Wiggled surface around the top of gas hydrate stability zone in the northeastern Sakhalin Slope, Okhotsk Sea: Is this present-day example for slope failure initiation associated with gas hydrate dissociation?

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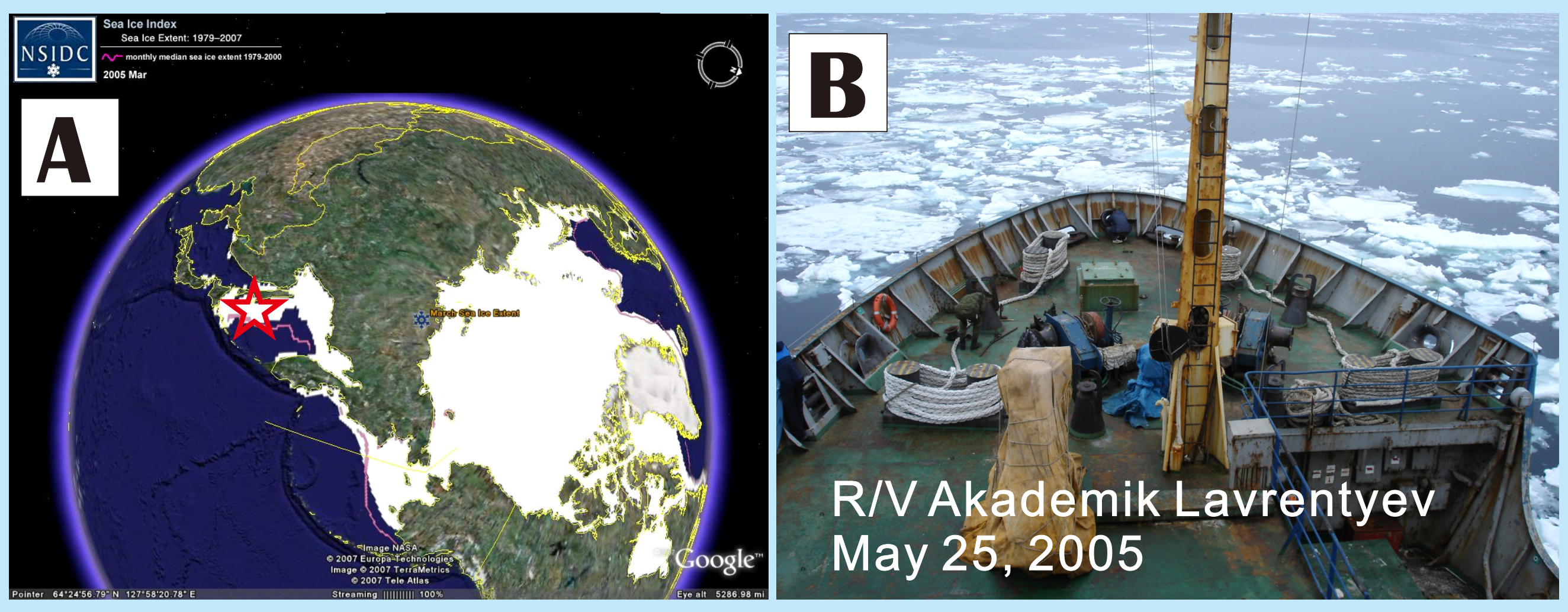
Young-Gyun Kim [a]*, Young Keun Jin [a], Boris Baranov [b], Anatoly Obzhirov [c], Hirotsugu Minami [d]

[a] Korea Polar Research Institute, KIOST, South Korea, *email: ygkim@kopri.re.kr
[b] P.P. Shirshov Institute of Oceanology, FEB RAS, Russia
[c] V. I. Il'ichev Pacific Oceanological Institute, FEB RAS, Russia
[d] Kitami Institute of Technology, Japan

