P-wave velocity anisotropy in an active methane venting pockmark: The Scanner Pockmark, northern North Sea



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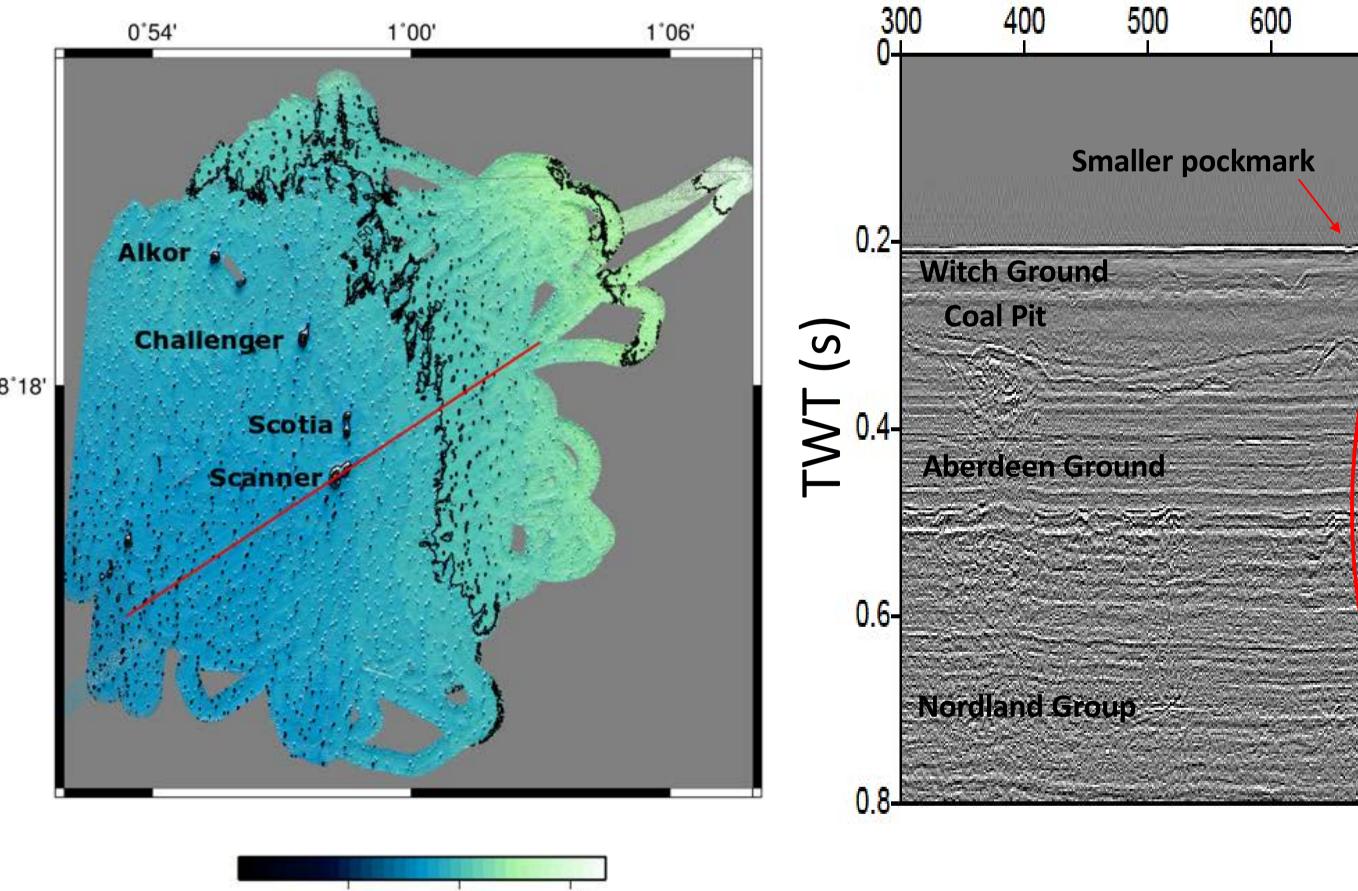
Figure 5: Tomographic

