Pre-Stack noise reduction in 3d-3c seismic data using Common Offset Vectors Gathers

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Abstract

This study describes a method to reduce pre-stack noise in the domain of Common Offset Vectors (COV) applied to 3D-3C land seismic data of orthogonal geometry and wide azimuth. It explains how to select and to gather seismic data to form different classes of COV and describes the main properties of the gathers. The geometric attributes of seismic data with regard to COV are compared with the attributes originating from other ways of ordering pre-stack data. The filtering process used here is Fxy deconvolution to reduce coherent and random noise within the usual processing sequence of converted waves. The viability of these methods can be verified on large volumes of seismic data as well as their effectiveness in dealing with pre-stack seismic data.

Introduction

In seismic 2D a natural way to gather pre-stack seismic traces is ordering data in Common Offset Gathers (COG), likewise in off-shore seismic 3D, offset gathers are defined by acquisition geometry and generally have good coverage of all seismic volume. In land seismic 3D, evidently, the acquisition geometry determines the distribution of offsets; however, unlike offshore 2D and 3D, there is not a unique natural way to gather traces to form the COGs. Due to the repetition of traces in certain bins and the total absence of traces in others, COGs are not well generated when they are formed. The natural way to construct ”offset planes” for orthogonal geometries of wide azimuth is to gather traces in Common Offset Vector Gathers known as COV. The way to organize these COVs is gathering traces according to inline-offset and crossline-offset ranks, forming as many one-fold planes as nominal folds are found in the registration geometry. For wide-azimuth orthogonal geometries, there are two possible ways of gathering data to obtain uniform or quasi-uniform spatial sampling: the cross-spread domain (XSPREAD) and the COV. The main advantage of arranging data in XSPREAD and COV lies in the possibility to use pre-stack 3D algorithms such as interpolation, DMO and migration. This work explains the use of techniques for suppression of random and coherent noise with Fxy deconvolution applied to data gathered in COV.

Reduction of random noise in the cross-spread domain is currently broadly in use (Roizman M.; 2005), and by applying Fxy deconvolution in this way, the results obtained are very satisfactory. For pre-stack suppression of coherent noise, in turn, FKxKy filtering should be applied in cross-spread. Source coherent (ground-roll) and random noise can be reduced to only one process if Fxy deconvolution is applied to data gathered in COV.

Offset Planes Definition of new distances

Source and receiver coordinates X Y can define completely the position of a seismic trace in space, provided the work is carried out with data to final plane, allowing us to work independently from source and receiver elevation. This reference system is useful when it comes to place our project in space.

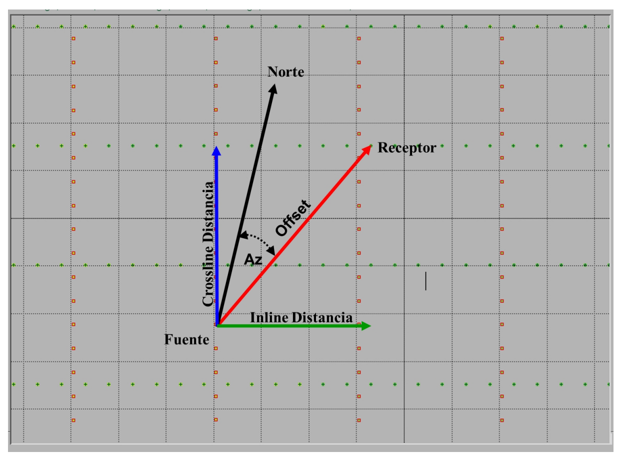

Figure 1: *R*eference Local Systems.

In seismic processing, it is natural and more effective to use a local system, having as origin the shooting point, defining a source-receiver distance or separation and an azimuth - hour angle measured from the geographic North to the source-receiver segment (local polar reference system). In the case of orthogonal acquisition geometries (where receiver and source lines cut one another in a right angle) it is recommended to use another local reference system where the distance vector is subdivided into two vectors: inline distance and cross-line distance (new local reference Cartesian system). Figure 1.

Analysis of Geometric Attributes.

The analysis of histograms of offset and azimuth geometric attributes of a land 3D Project (Figure 2) shows that distance and angle gathers do not appear in a discrete form because gathers are not divided into small groups like in the case of 2D seismic lines (Figure 3). This is why it is possible to have different ways to select offset planes in land 3D data. When forming a common offset plane (generally defined by the central offset and the space between each plane), the plane obtained is not covered uniformly along the registration area. Figure 4.