Abstract

One of important geological process related to the gas hydrate in the continental margins is the slope failure induced from increase of slope instability due to gas hydrate dissociation. The continental margins has experiences long-term global warming up to now since the Last Glacial Maximum and accordingly the gas hydrate stability zone (GHSZ) in there has shrunk. However, very few candidate sites for slope failure associated with gas hydrate dissociation have been found on the present-day ocean floor. In the northeastern Sakhalin Slope (Okhotsk Sea) numerous gas hydrate-related manifestations on and below the seafloor as well as in the water column have been reported. The bottom of the GHSZ estimated with 35 mK/m in geothermal gradient is consistent with the observed bottom-simulating reflector (BSR) depths on continental slope. From several sparker seismic profiles across the continental slope we found that the BSR depth shoals toward the shore and finally intersects the seafloor nearly at the top of the GHSZ, and also that wiggled surface only occurs in the limited interval around the top of the GHSZ. We speculate the wiggled surface stems from deformation related with gas hydrate dissociation at the top of gas hydrate stability zone. This is because internal sedimentary features are not consistent with those of well-reported sedimentary wave, and sedimentary strength of the sediment core retrieved from the shallower depth than the top of the GSHZ is significantly higher than that from the deeper. At this stage limitation in observation, i.e., low resolution of the sparker seismic profile and small number of sedimentary strength measurements, cannot lead us to the firm conclusion, however, further surveys unravelling characteristics of such wiggled surface may provide a good chance to understand the nature of ongoing slope failure process associated with shrink of the gas hydrate stability zone.



Figs. A-B. Sea ice cover in Okhotsk Sea (star) in May.

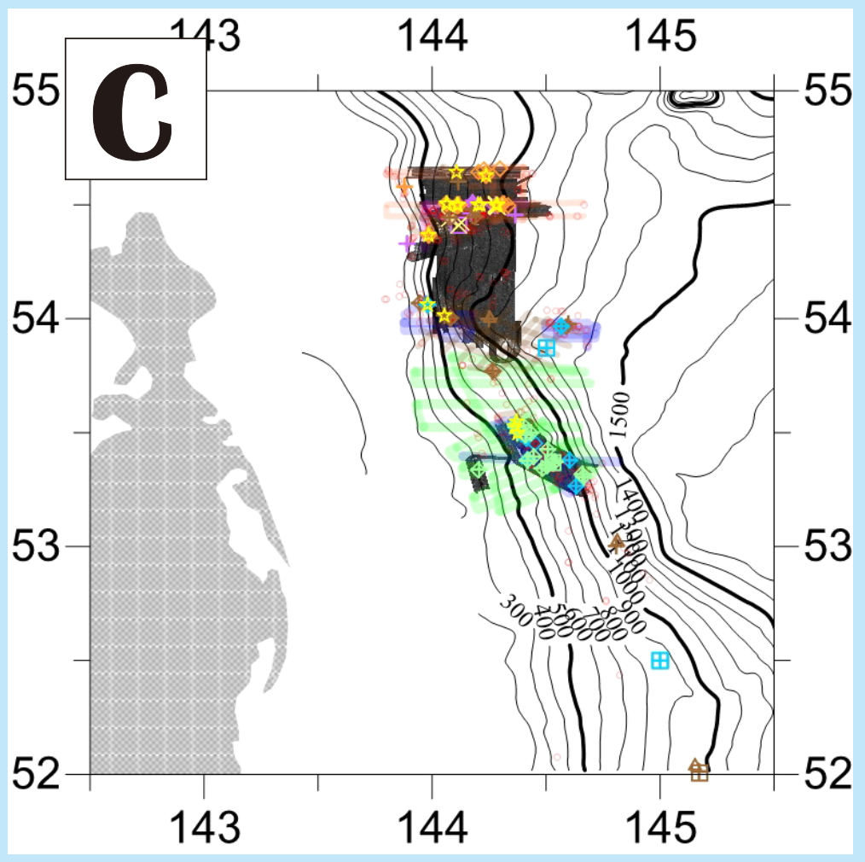


Fig. C. Multidisciplinary surveys in the northeastern continental slope of Sakhalin Island have been carried out with an international collaboration of Korea-Japan-Russia since 2003. Pupple = CHAOS I (2003), Brown = CHAOS II (2005), Orange = CHAOS III (2006), Pink = SSGH07 (2007), Red = SSGH08 (2008), Blue = SSGH09 (2009), Green = SSGH10 (2010) surveys. Stars indicate gas hydrate occurrence.

