

CLAIMS

What is claimed is:

1. A method of seismic exploration above a region of subsurface containing structural or stratigraphic features conducive to determining a presence,
5 migration, or accumulation of hydrocarbons, the method comprising:
accessing a seismic dataset of a seismic survey that images at least a portion of
a predetermined volume of Earth;
sorting the seismic dataset into a time or depth and space domain such that the
seismic response by the Earth is coherent in the sorted domain to generate a sorted
10 seismic dataset;
splitting the seismic dataset in time or depth and space domain into smaller
overlapping windows of at least one sub-dataset;
calculating a multi-dimension Fourier transform spectrum from each sub-
dataset to produce multi-dimension Fourier transformed data;
15 determining a plurality of maximum frequency spectral values from the multi-
dimension Fourier transformed data, wherein each maximum frequency spectral value
of the plurality of maximum frequency spectral values corresponds to a maximum
energy value at a particular frequency of a set of frequencies of a seismic frequency
spectrum;
20 selecting a plurality of threshold values, wherein each threshold value of the
plurality of threshold values corresponds to one frequency of the set of frequencies;
decrementing each threshold value of the plurality of threshold values
iteratively to generate a decremented threshold value corresponding to each frequency
of the set of frequencies;

- generating a modified Fourier transformed dataset, wherein the modified Fourier transformed dataset is modified by setting Fourier samples of the multi-dimension Fourier transform spectrum having an energy magnitude less than the decremented threshold value at each frequency of the set of frequencies to zero;
- 5 inverse transforming the modified Fourier transformed dataset to generate a plurality of interpolated traces;
- substituting each interpolated trace of the plurality of interpolated traces into originally empty traces of the seismic dataset where no seismic energy is acquired in data acquisition;
- 10 repeating a Fourier transform, thresholding and inverse transform until the threshold value is sufficiently small to create a modified sub-dataset as an interpolated seismic sub-dataset; and
- merging all overlapping windows of the interpolated seismic sub-dataset to create an interpolated seismic data to be utilized to explore for hydrocarbons within at
- 15 least the portion of the predetermined volume of the Earth.

2. The method of claim 1, comprising determining which maximum spectral value of the plurality of maximum spectral values has a highest energy value in a Fourier transformed domain for each frequency of the set of frequencies.

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3. The method of claim 2, comprising generating the threshold based on the maximum spectral value having the highest energy value and a predetermined number of iterations.

4. The method of claim 1, wherein the threshold comprises a respective threshold corresponding to each frequency of the set of frequencies.

5. The method of claim 4, comprising generating the respective threshold
5 corresponding to each frequency of the set of frequencies based on the maximum spectral value corresponding to each frequency of the set of frequencies.

6. The method of claim 1, wherein each frequency of the set of frequencies corresponds to an individual frequency value.

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7. The method of claim 1, wherein each frequency of the set of frequencies corresponds to a finite frequency range including two or more individual frequency values.

15 8. The method of claim 1, comprising determining whether the decremented threshold value for each frequency is equal to zero or is approximately equal to zero.

9. The method of claim 8, comprising determining whether a maximum
20 iteration count has been reached.

10. The method of claim 9, comprising:
calculating a second Fourier transform spectrum of the modified dataset;
decrementing each decremented threshold value by a predefined decreasing
25 function of the maximum spectral value and a number of iterations to generate a

second decremented threshold value corresponding to each frequency of the set of frequencies;

generating a second modified Fourier transformed dataset, wherein the second modified Fourier transformed dataset is modified by setting Fourier samples of the second Fourier transform spectrum having an energy magnitude less than the second decremented threshold value at each frequency of the set of frequencies to zero;

inverse transforming the second modified Fourier transformed dataset to generate a plurality of second interpolated traces; and

substituting each second interpolated trace of the plurality of second interpolated traces into the originally empty traces of the seismic dataset where no seismic energy is acquired in data acquisition to create a second modified dataset based upon the determining of whether the decremented threshold value for each frequency is equal to zero or is approximately equal to zero and whether a maximum iteration count has been reached.

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11. A tangible, non-transitory, machine readable media, comprising instructions configured to cause a processor to:

access a seismic dataset of a seismic survey that images at least a portion of a predetermined volume of Earth,

20 sort the seismic dataset into a time or depth and space domain such that the seismic response by the Earth is coherent in the sorted domain to generate a sorted seismic dataset,

splitting the seismic dataset in time or depth and space domain into smaller overlapping windows of at least one sub-dataset;

calculate a multi-dimension Fourier transform spectrum from each sub-dataset
to produce multi-dimension Fourier transformed data;

determine a plurality of maximum frequency spectral values from the multi-
dimension Fourier transformed data, wherein each maximum frequency spectral value
5 of the plurality of maximum frequency spectral values corresponds to a maximum
energy value at a particular frequency of a set of frequencies of a seismic frequency
spectrum;

select a plurality of threshold values, wherein each threshold value of the
plurality of threshold values corresponds to one frequency of the set of frequencies;
10 decrement each threshold value of the plurality of threshold values iteratively
to generate a decremented threshold value corresponding to each frequency of the set
of frequencies;

generate a modified Fourier transformed dataset, wherein the modified Fourier
transformed dataset is modified by setting Fourier samples of the multi-dimension
15 Fourier transform spectrum having an energy magnitude less than the decremented
threshold value at each frequency of the set of frequencies to zero;

inverse transform the modified Fourier transformed dataset to generate a
plurality of interpolated traces; and

substitute each interpolated trace of the plurality of interpolated traces into the
20 empty traces of the seismic dataset where no seismic energy is acquired in data
acquisition;

repeat a Fourier transform, thresholding and inverse transform until the
threshold value is sufficiently small to create a modified sub-dataset as an interpolated
seismic sub-dataset; and

merge all overlapping windows of the interpolated seismic sub-dataset to
create an interpolated seismic data to be utilized to explore for hydrocarbons within at
least the portion of the predetermined volume of the Earth.

