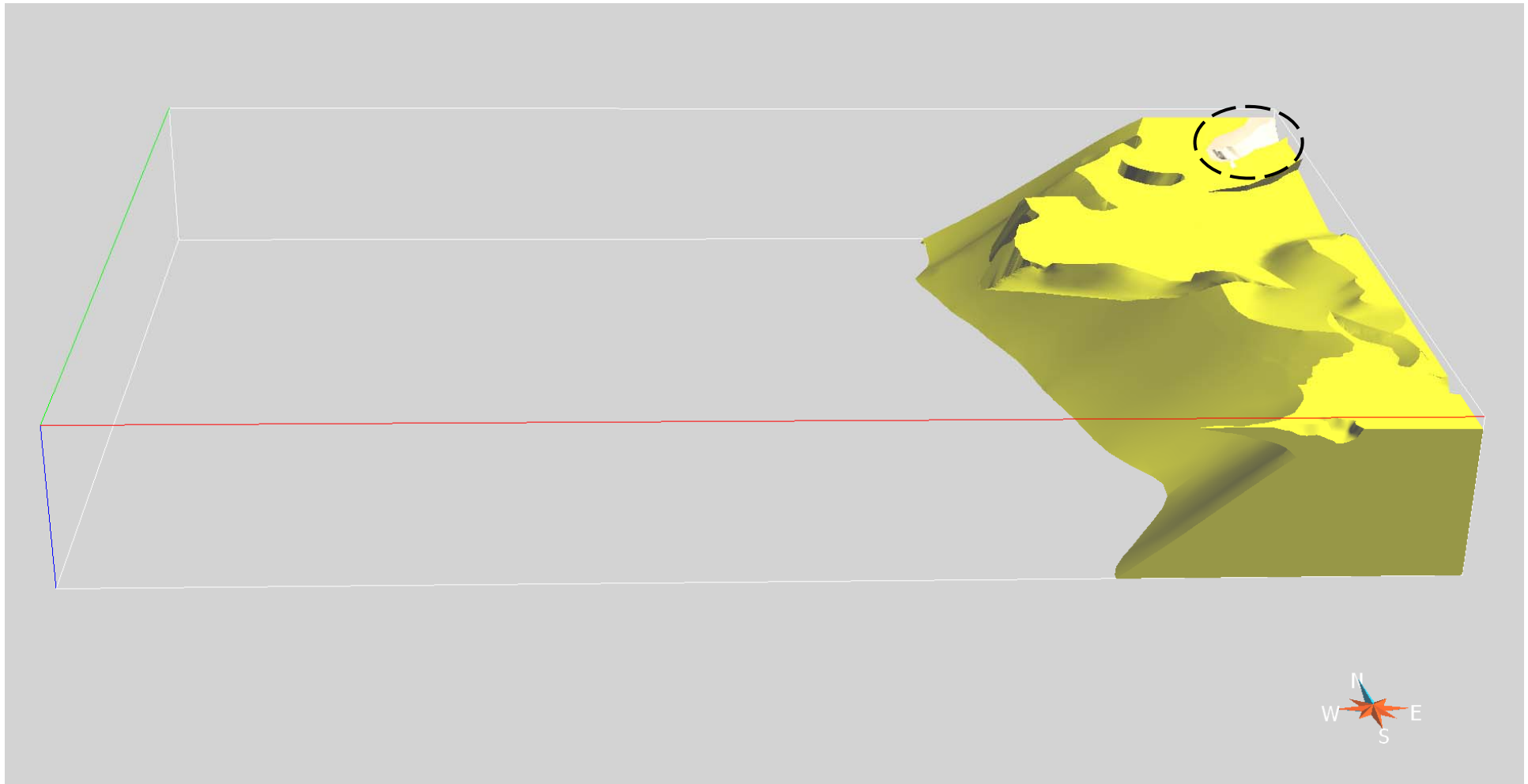
Entire rock domain model





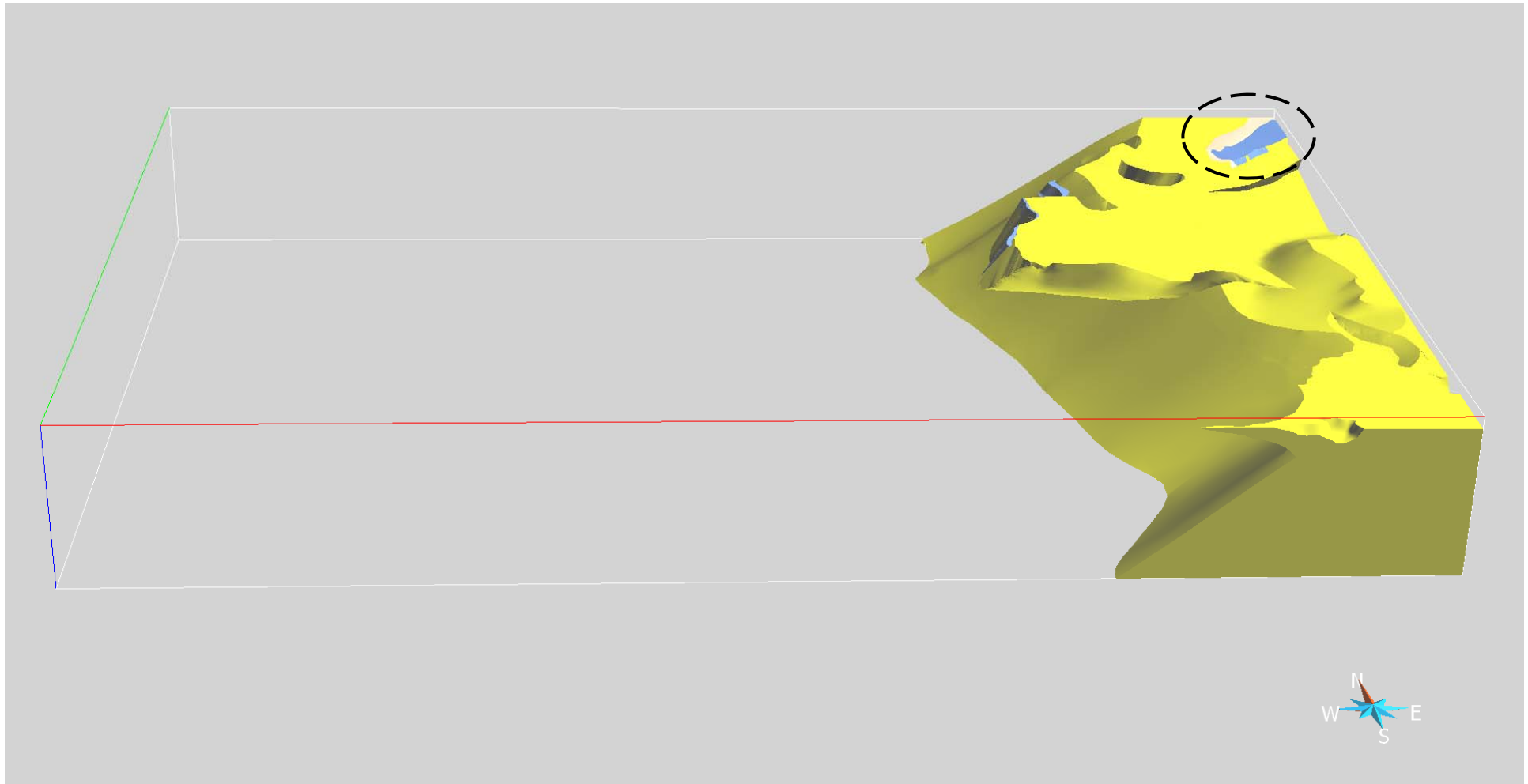


**Metavolcaniclastic rock, 1.9 Ga.**  
Svecokarelian metamorphism varies from medium-grade in the northern part to high-grade (migmatitic) in the southern part. Affected by Sveconorwegian, low-grade shear zones.

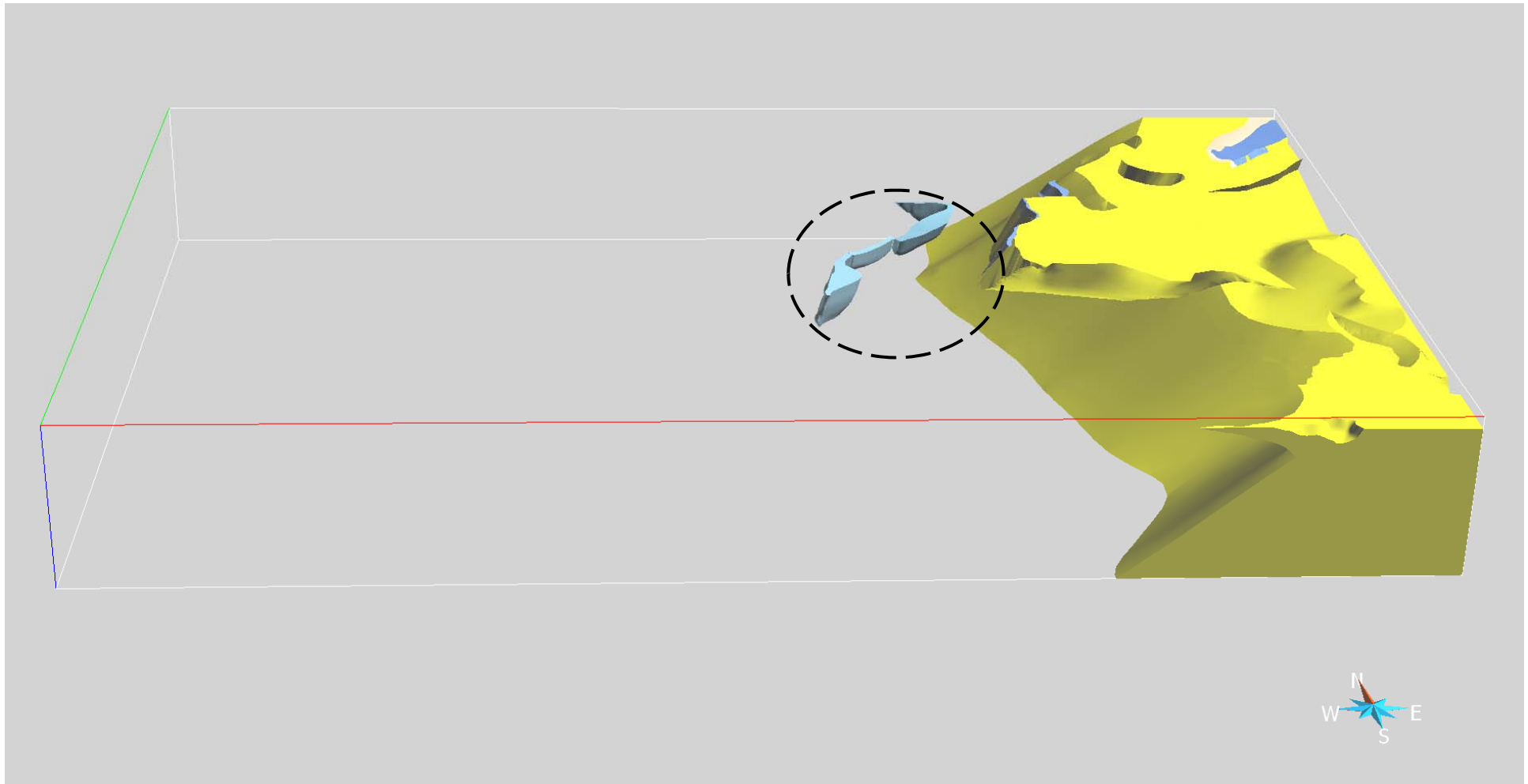


**Fine-grained metavolcaniclastic rock, 1.9 Ga. Low-grade, Svecokarelian metamorphism. Affected by Sveconorwegian, low-grade shear zones.**



