SYSTEM AND METHOD FOR SEISMIC SENSOR RESPONSE CORRECTION

BACKGROUND

[0001] Seismic surveys are conducted to map subsurface features. For example, seismic surveys can help locate oil and gas reservoirs. Land based seismic surveys may include hundreds or thousands of individual seismic sensors placed in or on the ground in a grid pattern over an area covering many square kilometers. An explosive charge, seismic vibrator or other suitable source of acoustic energy generates sound waves that propagate through subsurface features. The sound waves are reflected back toward the surface and sensed by the seismic sensors in the grid. Signals from the sensors are collected and used to map the subsurface features in the survey area.

SUMMARY

[**0001a**] According to a first aspect of the present disclosure, there is provided a system for acquiring and processing seismic data, including: a seismic data acquisition unit, comprising: a data storage memory configured to store a transfer function of a seismic sensor coupled to the seismic data acquisition unit, wherein the transfer function relates a motion of the seismic sensor to signals generated by the seismic sensor responsive to the motion; and a second data storage memory configured to store the signals generated by the seismic sensor; a data extraction unit configured to: retrieve, from the seismic data acquisition unit, the signals stored in the data storage memory; and format the signals for transport to a seismic data processing system, wherein the seismic data processing system is configured to identify the seismic sensor coupled to the seismic data acquisition unit that generated the signals, the seismic sensor is identified from among a plurality of other seismic sensors, and the seismic data processing system is configured to retrieve the sensor transfer function that corresponds to the identified seismic sensor; a sensor tester configured to: apply a test signal to the seismic sensor as part of a field test; record a response of the seismic sensor to the test signal; process the response to generate the transfer function; and store the transfer function for use by the seismic data processing system in generating an inverse filter that when applied to the signals changes parameters of the signals to correspond to the signals being generated with the seismic sensor having a reference transfer function.

[**0001b**] According to a second aspect of the present disclosure, there is provided a method for processing seismic data, including: receiving, by a seismic data processing system, signals representing seismic data recorded at a remote location; receiving, by the seismic data processing system in conjunction with the signals, identification of a seismic sensor via which the signals were acquired, wherein the seismic sensor is identified from among a plurality of other seismic sensors; retrieving, by the seismic data processing system, a sensor transfer function that corresponds to the identified seismic sensor and relates a motion of the seismic sensor to the signals; generating, by the seismic data processing system, based on the sensor transfer function and a reference transfer function, an inverse filter that when applied to the signals changes parameters of the signals to correspond to the reference transfer function; and applying, by the seismic data processing system, the inverse filter to the signals to conform the parameters of the signals to the reference transfer function.

[**0001c**] According to a third aspect of the present disclosure, there is provided a method for processing seismic data, including: as part of manufacturing test of a seismic sensor to be used for acquisition of seismic data: deriving a sensor transfer function of the seismic sensor, wherein the sensor transfer function relates a motion of the seismic sensor to signals generated by the seismic sensor responsive to the motion; storing the sensor transfer function for use by a seismic data processing system in generation of an inverse filter; as part of seismic data acquisition: acquiring seismic data via the seismic sensor; extracting the seismic data from a seismic data acquisition unit coupled to the seismic sensor; formatting the seismic data for transport to the seismic data processing system that is at a different location from the seismic data acquisition unit, the formatting comprising providing identification of the seismic sensor for transport with the seismic data, wherein the seismic sensor is identified from among a plurality of other seismic sensors; as part of processing of the seismic data by the seismic data processing system: retrieving the sensor transfer function based on the identification of the seismic sensor; generating, based on the sensor transfer function and a reference transfer function, the inverse filter that when applied to the seismic data changes parameters of the seismic data to correspond to the seismic data being generated with the seismic sensor having the reference transfer function; applying, by the seismic data processing system, the

inverse filter to the seismic data to conform the parameters of the seismic data to the seismic data being generated with the seismic sensor having the reference transfer function.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] For a detailed description of exemplary embodiments, reference will now be made to the accompanying drawings, in which:

[0003] Figure 1 shows a flow diagram for a method for seismic sensor response correction in accordance with principles disclosed herein;

