GeoStreamer X Viking Graben Delivers Game Changing Results

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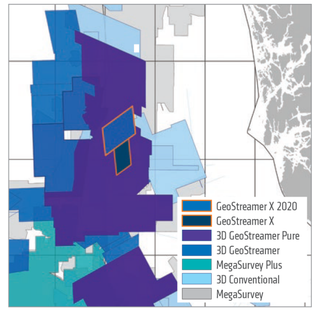
Full integrity PSDM data from the 2019 PGS GeoStreamer X acquisition program in the Lille Prinsen area of the Viking Graben is now available. It delivers on all its promises to provide the highest quality seismic imaging and attributes available today.

The highly prolific Viking Graben has seen spectacular exploration successes over the last decades and is to date a coveted area with multiple proven and partially stacked plays covering Eocene Grid sands to Zechstein carbonates and fractured/weathered basement.

The exploration target richness, however, also introduces multiple subsurface imaging challenges. These range from shallow subsurface channels and glacial features, Tertiary low velocity anomalies and high velocity sand injectites (V-brights), to multiple contamination in the polygonal faulted Paleogene and below the high impedance rugose Chalk.

The 2019 program has delivered impressive results as shown in the foldout figure, and we are eagerly awaiting the results from the 2020 acquisition campaign to the north over the Balder/Ringhorne area. Fast-track data from the 2020 survey will be ready early October 2020, and the full integrity processing in June 2021.



