EXPLORING FOR SUBTLE MISSION CANYON STRATIGRAPHIC TRAPS WITH ELASTIC WAVEFIELD SEISMIC TECHNOLOGY

SEMI-ANNUAL PROGRESS REPORT

February 6 – August 5, 2003

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Report Issue Date: October 2003

DOE Award DE-FC26-03NT15421

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Abstract

A source-receiver geometry was designed for a 9C3D seismic survey in Montrail County, North Dakota, that will involve the largest number of active 3-component stations (1,800 to 2,100) ever attempted in an onshore U.S. multicomponent seismic survey. To achieve the data-acquisition objectives, 3-component geophone strings will be provided by the Bureau of Economic Geology, Dawson Geophysical, and Vecta Technology. Data acquisition will commence in late October 2003.

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Introduction

The general objective of this study is to demonstrate the value of multicomponent seismic technology for exploring for subtle oolitic-bank reservoirs in the Mission Canyon Formation of the Williston Basin. The work tasks done during this report period concentrated on developing an optimal design for the seismic survey. This first semi-annual report defines the geographical location and geometrical shape of the survey and documents the key acquisition parameters that will be implemented to yield high-fold, high-resolution 9-component seismic data.

Executive Summary

One objective of this project is to determine whether multicomponent seismic technology is, or is not, essential for exploring for subtle stratigraphic traps in the Williston Basin. The targeted study interval is the Mission Canyon Formation where prolific oolitic-bank reservoirs are difficult to image with conventional P-wave seismic technology. To achieve this objective, the research team will acquire, process, and interpret 9-component 3-D seismic data, which will allow every type of seismic mode (P-P, SH-SH, SV-SV, P-SV, SV-P, fast-S, slow-S) to be used to image a selected portion of this oolitic reservoir trend. This report documents the conclusions of a seismic survey design analysis that was done by the research team during the report period. The objective of the design effort was to create an acquisition grid that will result in optimal fold and azimuth-offset distributions for all of the elastic modes involved in 9-component data.

Experimental

The seismic design research done this period utilized simple, straight-raypath techniques to position CMP and CCP coordinates across seismic image space.

Results and Discussion

During this reporting period, we evaluated a variety of source-receiver geometries that could be used to acquire 9C3D seismic data across the selected Mission Canyon study area in Mountrail County, North Dakota. The objectives of these survey design exercises were to create an acquisition template that provides a full range of offsets in all azimuth directions, results in a high, uniform fold for both CMP and CCP binning, and keeps the seismic acquisition costs within the allotted budget.

This design work demonstrated the technical advantage and the cost-containment benefits of deploying the largest possible number of receiver stations at the smallest possible spatial intervals across the total area of the acquisition template. This design philosophy reduces the number of source stations required, thereby reducing the cost of the survey, yet provides data having optimal fold, offset, and azimuth statistics.

Discussions and interactions among Vecta Technology, Exploration Geophysics Laboratory (EGL), and seismic contractor personnel resulted in a final survey design that was acceptable to all, in agreements to expand the channel capacity of the acquisition system, and in the mobilization of additional 3-C geophone strings to the survey area. The survey in Mountrail County will involve what we understand is the largest number of 3-C geophone strings (2,400) and the largest number of active 3-C receiver stations (1,800 or more) ever deployed in a U.S.-based onshore multicomponent seismic survey. The acquisition system provided by Dawson Geophysical has to maintain about 6,000 active data channels to carry out this data-acquisition program, which is pushing the technology envelope for onshore work. Data acquisition should occur early in the next reporting period.

Included in this report are selected examples of the final survey design provided by Dawson Geophysical. Expanded captions are added to the figures to explain the principles that are illustrated.

In addition to this seismic design work, Bureau and Vecta personnel compiled geologic information needed for prospect evaluation and created basic graphical displays that can be used for technology transfer workshops and DOE reports. The construction of the sequence stratigraphic models was initiated.

Conclusions

A seismic survey design that will push the technical envelope of onshore multicomponent seismic data acquisition is on the verge of being implemented in Montrail County, North Dakota to explore for subtle Mission Canyon stratigraphic traps. Barring data-acquisition problems, exemplary 9C3D seismic data produced in this project could become a centerpiece of DOE’s technology transfer program.