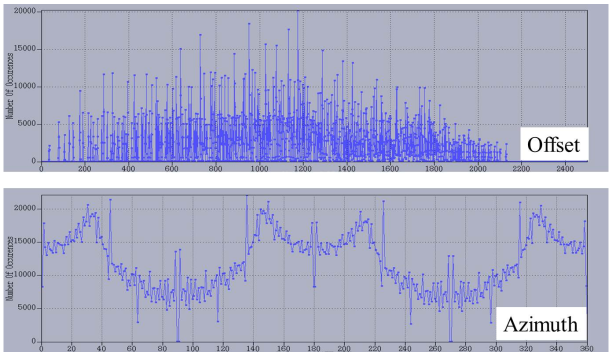

Figure 2: *O*ffset and Azimuth Histograms Corresponding to Land 3D.

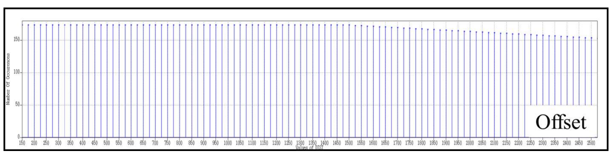

Figure 3: *O*ffset Distribution Histogram for Land 2D Seismic Line.

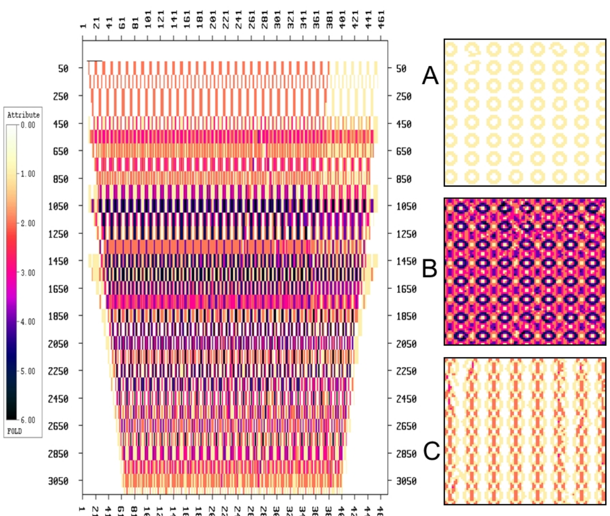

Figure 4: *C*overage of Offset Planes used as PSTM Entry.

COVS Construction.

The analysis of the histograms of the new attributes: inline-distance (i-dist) and xline-distance (x-dist) (Figure 5), shows that these are distributed in a discrete form. Ranks of the new distances can be taken and the corresponding seismic traces can be used to form a collection of data that come near to constant offset planes. According to the sign of these distances, it is possible to gather them in constant azimuth and offset planes.COV in land 3D seismic data may be thought of as being equivalent to Common Offset Gathers in Seismic 2D, where in most cases they appear as regular.

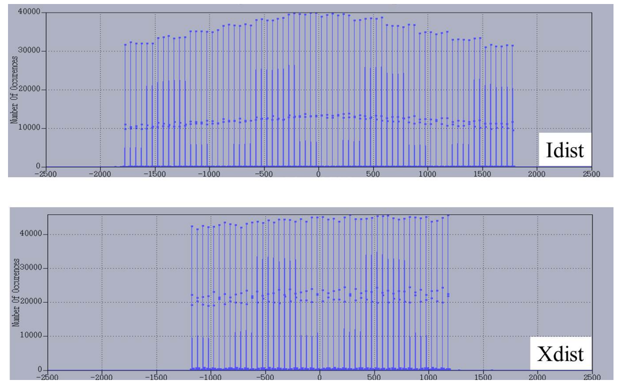

Figure 5: *H*istogram of Inline and Crossline Distances.