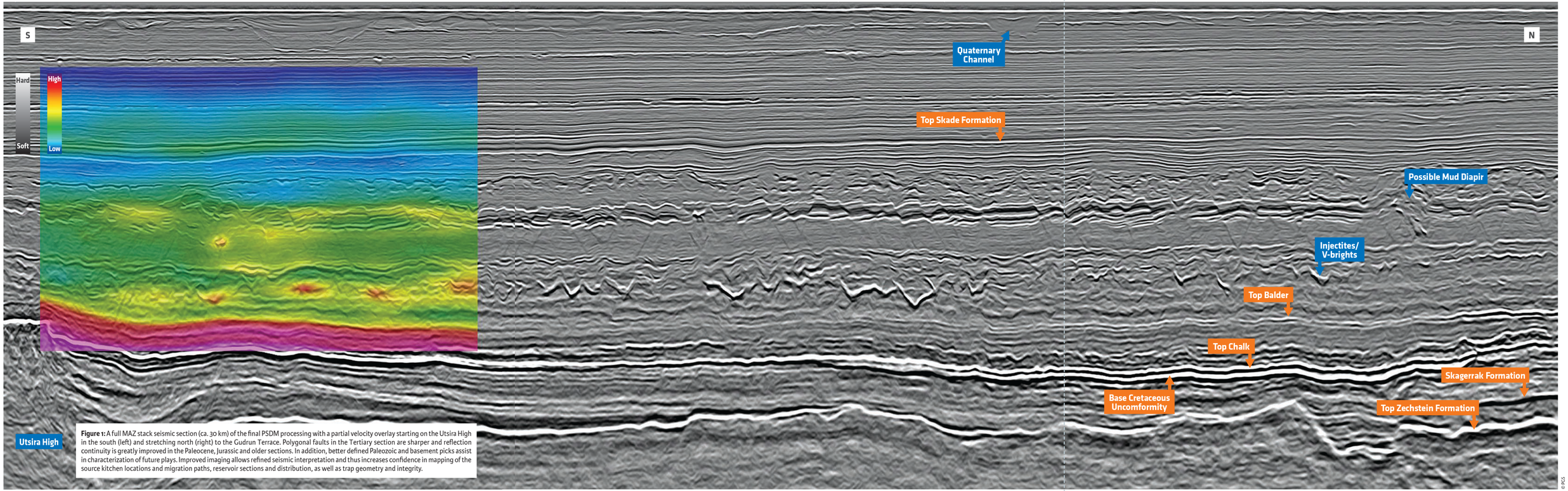


Figure 1: A full MAZ stack seismic section (ca. 30 km) of the final PSDM processing with a partial velocity overlay starting on the Utsira High in the south (left) and stretching north (right) to the Gudrun Terrace. Polygonal faults in the Tertiary section are sharper and reflection continuity is greatly improved in the Paleocene, Jurassic and older sections. In addition, better defined Paleozoic and basement picks assist in characterization of future plays. Improved imaging allows refined seismic interpretation and thus increases confidence in mapping of the source kitchen locations and migration paths, reservoir sections and distribution, as well as trap geometry and integrity.

More Azimuths and Near-Offsets

GeoStreamer X the All-in-one Survey Design

The innovative acquisition setup of GeoStreamer X has enabled a step change in data quality in this exciting petroleum province. The wide-tow source setup together with a high-density streamer configuration provides improved near-offsets for robust AVO analysis, and the necessary high-resolution images for identifying shallow hazards and delineating prospects. In addition, the long streamer tails provide long-offset data for a robust Full Waveform Inversion (FWI) and deliver a detailed velocity model at all depths. The wide-tow multi-azimuth survey (MAZ) design enhances the azimuthal distribution in the data by providing six azimuth classes out of the three acquisition directions, delivering optimal illumination of the complex geology in the area.

Thanks to recent advances in source and streamer towing capabilities and innovative survey designs, PGS can provide a multi-azimuth (MAZ) long-offset survey, which is equally rich in ultra near-offsets, using a single streamer vessel. In both the 2019 and 2020 GeoStreamer X acquisitions, two new acquisition directions were acquired to complement an existing 2011 dataset. This optimizes the total offset and azimuth distributions as well as improving the overall survey efficiency. The multisensor streamer spread, towed at depths between 20 and 25 m, combined 6 km cables with 10 km long tails, and the acquisition proved to be robust and safe. The additional long offset data contributes to better velocity estimates, therefore improving the overall quality of the final image and the pre-stack attributes.

The wide-tow triple-source configuration combined with reduced minimum inline offset (which was approximately 65 m in the 2019 study), improves very near-offset coverage, leading to higher resolution imaging capabilities. In 2019, the outer sources were separated by 225 m throughout the pilot program, which took place in marginal weather conditions at the end of the North Sea season. Adding the data from the two new survey directions to the vintage 2011 dataset practically eliminated the traditional acquisition footprint, as shown in Figure 2. Having a better resolved shallow section aids shallow subsurface interpretation studies such as shallow hazard analysis or prospect identification (such as in the Barents Sea and other provinces with highly prospective shallow subsurface), and also improves the imaging of the deeper stratigraphy and structure below. In 2020, the outer source separation was further increased to 250 m; another wide-tow record in two consecutive years, therefore demonstrating the reliability of the method in the field as well as its potential for future improvements in source sampling and survey efficiency.