Acronyms and Abbreviations

CCP: common conversion point
CMP: common midpoint
EGL: Exploration Geophysics Laboratory (Bureau of Economic Geology)
3-C: three-component
9C3D: nine-component and three-dimensional

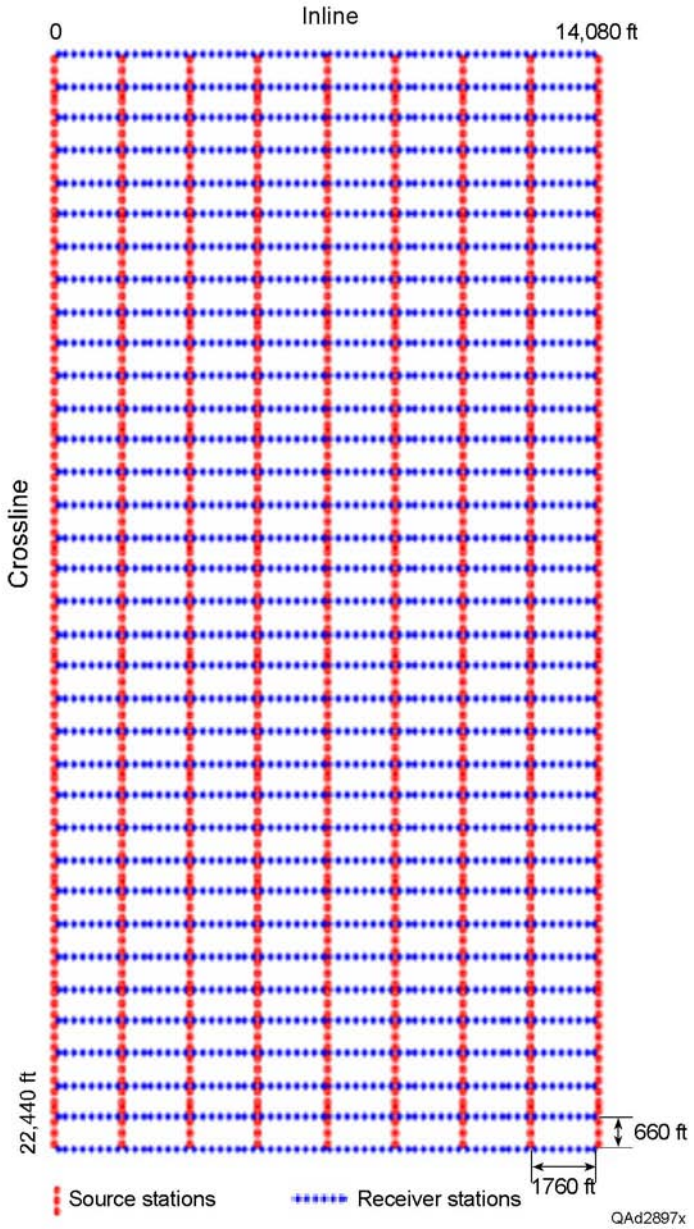

Figure 1. The geometrical distribution of source and receiver stations that will be used across the survey area. This seismic design grid extends 14,080 ft (2.67 mi) in the inline direction, 22,440 ft (4.25 mi) in the crossline direction, and covers an area of 11.33 mi^2.