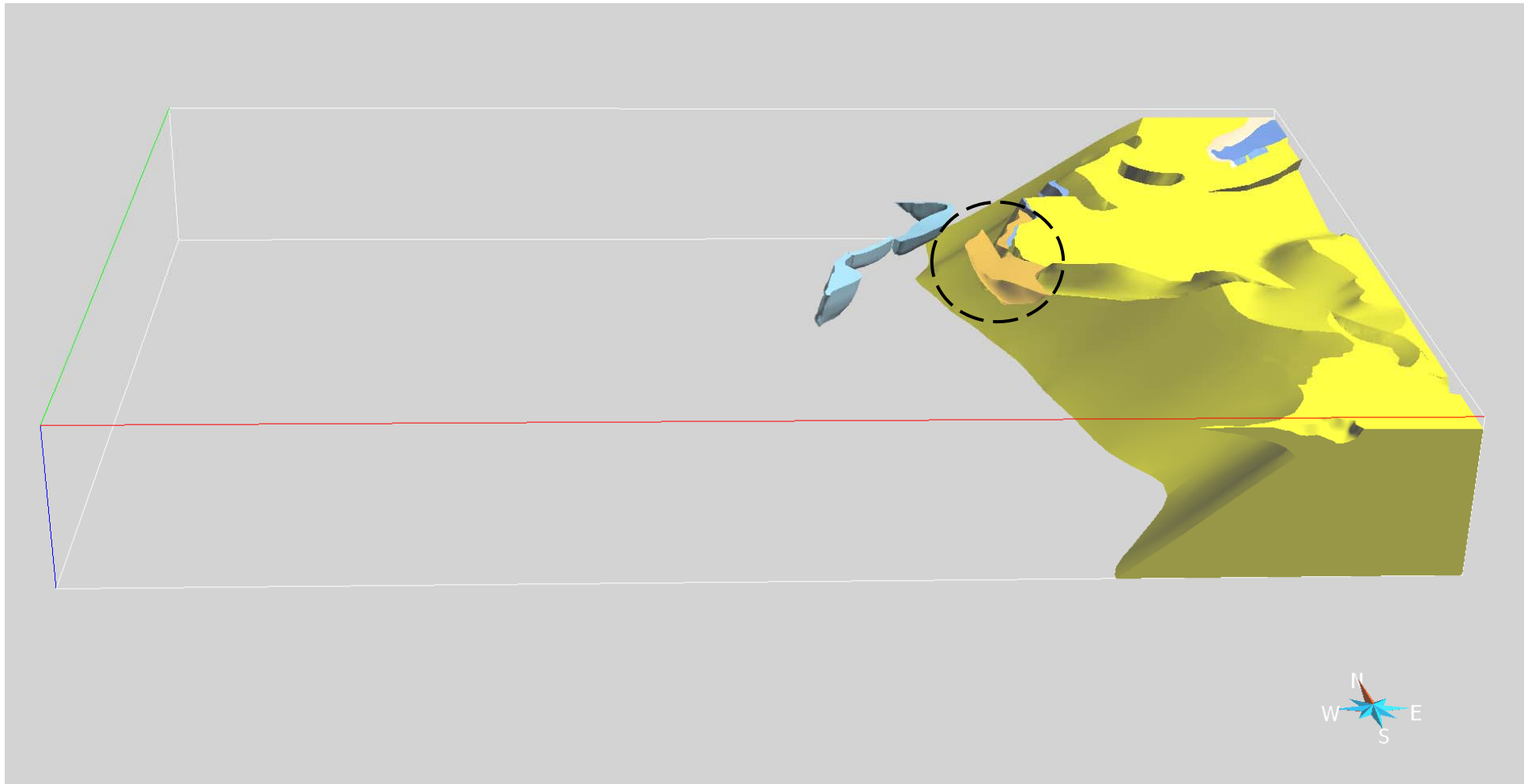


**Marble, 1.9 Ga. Low-grade, Svecokarelian metamorphism. Affected by Sveconorwegian, low-grade shear zones.**

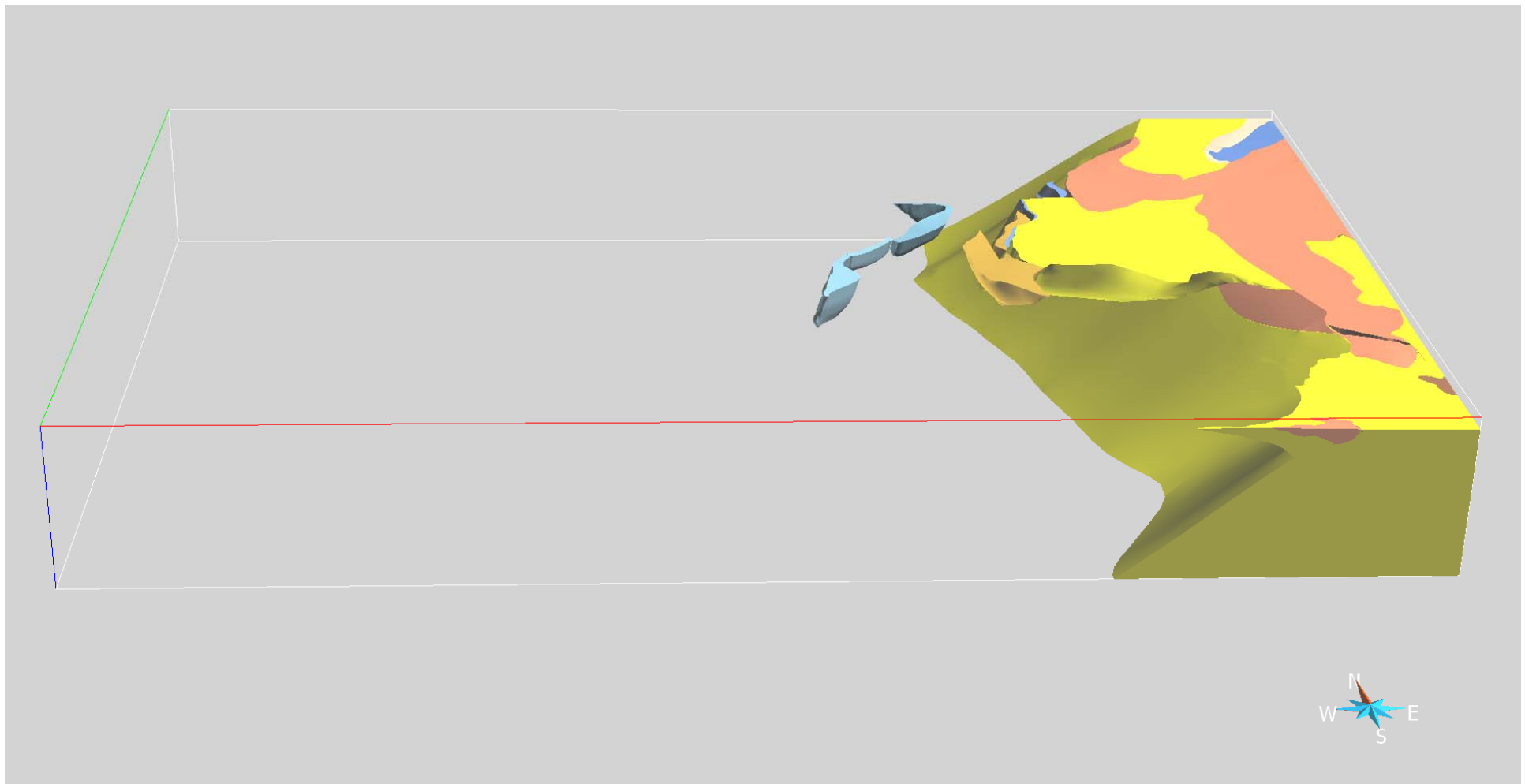


**Metasedimentary rock, 1.9 Ga. High-grade Svecokarelian metamorphism (migmatitic). Affected by Sveconorwegian, low-grade shear zones.**



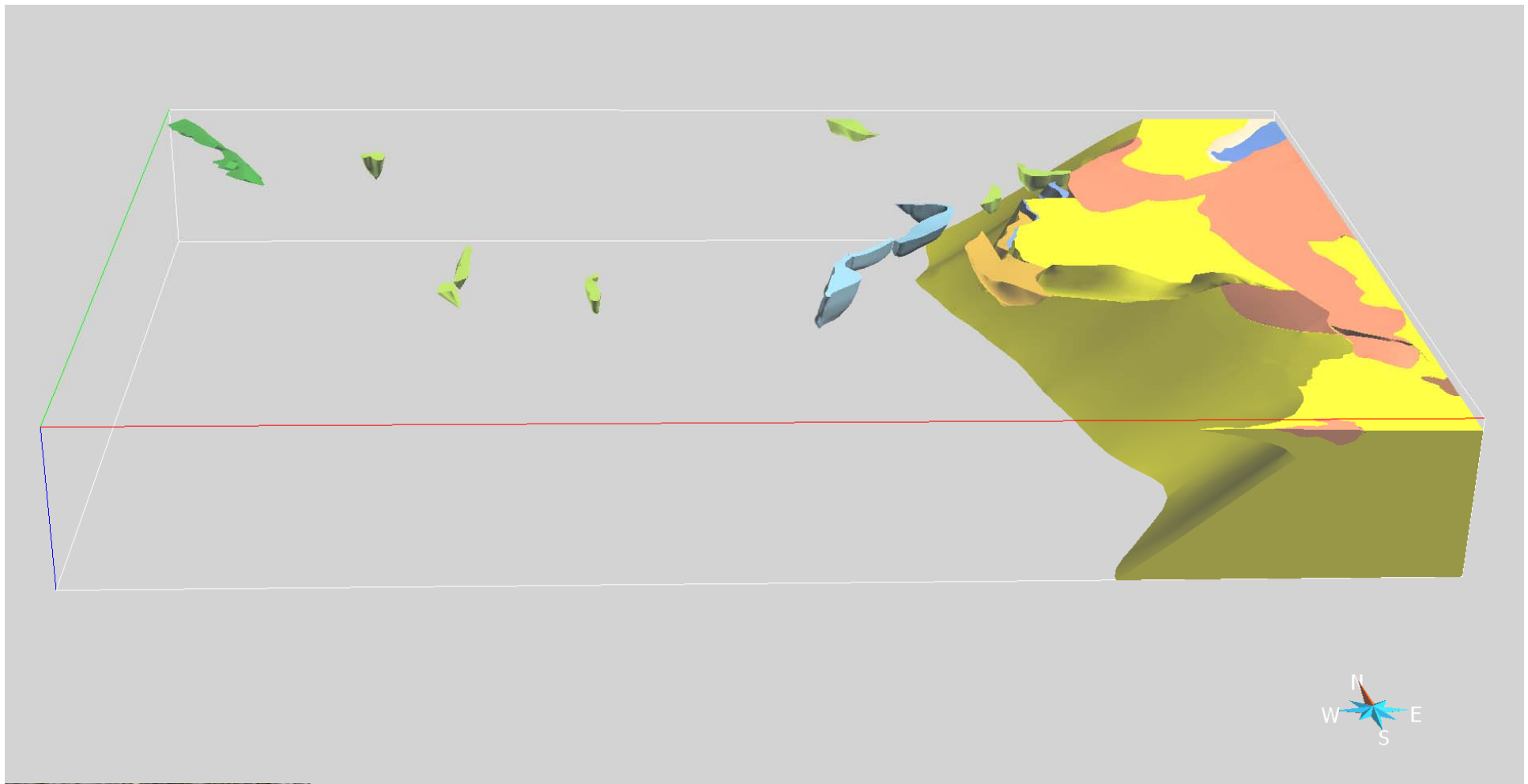


**Contact metamorphic rocks (hornfels).**  
Inferred sedimentary protolith, 1.9 Ga.  
Low-pressure, granulite-grade contact  
metamorphism, 1.8 Ga. Affected by  
Sveconorwegian, low-grade shear zones.



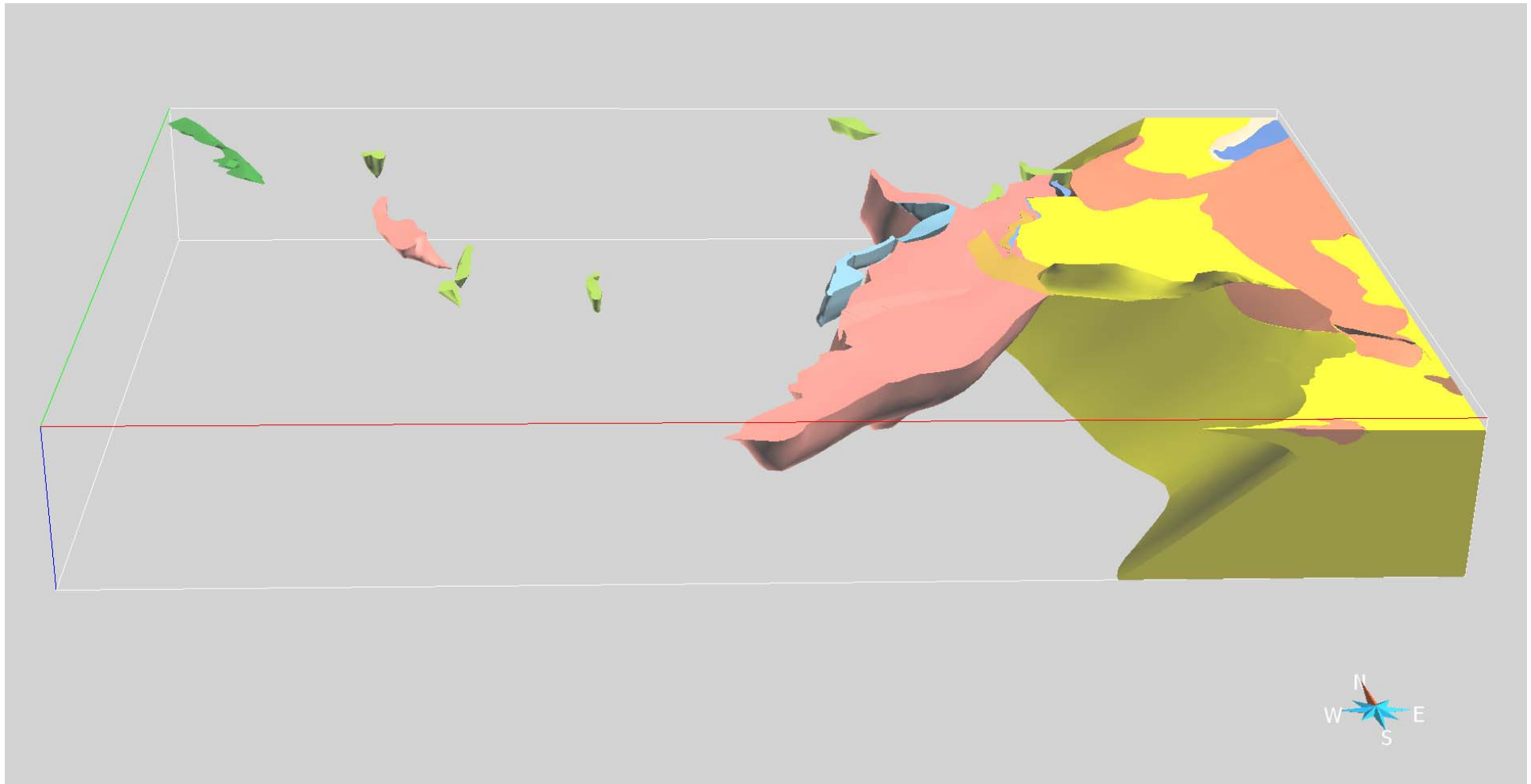
**Granite-pegmatite suite, 1.8 Ga. Affected by Sveconorwegian, low-grade shear zones.**