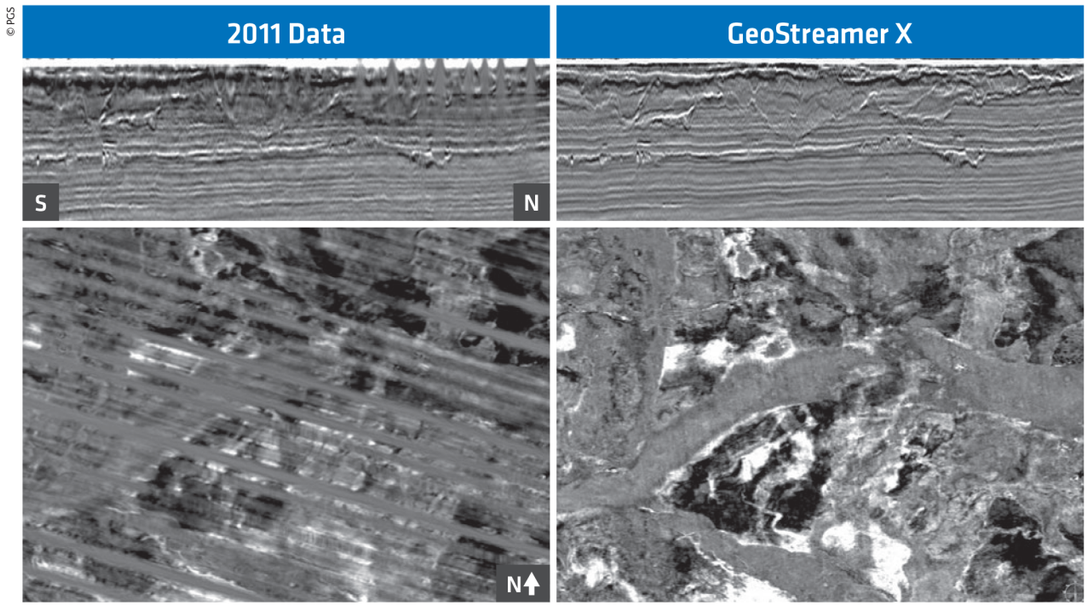


Figure 2. Shallow seismic cross-sections (top), and time slice at 224 ms (bottom). The acquisition footprint is clearly visible on the 2011 data (NW-SE direction). Very near-offset data is lacking in the standard 3D seismic and results in illumination gaps. In contrast, GeoStreamer X delivers a high level of detail in the near surface, which would not be recovered by simple data interpolation. Quaternary channels with internal geometry and a clear channel base are revealed in detail as well as underlying, possibly gas filled sand mounds and minor scours or ploughmarks present in the volume.