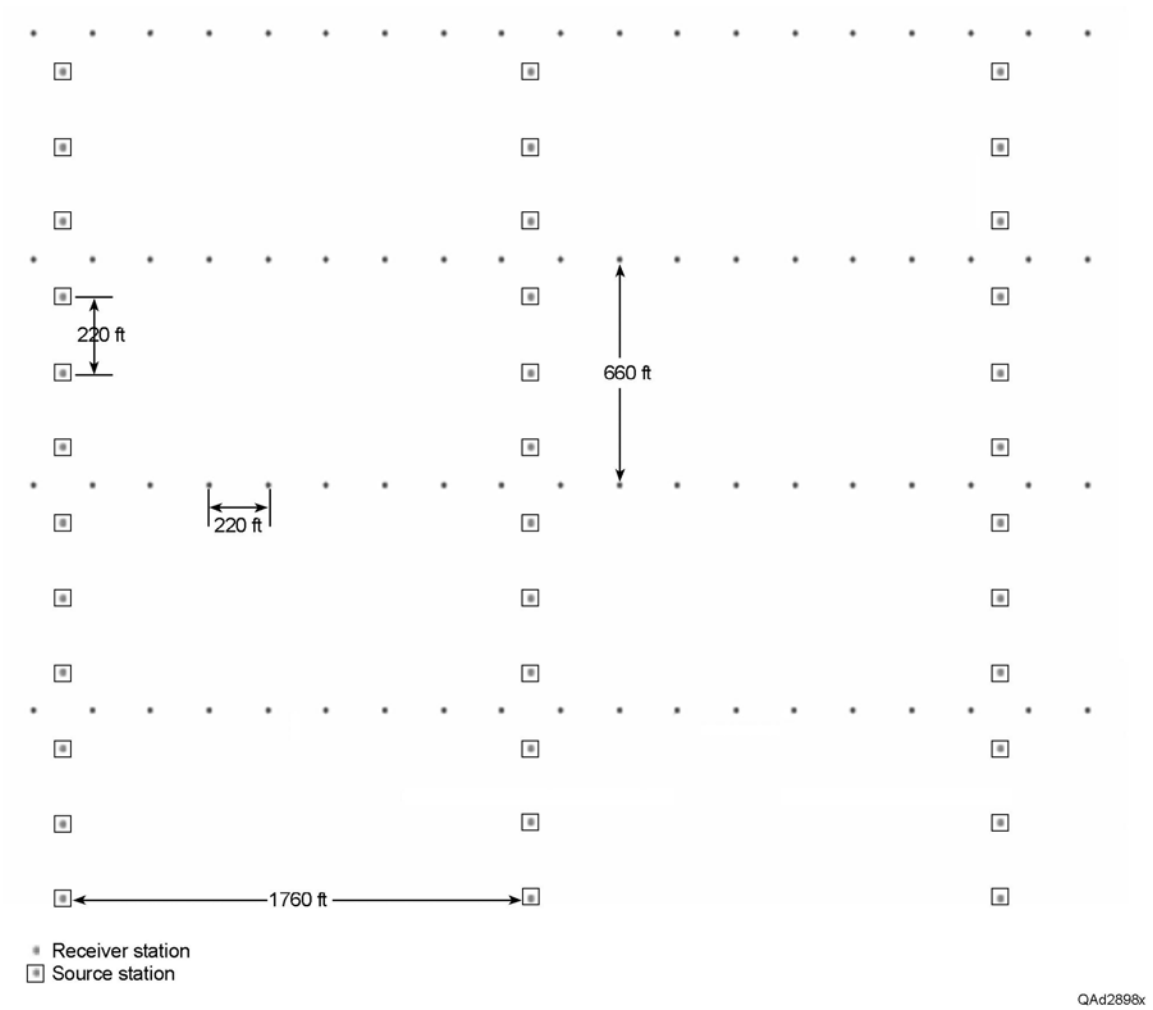

Figure 2. Expanded view of geometrical distribution of source/receiver lines and stations.