**Diorite-gabbro, 1.8 and 1.7 Ga.**  
Affected by Sveconorwegian, low-grade shear zones

**Metadiorite, 1.7 Ga (dark green in NW corner).** Pervasive Sveconorwegian medium-grade structural overprinting.

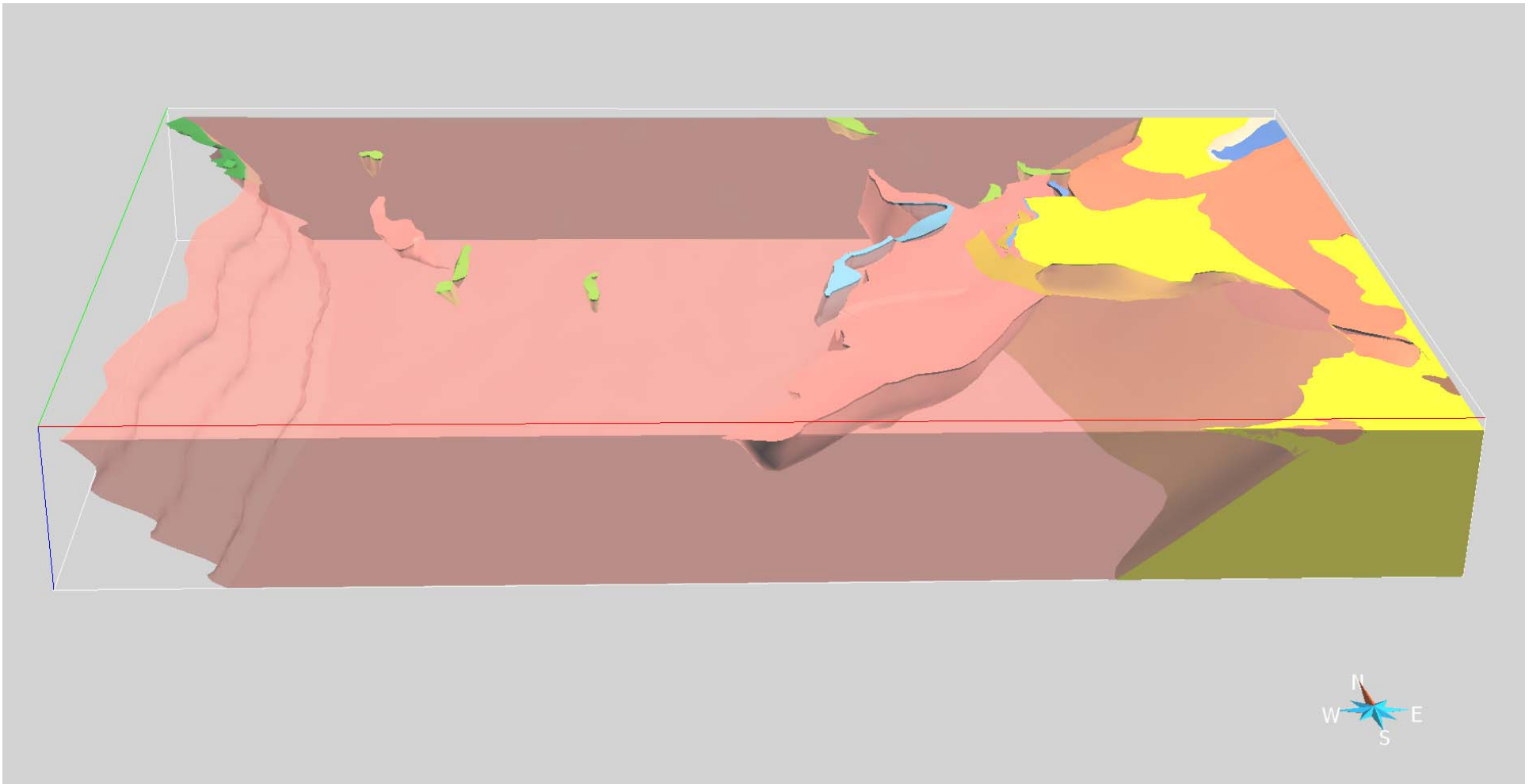


**Granite, equigranular, locally  
charnockitic (TIB), 1.8 Ga.**

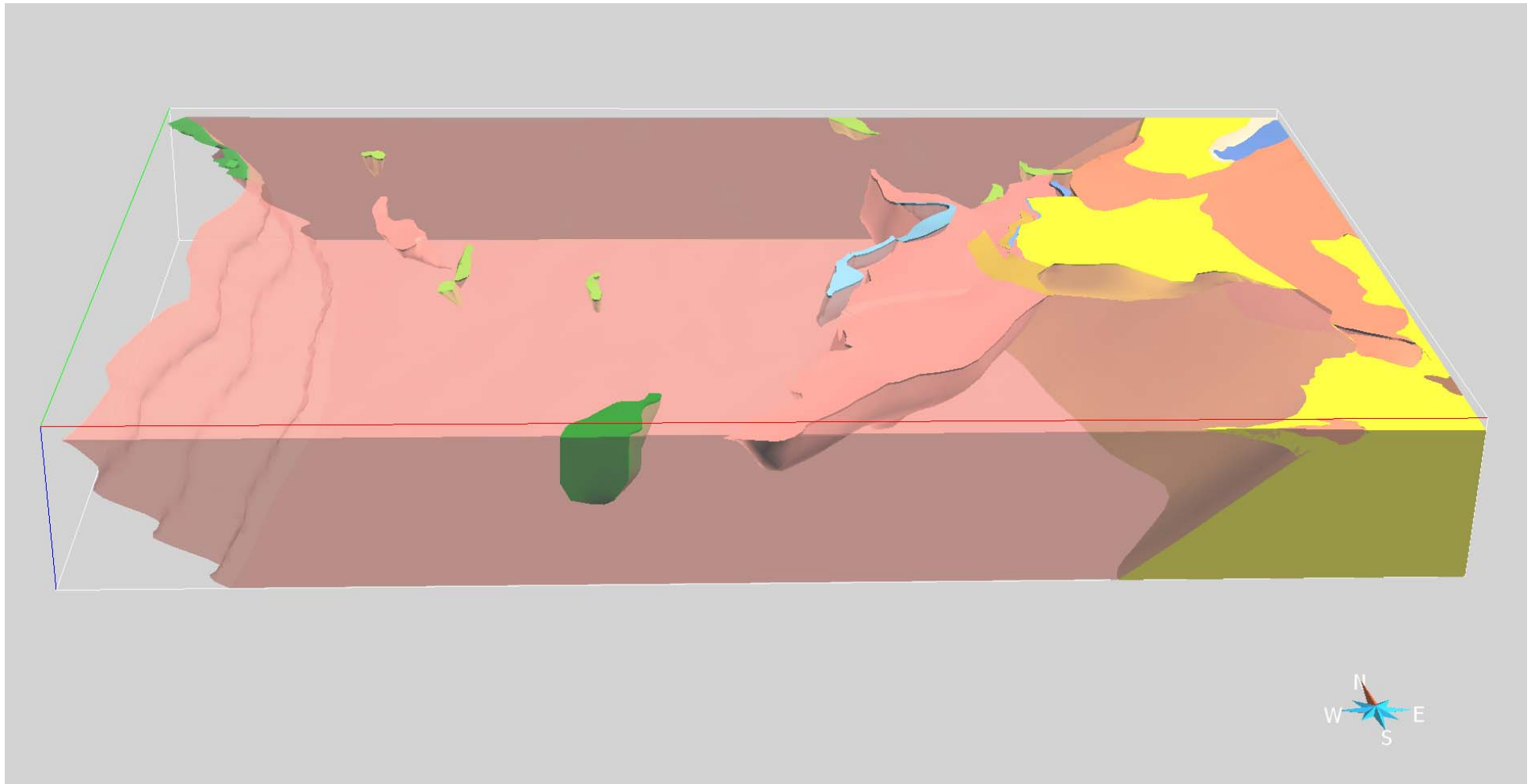
**Granite, equigranular (TIB), 1.8 Ga  
(smaller body to the west).**

**Affected by Sveconorwegian, low-grade  
shear zones.**



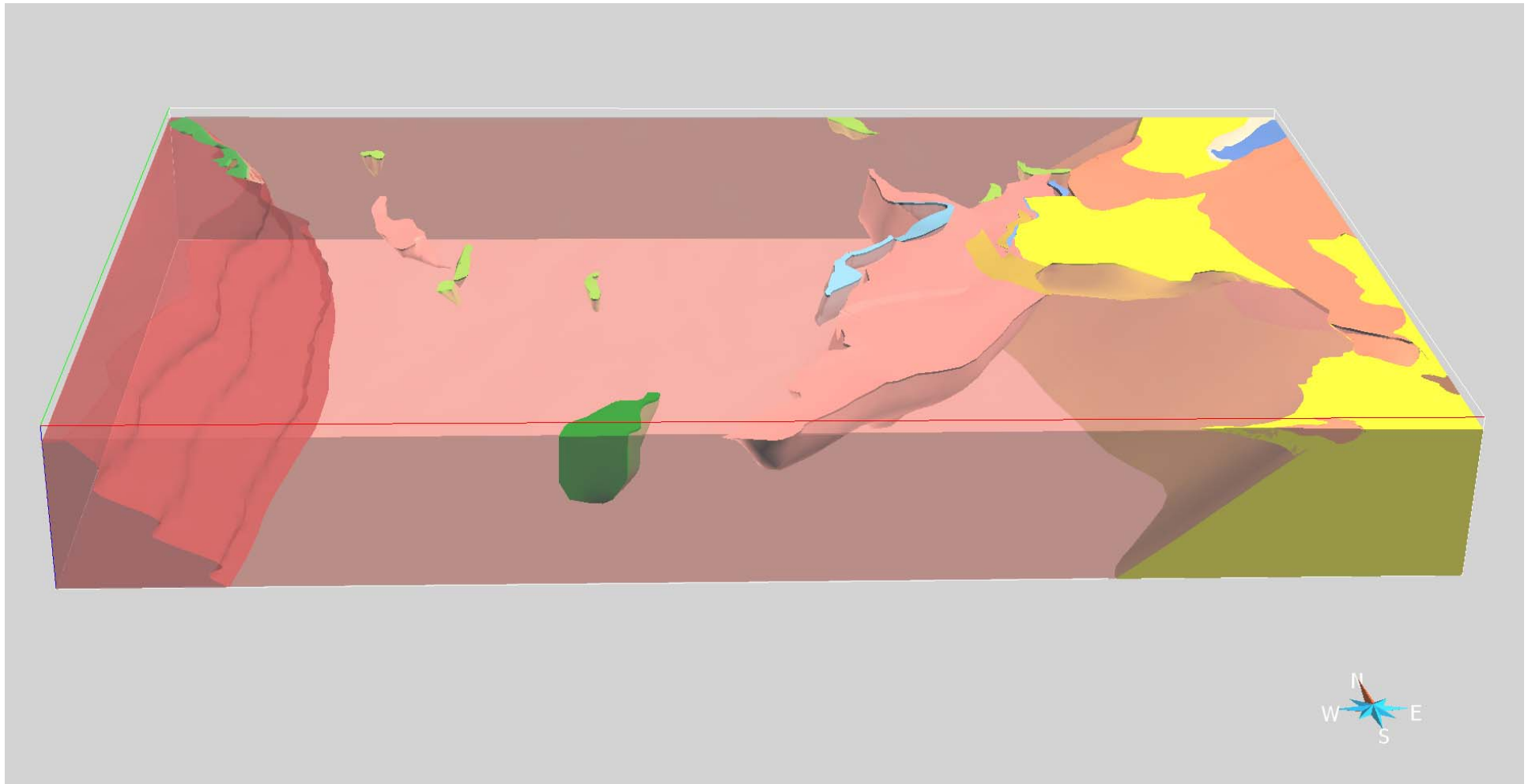


**Quartz monzodiorite to granite, porphyritic (TIB), 1.8 and 1.7 Ga. Degree of semi-pervasive Sveconorwegian low-grade structural overprinting increases westwards.**

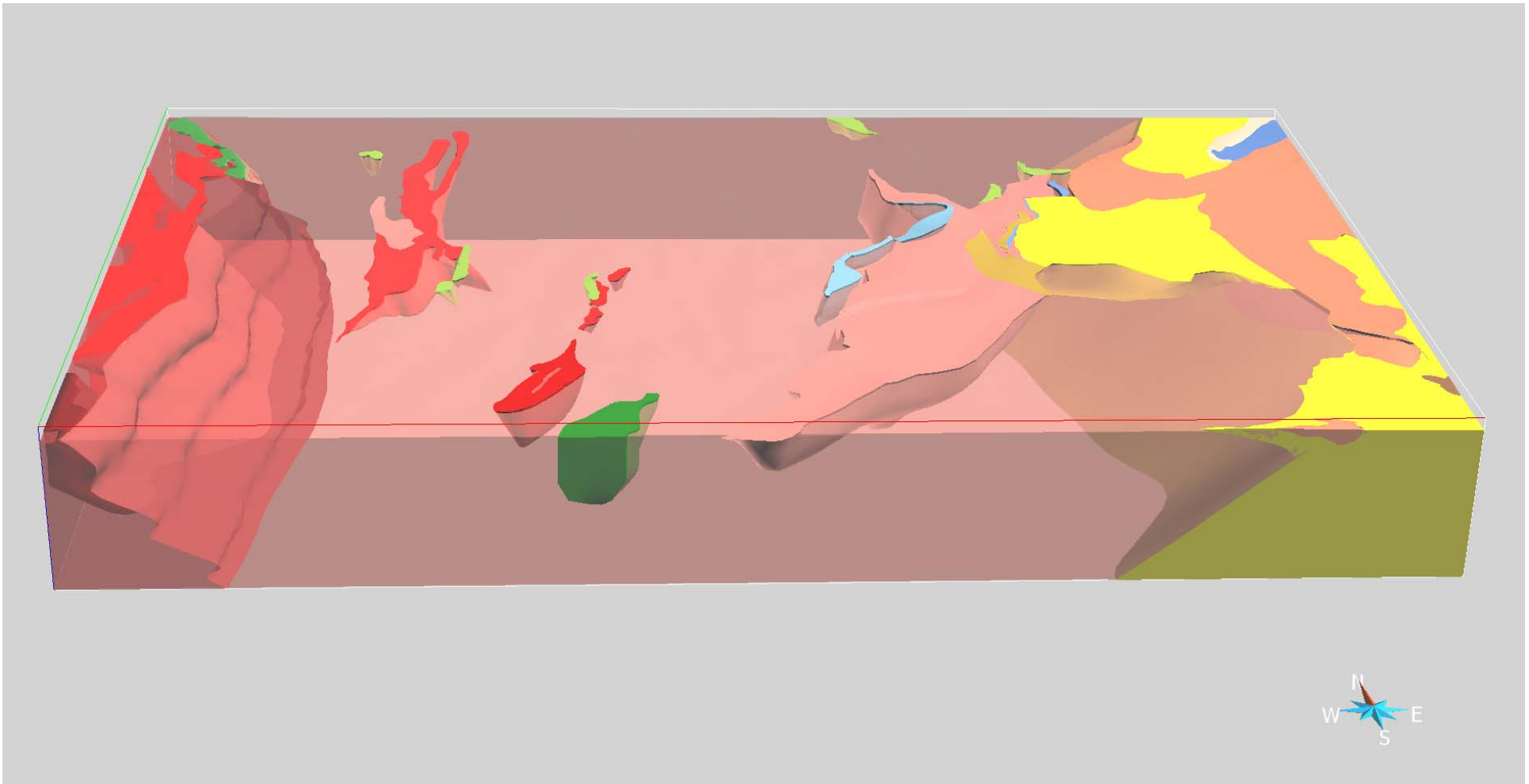


**Monzodiorite (TIB), 1.7 Ga.**  
Thermal contact aureole  
(hornfels alteration) and dykes  
in the surrounding 1.8 Ga TIB  
rock. Affected by  
Sveconorwegian, low-grade  
shear zones.