- 5 12. The tangible, non-transitory, machine readable media of claim 11,
wherein the instructions cause the processor to:
- determine which maximum spectral value of the plurality of maximum
spectral values has a highest energy value in a Fourier transformed domain for each
frequency of the set of frequencies; and
- 10 generate the threshold based on the maximum spectral value having the
highest energy value and a predetermined number of iterations.
13. The tangible, non-transitory, machine readable media of claim 11,
wherein the threshold comprises a respective threshold corresponding to each
- 15 frequency of the set of frequencies, wherein the instructions cause the processor to
generate the respective threshold corresponding to each frequency of the set of
frequencies based on the maximum spectral value corresponding to each frequency of
the set of frequencies.
- 20 14. The tangible, non-transitory, machine readable media of claim 11,
wherein each frequency of the set of frequencies corresponds to an individual
frequency value.

15. The tangible, non-transitory, machine readable media of claim 11,
wherein each frequency of the set of frequencies corresponds to a finite frequency
range including two or more individual frequency values.

5 16. The tangible, non-transitory, machine readable media of claim 11,
wherein the instructions cause the processor to:
determine whether the decremented threshold value for each frequency is
equal to zero or is approximately equal to zero; and
determine whether a maximum iteration count has been reached.

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17. The tangible, non-transitory, machine readable media of claim 16,
wherein the instructions cause the processor to:
calculate a second Fourier transform spectrum of the modified dataset;
decrement each decremented threshold value by a predefined decreasing
15 function of the maximum spectral value and a number of iterations to generate a
second decremented threshold value corresponding to each frequency of the set of
frequencies;
generate a second modified Fourier transformed dataset, wherein the second
modified Fourier transformed dataset is modified by setting Fourier samples of the
20 second Fourier transform spectrum having an energy magnitude less than the second
decremented threshold value at each frequency of the set of frequencies to zero;
inverse transform the second modified Fourier transformed dataset to generate
a plurality of second interpolated traces; and
substitute each second interpolated trace of the plurality of second interpolated
25 traces into the originally empty traces of the seismic dataset where no seismic energy

is acquired in data acquisition to create a second modified dataset based upon whether the decremented threshold value for each frequency is equal to zero or is approximately equal to zero and whether a maximum iteration count has been reached.

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18. A method of seismic exploration above a region of subsurface containing structural or stratigraphic features conducive to determining a presence, migration, or accumulation of hydrocarbons, the method comprising:

accessing a seismic dataset of a seismic survey that images at least a portion of
10 a predetermined volume of Earth,

setting a residual to the seismic dataset;

combining the residual into a common receiver gather;

splitting the common receiver gather into smaller overlapping windows of at
least one sub-dataset;

15 calculating a multi-dimension Fourier transform spectrum from each sub-dataset to produce multi-dimension Fourier transformed data;

determining a plurality of maximum frequency spectral values from the multi-dimension Fourier transformed data, wherein each maximum frequency spectral value of the plurality of maximum frequency spectral values corresponds to a maximum
20 energy value at a particular frequency of a set of frequencies of a seismic frequency spectrum;

selecting a plurality of threshold values, wherein each threshold value of the plurality of threshold values corresponds to one frequency of the set of frequencies;

decrementing each threshold value of the plurality of threshold values
iteratively to generate a decremented threshold value corresponding to each frequency
of the set of frequencies;

generating a modified Fourier transformed dataset, wherein the modified
5 Fourier transformed dataset is modified by setting Fourier samples of the multi-
dimension Fourier transform spectrum having an energy magnitude less than the
decremented threshold value at each frequency of the set of frequencies to zero;

inverse transforming the modified Fourier transformed dataset to generate a
plurality of deblended traces;

10 merging all windows of the at least one sub-dataset from the inverse Fourier
transform to create a deblended common receiver gather;

updating a primary signal estimate utilizing the deblended gather to generate
an updated primary signal estimate;

updating the residual based upon the updated primary signal estimate to
15 generate an updated residual;

repeating the primary signal estimate by combining the updated residual and
continuing the processing steps above until the residual is sufficiently small;

outputting the updated primary signal estimate as a deblended result to be
utilized to explore for hydrocarbons within at least the portion of the predetermined
20 volume of the Earth.

19. The method of claim 18, wherein the deblended result is outputted
based upon a determination of whether a value of an amplitude of the updated residual
meets a threshold value.

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20. The method of claim 18, wherein updating the residual based upon the updated primary signal estimate to generate an updated residual comprises:

blending traces from the updated primary signal estimate into a continuous record with a time shift applied to each of the traces from the updated primary signal estimate corresponding to a time of source excitation to generate blended continuous data; and calculating the difference between original continuous recording and the blended continuous data as the updated residual.