

Despite the utility of the foregoing methods, a need exists for generating improved images of underwater geological structures.

SUMMARY

[0012] According to a first aspect of the present invention, there is providedAs detailed herein, a method for de-ghosting seismic data related to a subsurface of a body of water, the method comprising: may include receiving input time-domain seismic data recorded by a plurality of seismic receivers, wherein the input seismic data is recorded in a time-space domain and the seismic receivers that are located at different depths (z_r) in the body of water; generating migration data (du) and mirror migration data (dd) from the seismic data;_i deriving a ghost free model (m) based on simultaneously using the migration data (du) and mirror migration data (dd), using the ghost free model to generate a deghosted dataset;_i and generating a final image (f) of the subsurface using the deghosted dataset.

[0012a] The migration data may be in the time or depth domain, with pre-stack dimension offset or angle, or the like.

[0013] Deriving the ghost free model may include solving an equation $d=Lm$ for m , where L is a linear operator that incorporates a first ghost lag model (τ_{gu}) corresponding to the migration data (du) and a second ghost lag model (τ_{gd}) corresponding to the mirror migration data (dd), m is a ghost free model of the seismic data, and d contains data from the migration data (du) and the mirror migration data (dd). The model (m) may be in the parabolic Radon domain, the linear Radon domain, the FK domain, the hyperbolic Radon domain or the like.

[0014] A computing device that incorporates the method for de-ghosting seismic data is also described herein.

[0014a] According to a second aspect of the present invention, there is provided a computing device configured to de-ghost seismic data related to a subsurface of a body of water, the computing device comprising: an interface configured to receive seismic data recorded by a plurality of seismic receivers that are towed by a vessel, wherein the seismic data is recorded in a time-space domain and the seismic receivers are located at different depths (z_i) in the body of water; a processor configured to generate migration data (du) and mirror migration data (dd) from the seismic data; the processor further configured to derive a ghost free model (m) based on simultaneously using the migration data (du) and mirror migration data (dd); the processor further configured to generate a deghosted dataset based on the ghost free model (m); and the processor further configured to use the deghosted dataset to generate a final image (f) of the subsurface.

[0015] According to a third aspect of the present invention, there is provided~~In addition to the foregoing,~~ a method for processing seismic data related to a subsurface of a body of water, the method comprising:~~includes~~ receiving migration data (du) and

mirror migration data (dd) generated from ~~input~~time-domain seismic data recorded by a plurality of seismic receivers that are towed by a vessel, wherein the seismic data is recorded in a time-space domain and the seismic receivers are located at different depths (z_r) in the body of water; deriving a first ghost lag model (τ_{gu}) corresponding to the migration data (du) that estimates a first ghost lag to a seismic source as a function of an offset h of each seismic receiver of the plurality of seismic receivers; deriving a second ghost lag model (τ_{gd}) corresponding to the mirrored migration data (dd) that estimates a second ghost lag to the seismic source as a function of an offset h of each seismic receiver of the plurality of seismic receivers; and processing the migration data (du) using the first and second ghost lag models to provide a final image (f) of the subsurface.

[0016] As described herein, the above apparatus and methods may be used to generate improved images of underwater geological structures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate one or more embodiments and, together with the description, explain these embodiments. In the drawings:

[0018] Figure 1 is a schematic diagram of a conventional seismic data acquisition system having a horizontal streamer;

[0019] Figure 2 is a schematic diagram of a seismic data acquisition system having a slanted streamer;

[0020] Figure 3 is a schematic diagram of a seismic data acquisition system having a curved profile streamer;

[0021] Figure 4 is a flowchart of a method for deghosting seismic data according to one embodiment;

[0022] Figure 5 is a flowchart of a method for ghost lag modeling of migration