Multifocusing improves seismic data

A new methodology provides coherent stacking of seismic data and has the potential to compute enhanced prestack seismic traces.

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The quality of recorded seismic data depends on many factors such as complexity of the subsurface, strong noise level, the topography of the earth's surface, near-surface inhomogeneities, etc. Irregular acquisition, short maximum offsets, and low common midpoint (CMP) fold all lead to low quality when processing and imaging vintage data.

Multifocusing technology

Multifocusing (MF) technology, based on multiparameter stacking, has been applied to enhance time imaging sections by dramatically increasing the fold of coherent summation of seismic signals. The MF correction formula is quite accurate, even for strongly curved reflectors. This can be attributed to the fact that it is not a simple hyperbolic Taylor expansion, but a double square-root equation.

Implementation of the MF method is technically challenging because it requires defining three moveout parameters in the 2-D case and eight in the 3-D case, as opposed to a single parameter (stacking velocity) in standard normal moveout velocity analysis.

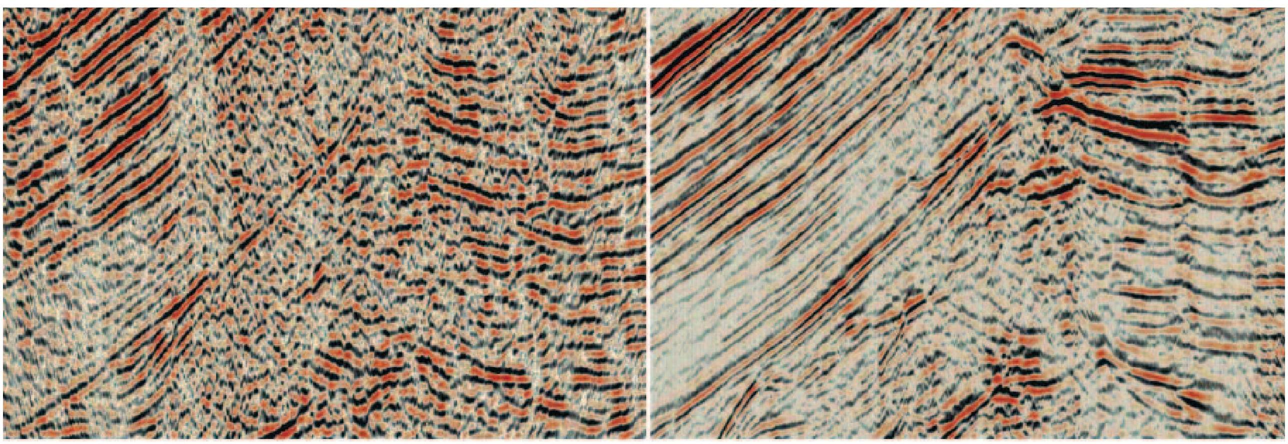
Although in principle "mixing" reflection events from a number of CMP gathers (i.e., a number of depth reflection points) might compromise the spatial resolution of the resulting stacked section and make random noise appear as an interpretable signal, the Geomage implementation of a simultaneous parameter search mostly avoids this effect and minimizes artifacts.

Key among potential benefits of MF stacking as compared to the CMP stack include:

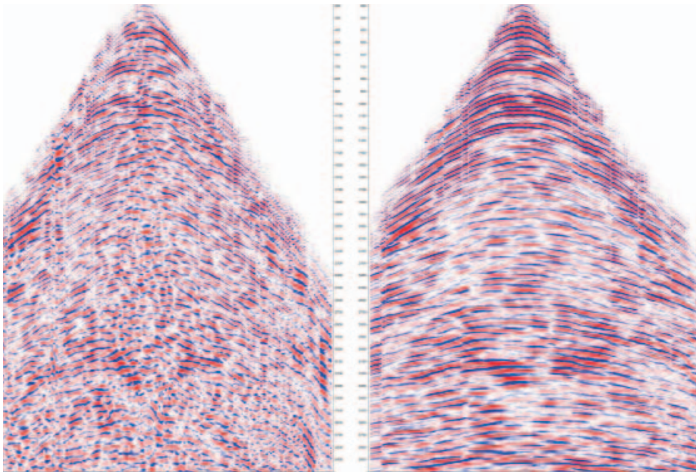
- Stacking a large number of traces covering many CMP gathers that can increase the stacking power and signal-to-noise ratio;
- A moveout correction that is "stretch-free," which dramatically increases vertical resolution and essentially can contribute to wide-angle amplitude versus offset analysis; and
- A moveout correction formula that is a double square-root equation and describes travel-time behavior for a wider class of subsurface models.