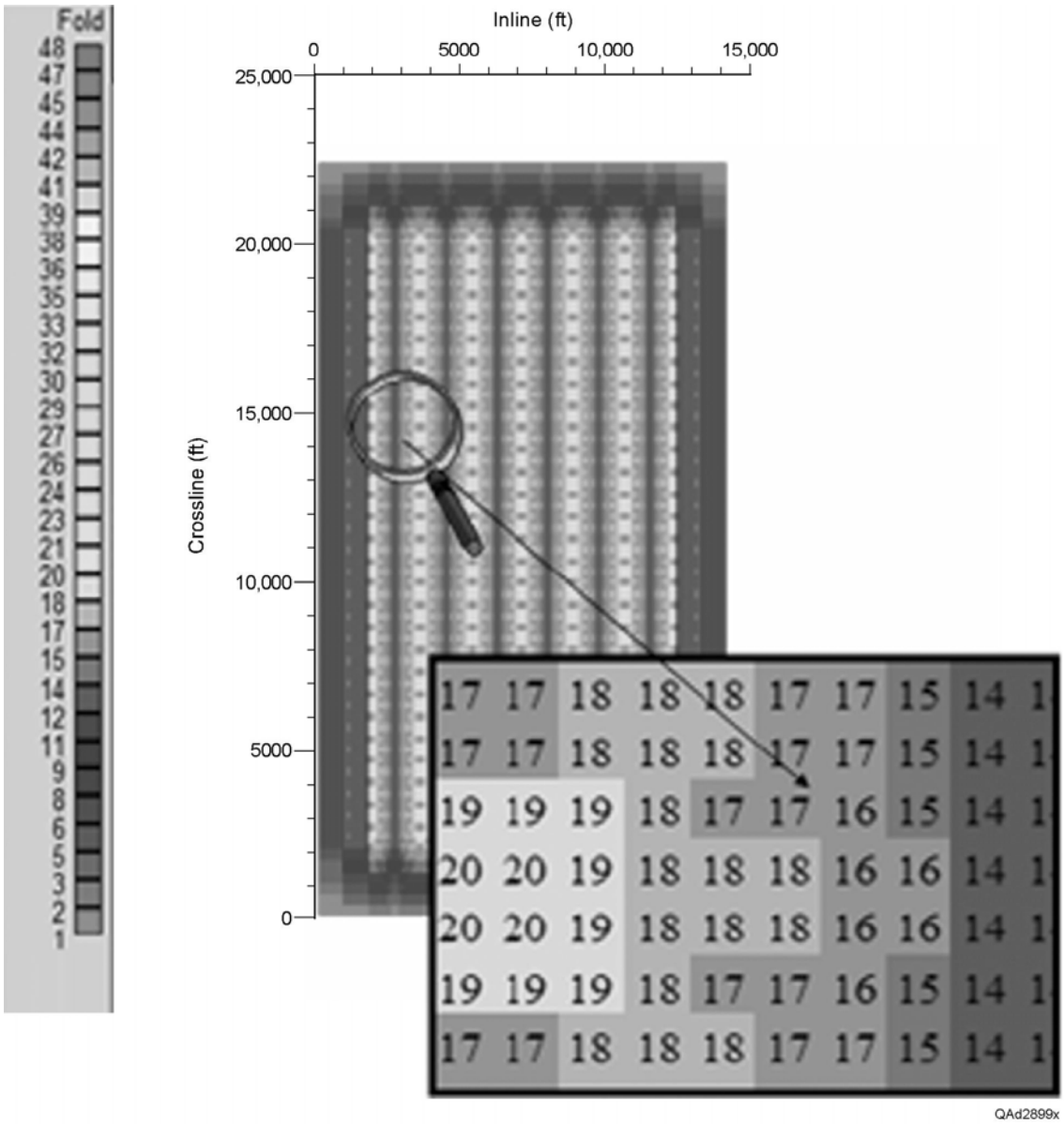

Figure 3. CMP stacking fold for target at depth of 5,000 ft in a portion of the image space. The fold ranges from 20 to 14. Data from approximately 16 receiver lines contribute to this imaging.

