

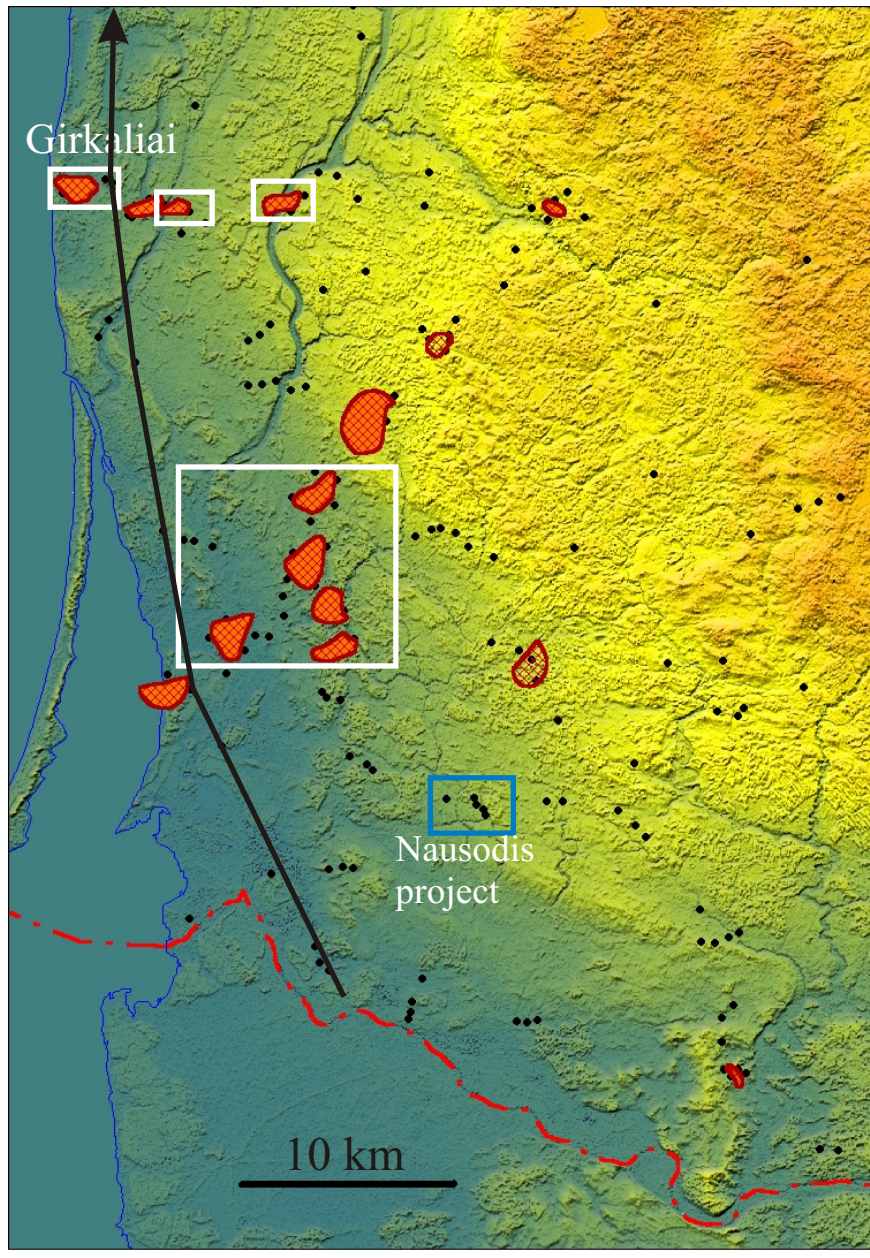
Application of oil exploration 3D seismic data for imaging potential HDR systems in Lithuania

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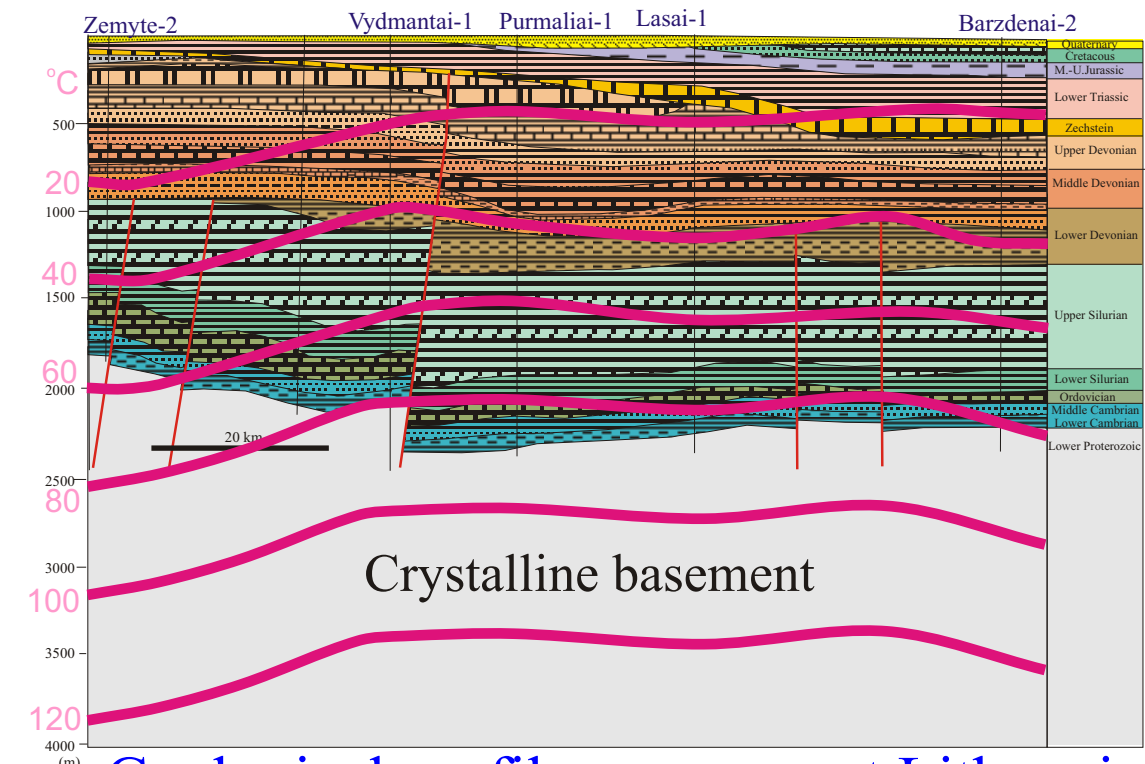
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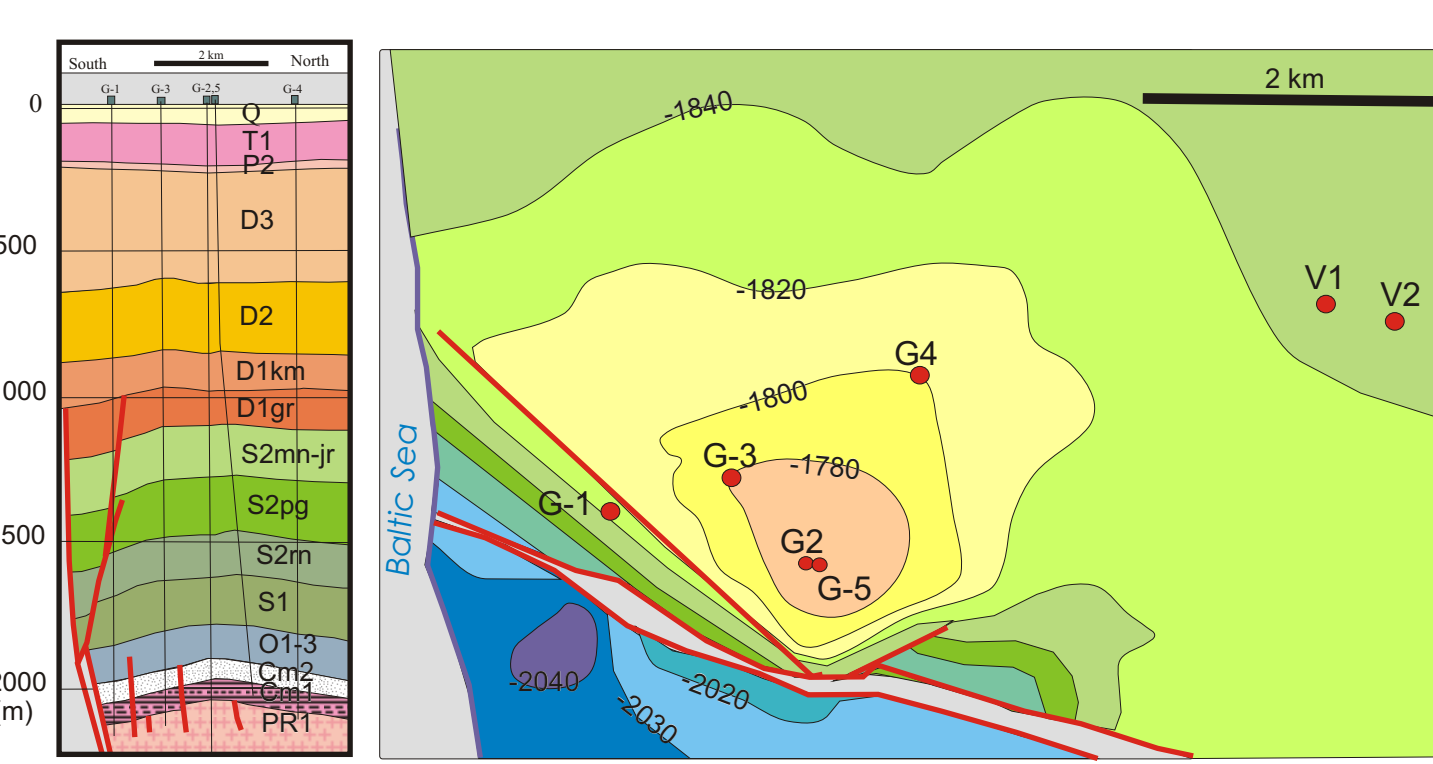
Seismic data acquisition, Girkaliai area