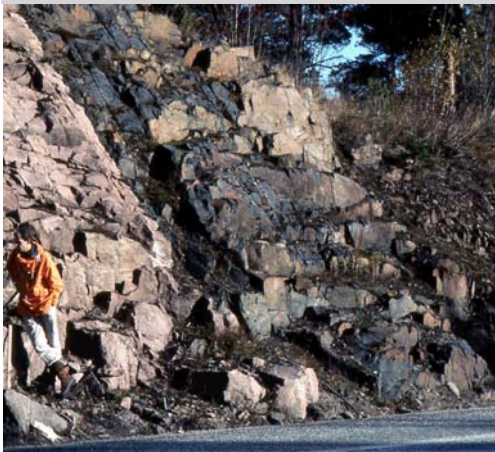
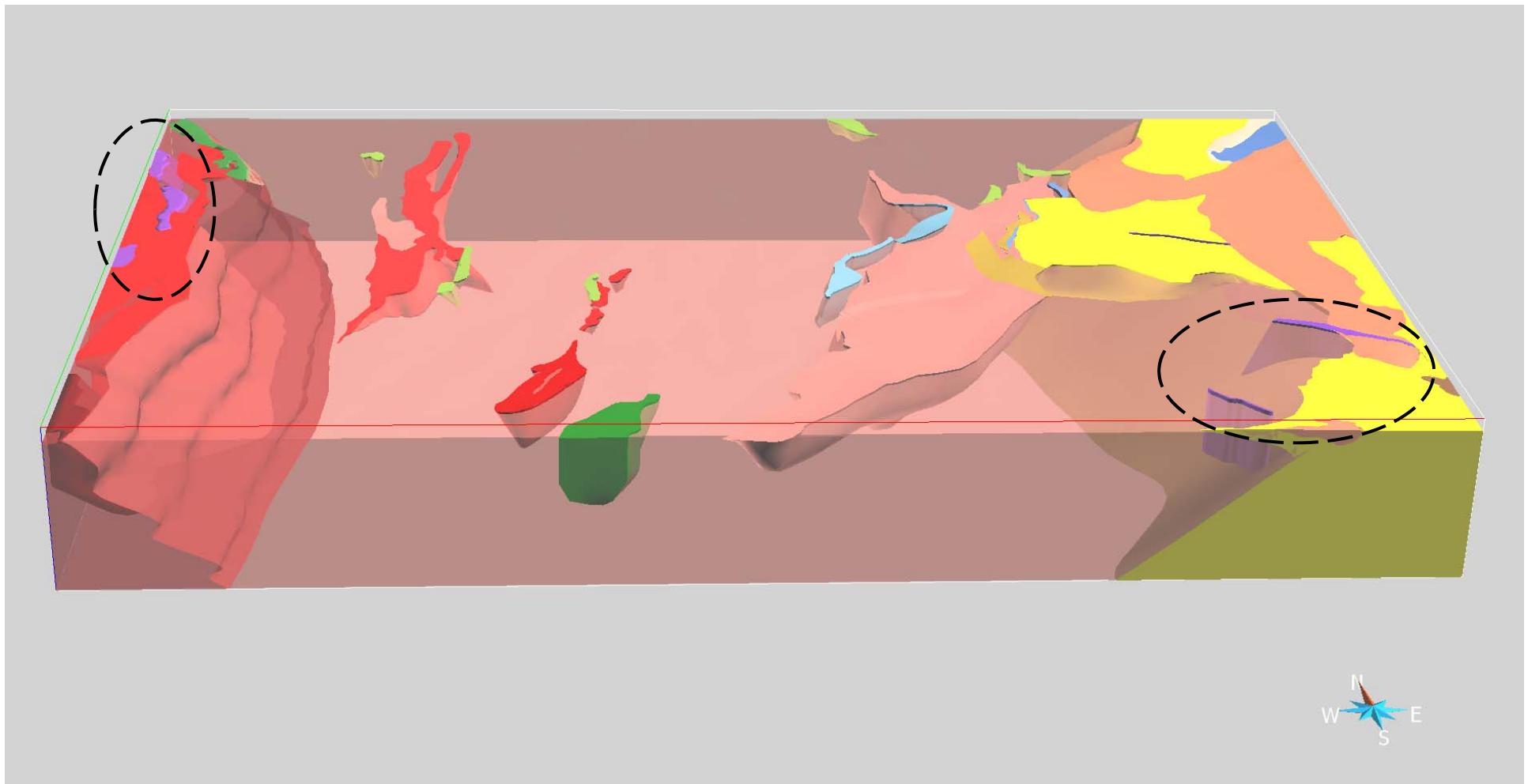
**Metaquartz monzodiorite to  
metagranite, porphyritic (TIB),  
1.7 Ga. Pervasive Sveconorwegian  
medium-grade structural overprinting.**



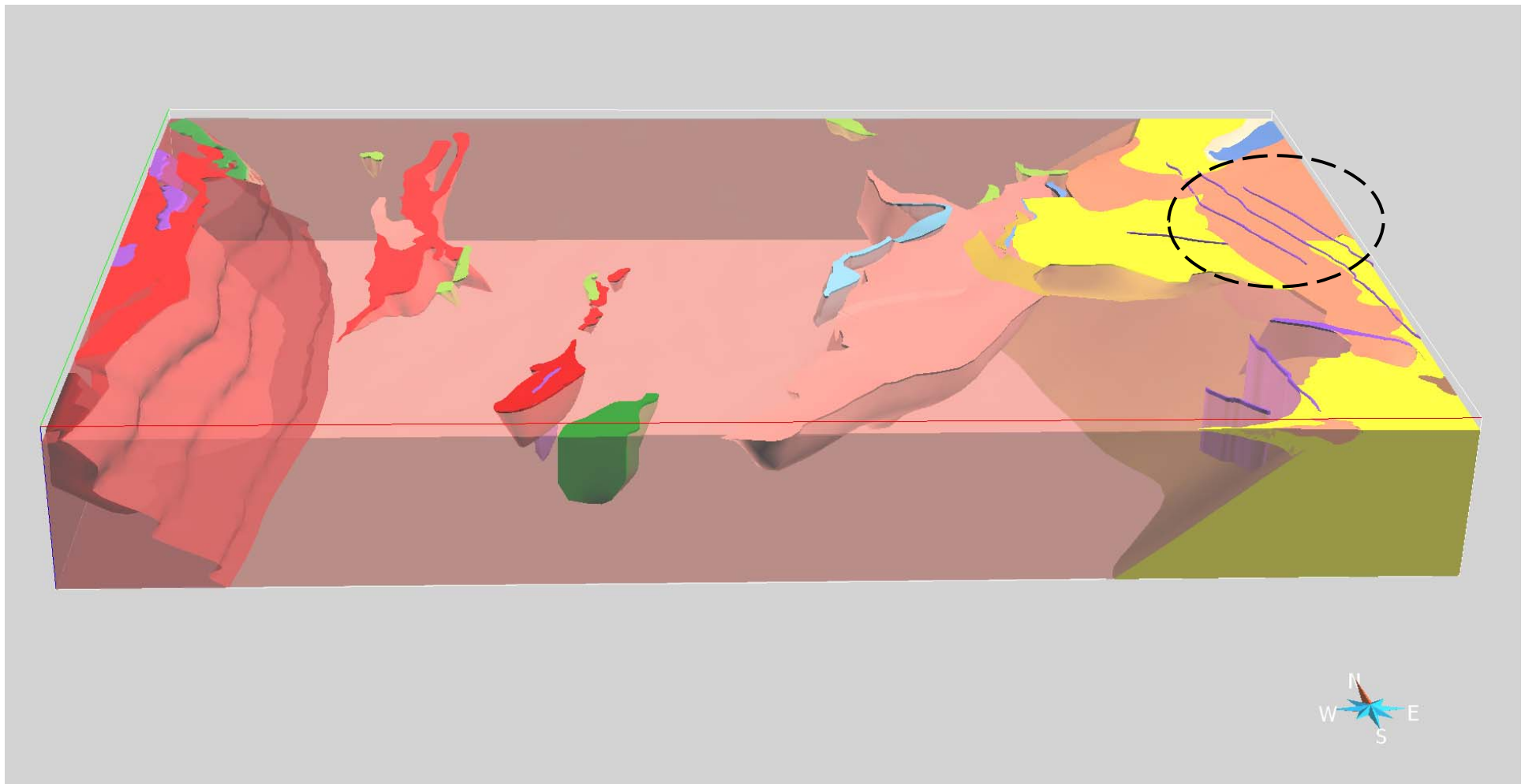
## **Granite (TIB) 1.7 Ga.**

**Semi-pervasive, low-grade and pervasive, medium-grade (in the west) Sveconorwegian structural overprinting.**



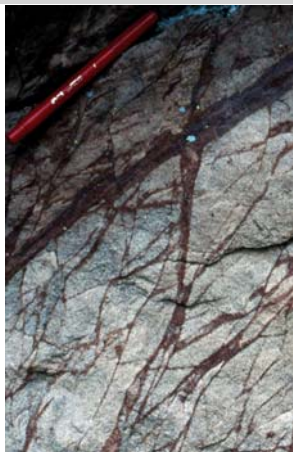
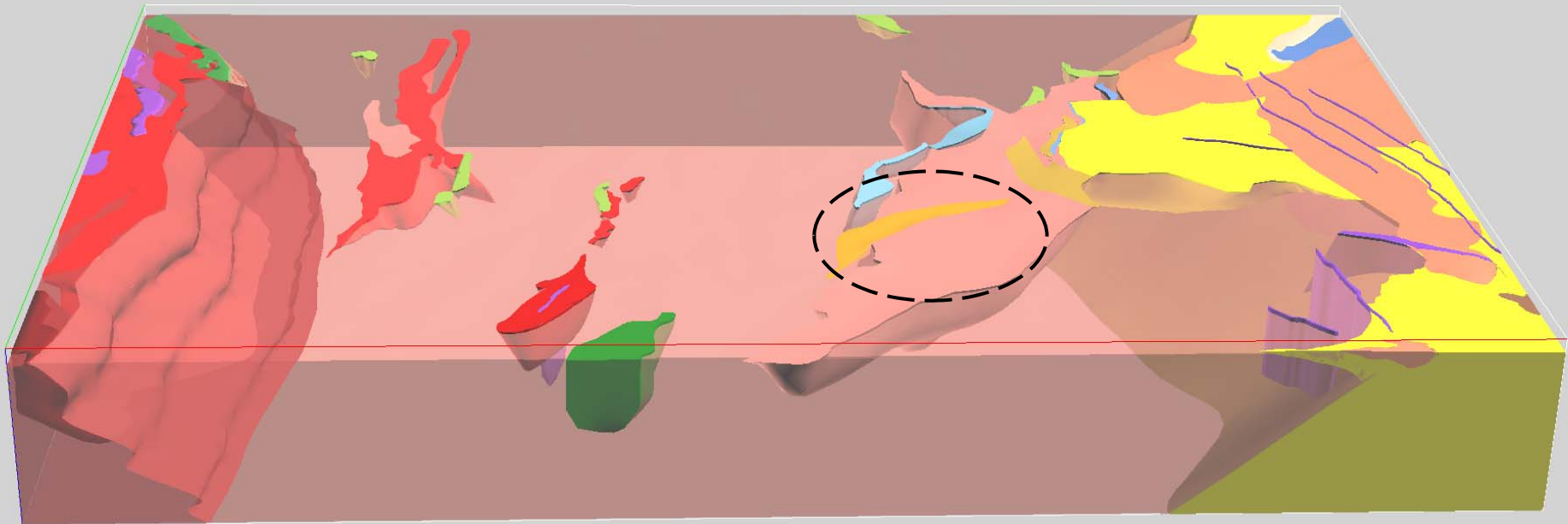


**Dolerite (hyperite), 1.57 Ga (in the west). Inhomogeneous, Sveconorwegian medium-grade structural overprinting.**  
**Dolerite (Breven), 1.60 Ga (in the east).**



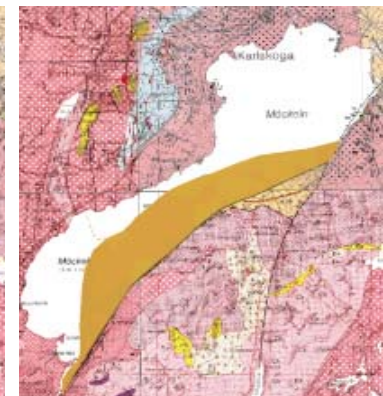
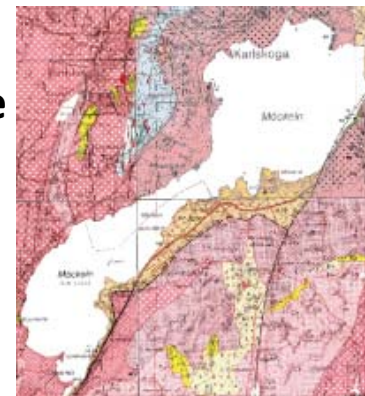
**Dolerite (BDD), 0.98-0.95 Ga. Affected by Sveconorwegian, low-grade shear zones.**