MF technology was applied to low-fold and low-quality data from northwestern Russia (Timano-Pechora Basin). All Timano-Pechora swells have a northwest trend and a horst-imbricate structure. They are broken up into wedge-like blocks that include anticline structures. The present structure of the Timano-Pechora swells resulted from different overlapping exposures of the Ural and Novaya Zemlya fold systems at some stages in their geological history. Ordovician-Silurian deposition took place under trough conditions. These formations are considerably thicker than in the western areas, where sedimentation took place in a shallower deep-sea environment.

The overlying Triassic formations inconsistently covered the underlying series.



MF technology was applied to low-fold and low-quality data from northwestern Russia (Timano-Pechora Basin). An interpreter would have a very difficult time unraveling this complex geological history using the conventionally processed section on the left. In the MF section on the right, the picture is much clearer. (Images courtesy of Geomage)



An original CMP gather was part of the proposed data enhancement idea. The original common supergather (left) has low signal-to-noise ratio and is characterized by a complex kinematics of reflection events due to the surface topography and subsurface geology. The MF-enhanced gather (right) shows essential signal-to-noise improvement, and it preserves all main kinematic and dynamic features of the original data.

A final tectonic episode of the Triassic period caused a horst and graben structure in the Upper Permian deposits and an erosion of the Triassic formations, especially on the anticlinoria crests. An interpreter would have a very difficult time unraveling this complex geological history using the conventionally processed section. In the MF section, the picture is much clearer.

Enhancing signal-to-noise ratio of prestack data

In particular, MF is very effective for processing and reprocessing low-fold CMP data due to MF's noise suppression wavefield. In many situations, the unmigrated time image itself can be regarded as a byproduct, and the improved prestack seismic traces with increased signal-to noise-ratio are requested. Typical examples of such situations are velocity model-building or prestack time or depth migrations.

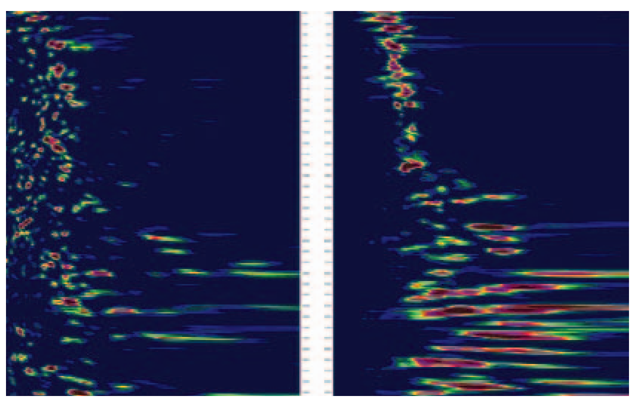
The quality of old seismic reflection data often is low due to the short maximum offsets, irregular acquisition, and low CMP fold. In this case, the quality of stacked and migrated sections is poor, and prestack data preconditioning for velocity analysis, velocity model-building, and prestack migrations is important, if not crucial, for successful subsurface imaging. The prestack traces of real (especially land) data might have irregular geometry such that it is necessary to regularize data and fill the gaps where data are missing.

Wavefield parameters estimated by the MF method can be used for prestack data regularization and enhancement. The idea is to apply the MF travel-time formula to compute new partially stacked supergathers, in which each trace is a result of summation of data along the MF stacking surface. The number and location of traces in the produced supergathers can be different from the input locations, and the resulting traces can be regular with increased signal-to-noise ratio due to partial coherent summation. The method is robust in the presence of non-coherent noise.

The algorithm for data enhancement can be described as follows: According to estimated MF parameters, the partial MF stack calculates a stacking surface around a specified CMP-offset location and performs the summation of data along that surface. The result of summation is assigned to the same CMP, offset, and time coordinates. Repeating this procedure for all desired points generates a new gather that is called the MF-enhanced supergather. An original CMP gather and a velocity analysis of the original data were part of the proposed data enhancement idea. The original common super-shot has a low signal-to-noise ratio and is characterized by a complex kinematics of reflection events due to the surface topography and subsurface geology.

The MF-enhanced gather shows essential signal-to-noise improvement, and it preserves all main kinematic and dynamic features of the original data. Velocity analysis performed on the enhanced gather is cleaner, with better definition of the primary reflection event compared to velocity analysis using the original data.

The MF method not only provides coherent stacking of seismic data with arbitrary source-receiver distribution to create high-quality time images, but it also has the potential to compute enhanced prestack seismic traces. The presented method uses a new MF moveout correction formula for approximation of the local moveout correction and is based on partial stacks along optimal travel-time trajectories. Due to the higher quality, the partially stacked gathers can be used instead of the original seismic traces, especially for sparse, low-quality data. Results of velocity analysis, stacking, and time or depth migration also might be improved using gathers generated by the new approach. E&P



A velocity analysis of the original data also was included in the proposed data enhancement idea (left). The velocity analysis improves with the MF-enhanced data (right).