3D seismic survey areas (oil fields and exploration wells)



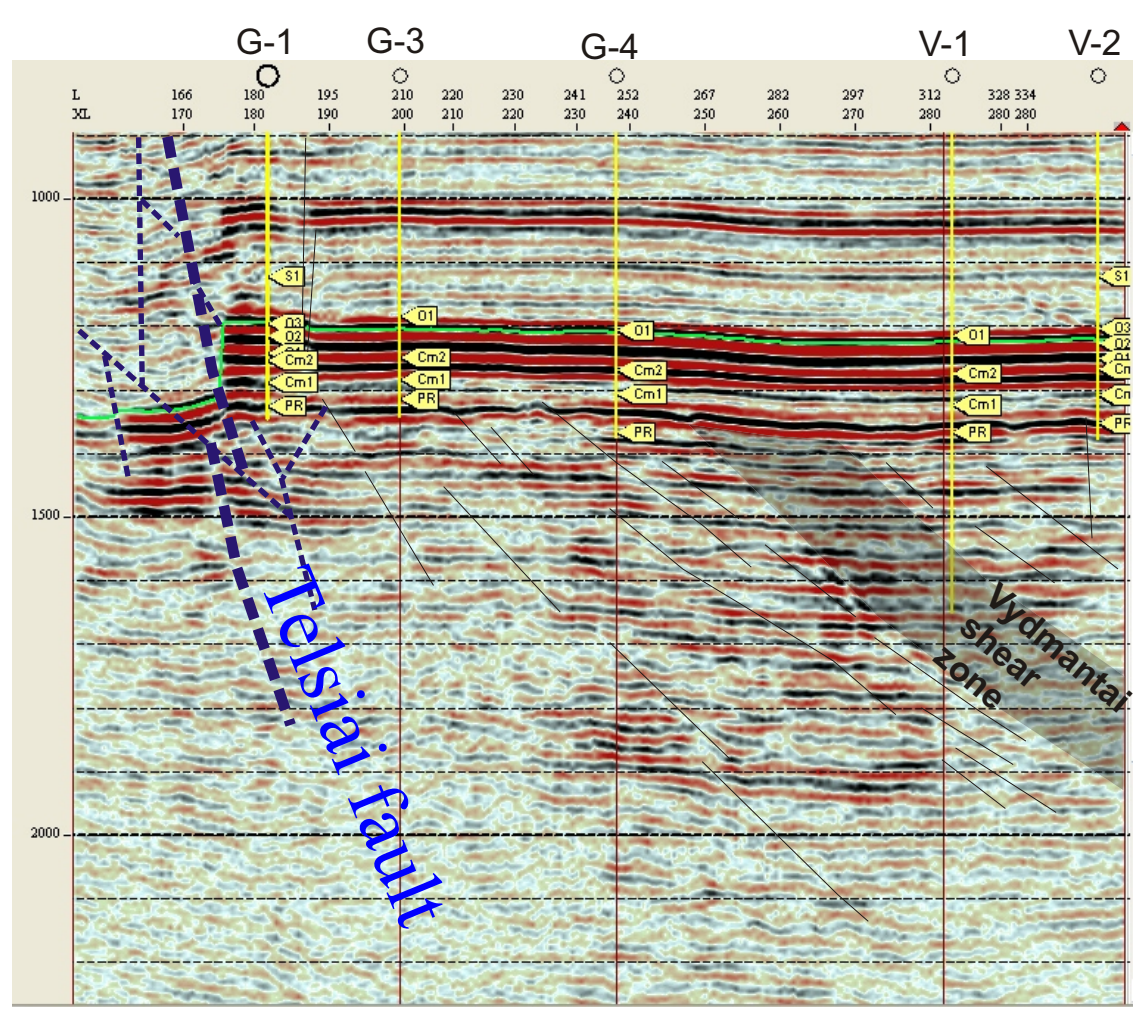
Geological profile across west Lithuania. Temperature distribution is indicated. Seismic line is shown on the left figure.



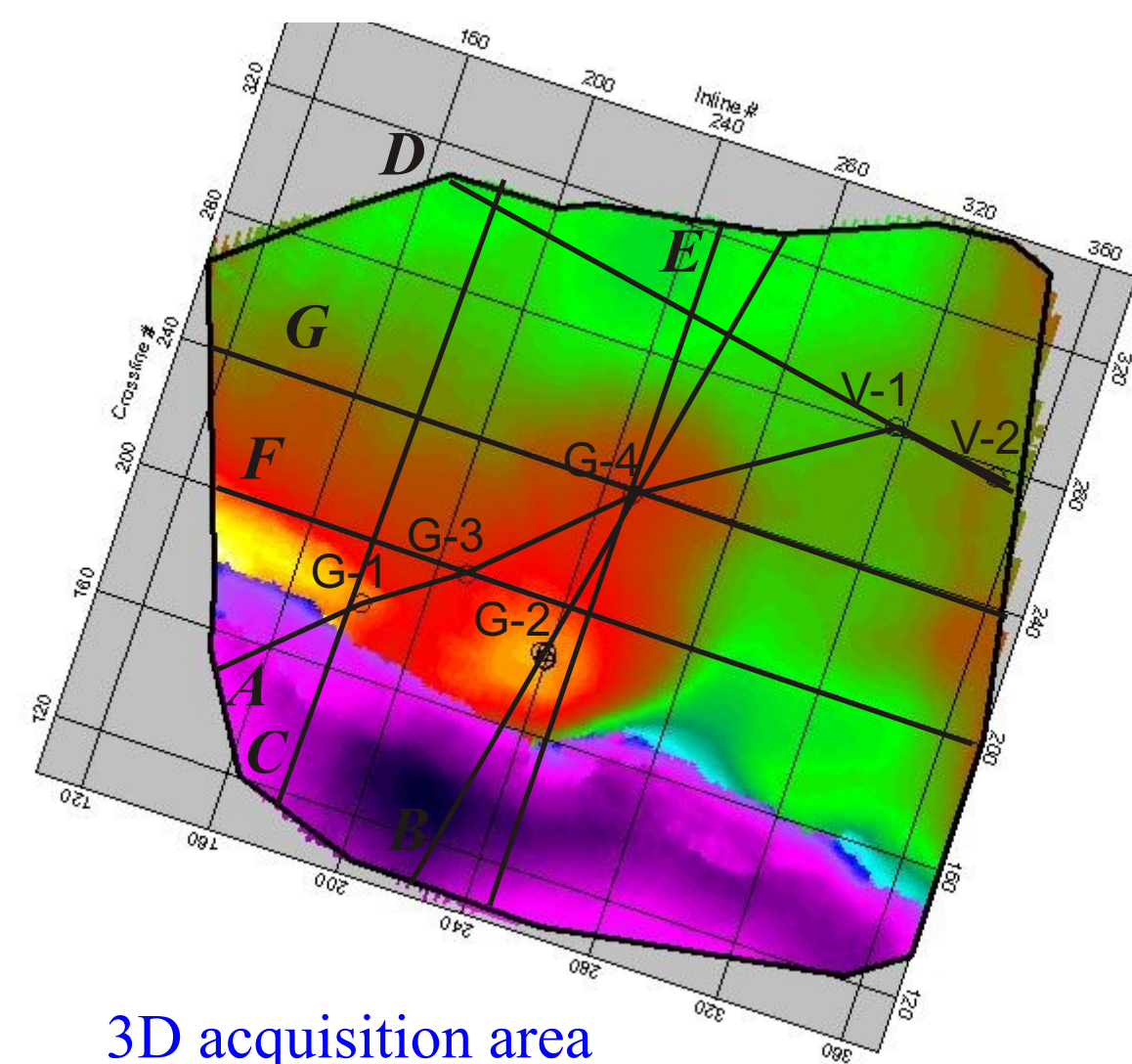
Geological profile and structural map of top of Cambrian of Girkaliai area