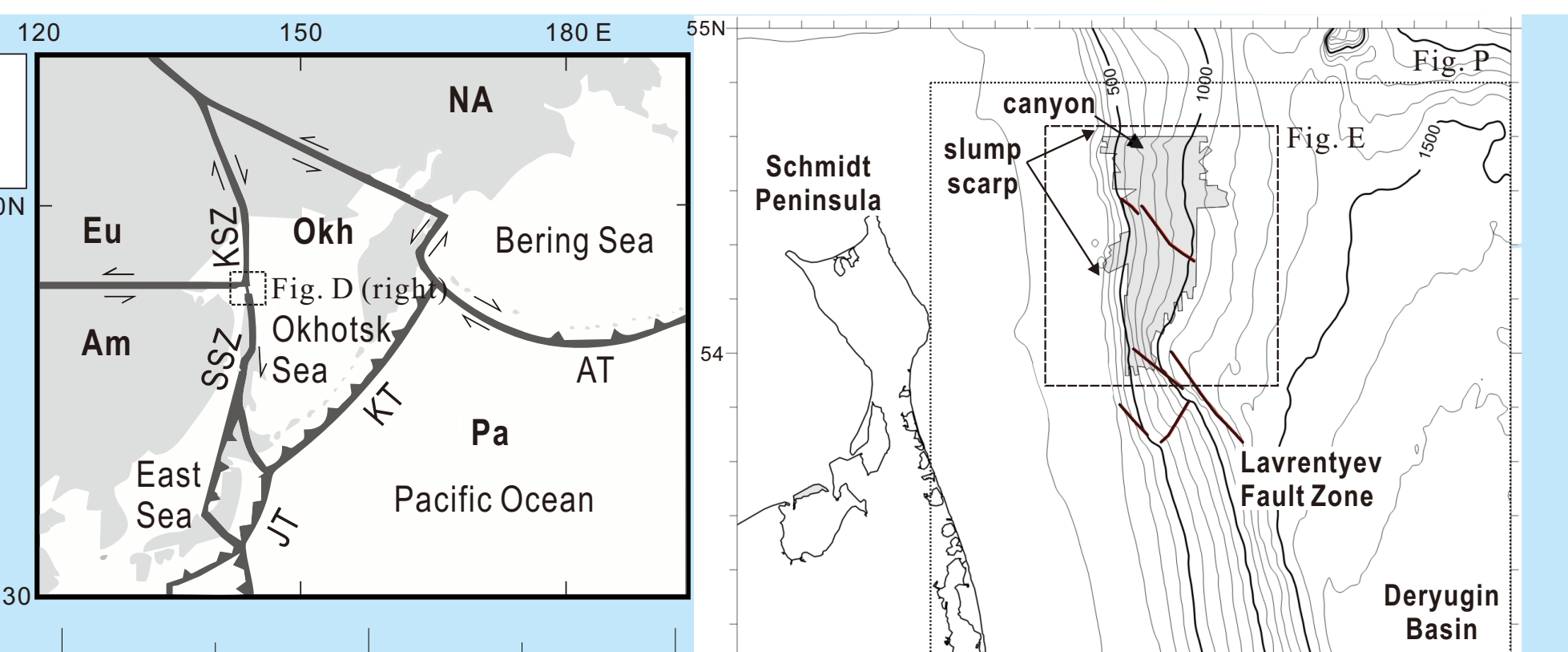


Fig. D. The location map of the northern slope of Sakhalin slope, Sea of Okhotsk. (left) The Okhotsk plate (Okh) is bounded by 4 tectonic plates: North America (NA), Eurasia (EU), Amurian (Am), and Pacific (Pa) plates. Kashevarov Shear Zone (KSZ) and Sakhalin Shear Zone (SSZ) exhibit dextral movement. JT = Japan Trench, KT= Kurile Trench, AT = Aleutian Trench. (right) The study area, presented as box, is located in the northeastern continental slope of Sakhalin Island. The Deryugin Basin lies to the west. The thick lines indicate major faults in this region. Lavrentyev Fault Zone in the southern part of the study area divide cross-section slope morphology into 2 types: concave-upward to the north of itself, and convex-upward to the south. The shaded area represents the coverage of side-scan sonar survey.