[0004] Figure 2 shows a block diagram of a seismic data acquisition unit suitable for use in seismic sensor response correction in accordance with principles disclosed herein;

[0005] Figure 3 shows a block diagram of apparatus suitable for testing a seismic sensor for determination of a transfer function of the seismic sensor in accordance with principles disclosed herein;

[0006] Figure 4 shows a block diagram of a seismic data acquisition system that includes seismic data acquisition units suitable for use in seismic sensor response correction in accordance with principles disclosed herein;

[0007] Figure 5 shows a block diagram of extraction of raw seismic data and sensor transfer function from a seismic data acquisition unit for use in seismic sensor response correction in accordance with principles disclosed herein;

[0008] Figure 6 shows a block diagram of a processing system suitable for correction of seismic sensor response in accordance with principles disclosed herein; and

CLAIMS

1. A system for acquiring and processing seismic data, comprising:

a seismic data acquisition unit, comprising:

a data storage memory configured to store a transfer function of a seismic sensor coupled to the seismic data acquisition unit, wherein the transfer function relates a motion of the seismic sensor to signals generated by the seismic sensor responsive to the motion; and

a second data storage memory configured to store the signals generated by the seismic sensor;

a data extraction unit configured to:

retrieve, from the seismic data acquisition unit, the signals stored in the data storage memory; and

format the signals for transport to a seismic data processing system, wherein the seismic data processing system is configured to identify the seismic sensor coupled to the seismic data acquisition unit that generated the signals, the seismic sensor is identified from among a plurality of other seismic sensors, and the seismic data processing system is configured to retrieve the sensor transfer function that corresponds to the identified seismic sensor;

a sensor tester configured to:

apply a test signal to the seismic sensor as part of a field test;

record a response of the seismic sensor to the test signal;

process the response to generate the transfer function; and

store the transfer function for use by the seismic data processing system in generating an inverse filter that when applied to the signals changes parameters of the signals to correspond to the signals being generated with the seismic sensor having a reference transfer function.

2. The system of claim 1, wherein the seismic data processing system is configured to:

receive the signals formatted by the data extraction unit;

generate, based on the sensor transfer function and the reference transfer function, the inverse filter; and

apply the inverse filter to the signals.

3. The system of claim 1 or claim 2, wherein the seismic data processing system is configured to generate the reference transfer function as an average of sensor transfer functions of a plurality of seismic sensors.

4. The system of any one of the preceding claims, wherein the test signal comprises an impulse or a plurality of frequencies applied to move the seismic sensor.

5. The system of any one of the preceding claims, wherein the sensor tester is configured to:

compare the transfer function of the sensor generated as part of a manufacturing test to the transfer function of the sensor generated as part of the field test; and

generate an alert signal based on a dissimilarity between the transfer function of the sensor generated as part of the manufacturing test to the transfer function of the sensor generated as part of the field test exceeding a predetermined amount.

6. The system of any one of the preceding claims, wherein the sensor comprises at least one of a piezoelectric crystal, a geophone, and an accelerometer.

7. The system of any one of the preceding claims, wherein the data extraction unit is configured to:

retrieve the transfer function from the data storage memory; and

format the transfer function for transport to the seismic data processing system in conjunction with the signals.

8. A method for processing seismic data, comprising:

receiving, by a seismic data processing system, signals representing seismic data recorded at a remote location;

receiving, by the seismic data processing system in conjunction with the signals, identification of a seismic sensor via which the signals were acquired, wherein the seismic sensor is identified from among a plurality of other seismic sensors;

retrieving, by the seismic data processing system, a sensor transfer function that corresponds to the identified seismic sensor and relates a motion of the seismic sensor to the signals;

generating, by the seismic data processing system, based on the sensor transfer function and a reference transfer function, an inverse filter that when applied to the signals changes parameters of the signals to correspond to the reference transfer function; and

applying, by the seismic data processing system, the inverse filter to the signals to conform the parameters of the signals to the reference transfer function.