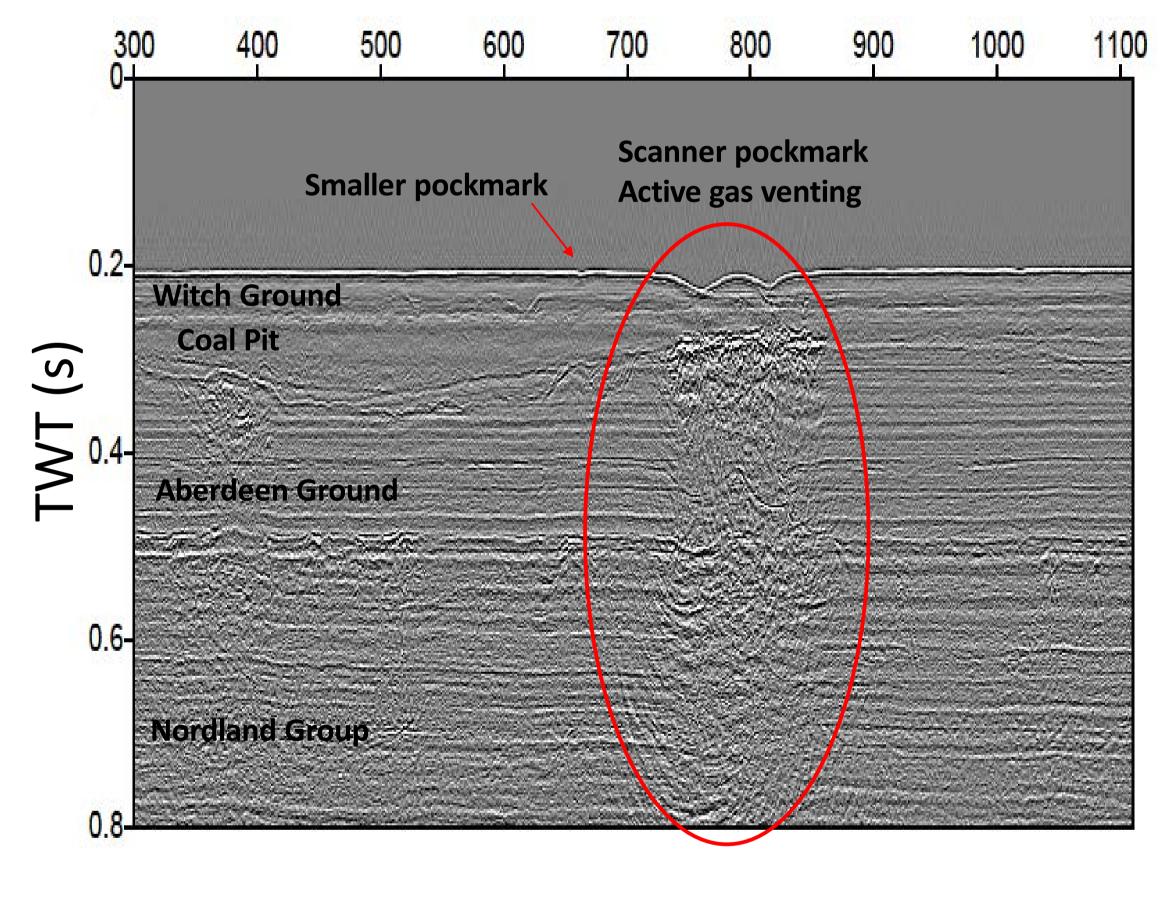
Abstract

Scanner pockmark is an active and continuous methane venting seafloor depression of $\sim 900 \text{ x} 450 \text{ m}$ wide and 22 m deep. It is located in the northern North Sea, within the Witch Ground basin where the seafloor and shallow sediments are heavily affected by pockmarks and paleo-pockmarks of various sizes. A seismic chimney structure is present below the Scanner pockmark. It is expressed as a near-vertical column of acoustic blanking below a bright zone of gas-bearing sediments. Seismic chimneys are thought to host connected vertical fractures which may be concentric within the chimney and align parallel to maximum compression outside it. The crack geometry modifies the seismic velocities and hence the anisotropy measured inside and outside of the chimney is expected to be different.

We carried out anisotropic P-wave tomography with a GI-gun wide-angle dataset recorded by the 25 Ocean Bottom Seismometers (OBSs) of the CHIMNEY experiment (2017). Travel times of more than 60,000 refracted phases propagating within a volume of 4 x 4x 4 km were inverted for P-wave velocity and the direction and degree of P-wave anisotropy. The grid is centred on the Scanner Pockmark and has a y-axis parallel to -340 N. The horizontal node interval is denser in the zone covered by the OBSs and the vertical node interval is denser near the seabed. A 3 iteration inversion leads to a chi2 misfit value of 1 and a root-mean-square misfit of < 10 ms. The results show a maximum P-wave anisotropy of 5%, an higher degrees of anisotropy correlate well with higher velocities. the fast P-wave velocity orientation, a proxy for fracture orientations is 460 N. The top of the chimney possibly links a bright spot mapped at 270 ms in two way travel time using RMS amplitudes of MCS data, to the surface gas emission. The bright spot corresponds to low tomographic P-wave velocity and anisotropy, suggesting that the gas is located in a zone with unaligned fractures and porosity. This observation is in good agreement with a sandy clay layer, the Ling Bank Formation, capped by an upper clay layer, the Coal Pit Formation.