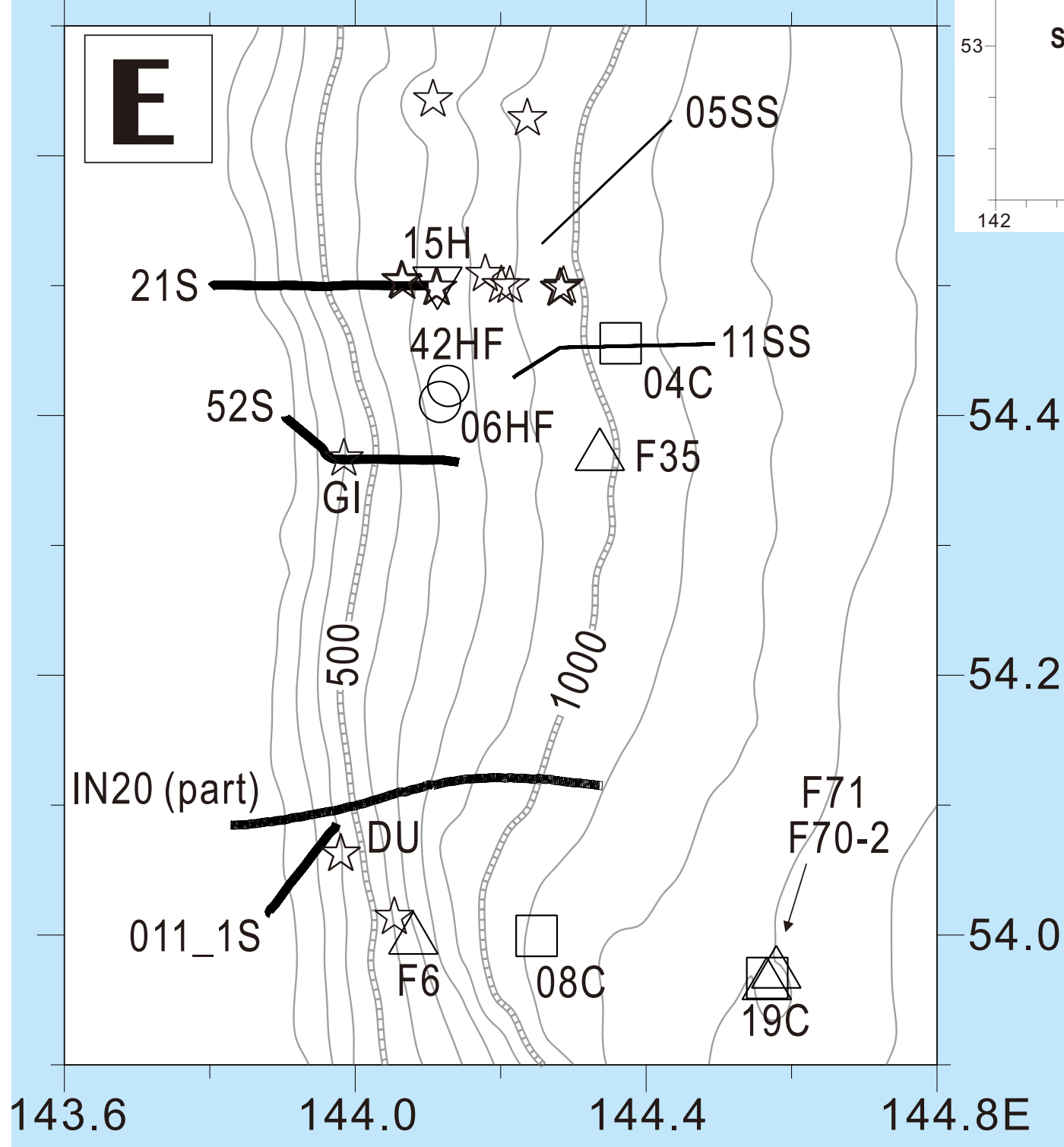


Fig. E. The detailed map of study area. The seismic survey lines (thick lines) conducted using the sparker instrument, the subbottom survey line (thin line), the locations of CTD casting sites to measure water temperature and salinity (squares), gas flare detected by hydroacoustic survey (triangles), and heat flow