By way of example, the acquisition of a 2D line under the stack-array modality, with 120 channel symmetric recording, 50 m spacing from each shot and receiver point, allows us to obtain 60 offset planes from 25 to 2975 m with 50m spacing. In land 3D, the equivalence to stack-array is obtained by means of an acquisition method that respects the principles of symmetric spatial sampling (Vermeer, 1998). In this case, it is possible to calculate COVs just like in 2D. The number of planes will be equal to the 3D nominal coverage, the spacing in xline direction will be equal to the distance between receiver lines, and the spacing in inline direction will be equivalent to the distance between source lines. In a 3D with 250 m between source lines and 150 m between receiver lines, with a maximum offset in the inline of 1625m and in the xline of 1125m, it is possible to take as fixed example, the i-dist rank centered in 125m with an aperture of +/- 125m, and to vary the x-dist ranks from 75m to 975m with an aperture of +/- 75m in order to generate 7 one-fold planes. Following the same procedure, completion up to the nominal fold is possible by increasing step by step the central distance of the inline rank from 125m up to 1375m every 250m.

Conversely, if I0 and X0 (Figure 6) are the inline and the xline central distances, and Δx and Δi are the average apertures given by the distance between source and receiver lines, then the distances for each plane are to satisfy the following conditions (1) and (2):

$$X0 - \triangle x <= Xdist <= X0 + \triangle x \quad (1)$$

and

$$I0 - \triangle i <= Idist <= I0 + \triangle i \quad (2)$$

Not having into account the sign of distances, the generation planes whose relevant property is the continuity of offsets is possible. The selection of traces with distances of the same sign creates planes whose main property is the continuity in the direction or azimuth. Finally, the selection of each trace according to the sign makes possible to honor direction and sense. The ways of gathering or selecting traces present advantages and disadvantages with respect to one another, and have different applications in turn.

Properties of different offset gathers.

If (I0, X0) defines the central coordinate, the distribution of offsets for a determined COV will be limited by equations (3) and (4):

$$Min\triangle = \sqrt{((I0 - \triangle i)^2 + (X0 - \triangle x)^2)} \quad (3)$$

and

$$Max\triangle = \sqrt{((I0 + \triangle i)^2 + (X0 + \triangle x)^2)} \quad (4)$$

And the azimuth rank by equation (5):

$$\triangle az = tg^{-}1((X0 + \triangle x)/(I0 - \triangle i)) - tg^{-}1((X0 - \triangle x)/(I0 + \triangle i)) \quad (5)$$

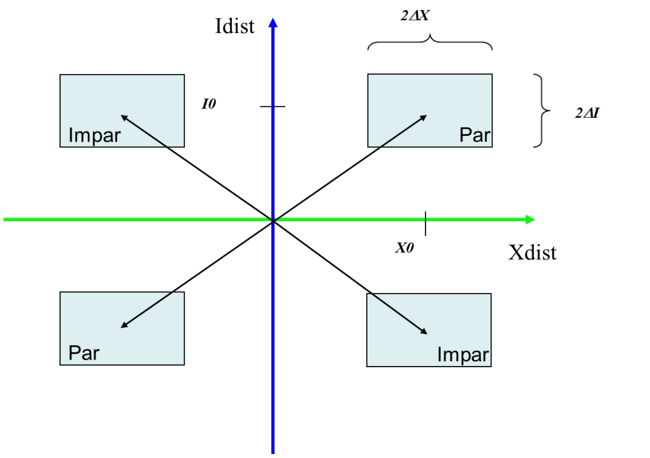

Figure 6: *C*OV Distance Definition.

If the sign of i-dist and x-dist distances is not taken into account, a selection with continuity in the offsets will be obtained. Azimuth variation given by Δaz decreases as COV central distance increases; however, given that only one of the four possible bins has been chosen, continuity in the azimuth will not be obtained. This selection of traces is appropriate for an effective suppression of seismic noise, random or coherent, generated by the seismic source. If data is corrected by NMO or NMO differential, with statics to final plane, source generated ground-roll waves will generally appear as random noise due to incorrect spatial sampling.