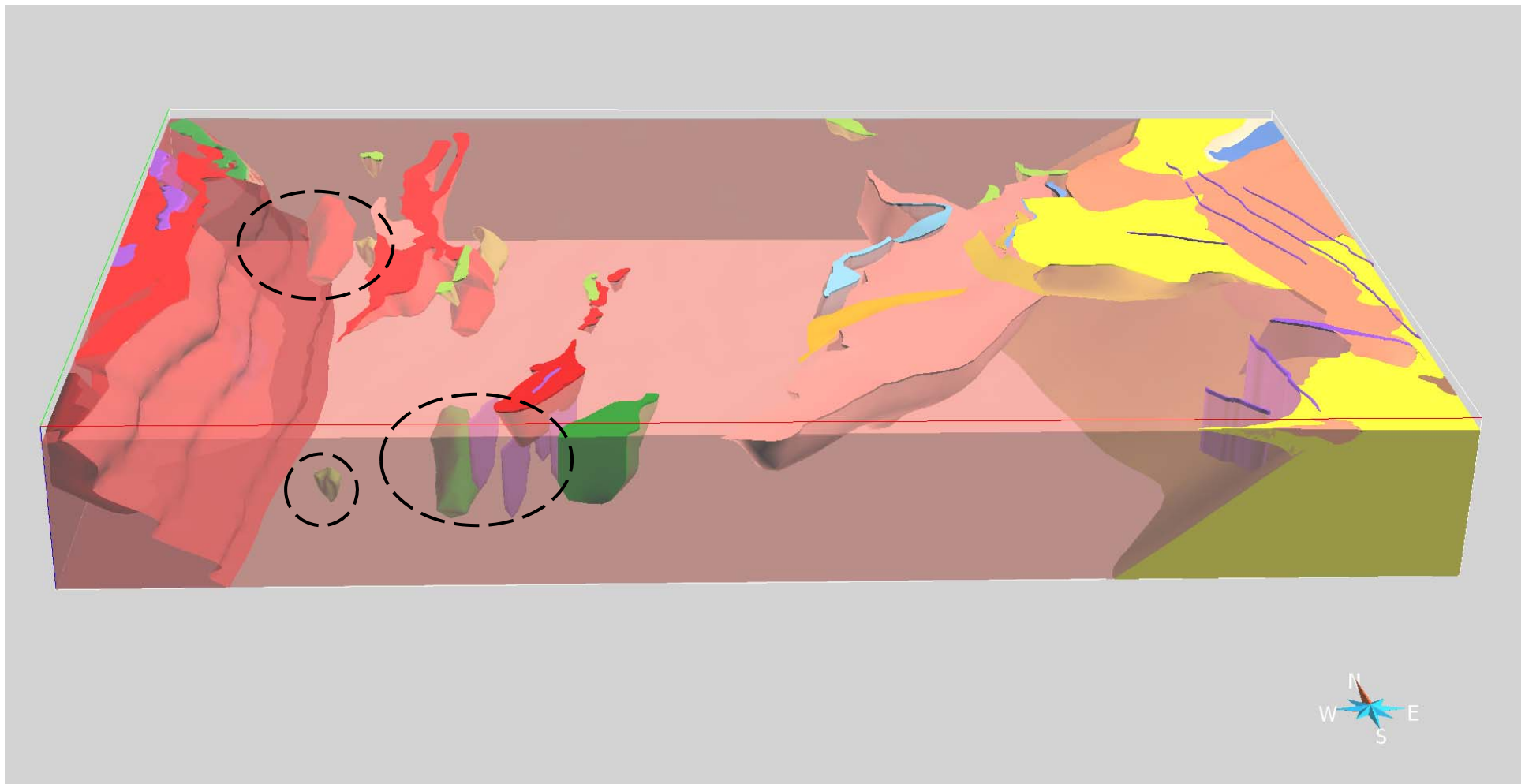




**Visingsö  
sandstone, 0.7-  
0.6 Ga (fault-  
bounded in the  
east).**

**The extent of the  
Visingsö sandstone  
has been adjusted  
(reduced) due to  
results of new  
groundwater wells**

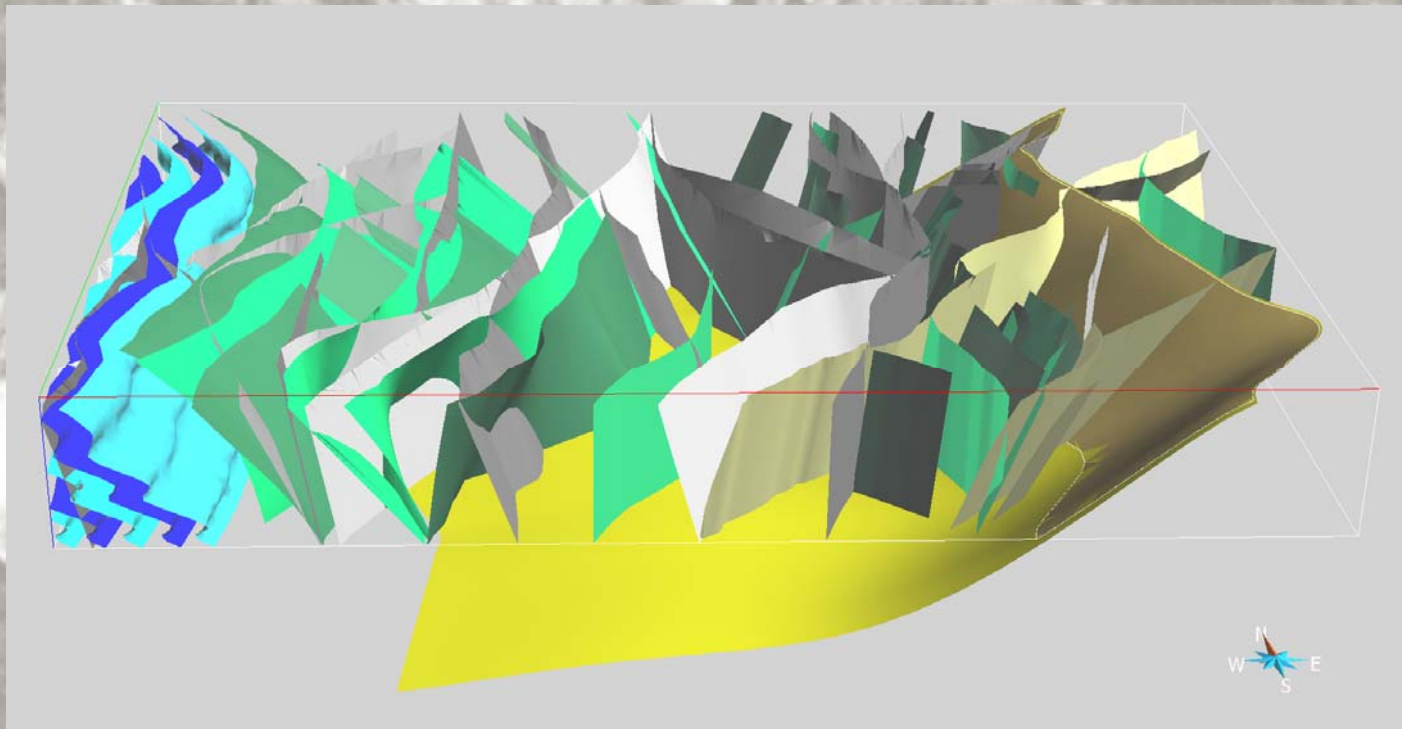




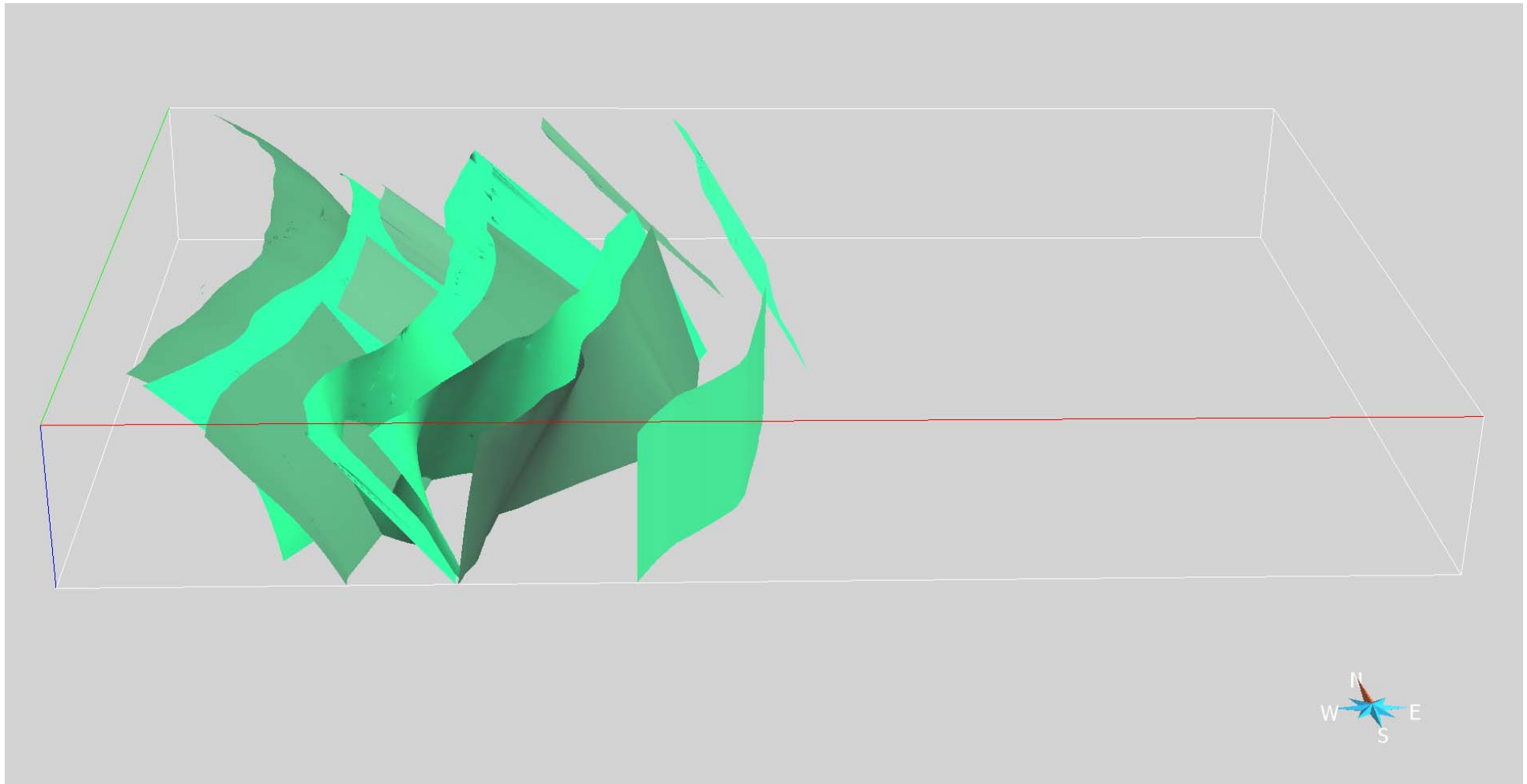
**Inferred occurrence at  
depth of rock types  
exposed at the ground  
surface.**



**Sequential presentation of the major ductile deformation zones from 0.97-0.93 Ga, subsequent brittle faulting including Phanerozoic reactivation**