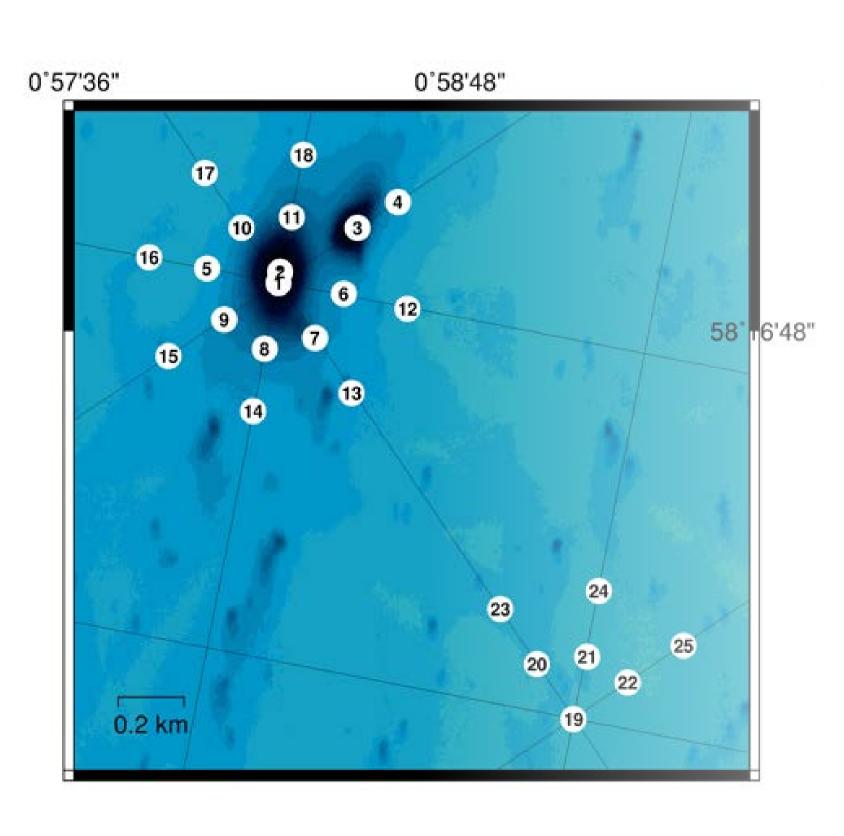
1. Rational





2. Experiment

Depth (m)



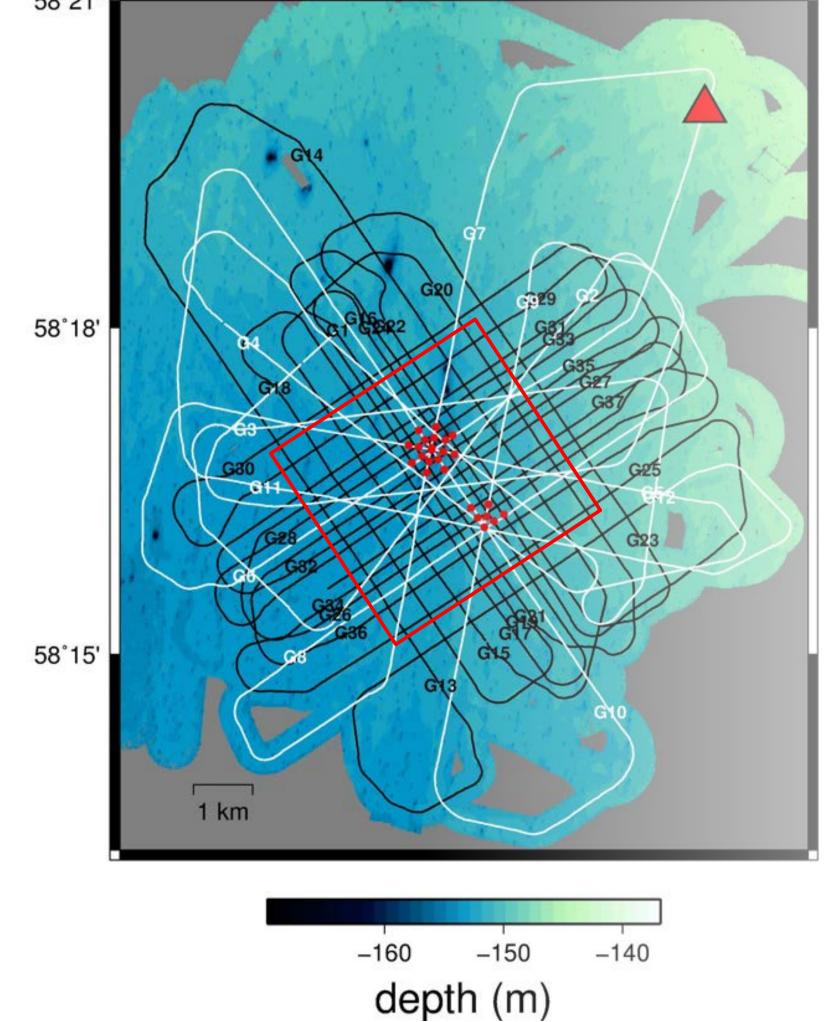


Figure 2:

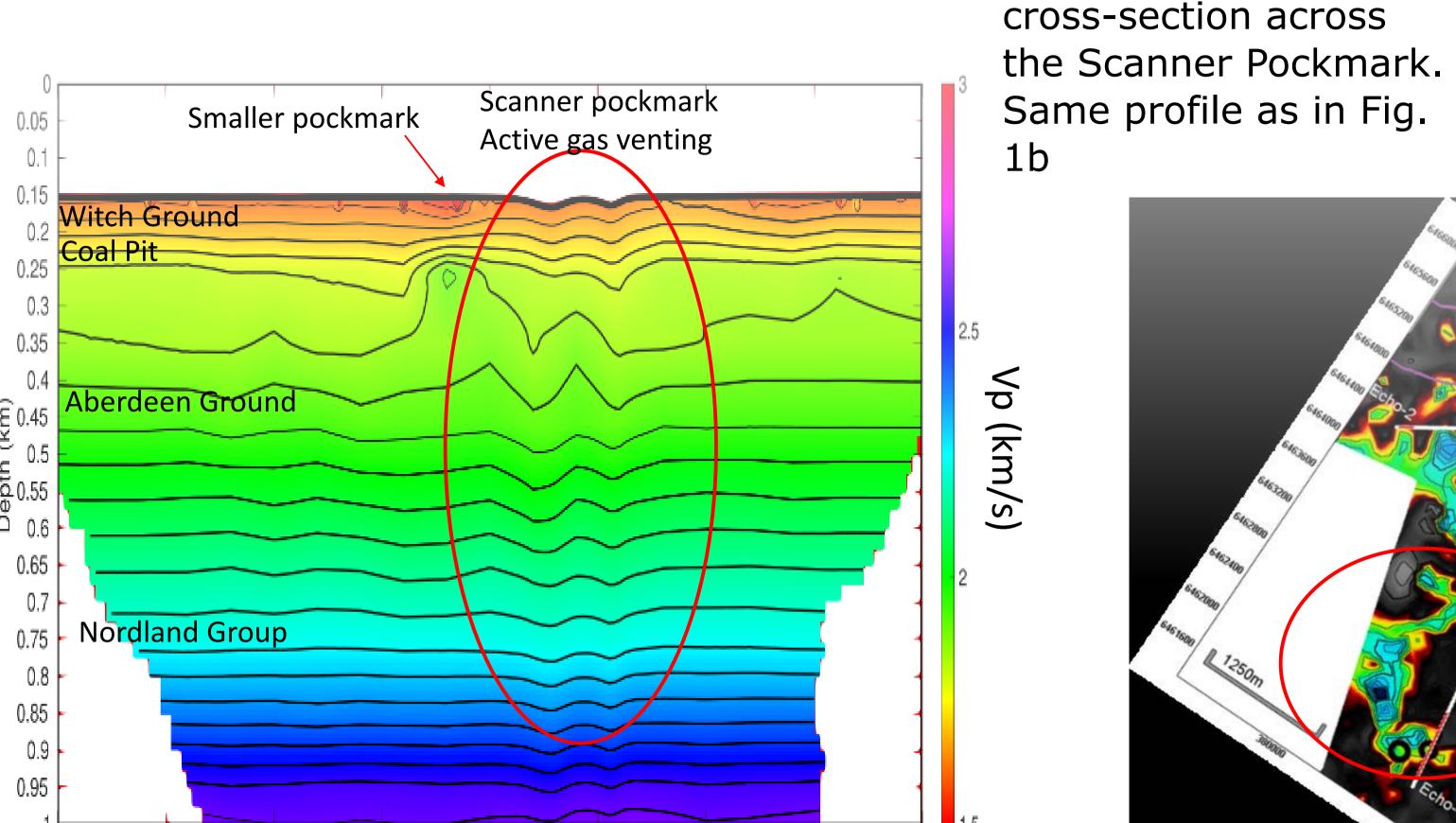
a) Map of the OBSs deployed during the CHIMNEY survey