3D seismic exploration was performed in a number of areas in west Lithuania to better understand the architecture of the oil fields in Cambrian reservoir. They show rather good penetration into the underlying basement. The 3D seismic data of the Girkaliai area was provided by AB Geonafita to assess the possibility of application of industrial seismic data for imaging potential HDR systems related to the crystalline basement. These data are supplemented by drill cores from four exploration wells drilled into the basement for 10-350 m. Furthermore, the 3D seismic area also covers the Vydmantai geothermal area, where two deep wells were drilled to the basement more than dozen years ago for utilization of the Cambrian and basement geothermal sources (conserved).

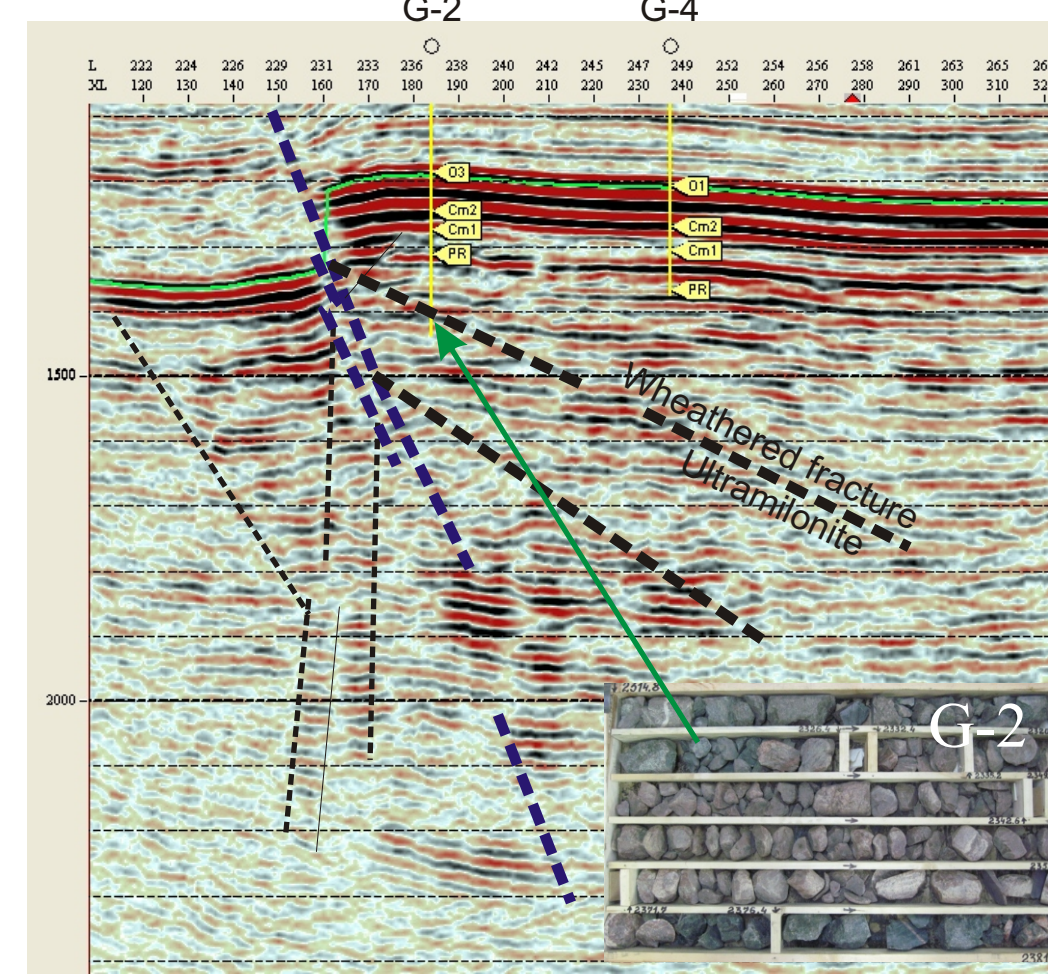
The crystalline basement of Lithuania is composed of high-grade metamorphic and igneous rocks of the Palaeoproterozoic age. Two major domains are defined i.e. the West Lithuanian Granulite Domain and East Lithuanian Domain. The former is characterized by high heat flow attaining 80-90 mW/m². The concept of HDR can be a prospective option in west Lithuania. The exploration of the HDR systems is difficult though, owing to thick sediment package (~2 km) covering the basement. The basal part of the sedimentary cover is represented by the Cambrian sandstones and shales that compose the major petroleum play in the Baltic basin. It directly overlies the basement rocks. A few hundred exploration wells were drilled into the basement. Still, the drill cores are not sufficient to consistently recognise the structural features of the crystalline basement. The geophysical methods should be applied to image the basement rock fabric.



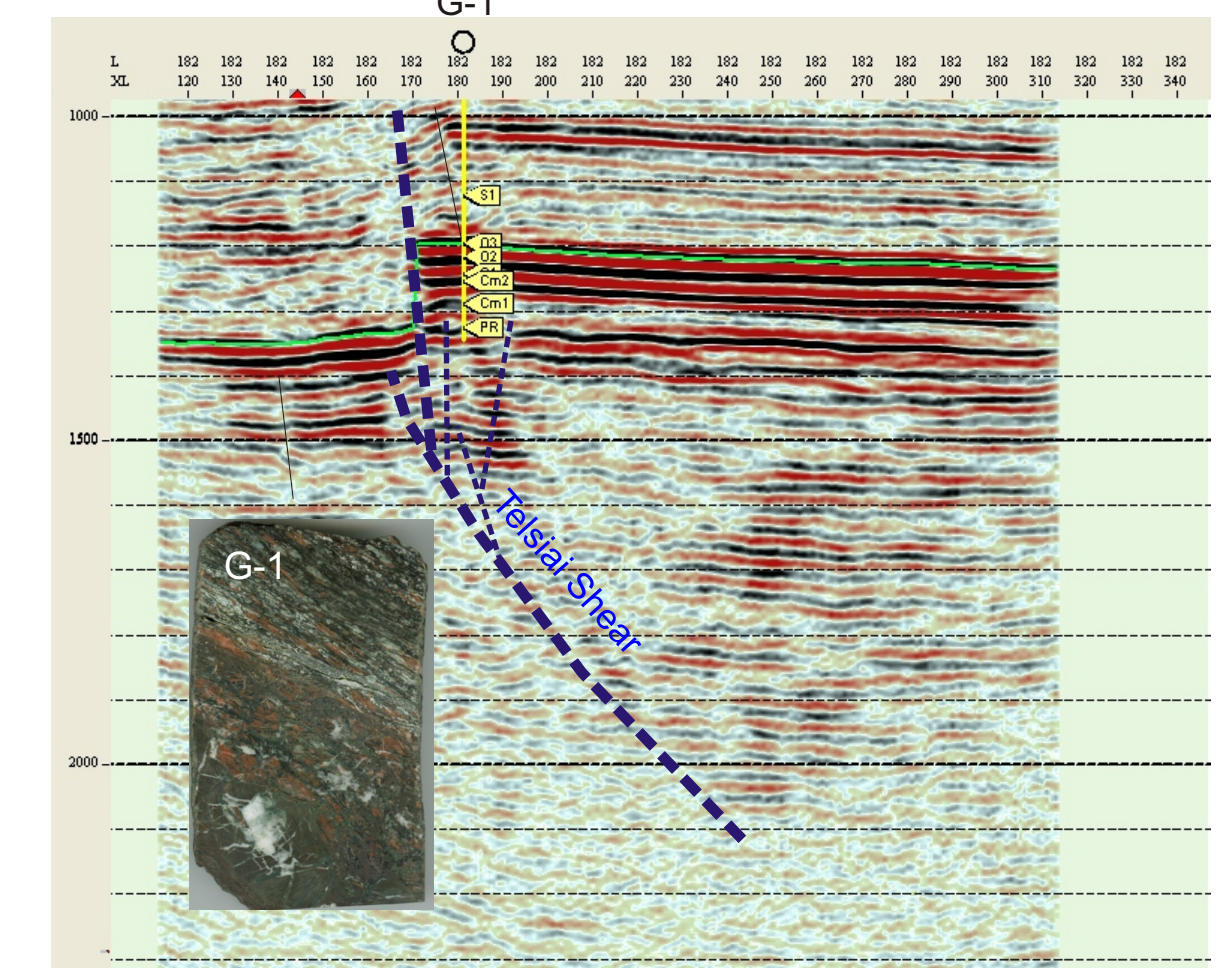
Profile A. The main feature is the Vydmantai shear zone dissected by well V-1. It is represented by fractured cataclites. The paralleling structures induce strong seismic anisotropy in the hosting rocks.