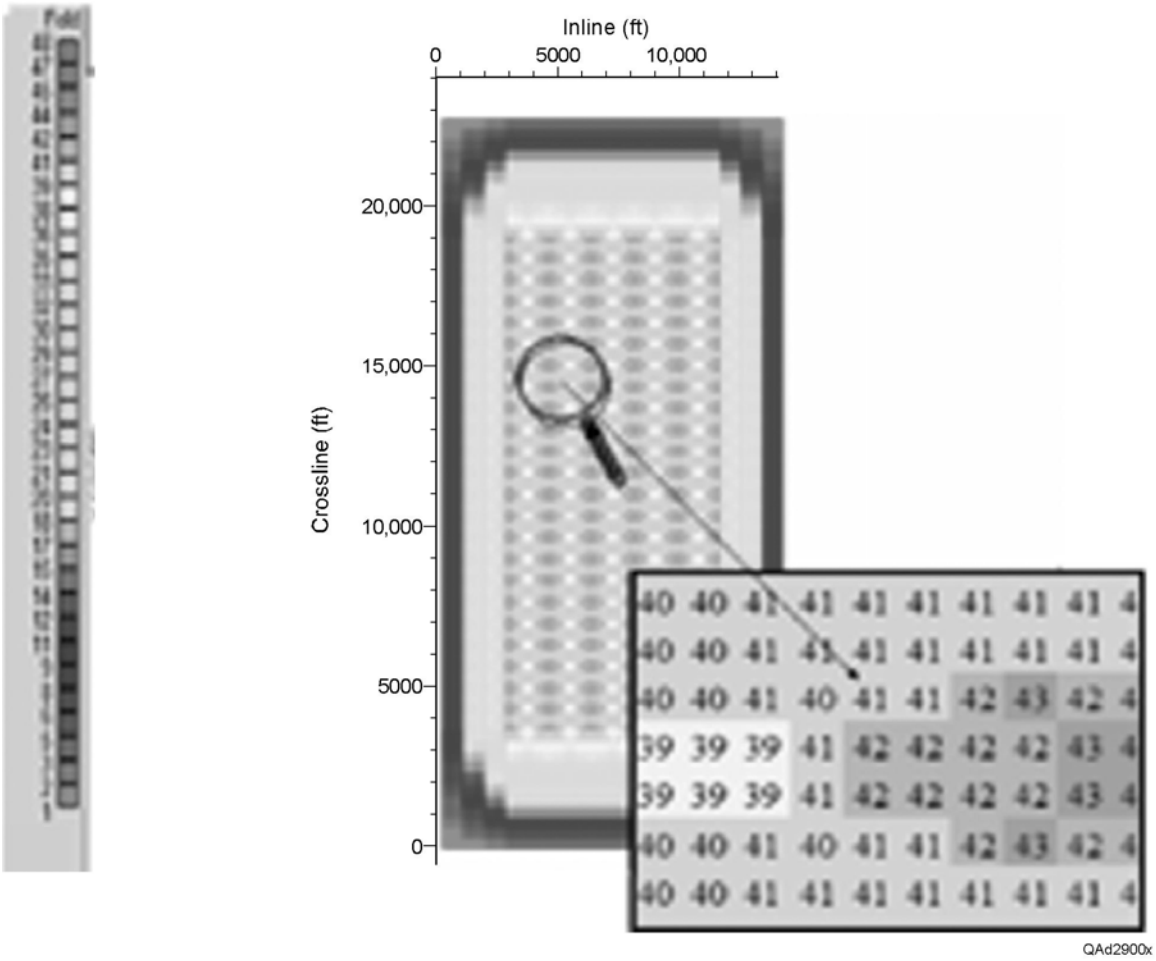

Figure 4. CMP stacking fold for target at depth of 8,000 ft in a selected portion of the image space. The fold stabilizes to a narrow range of 39 to 43 at this target depth, which is the depth of the Mission Canyon reservoir targets at the selected study site. Data from approximately 26 receiver lines contribute to this imaging.

