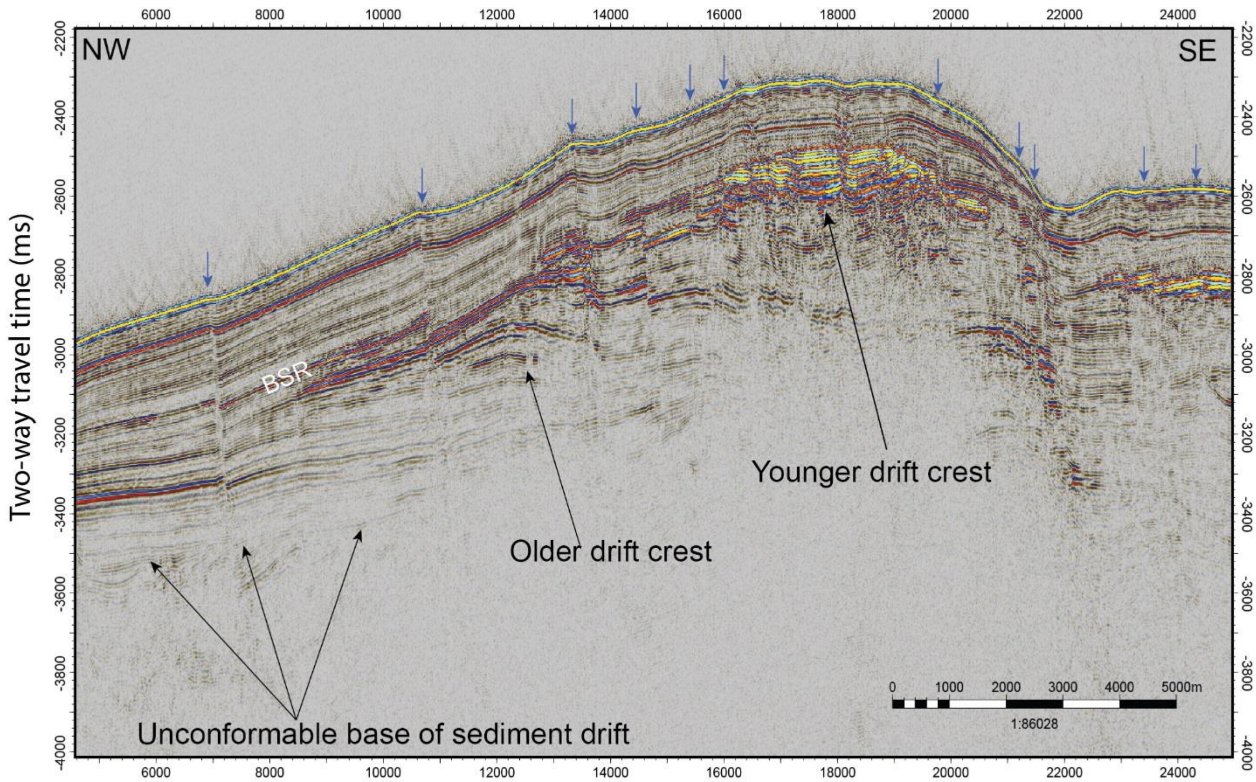

DR Figure 1. The NW-SE high resolution seismic profile across the portion of the drift south of the MTF shown in Figure 3, but here including the NW extent, location in Figure 1. A well-defined BSR-Bottom Simulating Reflector and free gas zone indicates the presence of gas hydrate. Chimney structures and seafloor pockmark are observed at the crest. Blue arrows indicate locations of high angle syn-depositional faults (greater offset at depth) indicating faulting was early and continued to propagate upward as the drift developed. Successive older and younger drift crests indicate eastward growth of the drift through time, consistent with the growth of the Vestnesa drift north of the MTF and the drifts of the western Yermak Plateau.