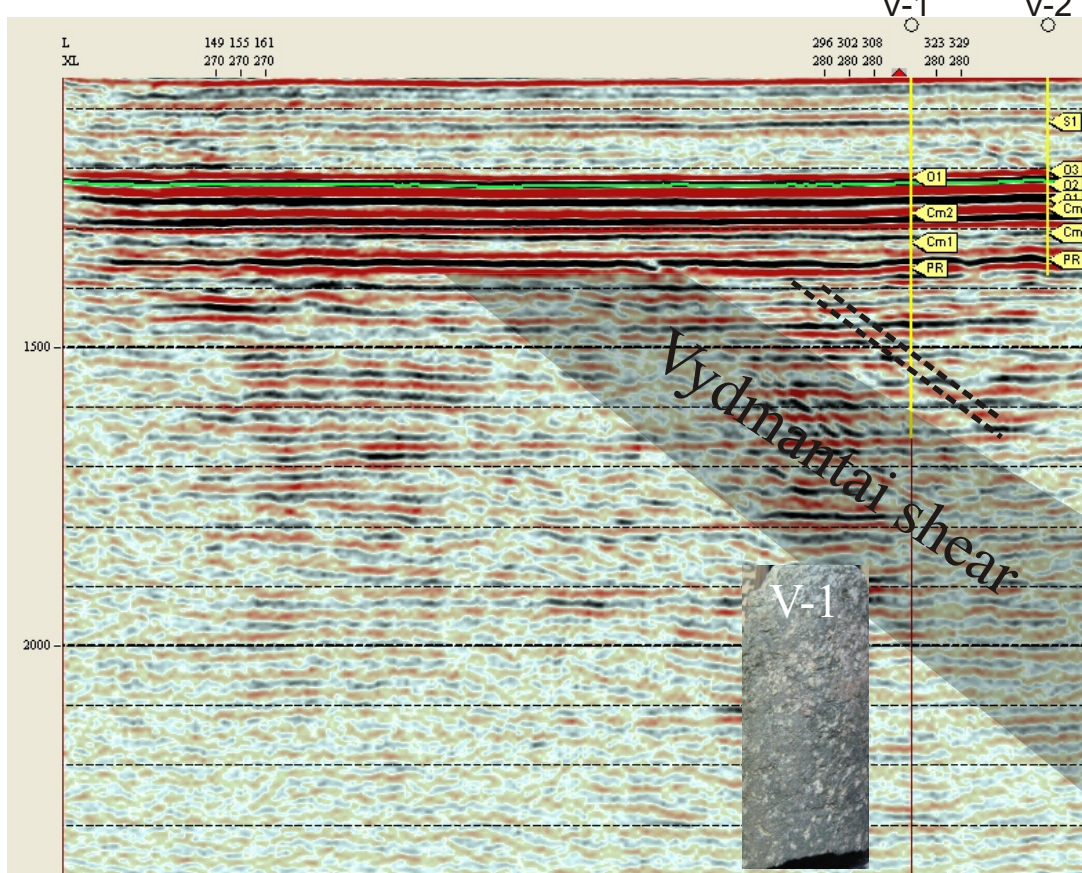
3D acquisition area
Depths of S11n reflector



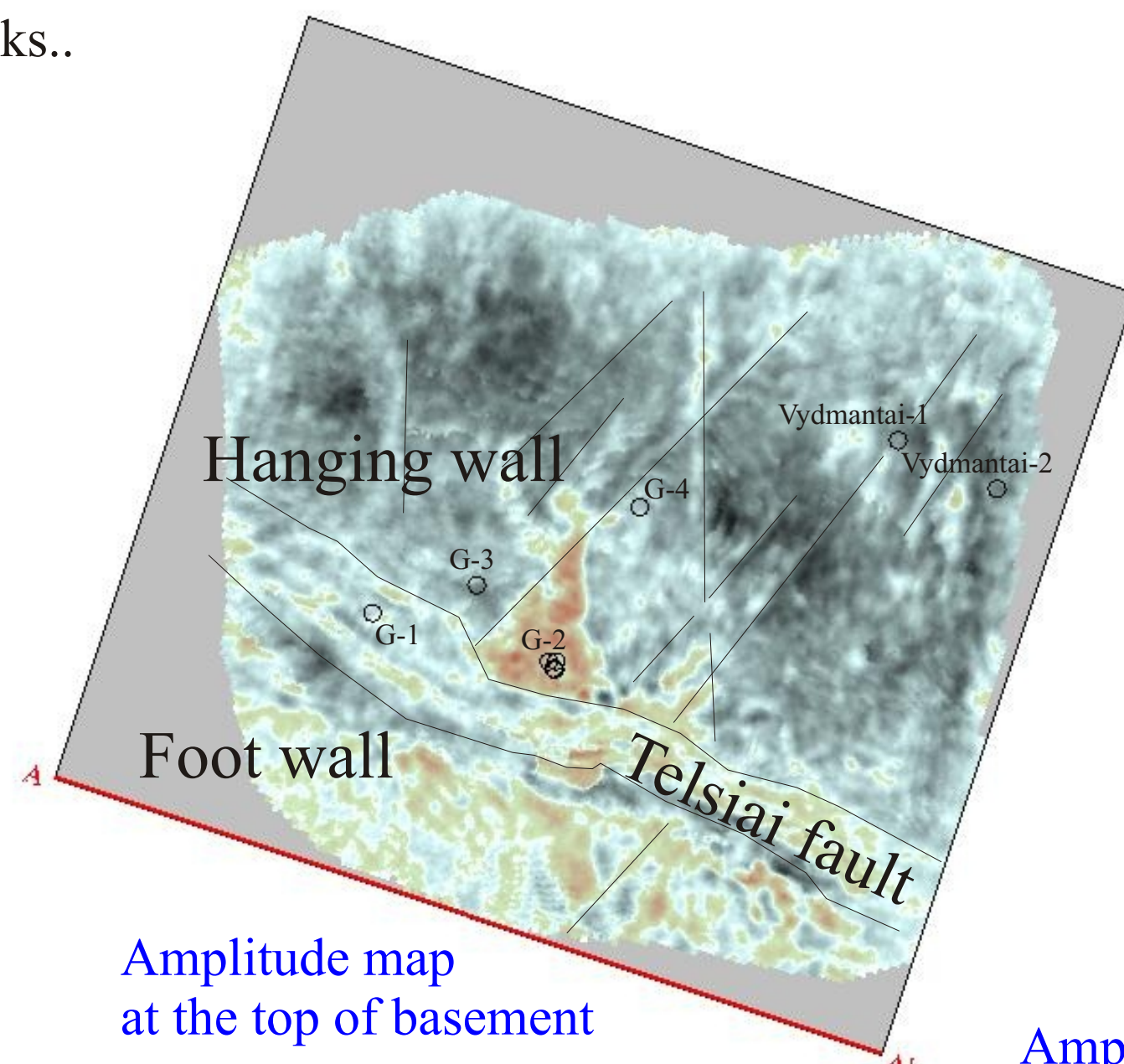
Profile B. Well G-2 crossed strongly fractured ultramylonitic weathered zone at depth 2315 m (photo). It correlates with low angle reflector. A complex geometry of Telsiai fault is seen.