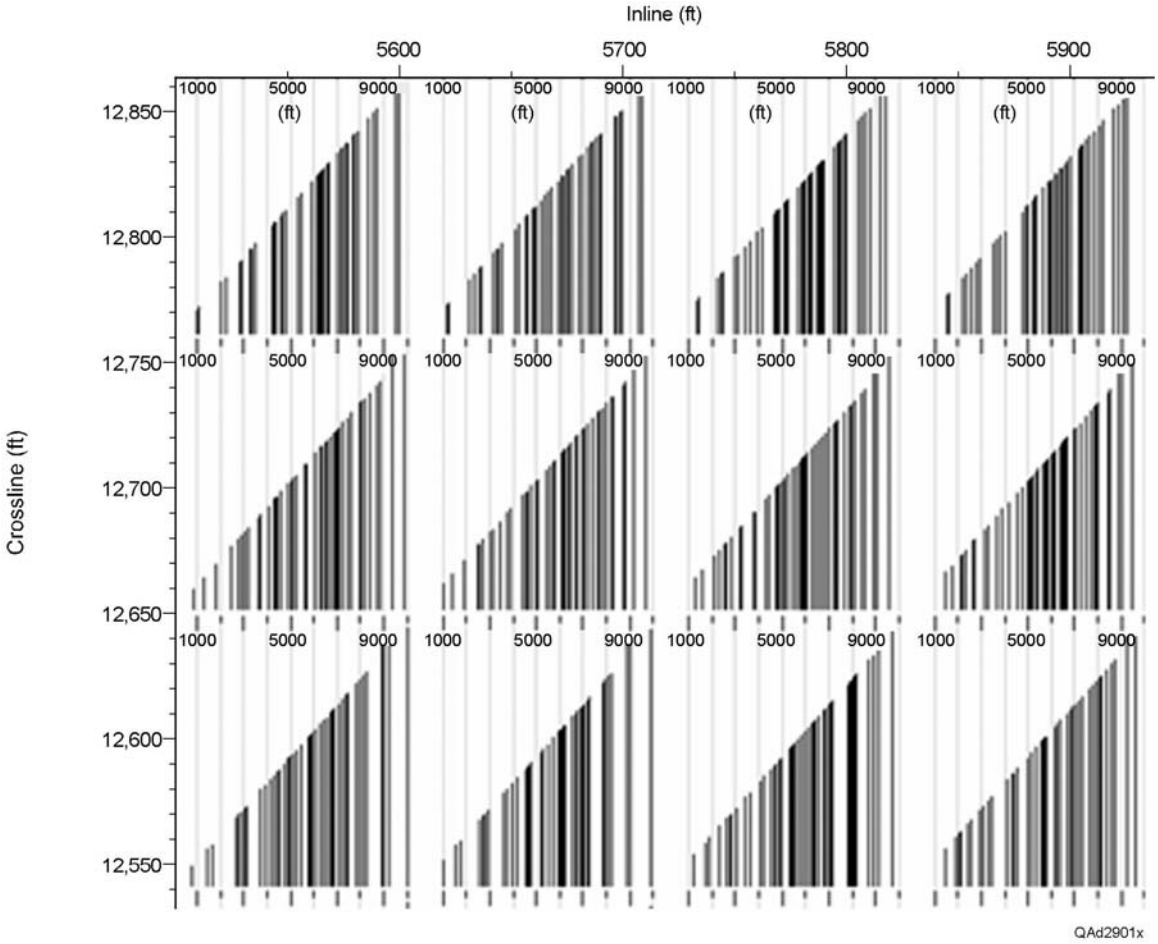

Figure 5. Offset distribution occurring in stacking bins near the center of the image space. The dimensions of each bin are 110 × 110 ft. There is a reasonably uniform distribution of offsets from 1,000 to 10,000 ft in each bin, which will provide good-quality trace gathers.

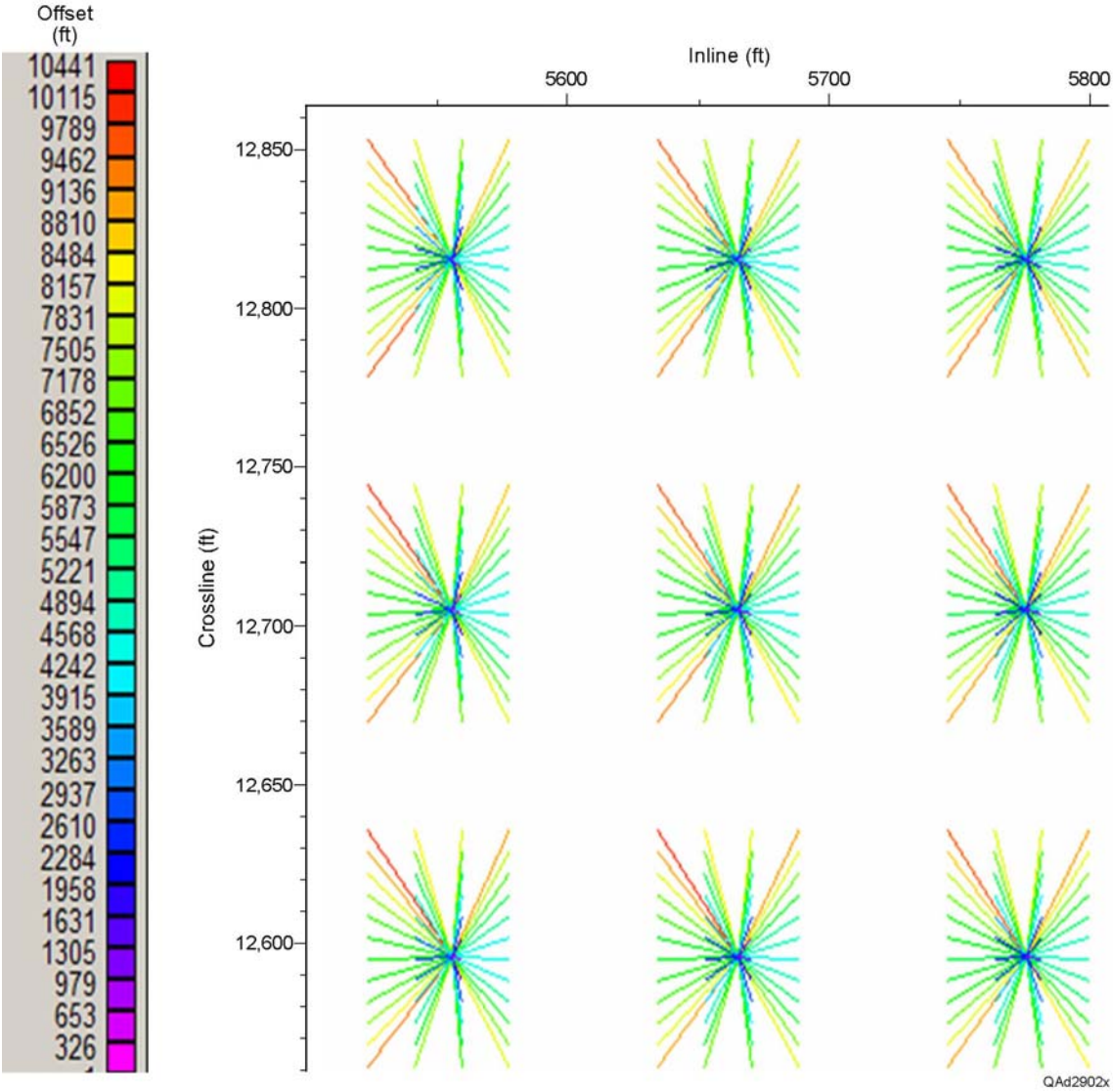

Figure 6. Spider plots showing azimuth distributions of offsets in stacking bins near the center of the image space. The selected source/receiver geometry allows data to be analyzed in all azimuth directions in each bin so azimuth-dependent anisotropy effects can be analyzed across the study site.