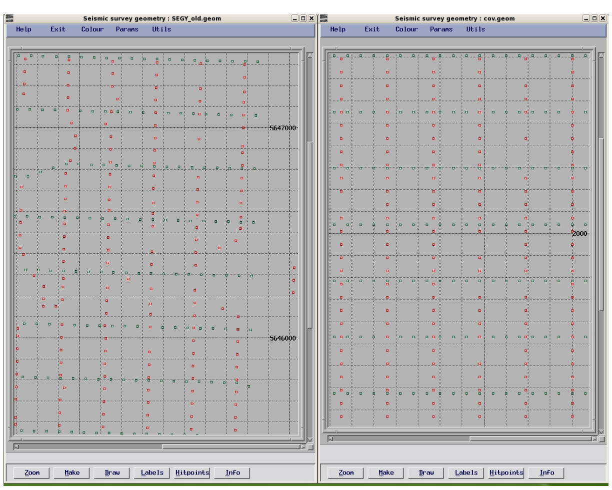

Figure 7: *F*inal Geometry (left) and "Theoretical" Geometry Used for Filtering (right).

This noise can now be eliminated by Fxy deconvolution, transformed Radon, or any other algorithm that takes advantage of the pros of having three-dimension-multi-channel data. If even and odd signs are taken separately, continuity in the azimuth is obtained quation (5); however, it will be necessary to duplicate both Δi and Δx to complete each plane. From the offset point of view, the increase of the difference between MinΔ and MaxΔ moves away from the ideal for a Pseudo Minimal Dataset. Taking some precautions, this domain is still the most suitable for seismic processing to take into account azimuth variations. Data processed in this way are apt to detect amplitude variations with (AVAZ) azimuth or to perform velocities azimuthal analysis for fracture detection.

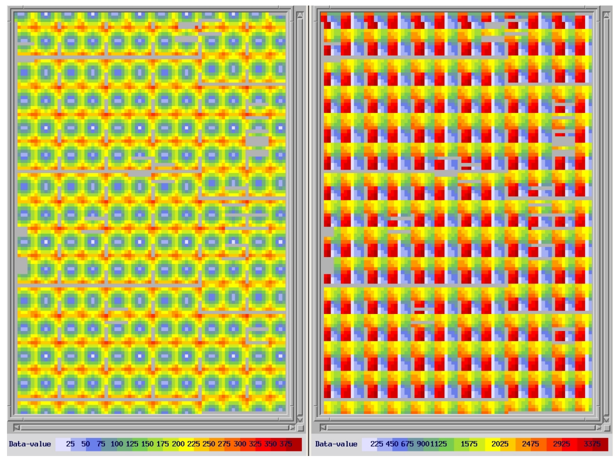

Figure 8: *A*zimuth and Distance for the First COV.

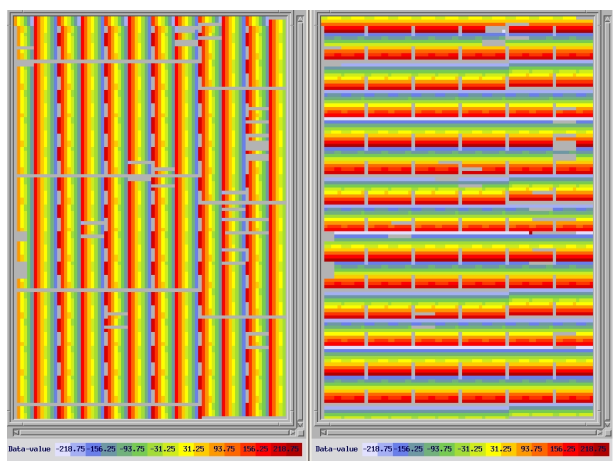

Figure 9: *I*nline and Crossline Distance for the First COV.

Application.

This way of collecting traces in COV gathers, is used for conditioning 3D3C seismic data from Blackfoot field, within a processing sequence for converted waves data. The 3D seismic data is acquired with good offset and azimuth distribution in their central part, thanks to the use of a quasi-square registration pattern.

After applying a typical processing sequence for converted waves, with the best set of static corrections and the final

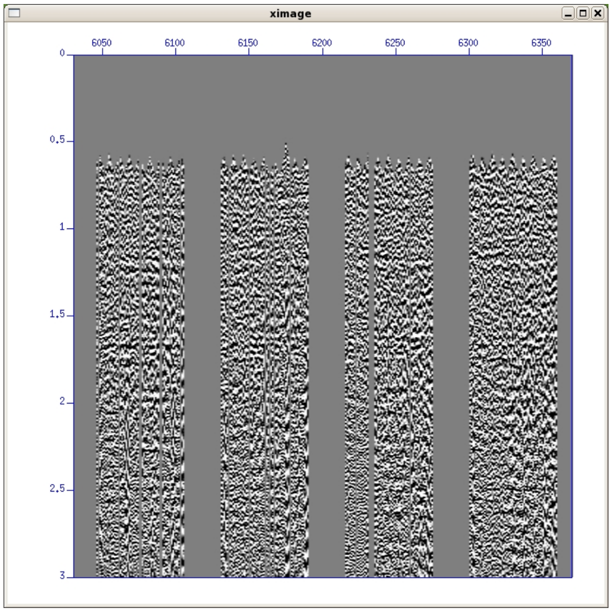

Figure 10: *I*nlines Extracted from Cov14 Without Filtering.