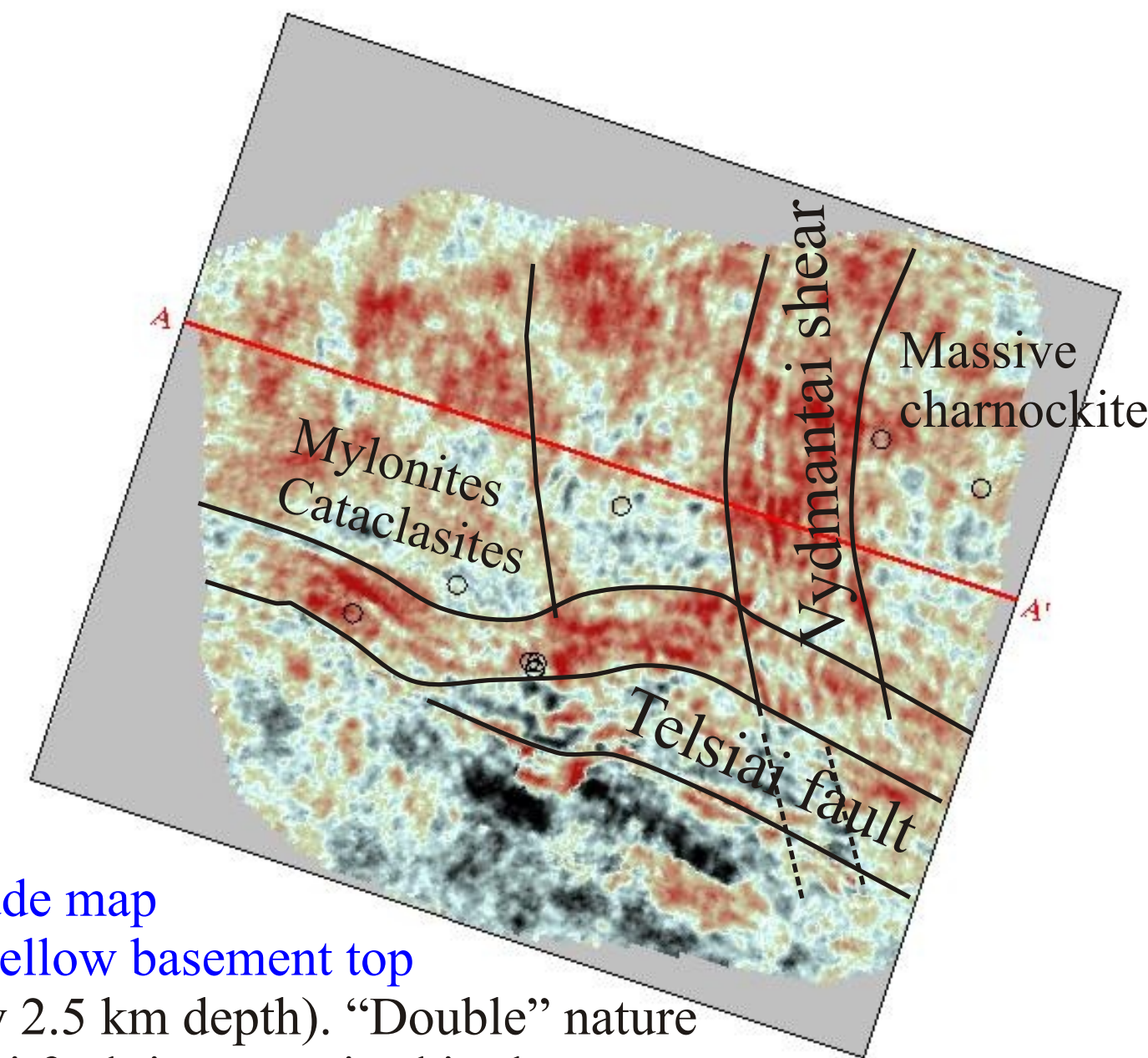
Profile C. Inclined Telsiai fault. Photo shows milonitised granulite. In the lower part the calcite punctuates the tachilite (fault activation during the platform stage)



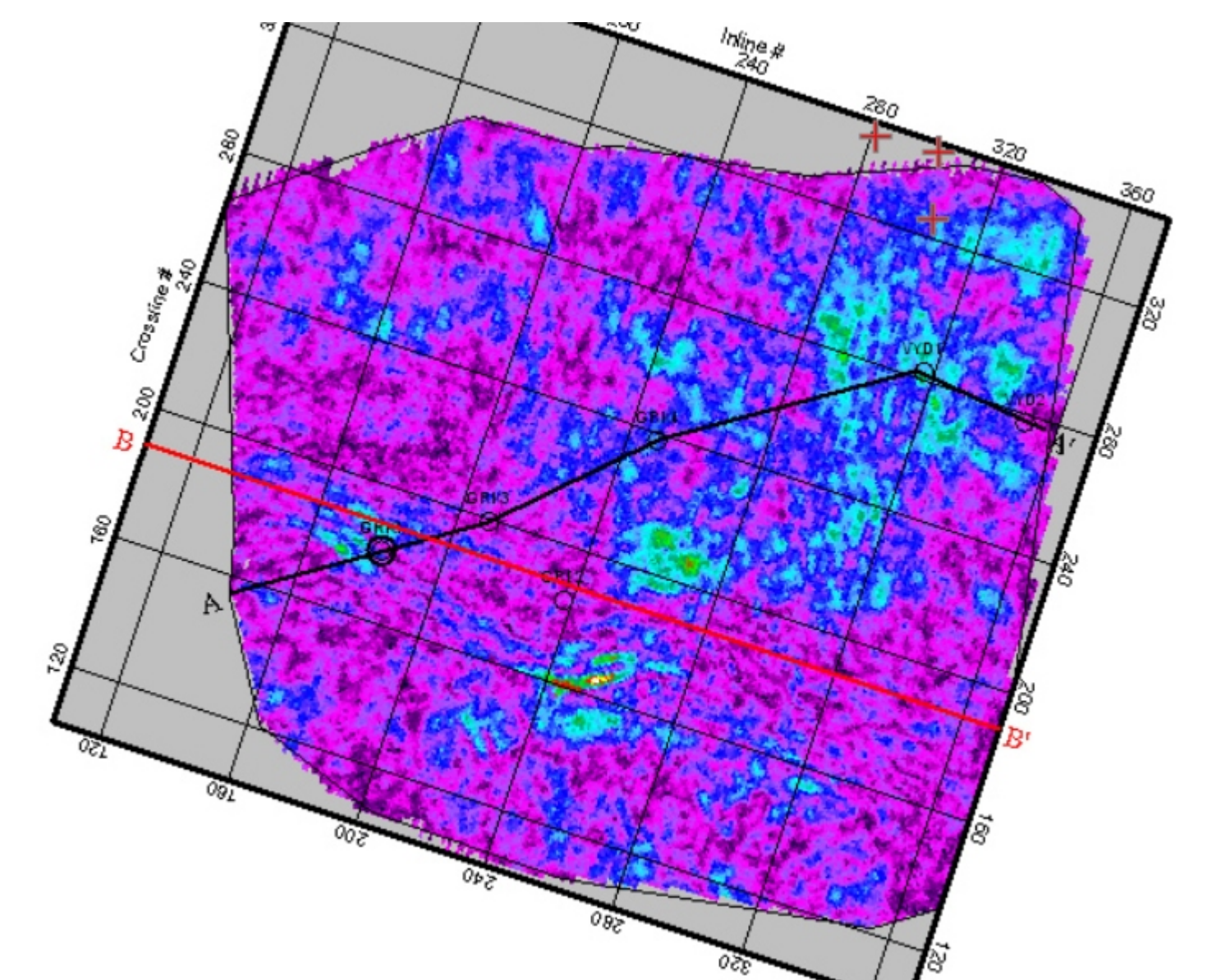
Profile D. Crosses Vydmantai geothermal wells. Vydmantai Shear is identified. Also, some paralleling features are visible that correlate with brecciated zones in well V-1. Photo shows cataclite from Vydmantai Shear.