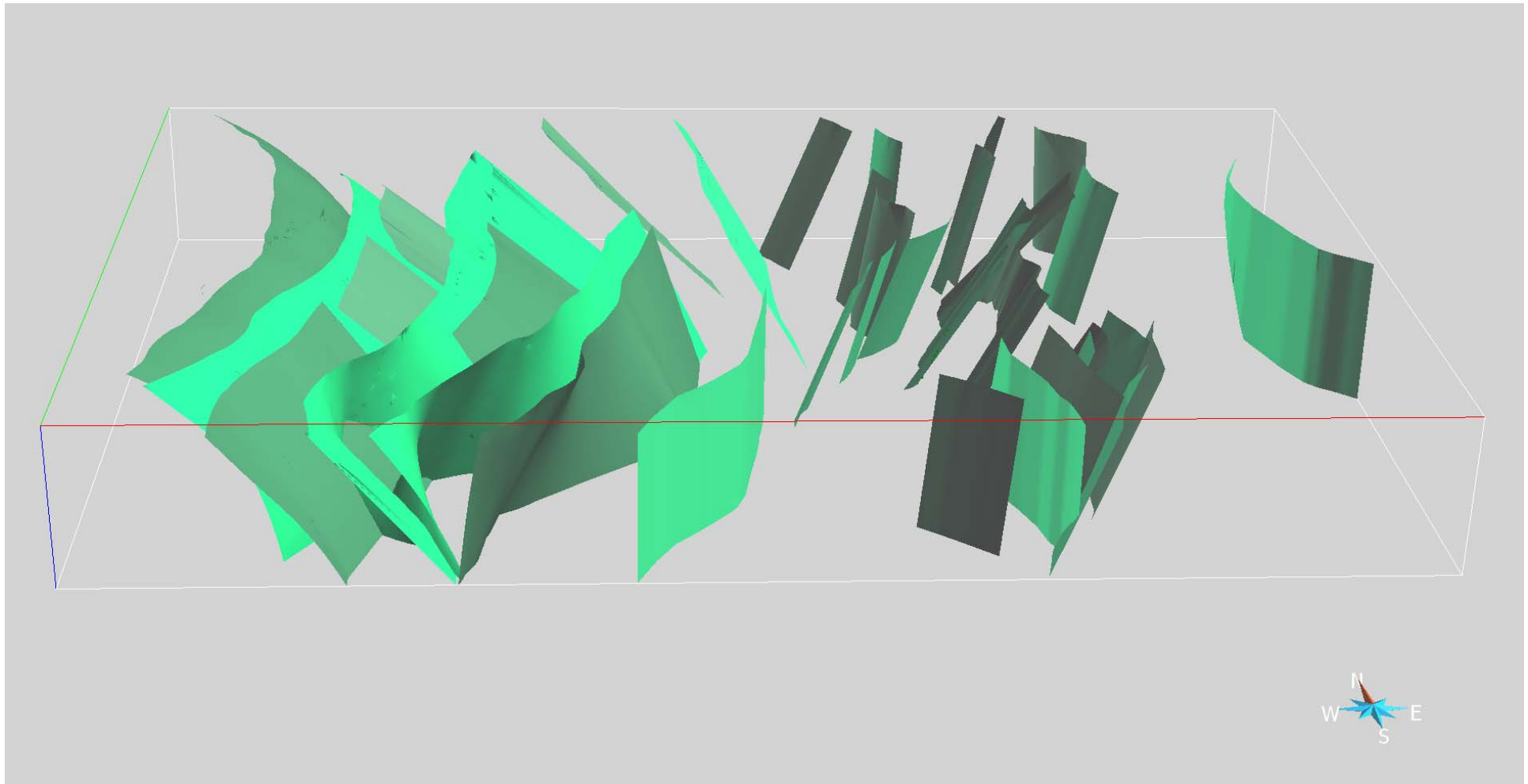


**Entire deformation zone model**

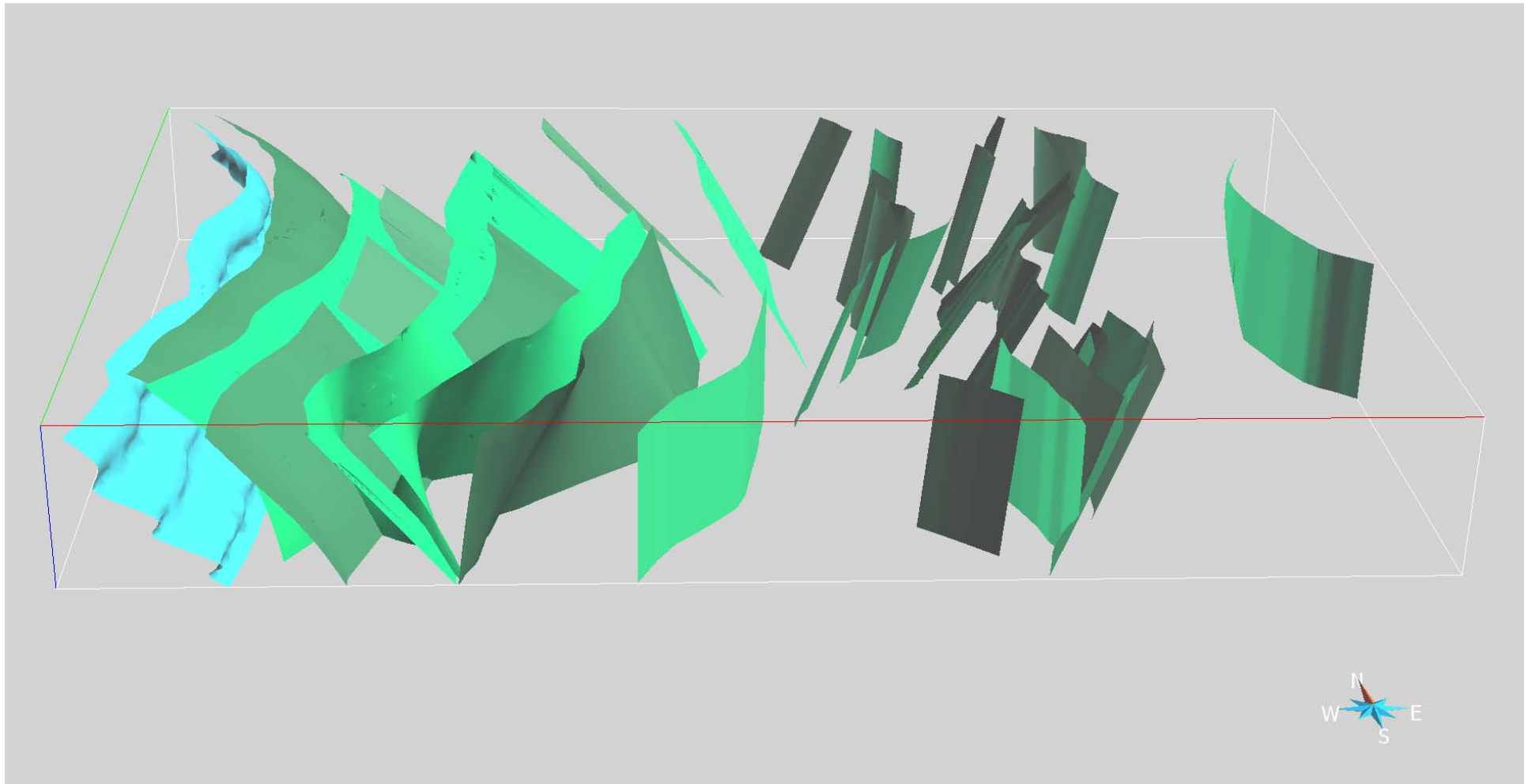


**Easterly dipping surfaces  
representing semi-pervasive  
ductile shear foliation, ('3D  
form lines'), 0.97 Ga.**



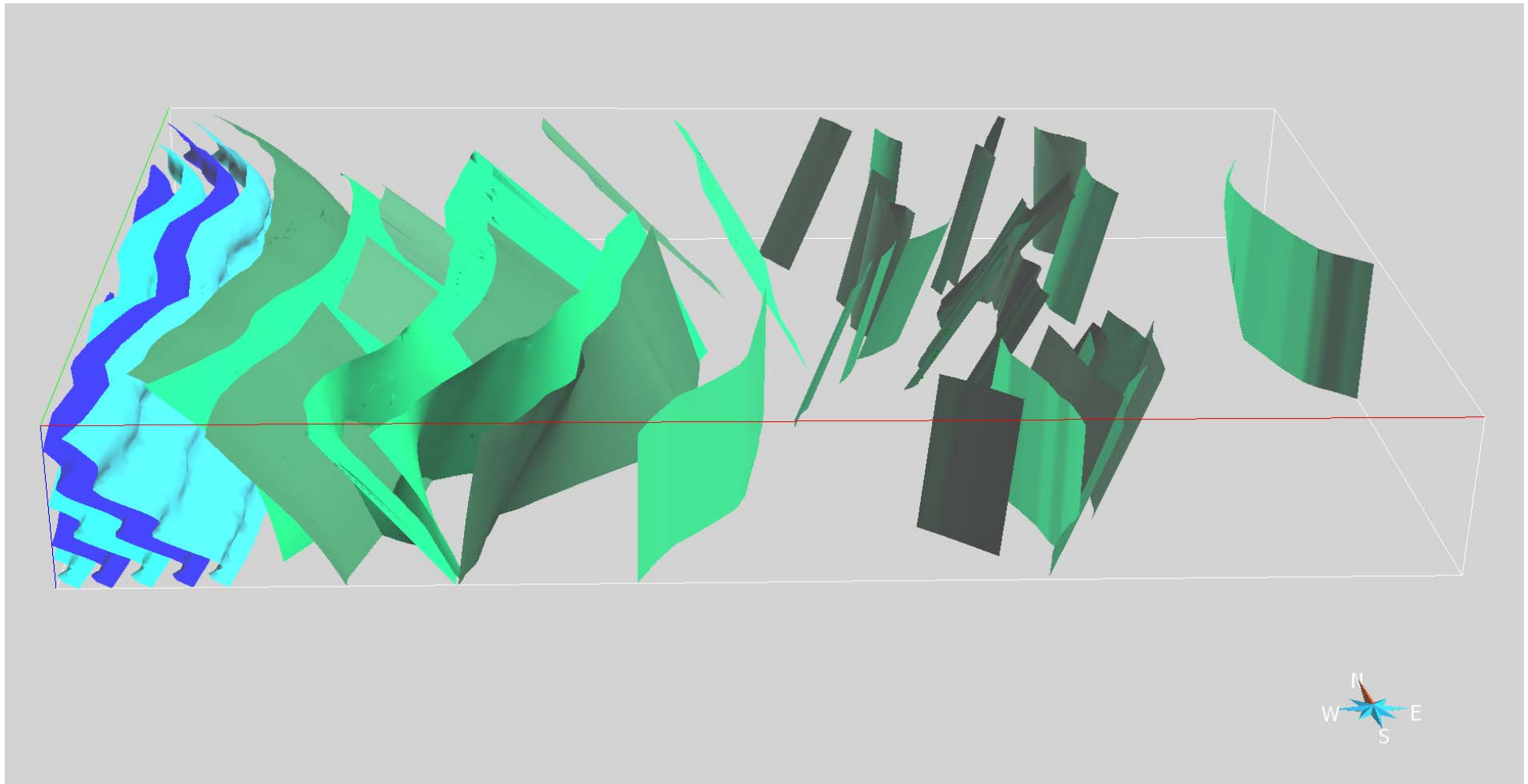


**Vertical to westerly  
dipping discrete ductile  
shear zones, 0.97 Ga.**

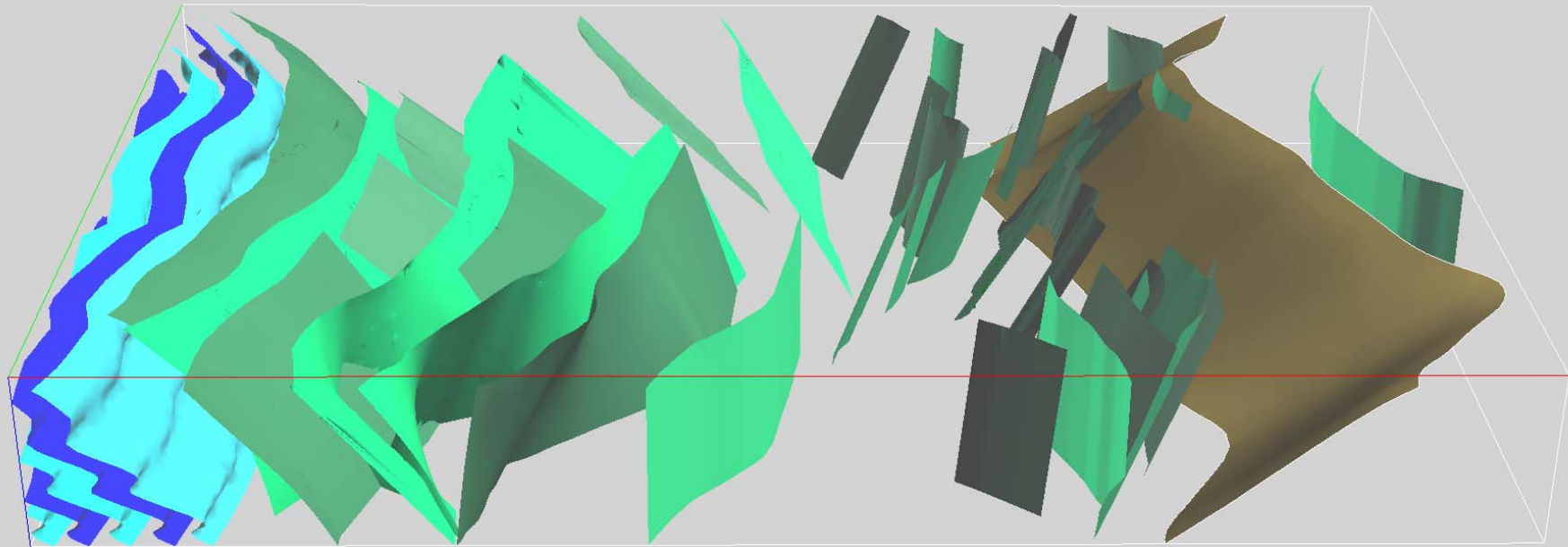


**Metamorphic domain boundary, 0.97 Ga  
-approximate easterly limit of pervasive ductile  
deformation. Marks the boundary between the middle  
and upper units in the Eastern Segment of the  
Sveconorwegian orogen (Bergman et al. 2012: SGU K 423).**