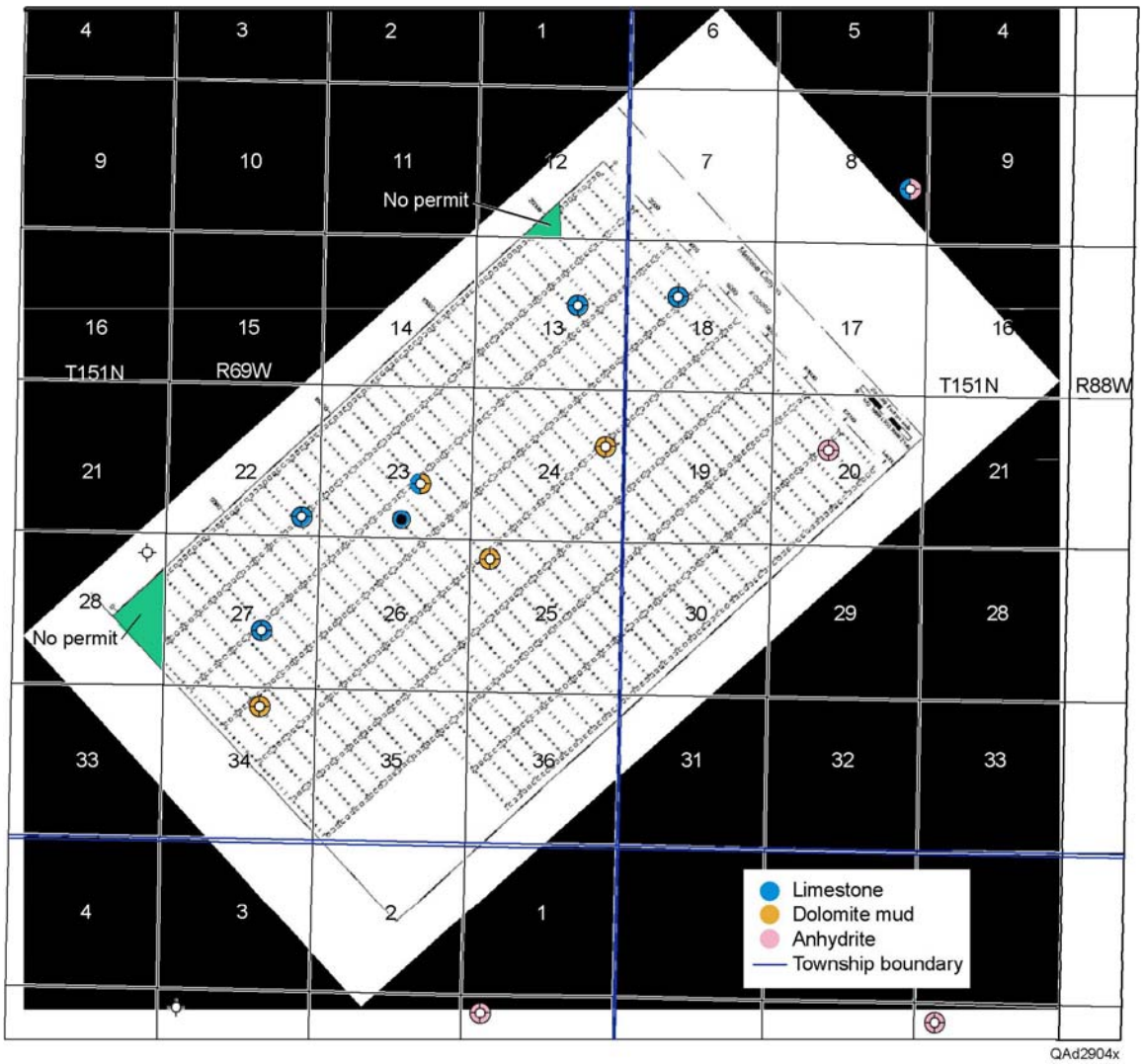

Figure 7. The specific source and receiver stations that should be deployed on the basis of current permit and cultural constraints. The line spacings and station spacings are those defined in Figures 1 and 2. The source-receiver stations cover approximately 10.33 mi^2 after exclusion zones are honored. The labeled townships, ranges, and sections are at the southern edge of Mountrail County, North Dakota. The well symbols define the lithofacies penetrated at the Mission Canyon interval.