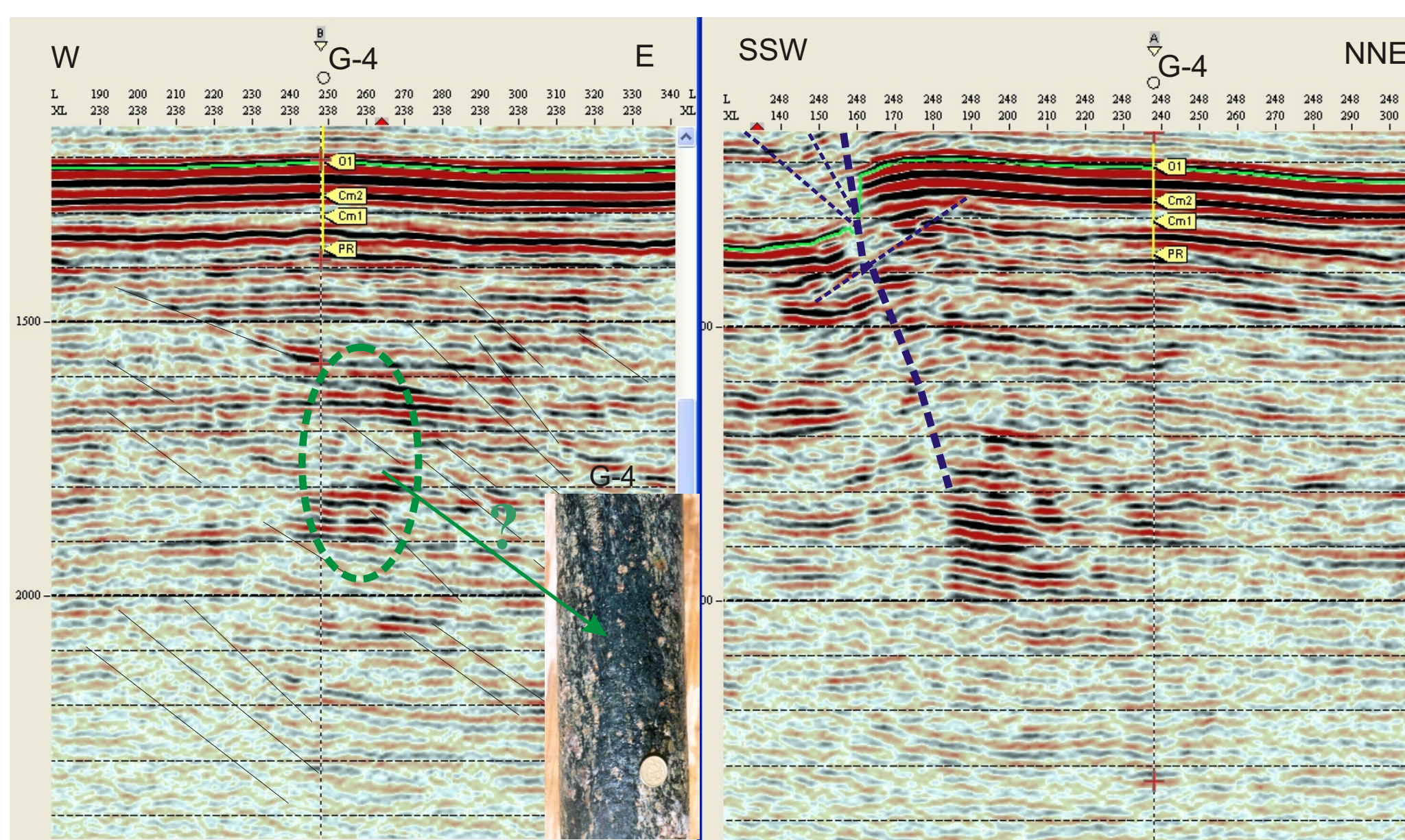
Amplitude map at the top of basement



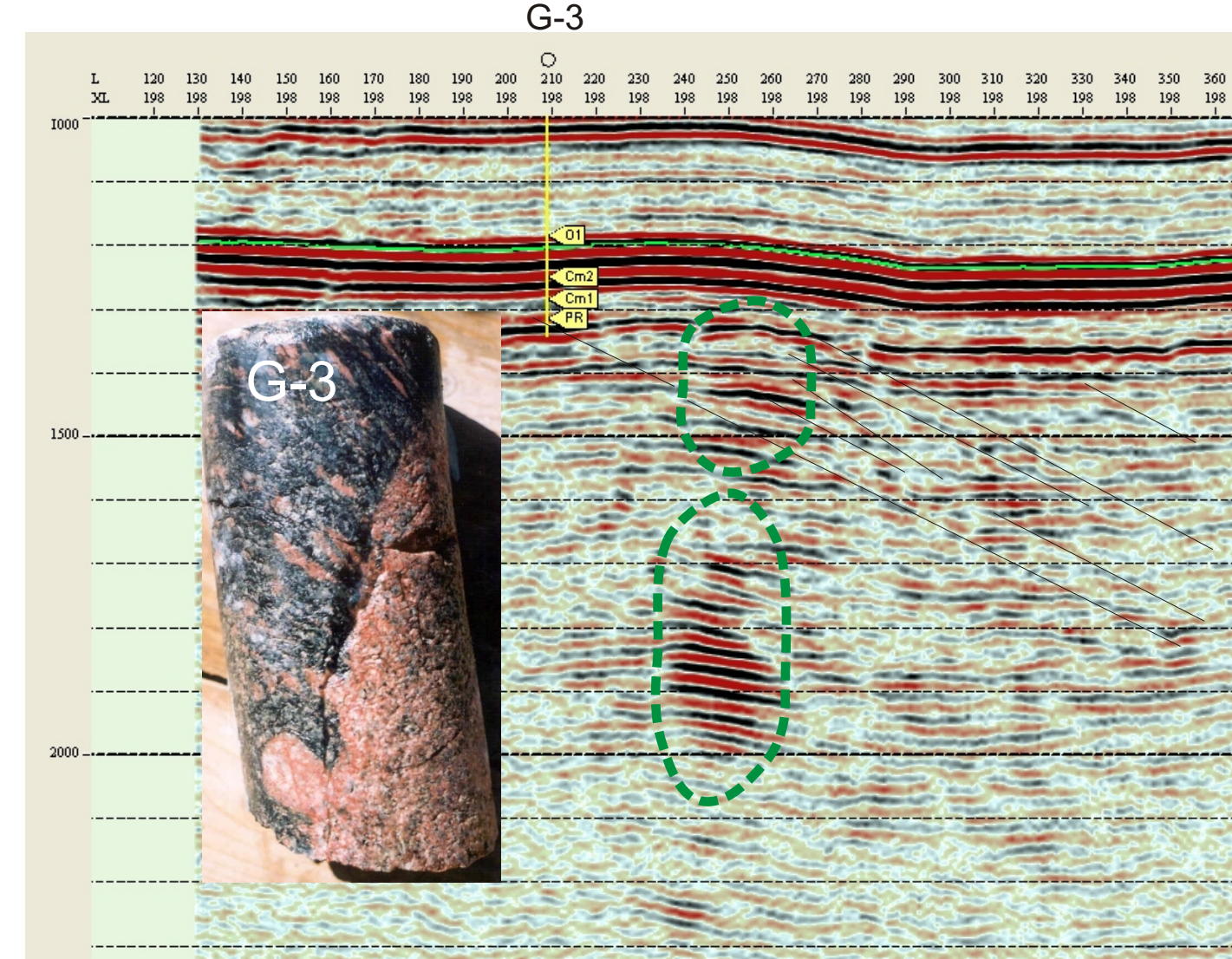
Amplitude map 500 m below basement top (roughly 2.5 km depth). "Double" nature of Telsiai fault is recognised in the east (subvertical and inclined to the north features). Vydmantai shear is clear. Anisotropic fabric is evident to the west.