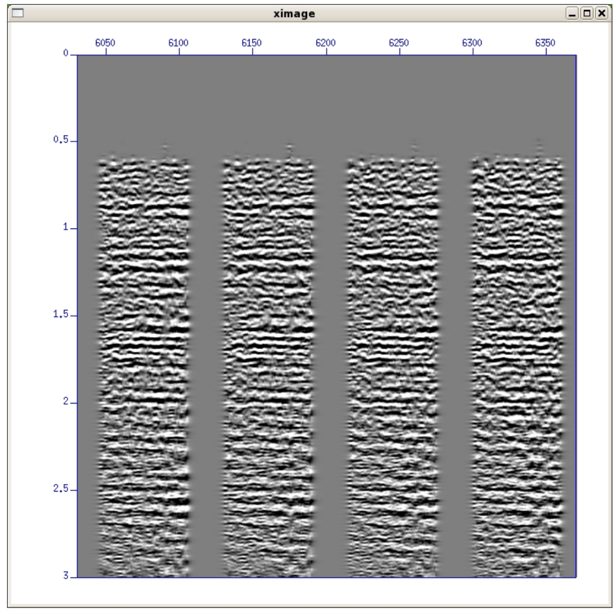

Figure 11: *I*nlines Extracted from Cov14 Filtered.

velocities field, data is corrected with PSNMO and taken to the final plane. Afterwards, Fxy deconvolution is applied to the data already ordered in COV. Even when all the sequence is treated with converted waves processing with the CCP bin instead of the CDP bin, in order to do the filtering in Fxy, the CDP geometry is temporarily used for filtering, and then, the data is re-arranged in CCP bins. Given that, in this case, the acquisition geometry does not differ much from the geometry planned in a regular way, and that seismic data is mainly sub-horizontal, a “theoretical geometry” is chosen to be calculated from the numbers of source and receiver stations. In Figure 7 the real and calculated geometries are compared in an area where offsets are found. The use of this technique avoids regularization or interpolation before noise suppression, and the need to form one-fold COVs.

Different geometric attributes are plotted for the whole area. Figure 8 shows azimuth and offset geometric attributes corresponding to the minimal offset COV cube. Figure 9 shows the corresponding attributes of Inline and Crossline distance.

Seismic traces without filtering, corresponding to COV 14 of lesser offset Inline are shown in the inline direction in Figure 10. All these traces have stack 1. Filtered traces are shown in Figure 11. It is possible to observe an enhancement of the signal-noise ratio for the 3 second data. Each of these filtered COVs, 40 altogether, has been stacked for Quality Control. The stacking can be observed in Figure 12, and it can be compared with the original stack showed in Figure 13. Now it is possible to observe how enhancement is not only evident in the shallow times but also in deeper ones, given that COVs with more central offset favor enhancement of these times. Finally, it can be observed how pre-filtered volume slices improve (Figure 14) after post-filtering with Fxy deconvolution (Figure 15).

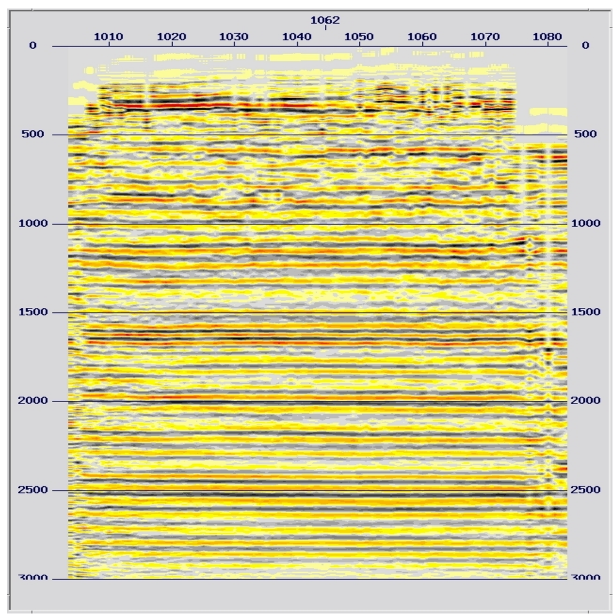

Figure 12: *S*tack with Fxy Pre-stack.