b) Map of the GI-

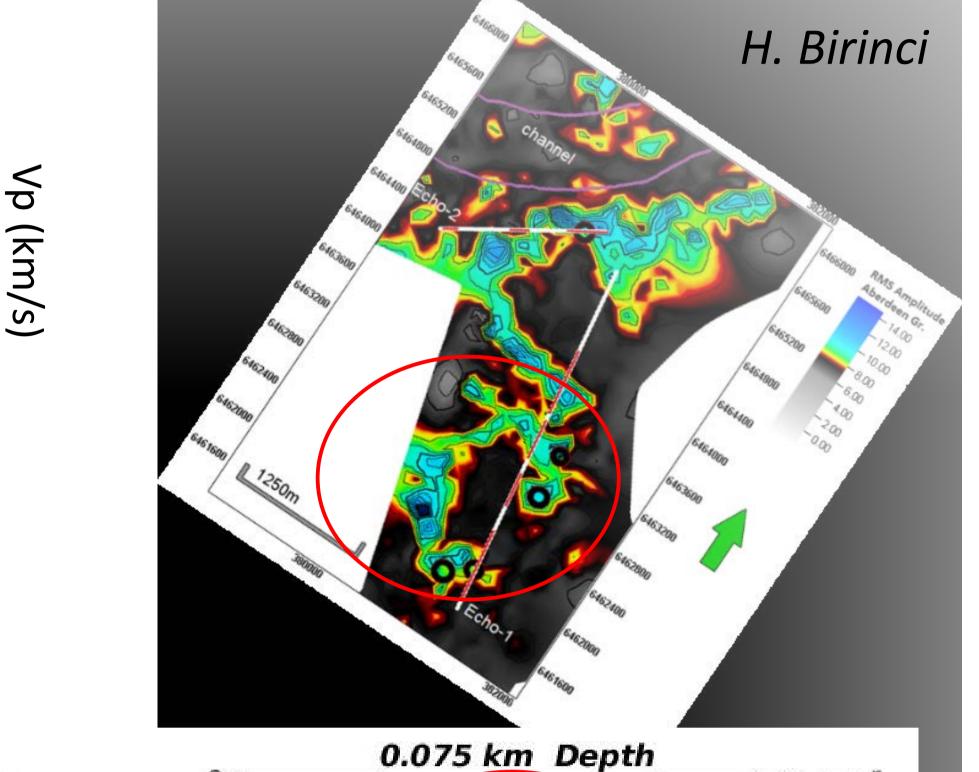
b) Map of the GI-Gun source shots acquired during the CHIMNEY survey