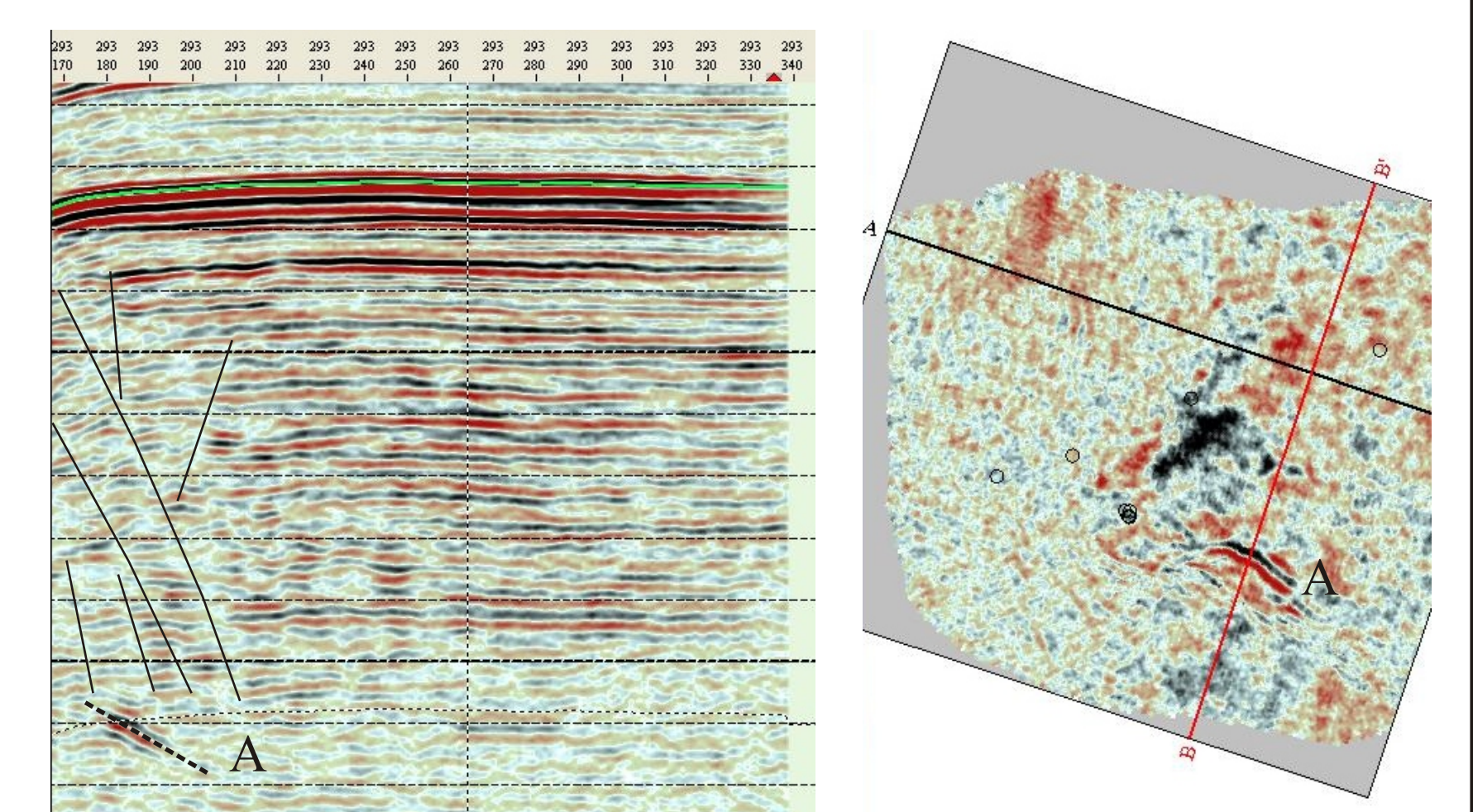
Seismic reflection strength map



Profiles E, G. Crosses well G-4 at two different directions. They reveal reflection anisotropy. A strong reflection body is crossed that is traced from well G-2 to well G-4. Its nature remains uncertain, but those wells show specific high-angle milonitisation and increased fracturing that hints to some milonitic zone.

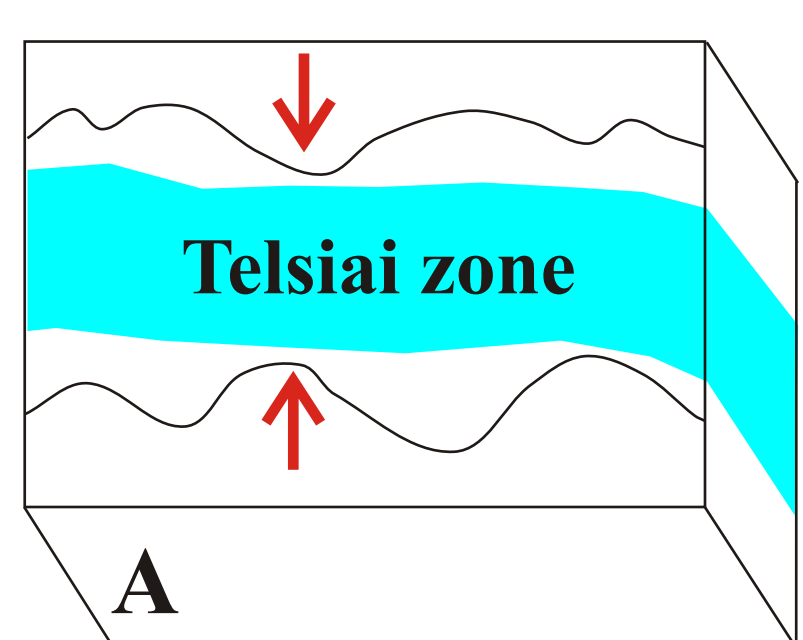


Profile F. Well G-3 penetrated milonites (angle 40°) (photo). Their anisotropic fabric is well seen on the seismic profile. It is cut by later-stage massive granites. To the east of well G3 the strong subvertical reflector mentioned in Prf E, G is clear.

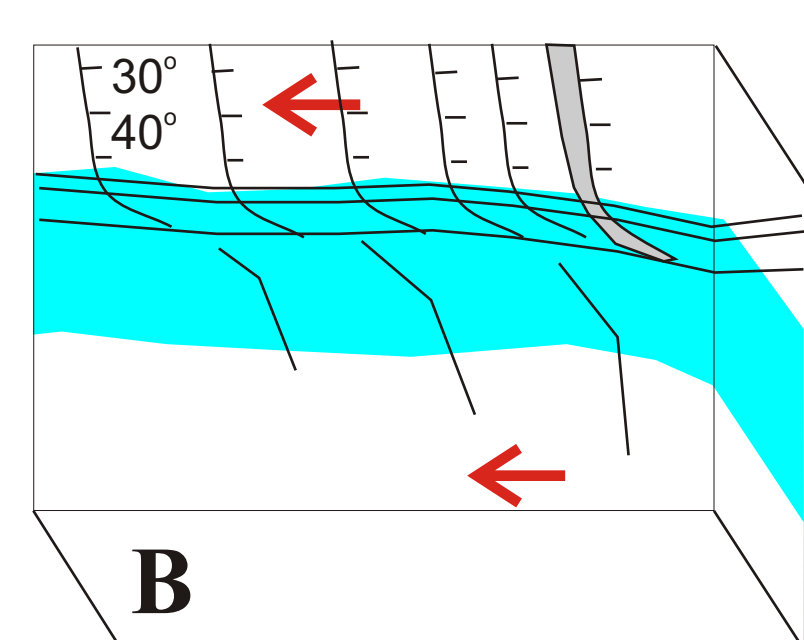


Seismic section and amplitude map, 1.1 km below the basement top. Telsiai fault is well identified. A strong reflector is traced at the depth 3.5 km that has similar features to low-angle zone identified in well G-2.