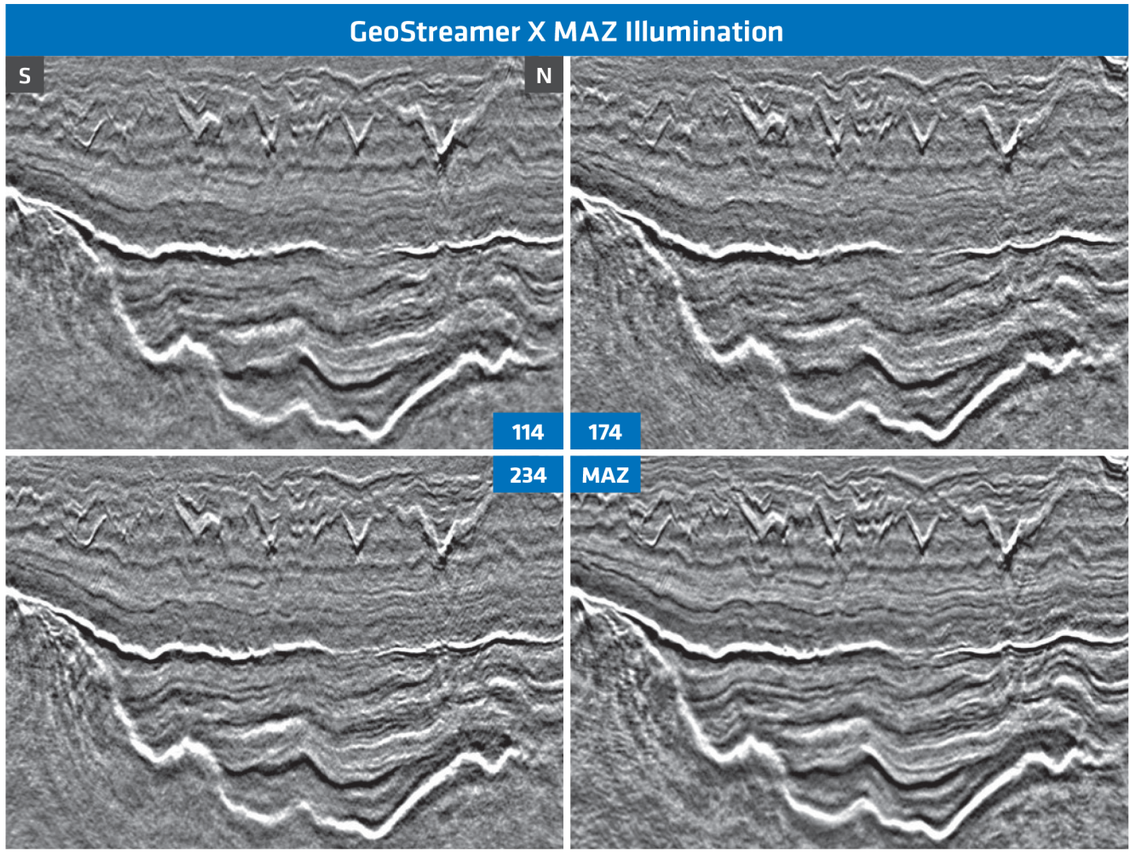


Figure 3. PSDM full stack sections of individual azimuth data (azimuth value in degrees clockwise from North) and MAZ (combined) volume. The MAZ stacking process improves reflector continuity, signal-noise-ratio and resolution. The display illustrates Eocene injectites at the top, underlain by an isopachous Paleocene section and the rugose bright top Chalk reflector over the BCU and the deeper Mesozoic rift section down to seismic basement. Note the detail of internal reflection configuration within the Paleocene and pre-Chalk sections as well as the injectite geometries on the MAZ data compared to single azimuth displays. Also, the onlap of the pre-BCU section onto the high on the left is distinct and details of the basement structure are discernable on the MAZ data.

Revealing New Opportunities from a Rich Dataset

Velocity Model Building (VMB) consisted of a combination of Full Waveform Inversion (FWI) and ray-based tomography. By utilizing data from the early stages of the processing sequence and through to de-multiple, each of the VMB phases benefited from the rich offset and azimuth information. The 6-10 km long offset data were used in the early refraction-based FWI updates and covered all depths down to the acoustic basement. The inversions were performed in low frequency bands with the uppermost frequency limit set to 15 Hz. These steps revealed to a large extent the presence of previously undetected Eocene-Miocene low velocity anomalies shown in Figure 1, which may represent undercompacted/overpressured plugs of remobilized shale.

All of the survey and azimuth data were then used jointly in reflection-based FWI and tomography updates. The later updates played a significant role in defining the V-bright injectite geometry and refining their velocity estimate, with a critical impact on focusing and positioning the deeper target reflectors. In parallel with the acquisition, the pre-processing up to and including de-multiple was run efficiently and with a similar performance on each individual acquisition direction. The combined datasets were fed simultaneously to a full offset and azimuth data regularization scheme prior to the final TTI MAZ Kirchhoff pre-stack depth migration, something previously reserved for datasets acquired in so-called wide-azimuth survey configurations.

Finally, the post-processing sequence ensured that all offset and azimuth data were constructively used in the final MAZ image (shown in the foldout) by optimizing the pre-stack data alignment and enhancing the multi-dimensional coherency of the signal. The quality of the final MAZ image far surpasses that of each individual azimuth stack, both in terms of illumination and resolution, as illustrated in Figure 3.

GeoStreamer X Delivering at a Fraction of OBS Cost

The pre-stack well to seismic tie is very good with over 10 wells used so far (rockAVO wells). Further QI work has started and will be presented soon. Whilst the 2020 program is well underway as a direct continuation of the 2019 pilot surveys, this fresh look at the MAZ streamer concept has clearly challenged the existing multi-azimuth solutions, including OBS surveys, as it can deliver a higher quality dataset at a fraction of the cost and reduced environmental impact. GeoStreamer X is a flexible and integrated acquisition and imaging solution which can be tailored to a wide range of geological and geophysical challenges.