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# *Interactive comment on* "Coherent diffraction imaging for enhanced fault and fracture network characterization" *by* Benjamin Schwarz and Charlotte M. Krawczyk

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Dear referee,

we appreciate the time you have invested. We believe that your comments are well justified and thank you for the valuable feedback which will helps to improve the quality of the manuscript. In the following, we provide you with our personal view on the issues you have raised and also indicate, how we intend to alter the manuscript to reflect the desired changes. For convenience, your individual comments appear bold, replies remain in standard font and intended textual modifications/additions are indicated by italic letters.



**The comment here I make in the following could be the topics in the discussion helping people without deep theoretical understanding (application paper) when to use the focussing method and how to interpret the diffracted image although you already mentioned the topics in a broad discussion. The paper nicely shows data examples of diffracted images and how use them in conjunction with the reflective image to characterise the subsurface. But what I am missing are the uncertainties and limitations of the method. Because diffractions are generally 3D a 2D profile will also show side diffractions. The hope is that the presented coherence method will cancel most of the events, but this has not been shown, most critical I see here the single channel data. Maybe additionally a simple guideline can help non-theoretical readers to understand what of information could be expected for this kind of focussing application depending on the input information: velocity knowledge, single-channel/multichannel, type of diffractions (generated by fault zones - edge wave with polarity change, point/volume diffractions without polarity change) apparent velocities, and time/depth errors from side echoes. Velocity knowledge: if multichannel data exist, the application of the velocity estimated from MCS reflections seems to be the most intuitive and hopefully the coherency will cancel the diffractor images which are generated from side echoes. A velocity estimation only from diffractions along a 2D profile would I not expect to be to accurate. I think all of the problems I mentions can be solved for 3D data with a multi-attribute analyses followed by projection which seems to get very powerful method in the future.**

We thank you for this comment and we are convinced that some more detail on what to expect and more broadly on what could go wrong, will prove valuable information for the reader. We are aware of the principal complications that can arise from out-of-plane scattering and briefly address this in line 408: "*However, it must also be noted that the process of diffraction is inherently three-dimensional, which can cause out-of-plane energy to contaminate the data with the potential to result in the occurrence of artefacts in the reconstruction.*" It seems indeed worthwhile to more extensively elaborate on this and other limitations. Following your advice, we will include the following additional sentences: "*Provided accurate velocity information is available, out-of-plane contributions in two-dimensional (2D) surveys are naturally suppressed, if the scattering structure is located reasonably far off the acquisition plane. However, less distant out-of-plane scattering can hardly be distinguished from valuable in-plane contributions, which is why 2D diffraction-based reconstructions must generally be assessed with care. This is particularly true for single-channel data, for which a reliable velocity model might not be available. In order to gain trust in diffraction-derived velocity information and coherent diffraction images the mere quality of focusing might be complemented by a joint assessment of the reflected wavefield. Powerful and reliable reflection-based velocity inversion schemes exist and can be used, if sufficient offset information is available. Thus, because reflected energy is less likely to stem from out-of-plane structures, the integrated interpretation of reflection and diffraction images can help to improve velocity models and identify off-plane scattering in 2D surveys (Preine et al., 2020). All these complications become superfluous for sufficiently dense three-dimensional acquisition strategies, which, therefore, are deemed ideally suited for reliable subsurface imaging with the diffracted wavefield.*" To better reflect the important issue you have raised and in order to increase readability we will rearrange and subdivide the discussion section into three distinct subsections ("*5.1 Potential and extension of the method*", "*5.2 Limitations and challenges*" and "*5.3 Geological interpretation*").

**Individual Correction / Comment: Page 3 Line 71 Correction/Comment: . . . when a wavefield encounters a relevant property change (e.g. that has a local curvature) of or below the wave length . . . Comment: a horizontal interface with an impedance anomaly will also create diffractions.**
You are right, but we would argue that this impedance anomaly itself represents a change in material properties and needs to be localized for wave diffraction to occur. Please let us know if we have a wrong perception of the scenario you are referring to, but like related works we specifically focus on non-Snell scattering, for which an anomaly is usually defined by means of a sufficiently high local curvature.



**Page 6 Figure 2 Correction/Comment: Left side: Focussing Section 3.2, Coherence measurement Section 3.1. Right side: Coherence measurement Section 3.1, Projection Section 3.3 Comment: not Section 2.x**
Many thanks for pointing this out – Figure 2 now shows the correct section numbers.

**Page 10 Figure 4 Comment: not clear what Phase-reversed semblance and augmented semblance means (I have some idea), but please reference to your equation what you did when. Page 10 Line 219 Correction/Comment: the polarity of diffractions can change near the apex for zero offset data, which . . .. Comment: for 2D offset data the phase change occurs along the boundary ray (e.g. edge diffractions). This position can be found e.g. by a double diffraction stack (vector stack) during the migration in a shot-gather (the stationary point / tangential alignment). Side echoes may have no phase change at all.**
You are right, the augmented version of the semblance deserves some more explanation. In fact, the double diffraction stack is exactly what we perform before augmentation. We will include the following sentences (in line 220): "*Every data point is once treated as a potential stationary point at which an artificial phase reversal is performed before evaluating the coherence measure. Both results, the one gained without reversing the phase, and the one for which the phase is reversed, are compared and the higher value contributes to the augmented image.*" In addition, we will replace the phrase "*near the apex*" with "*at the stationary point*" and specifically refer to the definition of the beam energy and the semblance norm (equations (2) and (4)).

**Page 13 Line 299 Correction/Comment: which appears as a largely (transparent) body with (weak), chaotic internal structure. Comment: it does not look transparent or weak with this gain applied to the section.**
We agree and will not refer to the respective layer as "*transparent*" or "*weak*".

On behalf of the authors, Benjamin Schwarz

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