Diffraction image- application to a Fractured Limestone

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Summary

Imaging fractures and fault in carbonate reservoirs are extremely important. Although some seismic attributes such as coherence and curvature can help identify fractures-prone area, they do not detect them directly,we evaluated diffraction-imaging workflows as a more direct mean of fracture detection, we established a new workflow and algorithm based on the prestack time migration to mostly image the scattering objects.

Introduction

Diffraction imaging has been proposed as the mean of detecting fractures during the past dacade, Kozlov (2004) modified the migration aperture to get rid of specular reflection, leaving diffractions behind enhanced, also Shtivelman and Kerdar(2005), and Fomel et al,(2006),and Moser and Howard(2008) use the diffraction imaging to generate high-resolution images of discontinuous objects. Most resently, Koren and Ravve (2010) implemented decomposition of full azimuth subsurface angle domain to enhance diffraction of fractures and faults.

Our study is based on the pre_stack migration with different offsets and azimuths. During the migration we bin the dataset with variety of Fresnel zones, my approach is selecting Fresnel zones to favor specular reflection from continuous structural surfaces, diffraction from the fault and fractures are reduced. We migrate the complete dataset with almost full aperture, which more seismic traces fall in, the stacked data consist energy from strong reflection and scattering objects. Finally we subtract the limited Fresnel stack from the full stack, thereby attenuating strong specular reflection energy, and get the scattering image from the scattering objects. we apply this algorithm and workflow on the Dickman seismic dataset acquired in central Kansas consist of fractures and Karst features to illuminate these scattering objects.

Method

Unlike most migration algorithm that bin the data according to the offset and azimuth of the surface source and receiver, our migration algorithm bin the data according to the offset and azimuth between the source and receiver midpoint, approximating Fresnel zones(Perez and Marfurt,2007)

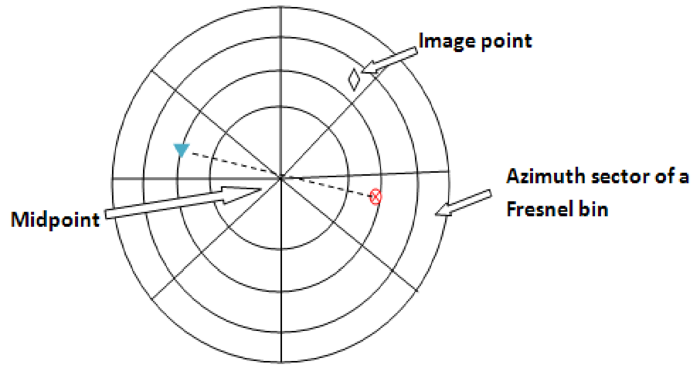

Figure 1： The output sample from a given sample on a source_receiver sector fall into Fresnel zone

In order to attenuate reflection signal, follow Kozlov(2004) and we analyze to abstain two migrated datasets, the first one with large and full aperture and migrated with large offset, the second one with small Fresnel zone.

Prestack 3D Kirchhoff migration can be implemented using the formula (Bleistein 2001; Biondi:2006)

$$\mathbf{m}(\mathbf{r},\mathbf{x_h},\tau) = \iiint_A W_m\, \partial_t[\mathbf{d}(\mathbf{x_m},\mathbf{x_h},t)]\,\mathrm{d}\mathbf{x_m}\,\mathrm{d}\tau$$

In which is $\mathrm{d}(\mathrm{x_m},\mathrm{x_h},t)$ denote 3D seismic data in common-offset gathers, W_m denote the weight function, $\mathrm{x_m}$ is the midpoint gather and $\mathrm{x_h}$ is offset position vector, and A constitute the migration aperture , and τ represents the vertical time of seismic data.

Based on the stationary phase formalism, the continuous reflected energy is mostly concentrated within the Fresnel zone, that's the reason we choose it as aperture. To emphasize the specular continuous reflectors, I would like add another weight function U to the mid-points of traces $\mathrm{x_h}$ fall in the aperture, which make the stacking process more selective. In all the common offset gathers, usually the near and small offset source-receiver pairs contribute mostly the reflection from specular objects, so it's essential to stack limited offset gathers to generate concentrated reflection energy. So we can put the weighting U on offset the $\mathrm{x_h}$,as shows blow:

$$\mathrm{U}=\begin{cases} 1\,, \alpha * \mathrm{A} < \mathrm{x_h} < \mathrm{A} \\ 0, \mathrm{x_h} < \alpha * \mathrm{A} \text{ and } \mathrm{x_h} > \mathrm{A} \end{cases}$$