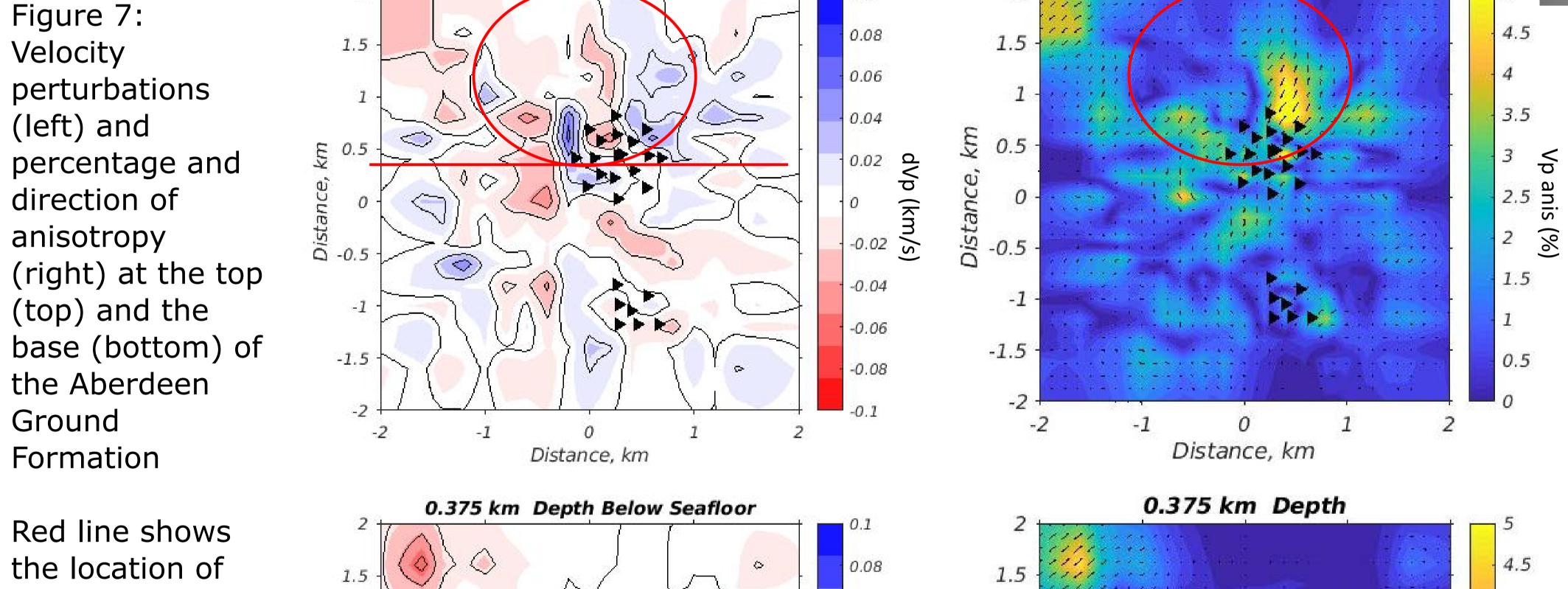
Y Survey

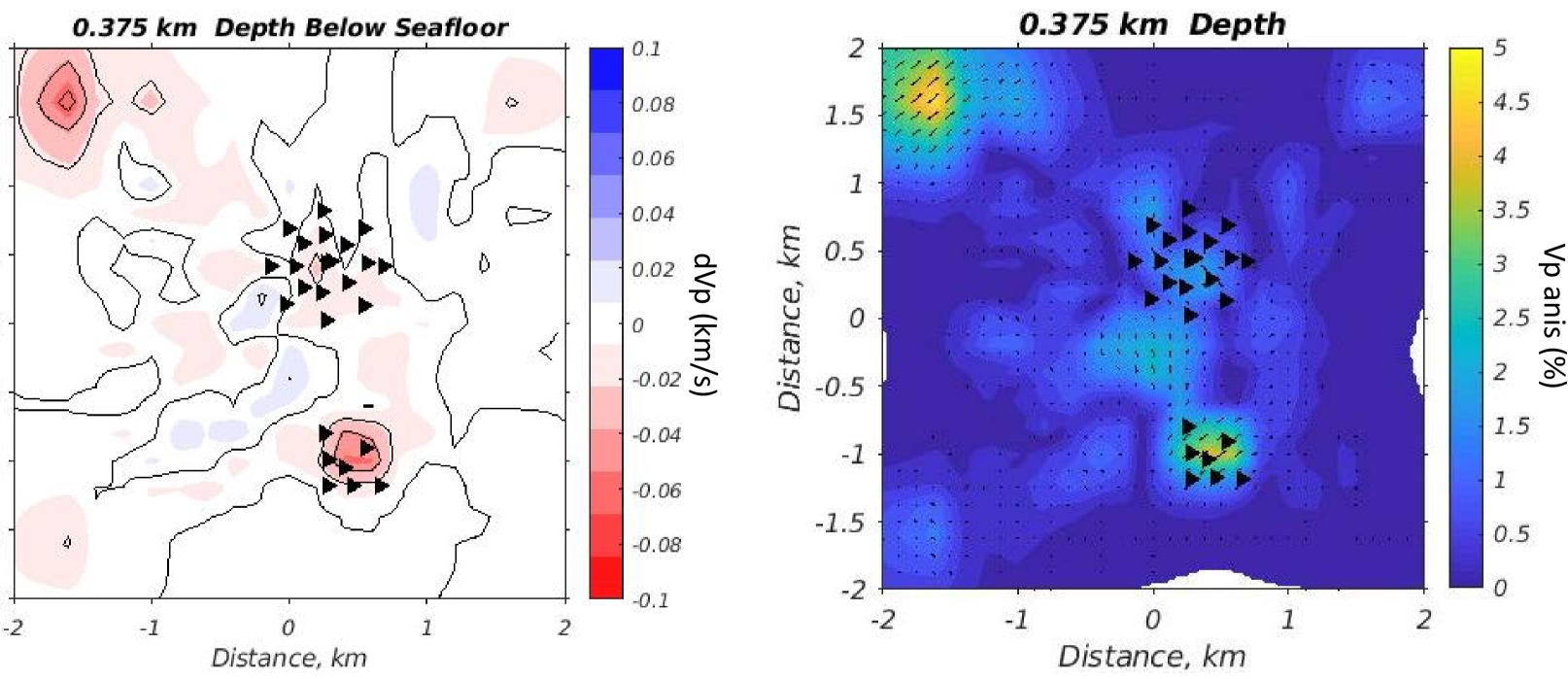
5. Results



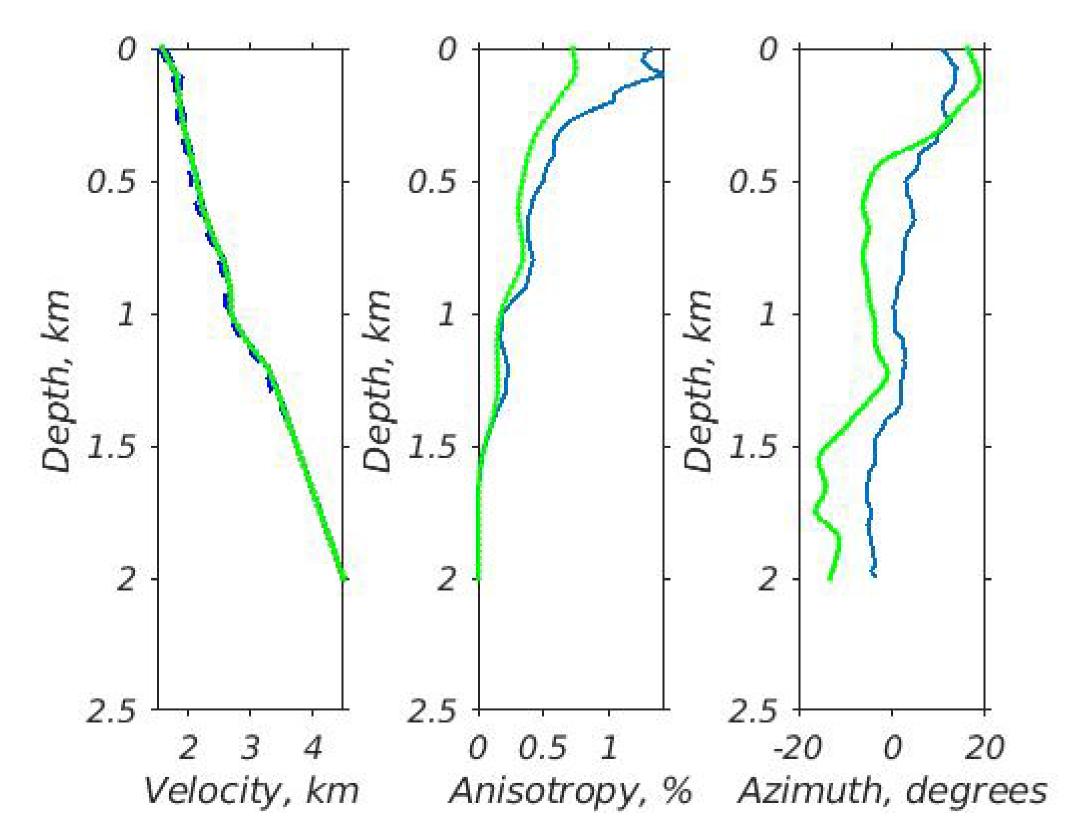
0.075 km Depth Below Seafloor







3. Inversion strategy



the cross-section

Red circle shows

the location of

zones observed

reflectivity map

gas bearing

in Fig. 5

on RMS

Step 1: Initial: 1D model from literature, 1D inversion, final: minimum 1D models for P-wave velocity (Vp) and percentage (Ar) and direction (At) of anisotropy