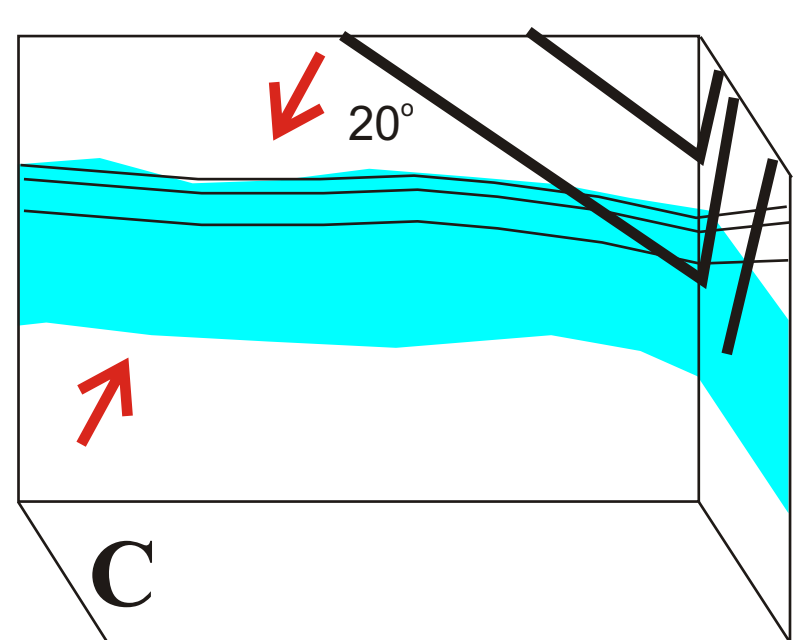
MAJOR STAGE OF STRUCTURING OF GIRKALIAI AREA



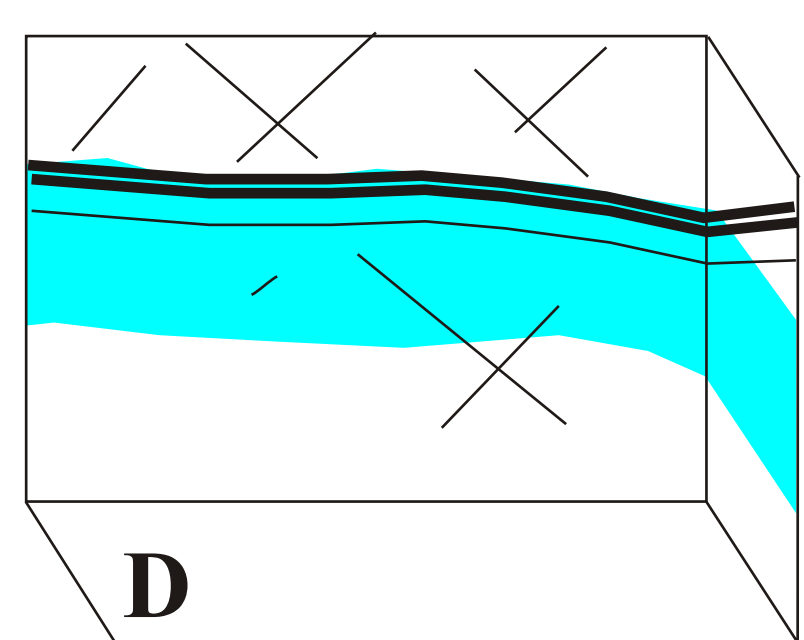
Crustal accretion stage. Establishment of large-scale Telsiai Zone.



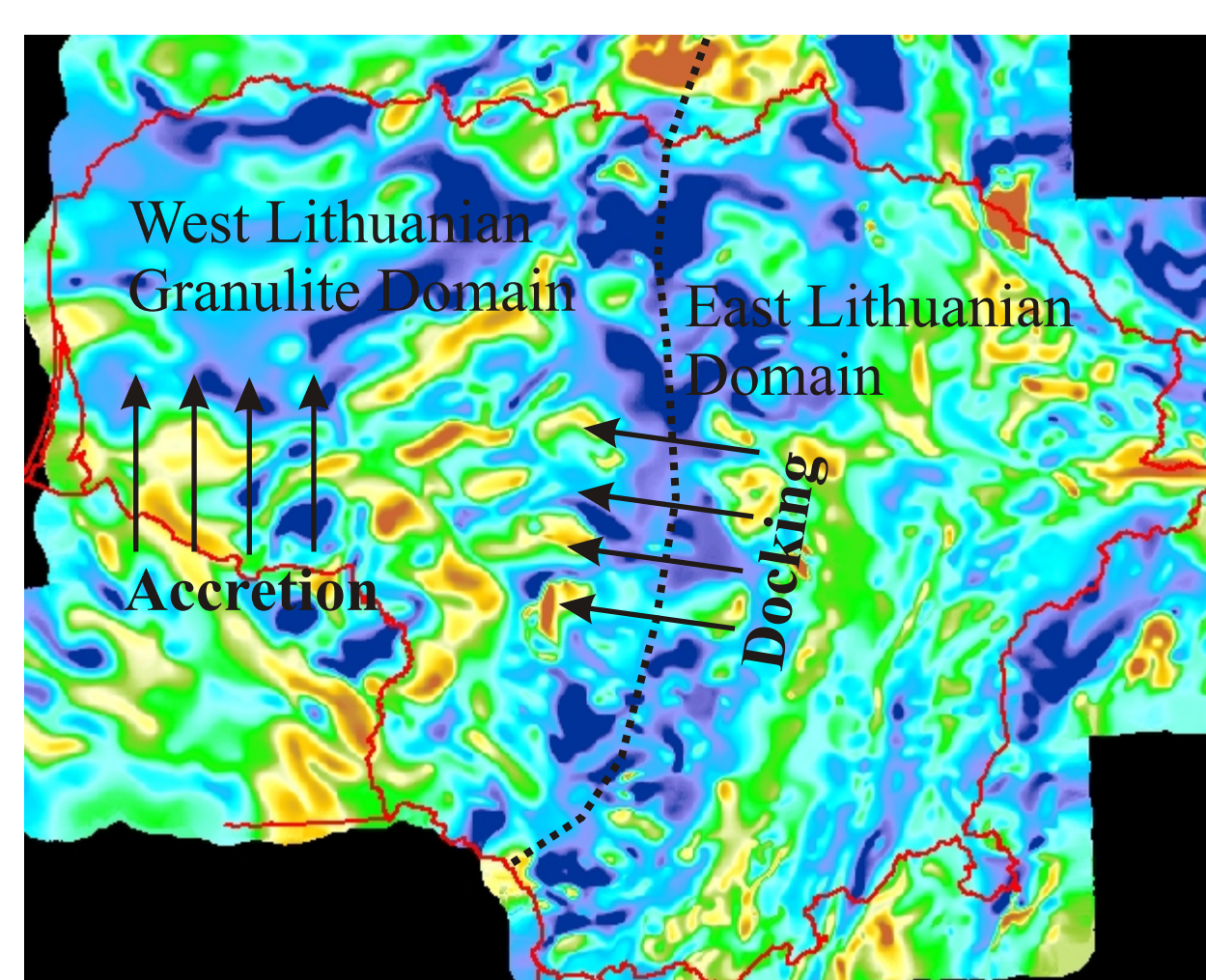
Collision of East Lithuanian Domain and West Lithuanian Domain. W-E crustal shortening (e.g. Vydmantai Shear).



Development of low-angle shear zones (e.g. G-2 zone)



Recurrent reactivation of the Telsiai fault during platform stage. Formation of small-scale faults.



Magnetic field map of Lithuania

The structural features identified in the crystalline basement from the 3D seismics are in concert with general structural development of Lithuania. The west-east oriented structures were formed during the crustal accretion in West Lithuanian Domain. It was followed by thrust-sheet tectonic event likely induced by docking of the East Lithuanian Domain to West Lithuanian Domain. The trend of low-angle fractures correlates with formation of Nemunas zone in the west.

CONCLUSIONS

Oil exploration 3D seismic data provide a powerful tool for imaging the potential HDR systems in the crystalline basement to the depths of 3.5-4 km.

Several stages of the structuring were identified in the Girkaliai area. The earliest milonitisation took place under granulite facies conditions during N-S crustal accretion stage. It was superimposed by cataclasis that induced strong structural anisotropy, well recognised in the seismic data, likely related to the crustal shortening W-E. Some major fracture zones were formed during this stage. It was followed by formation of low-angle tectonic zones characterised by intense brecciation. These two latter stages provide the major tectonic framework for developing potential EGS.

During the platform stage the Telsiai fault was recurrently reactivated.

The Girkaliai experiment shows that oil exploration seismic data can be effectively used in other west Lithuanian areas as the first step for identification of the potential EGS sites.