And α is the coefficient added on the offset selective process, A is the Fresnel zone. In order to generate the energy consist both the reflected and scattering energy, next step, I would change the aperture more larger, which can enable more traces fall in, both the near offset and far offset.

$$U^*=\begin{cases}1\,, x_h < B\\ 0, x_h \geq B\end{cases}$$

In which the B denote the greatest distance from midpoint of source receiver pair to common depth point.
During migration, I use these two weight function in the offset part, to get the full stacked data and specular reflected data, by subtracting these two, we get the scattering enhanced image.

Field Example

Dickman field , located in northern County, Kansas, is a typical super mature Mississippian reservoir. In the field the Pennsylvanian strata unconformity overlie Mississippian reservoir rocks of the Meramecian Spergen and Warsaw limestones. The Mississippian reservoir in Dickman field is composed of shallow-shelf carbonates, also karst- enhanced fractures have been documented to extend several meters below the regional unconformity surface.
 I apply the workflow to the Dickman gathers, first I migrate the raw data with weighting function one U, to generate the full aperture and large offset stacked data, which include both the reflected and diffraction signal from subsurface (Figure 2), and from this we can see that, the continuous reflection is very strong and small faults and Karst features can exhibited.
 After that I use the limited aperture and offset, I produce the stacked data consist mostly the specular energy, the reflection is much smoother, also we compare with the figure 2, and we can find that in some part, just as the black arrow denoted, the energy from discontinuous scatter objects can be attenuated most with respect to the unchanged reflection energy.

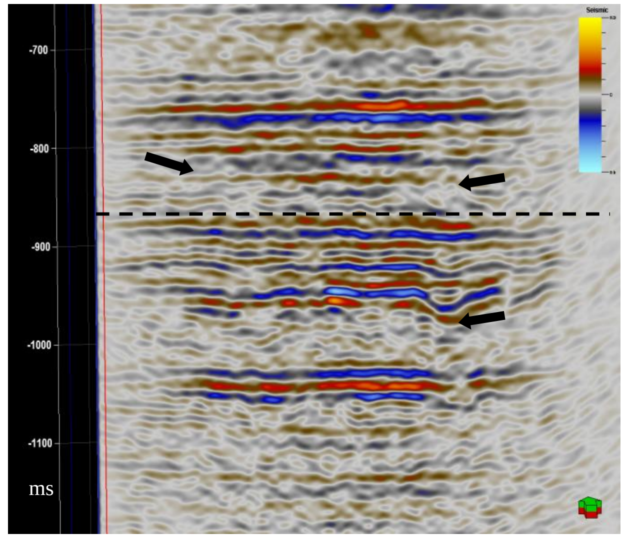

Figure 2； Full aperture and large offset stacked data

So in the last step, I subtract the most reflection stacked data figure 2 from the full stacked data, and get the most diffraction energy figure 4. From -800 to -1000 ms we can find that some discontinuous objects can enhanced, especially the Karst feature and some small faults, which can’t not easily observed in the full stack data, but visible in the diffraction image.