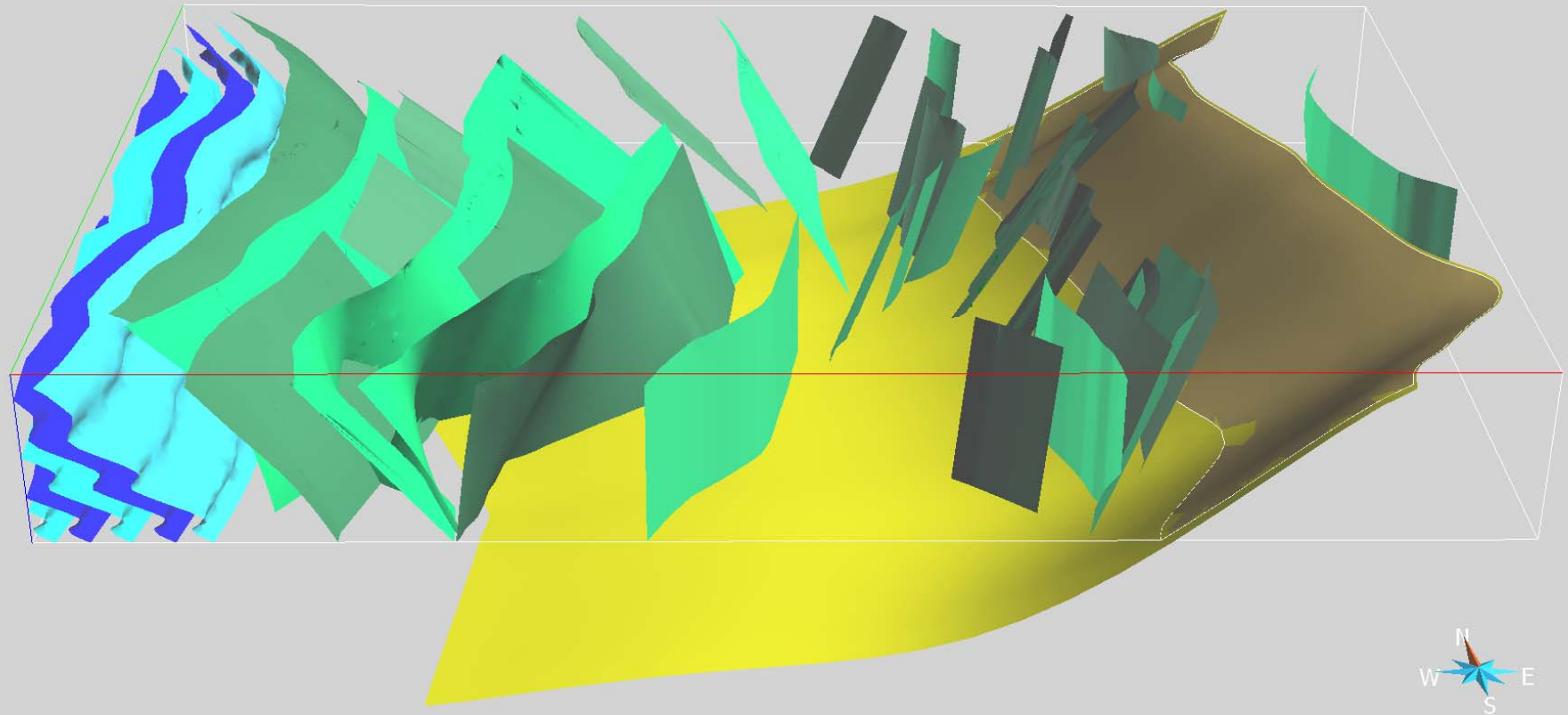


**Easterly dipping surfaces  
representing pervasive ductile shear  
foliation, ('3D form lines'), 0.97 Ga.**

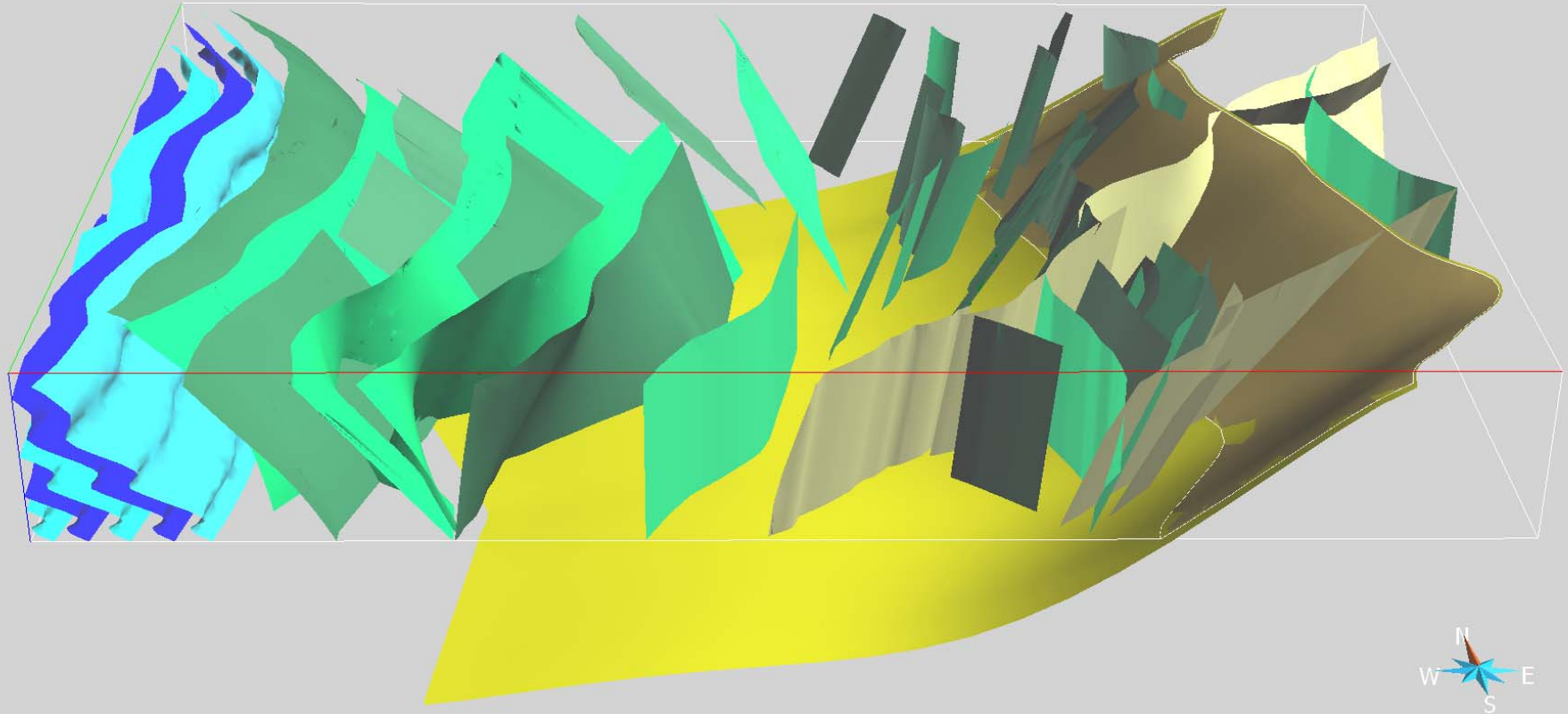


**Sveconorwegian frontal  
deformation zone (SFDZ), 0.93 Ga.  
The eastern boundary of the  
Sveconorwegian orogen.**





**Sveconorwegian frontal deformation zone (SFDZ), 0.93 Ga. ), with inferred listric extension.**

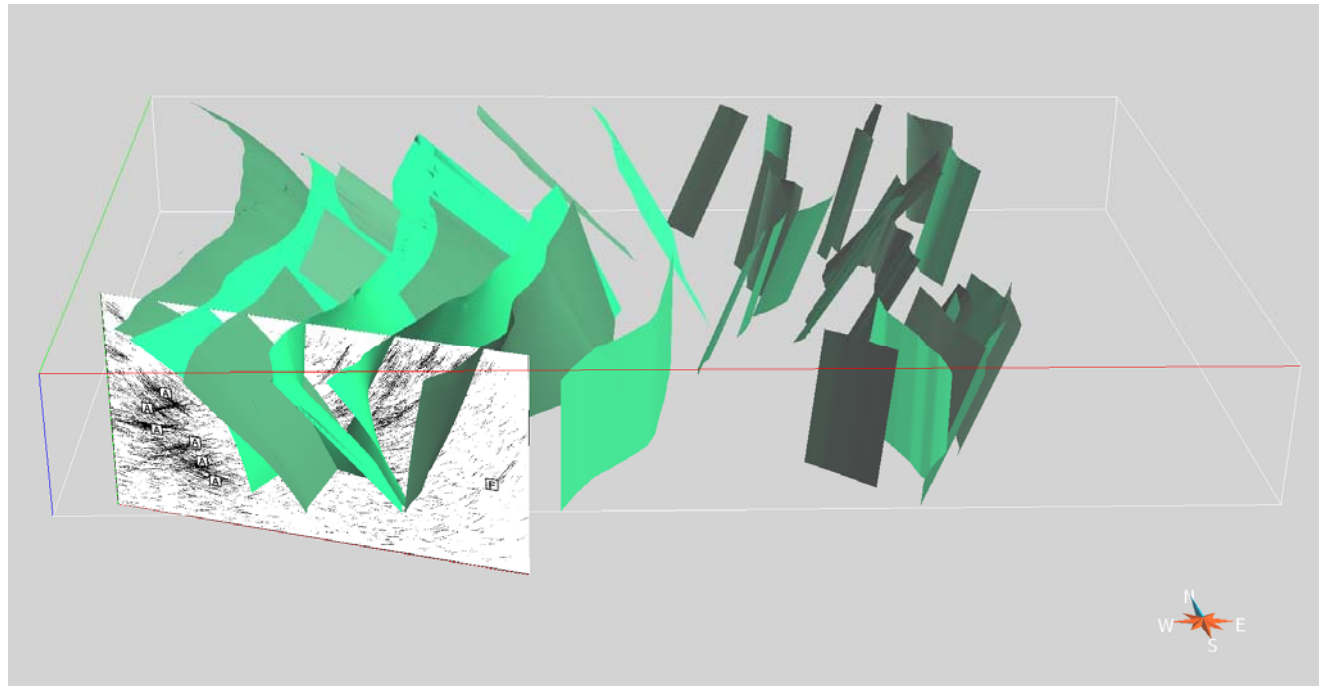


Increasing crustal depth exposed

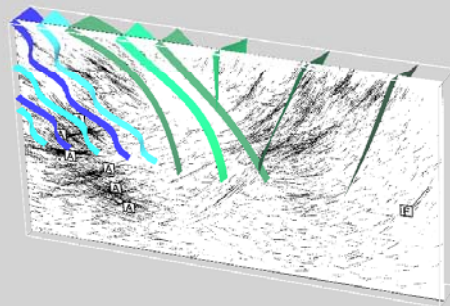


**Sveconorwegian frontal deformation zone (SFDZ), with associated discrete low-grade ductile to brittle-ductile shear zones, 0.92 Ga.  
*≈ End of ductile deformation ≈***

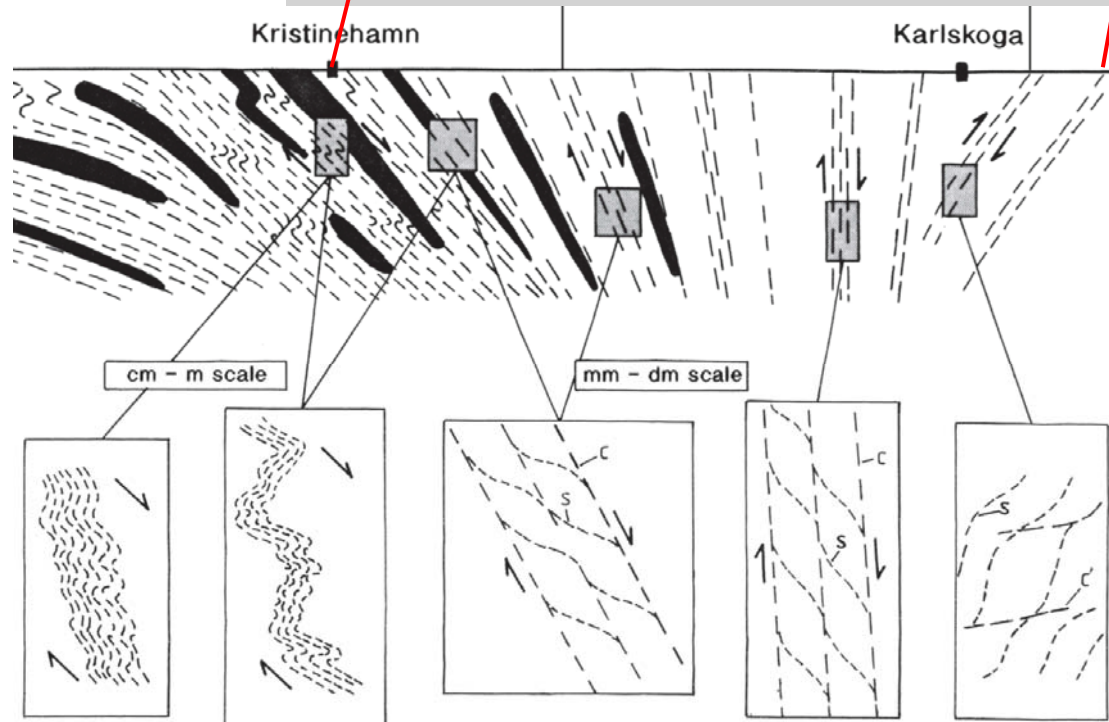
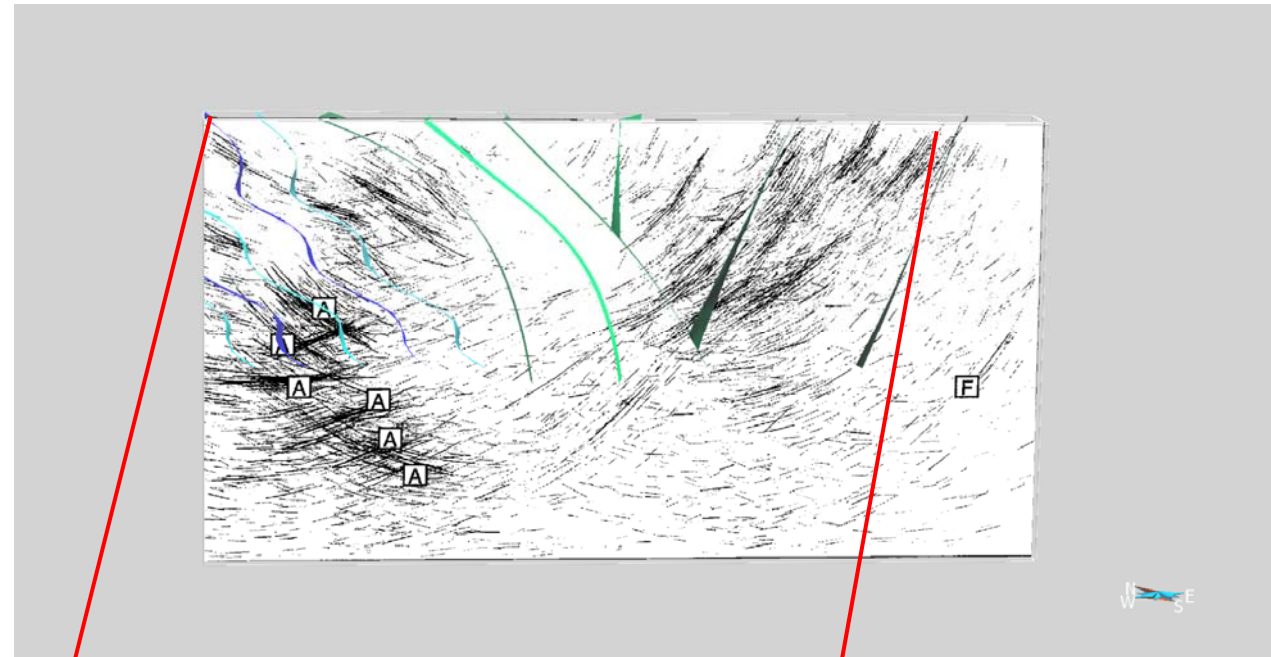




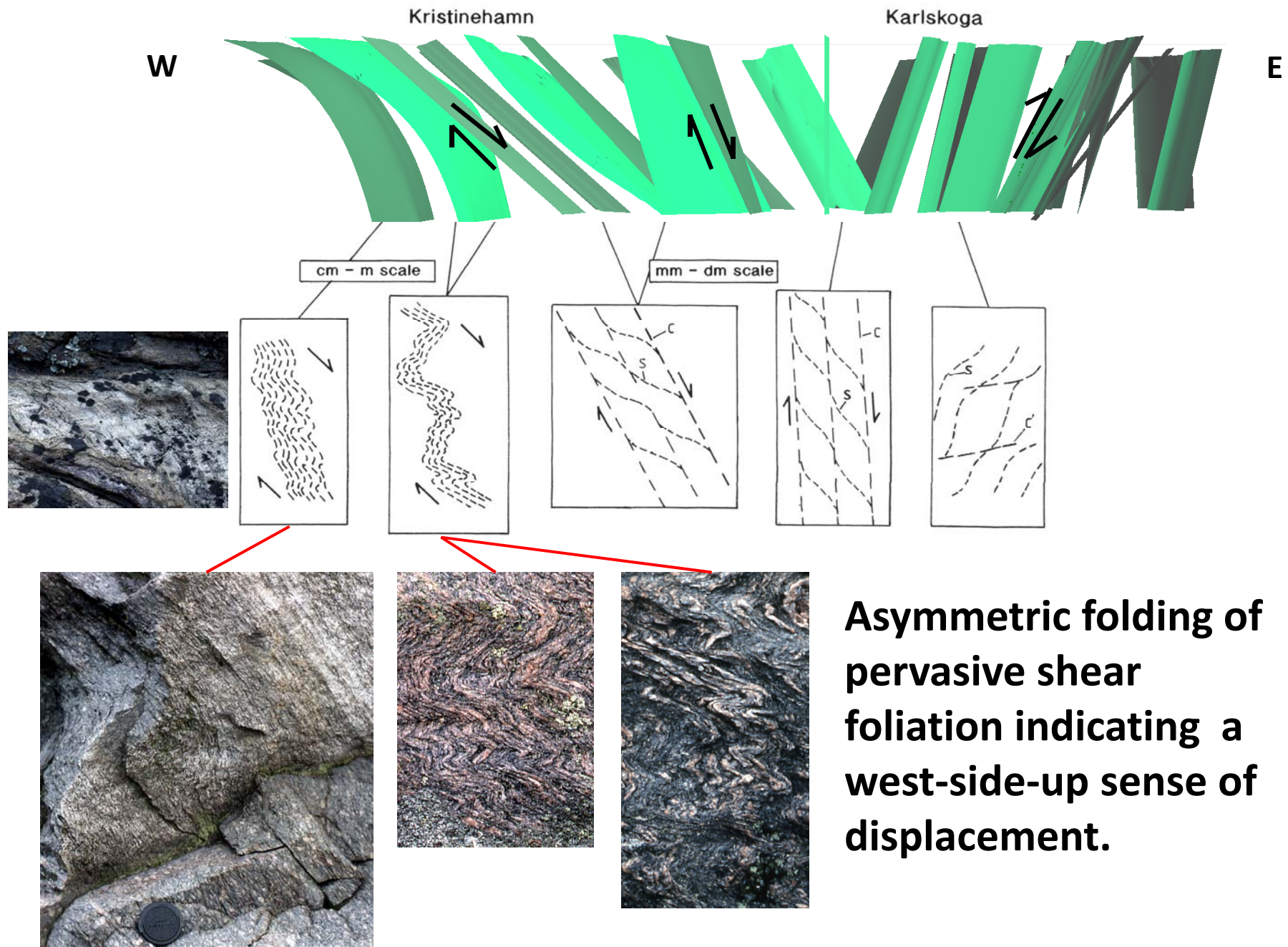
## Seismic reflection profile (Juhlin et al. 2000)



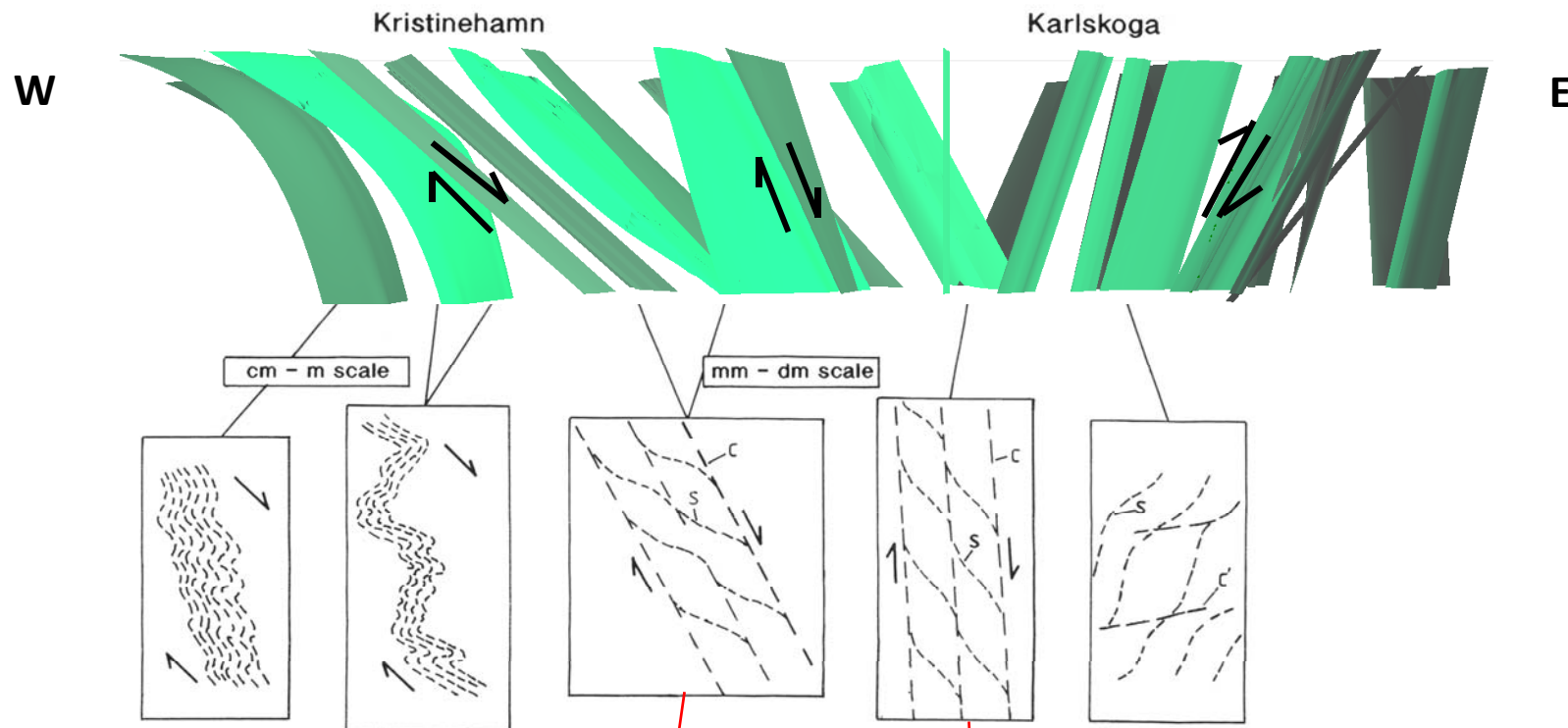
**Seismic  
reflection  
profile (Juhlin  
et al. 2000)**