METHODS

Modeled vs. Observed BSRs

To determine whether the gas hydrate systems north and south of the MTF are in equilibrium with the current geothermal environment, we model the expected depth of the BSR using the CSMHYD program (Sloan and Koh, 2007). The CSMHYD program generates hydrate stability phase diagrams taking into account different pressure and temperature conditions, the composition of gas forming hydrates, and the presence of inhibitors of hydrate formation (e.g., salt). To constrain the region of hydrate formation using CSMHYD, we assume two different gas compositions, pure (100%) methane and a gas composition measured from gas hydrates from the Vestnesa Ridge (Smith et al., 2014) north of the MTF, and assume a constant pore water salinity of 35 ‰ under a hydrostatic pressure regime (assuming a seawater density of 1027 kgm^{-3}). A two-dimensional thermal profile is generated using measured thermal gradients (Crane et al., 1991) and bottom water temperature data from CTD measurements (collected during seismic data acquisition) in close proximity to each modeled seismic profile. The modeled BSR was time-converted using a water velocity of 1469 m/s. Geothermal gradients are then compared with BSR-derived geothermal gradients. Results show good agreement with the observed BSRs in Figure 3 and an offset in Figure 4 (discussed in the text). Small deviations between the modeled and observed BSR could be due to local variations in gas composition, heat flow, and/or pore water salinity.

BSR Derived Heat Flow

BSR depths from the seismic data from the eastern flank of Molloy Ridge and the western flank of Knipovich Ridge are used in association with gas hydrate stability modeling to estimate the heat flow values shown in Figure 3. Keeping all parameters, except the thermal gradient, in the hydrate stability model constant, we iterate thermal gradient values until a best fit with the observed BSR depth is reached. Heat flow is calculated from these thermal gradients using measured sediment thermal conductivities (Crane et al., 1991). We use a 100% methane composition for the gas hydrate for these calculations.

Stability of the Gas Hydrate System south of the MTF

We tested threshold conditions to completely destabilize gas hydrates within the sediments using the BSR modeling approach described above, to verify the stability of the deep water gas hydrate systems on the lower slope of continental margins. For a system of pure methane, at 1800 m water depth (approximate water depth of the drift south of the MTF), and assuming a maximum possible thermal gradient of 500 °C/km (measured thermal gradient in the active Knipovich Ridge (Crane et al., 1991)), we estimate the ocean bottom water temperature has to be greater than +17 °C to destabilize gas hydrates completely within the sediments. Considering a maximum sea level variation of -400 m, the bottom water temperature would still need to be >+14 °C in order to eliminate the gas hydrate stability zone within the sediments. This shows that the stability of deep gas hydrate systems primarily depends on variations in bottom water temperatures. However, the bottom water temperature values necessary to completely destabilize hydrates are unrealistic, suggesting deep-water gas hydrate systems on lower continental slopes are extremely stable. Increasing water depth has a positive impact on the thickness of gas hydrate stability zone, resulting in thicker gas hydrate stability zones within the sediments. The gas hydrate system in the drift south of the MTF, is likely to only get more stable with time as it is translated and subsided along the MTF into deep water.

Crustal Structure: West Flank Knipovich Ridge

The only published seismic refraction line in our study area (Ritzmann et al., 2004) crosses Vestnesa Ridge, the MTF, the west flank of Knipovich Ridge, and ends at Hovgard Ridge. The crustal structure of the west flank of the Knipovich Ridge (just north and west of the drift deposit south of the MTF) indicates thinned crust (1-2 km), characteristic of ultra-slow spreading and a mantle with reduced seismic velocities consistent with serpentinization. In the location of the sediment drift at the inside corner of a ridge transform junction, we would anticipate detachment fault development and large slip (as we observe in Fig. 4), allowing serpentinized mantle to be exhumed toward the seafloor. Detachment faults are also imaged at the southern end of the drift south of the MTF in Amundsen et al. (2011).

Supplemental References:

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