Conclusions.

As it has been shown in this work, data gathering in COV is useful to apply pre-stack noise suppression techniques to 3D-3C data. By applying Fxy to COVs, seismic data become appropriately conditioned for subsequent processes, such as PSTM migration and velocities picking. With filtered COVs more suitable migrated gathers will be obtained to be used, for instance, in the calculation of pre-stack attributes. The limitation of the technique used in this study is to be established by the acquisition geometry and the possibility to use a ”theoretical geometry” not differing much from the real coordinates, where irregular geometry cases will require a special study.

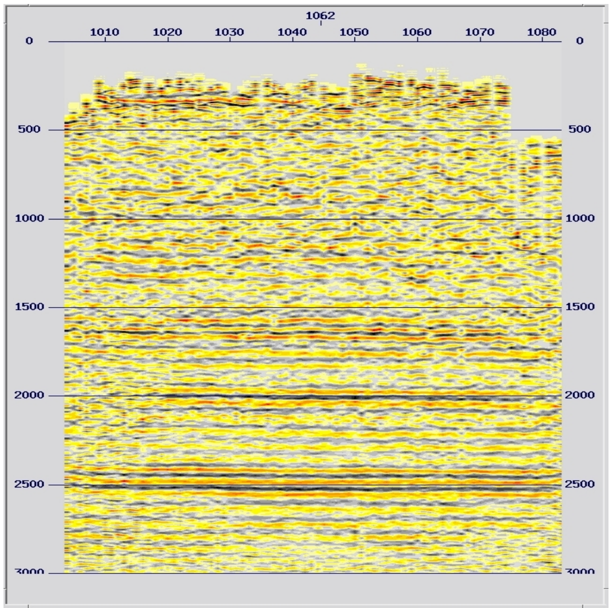

Figure 13: *N*on Filtered Stack.

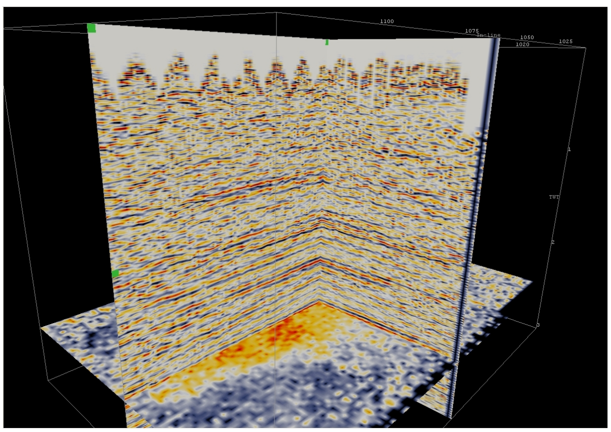

Figure 14: *C*OV Not Filtered Volume.

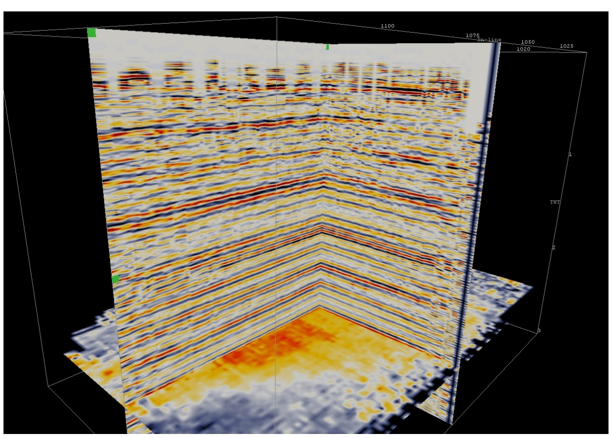

Figure 15: *C*OV Volume with Fxy Pre-Stack.

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Acknowledgments

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