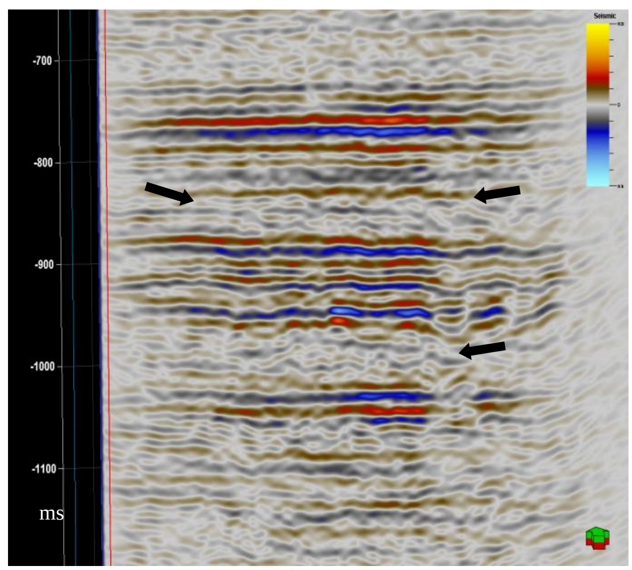

Figure 3: Limited aperture and offset stacked data

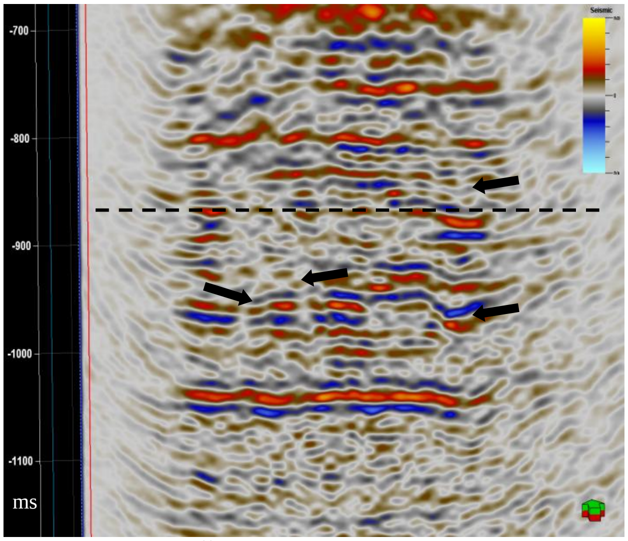

Figure 4 : Enhanced diffraction image

I also generated time slice from the Karst enhanced fractures in -875ms, we can see that Figure 5a shows the full stacked data consist the reflected and diffraction energy, Figure 5b is the enhanced diffraction energy. We can see that in the 6b the resolution is better than in the 6a, and small fractures can be illuminated.

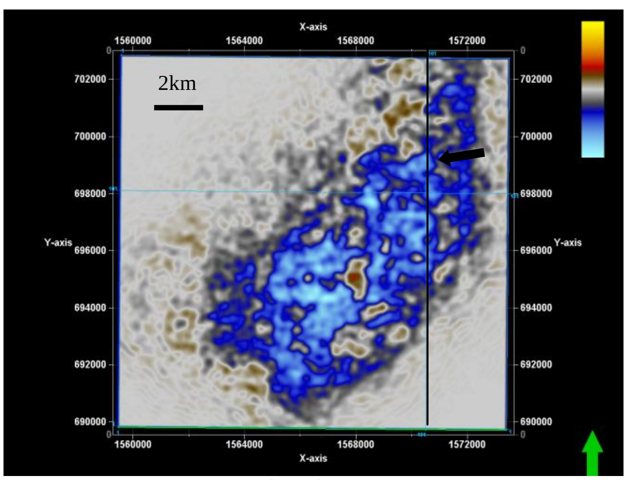

Figure5: Time slice at -875ms from full stacked data (a)

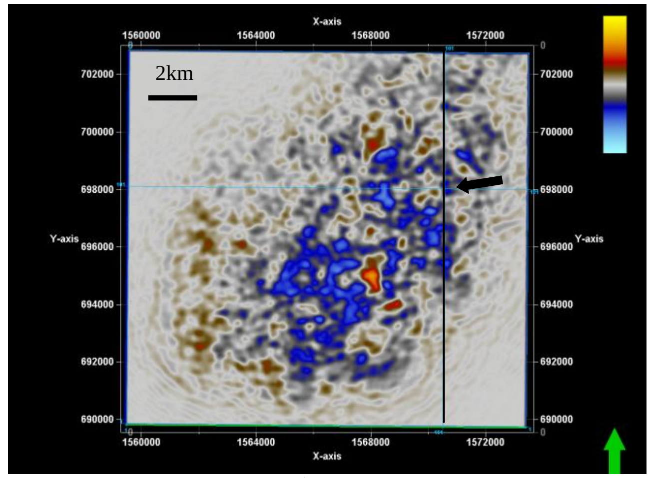

Figure5, Time slice at -875 ms from enhanced scattering image data (b).

Conclusions

We have proposed a new technique to detect some scattering objects, which is base on the limited aperture and offset stacking during Kirchhoff migration, this procedure first generate full stacked data include reflection and diffracted signal, then by subtracting the mostly specular reflection data from original one, we obtain the enhanced scattering image, such as faults, karsts, and fractures. Also we use this technique in the Dickman dataset to illuminate the Karst enhanced fractures below the Mississippian reservoir, we found that the limited aperture and offset stacking can attenuate the scattering energy deeply, after we get the diffraction image, in which some small faults and Karst feature can enhanced, but it is not clearly illuminated in the original stacked data.

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