Step 2: Initial: min 1D models, 3D inversion, final: 3D models (Vp, Ar, At) averaged at well resolved nodes (blue)

<u>Step 3</u>: Initial: models from Step 2 (blue), 3D inversion, picking uncertainty= 2 ms, final (green)

Figure 3: Initial 1D model (blue) and final average model (green) of the Step 3 inversion

4. Residuals

Step 3: Final RMS residual of 97343 refracted arrivals is 4 ms and the final X2 is 4



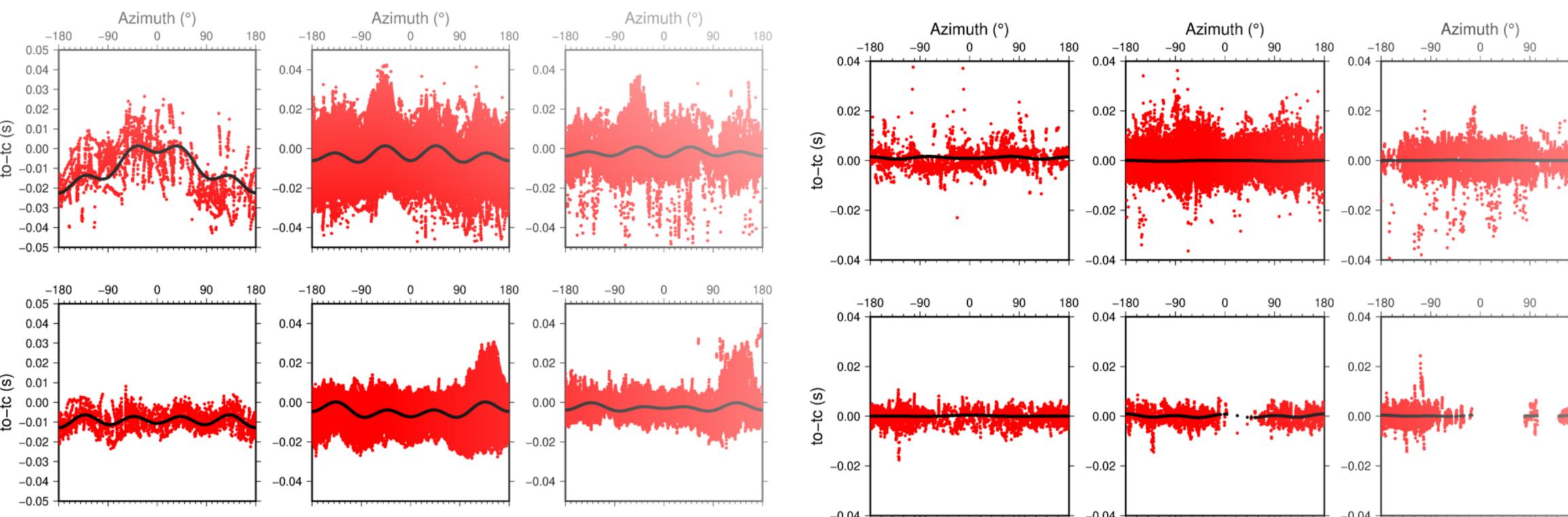


Figure 4: The black line is the $cos(4\Theta)$ curve that fits the residuals best.