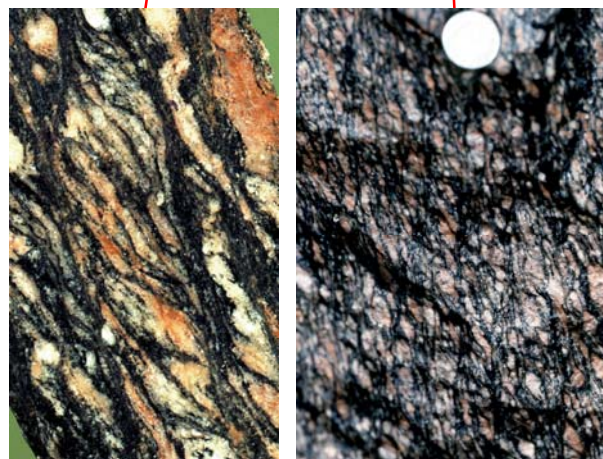
**Schematic cross-  
section  
(Wahlgren et al.  
1994)**

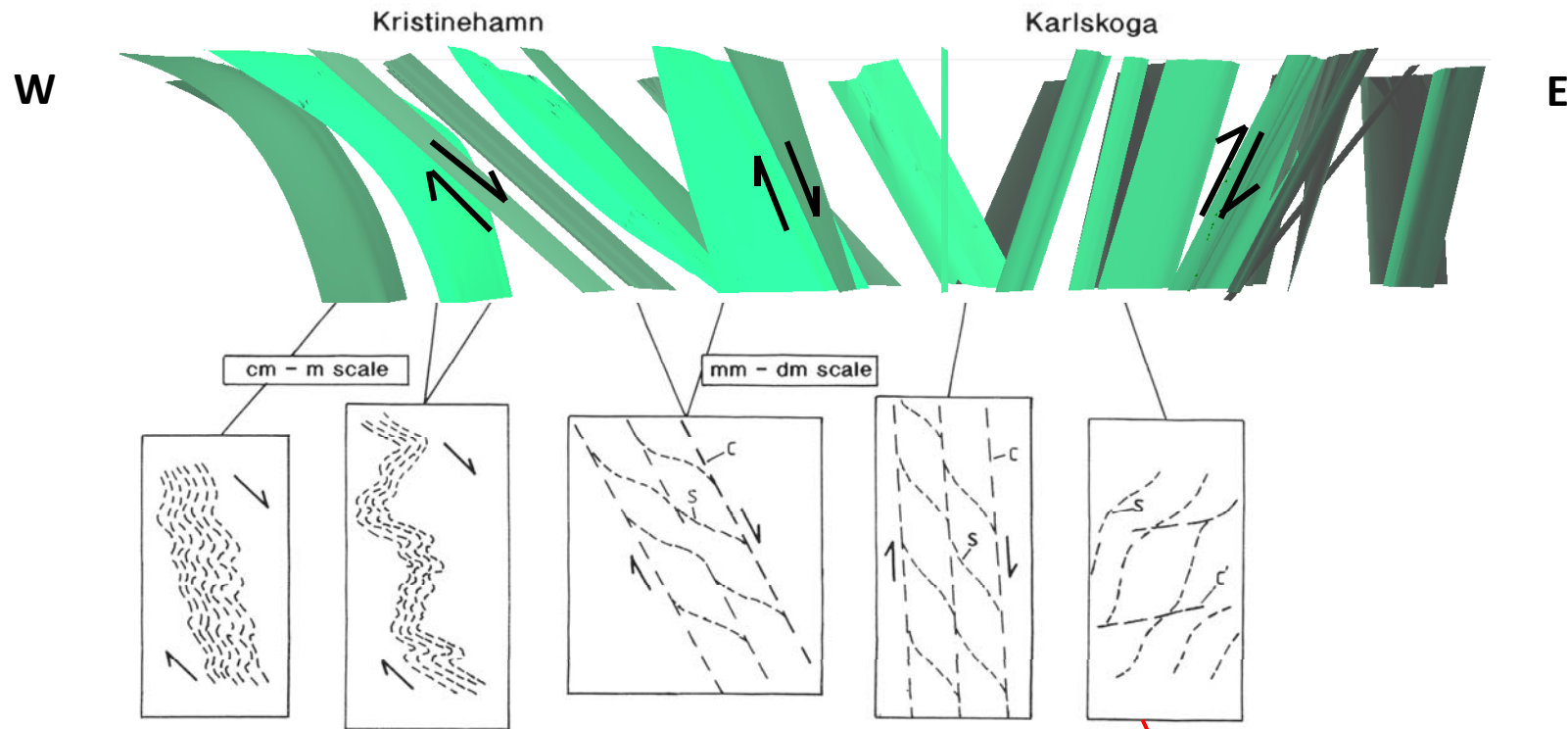






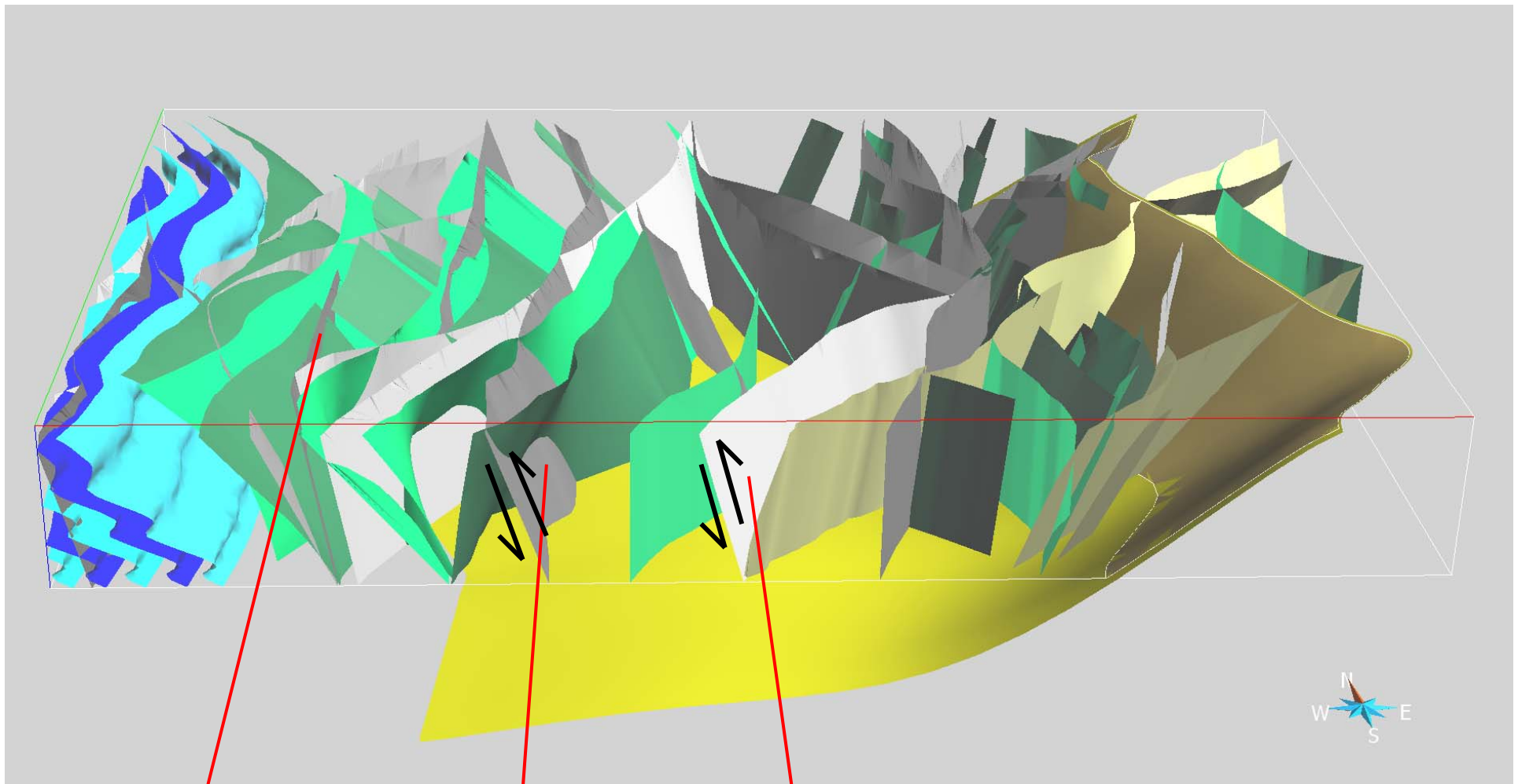
**C/S fabric  
indicating west-  
side-up sense of  
displacement.**





**Shear band  
cleavage (C'/S)  
indicating a west-  
side-up sense of  
displacement.**

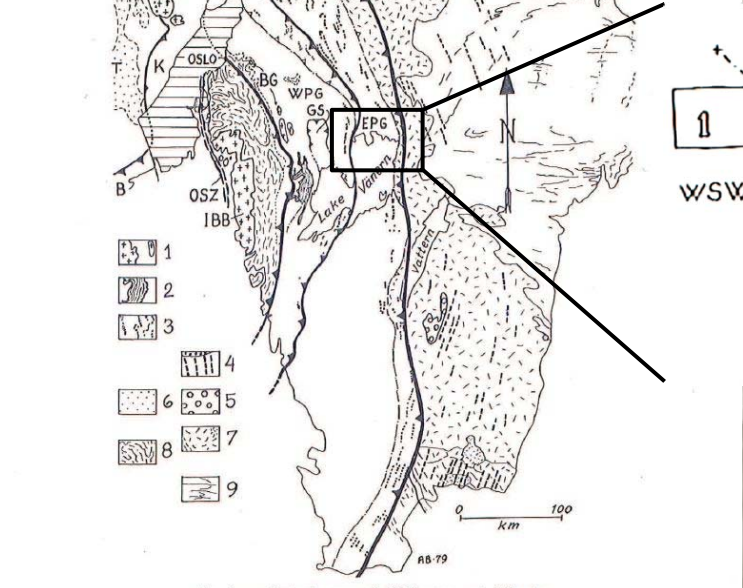




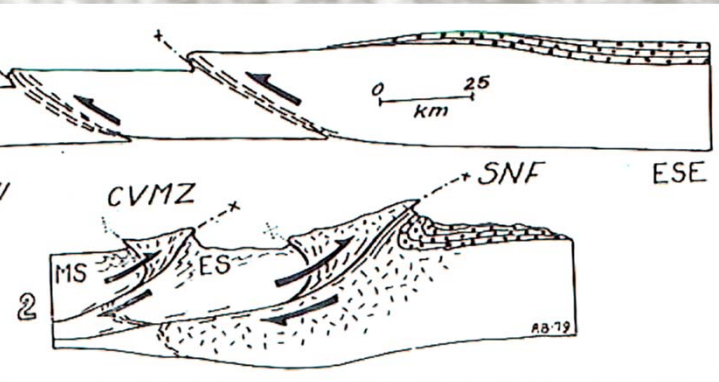
**Brittle deformation zones (faults), post-Sveconorwegian (< 0.92 Ga) with later reactivation during the Phanerozoic (later than 0.54 Ga).**



# Previous tectonic interpretation of the frontal part of the Sveconorwegian orogen



1, Postkinematic granites (BBF-F; Bohus-lunde-fjord-fla belt; BG: Blomskog belt). — 2, Dal Group. — 3, Metamorphosed and deformed late-Ionian basic rocks. — 4, Late-Ionian basic dykes and effusives. — 5, Jonian sandstone. — 6, Telemark supracrustals (T), mainly quartzites. — 7, c. 1660-1600 Ma old intrusives, volcanics and associated supracrustals (i.e. "Gothian" and Sub-Jonian). — 8, Stora Le Mastrand series. — 9, Svecofennian interference patterns. — EPG, "Eastern Pregothian" — WPG, "Western Pregothian" — GS, Gillsbergare syneform. OSZ, Oslo fjord shear zone. — B, Bamle region. — K, Kongsberg region.



**Figures from Berthelsen  
(1980) (not photograph!)**





# Input data for modelling

Publications concerning the geological development in the area:

- Berthelsen 1980: Towards a palinspastic tectonic analysis of the Baltic Shield. *In* Geology of Europe from Precambrian to Post-Hercynian Sedimentary Basins. International Geological Congress Colloquim C6, Paris
- Andersson, Larsson & Wikström 1992: Charnockites, pyroxene granulites and garnet-cordierite gneisses at a boundary between Early Svecofennian rocks and Småland-Värmland granitoids, Karlskoga, southern Sweden. GFF 114.
- Stephens, Wahlgren & Annertz 1993: U-Pb zircon dates in two younger suites of Palaeoproterozoic intrusions, Karlskoga area, south-central Sweden. SGU serie C 823.
- Wahlgren, Cruden & Stephens, 1994: Kinematics of a major fan-like structure in the eastern part of the Sveconorwegian orogen, Baltic Shield, south-central Sweden. Precambrian Research 70.
- Wahlgren, Heaman, Kamo & Ingvald, 1996: U-Pb baddeleyite dating of dolerite dykes in the eastern part of the Sveconorwegian orogen, south-central Sweden. Precambrian Research 79.
- Page, Stephens & Wahlgren, 1996:  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology in the Eastern Segment of the Sveconorwegian Orogen, south-central Sweden. Special pub. 112, Geol. Soc. London
- Söderlund, Jarl, Persson, Stephens & Wahlgren, 1999: Protolith ages and timing of deformation in the eastern, marginal part of the Sveconorwegian orogen, southwestern Sweden. Precambrian Research 94.
- Juhlin, Wahlgren & Stephens, 2000: Seismic imaging in the frontal part of the Sveconorwegian orogen, south-western Sweden. Precambrian Research 102.
- Wahlgren & Stephens 2000: Structural and geochronological evolution of the northeastern part of the Sveconorwegian orogen, south-central Sweden. Bulletin of the Geological Society of Denmark 46.



# Input data for modelling

**Publications concerning the geological development in the area:**

**1:50 000 bedrock map series**

- **Wikström 1991: Bedrock map 10E Karlskoga SO, SGU Af 183**
- **Wahlgren 1992: Bedrock map 10E Karlskoga NV, SGU Af 176**
- **Wahlgren 1993: Bedrock map 10E Karlskoga SV, SGU Af 182**
- **Stephens 1998: Bedrock map 10E Karlskoga NO, SGU Af 184**





**Dynamic section through the model**



**Entire model including rock domains,  
ductile deformation zones and faults**