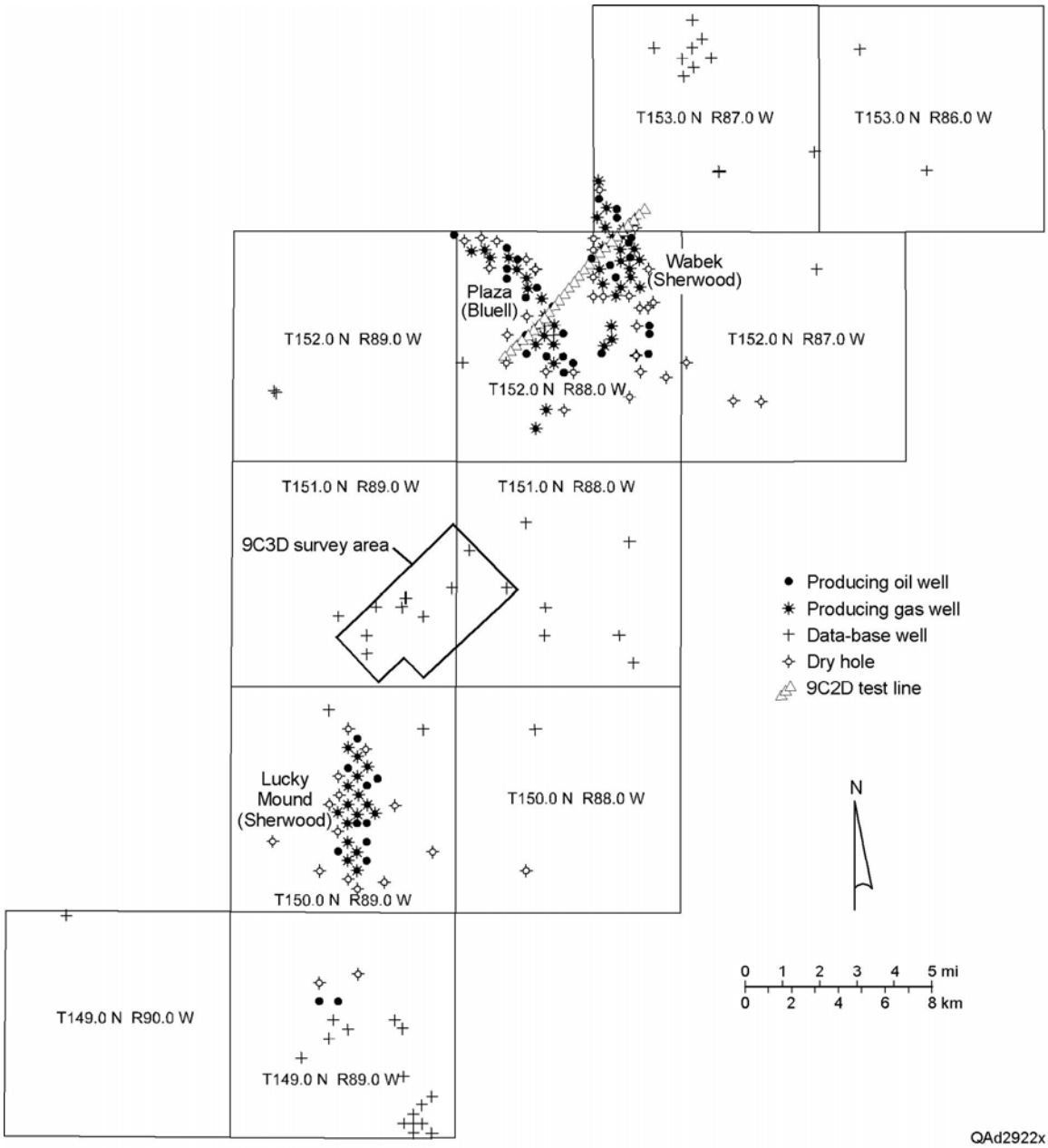

Figure 8. Large-scale view of the location of the seismic survey area relative to local Mission Canyon production and drilling.