6. Quality assessment

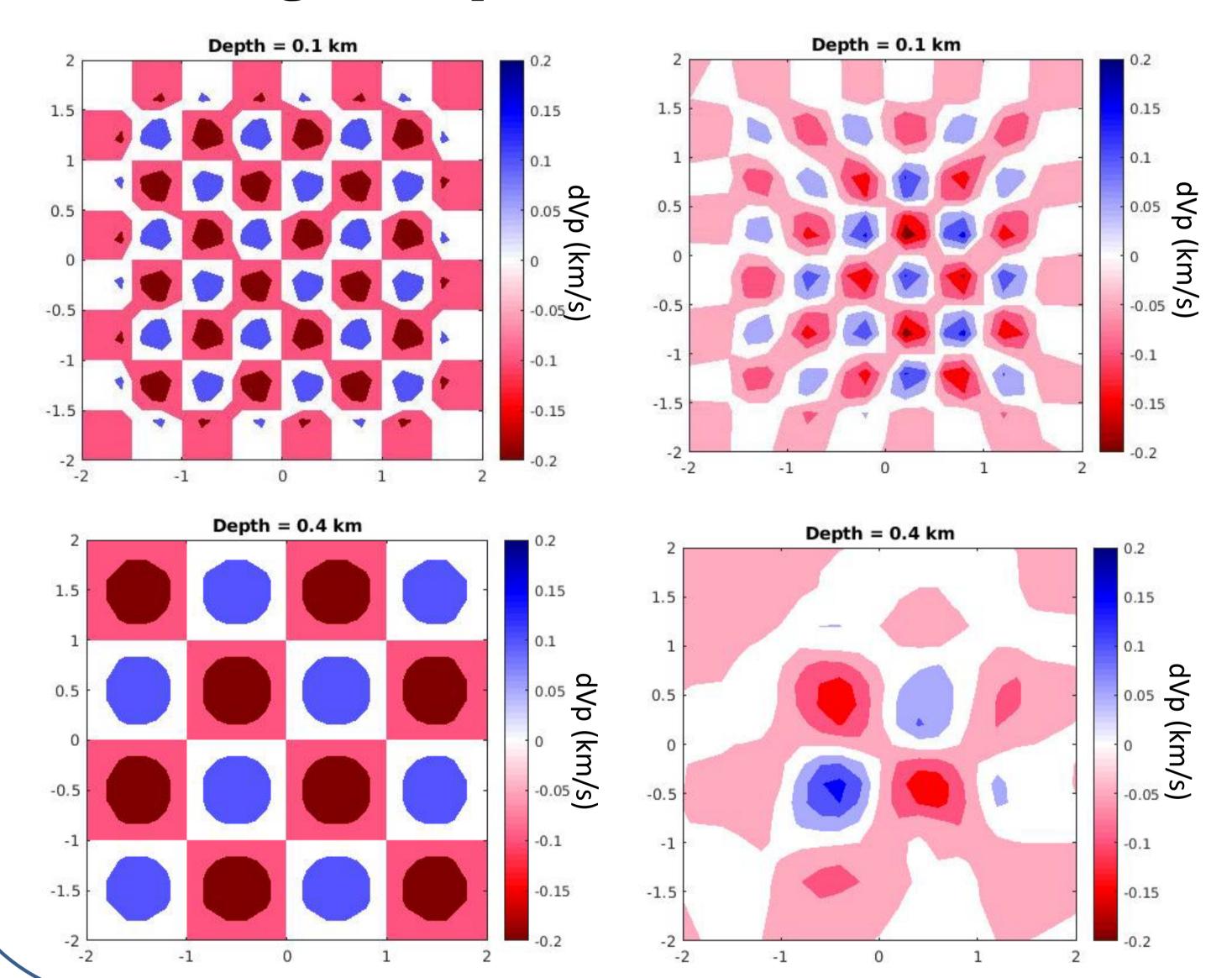


Figure 8: Checkerboard models (left) and results (right) at the top (top) and the base (bottom) of the Aberdeen Ground Formation.

A velocity anomaly of 0.2% of amplitude is injected.

At the top of the Aberdeen Ground Formation anomalies of 0.5 x 0.5 km are perfectly resolved.

At the base of Aberdeen Ground Formation 1 x 1 km anomalies are well resolved beneath the region covered by OBSs.

7. Conclusions

Tomographic results show a low velocity zone beneath the Scanner pockmark (Figs. 5 and 7)

The southeastern rim of the pockmark is marked by high velocities within the Aberdeen Ground Formation (Figs. 5 and 7)

A maximum of 4.5% of P-wave velocity anomaly is observed within the study region with an azimuth close to North (Fig. 7)

The average P-wave anisotropy is low, only 0.5% at the topmost layers

Gas bearing, high reflectivity zone (the tunnel valley) shows (Fig. 6, red circle) low percentage of anisotropy (Fig. 7, red circle)

Highest percentage of anisotropy (Fig. 7, red circle) correspond to high velocity zones

Above observations suggest that the gas is contained in regions where a random, high density crack network is superimposed on top of a pervasive and regional crack network

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