9. The method of claim 8, further comprising:

storing the sensor transfer function in a data storage memory of a seismic data acquisition unit coupled to the seismic sensor prior to deployment of the seismic data acquisition unit;

after use of the seismic data acquisition unit to record seismic data:

retrieving the signals stored in a data storage memory of the seismic data acquisition unit; and

formatting the signals for transport to the remote data processing system.

10. The method of claim 8 or claim 9, further comprising:

applying a test signal to the seismic sensor, as part of a manufacturing test or a field test, wherein the test signal comprises at least one of an impulse or a range of frequencies applied to move the seismic sensor;

recording response of the seismic sensor to the test signal;

processing the response to generate the transfer function; and

storing the transfer function for use by the remote data processing system in generating the inverse filter.

11. The method of claim 10, further comprising:

comparing the transfer function of the seismic sensor generated as part of the manufacturing test to the transfer function of the seismic sensor generated as part of the field test; and

generating an alert signal based on a dissimilarity between the transfer function of the seismic sensor generated as part of the manufacturing test to the transfer function of the seismic sensor generated as part of the field test exceeding a predetermined amount.

12. The method of any one of claims 8 to claim 11, further comprising generating, by the seismic data processing system, the reference transfer function as an average of sensor transfer functions of a plurality of seismic sensors.

13. The method of claim 8, further comprising:

retrieving, from a transfer function memory of a seismic data acquisition unit, the transfer function; and

formatting the transfer function for transport to the remote data processing system in conjunction with the signals.

14. A method for processing seismic data, comprising:

as part of manufacturing test of a seismic sensor to be used for acquisition of seismic data:

deriving a sensor transfer function of the seismic sensor, wherein the sensor transfer function relates a motion of the seismic sensor to signals generated by the seismic sensor responsive to the motion;

storing the sensor transfer function for use by a seismic data processing system in generation of an inverse filter;

as part of seismic data acquisition:

acquiring seismic data via the seismic sensor;

extracting the seismic data from a seismic data acquisition unit coupled to the seismic sensor;

formatting the seismic data for transport to the seismic data processing system that is at a different location from the seismic data acquisition unit, the formatting comprising providing identification of the seismic sensor for transport with the seismic data, wherein the seismic sensor is identified from among a plurality of other seismic sensors;

as part of processing of the seismic data by the seismic data processing system:

retrieving the sensor transfer function based on the identification of the seismic sensor;

generating, based on the sensor transfer function and a reference transfer function, the inverse filter that when applied to the seismic data changes parameters of the seismic data to correspond to the seismic data being generated with the seismic sensor having the reference transfer function;

applying, by the seismic data processing system, the inverse filter to the seismic data to conform the parameters of the seismic data to the seismic data being generated with the seismic sensor having the reference transfer function.

15. The method of claim 14, wherein storing the sensor transfer function comprises storing the sensor transfer function in a data storage memory of the seismic data acquisition unit coupled to the seismic sensor or storing the sensor transfer function in a database accessible to the seismic data processing system.

16. The method of claim 14 or claim 15, wherein deriving the sensor transfer function comprises:

applying a test signal to the seismic sensor, wherein the test signal comprises at least one of an impulse or a range of frequencies applied to move the seismic sensor;

recording a response of the seismic sensor to the test signal;

processing the response to generate the transfer function; and

storing the transfer function for use by the seismic data processing system in generating the inverse filter.

17. The method of claim 16, wherein applying the test signal comprises:

affixing the seismic sensor to a movable structure; and

applying a motion impulse or motion over a range of frequencies to the movable structure.

18. The method of claim 14, further comprising:

as part of seismic data acquisition:

retrieving, from a transfer function memory of a seismic data acquisition unit, the transfer function; and

formatting the transfer function for transport to the data processing system in conjunction with the seismic data; or

as part of the seismic data acquisition:

comparing the transfer function of the sensor generated as part of the manufacturing test to the transfer function of the sensor generated as part of a field test;

generating an alert signal based on a dissimilarity between the transfer function of the sensor generated as part of the manufacturing test to the transfer function of the sensor generated as part of the field test exceeding a predetermined amount.

19. The method of any one of claims 14 to 18, further comprising, as part of processing of the seismic data by the seismic data processing system, generating the reference transfer function as an average of sensor transfer functions of a plurality of movable sensors.