measurements (circles) are shown. The reverse triangle represents a site where core containing the gas hydrate was retrieved (see text). The bathymetric contour is shown at 100-meter interval. Sites where sediment cores containing gas hydrates were taken are shown in star symbols: DU = Dungeon and GI = Gisella structure.

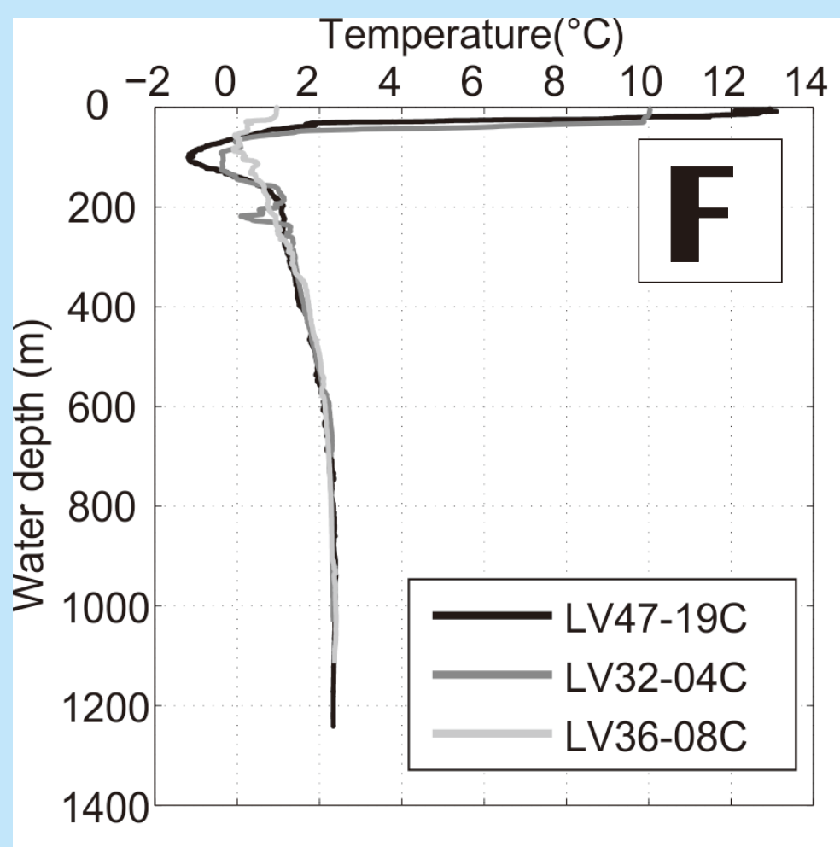
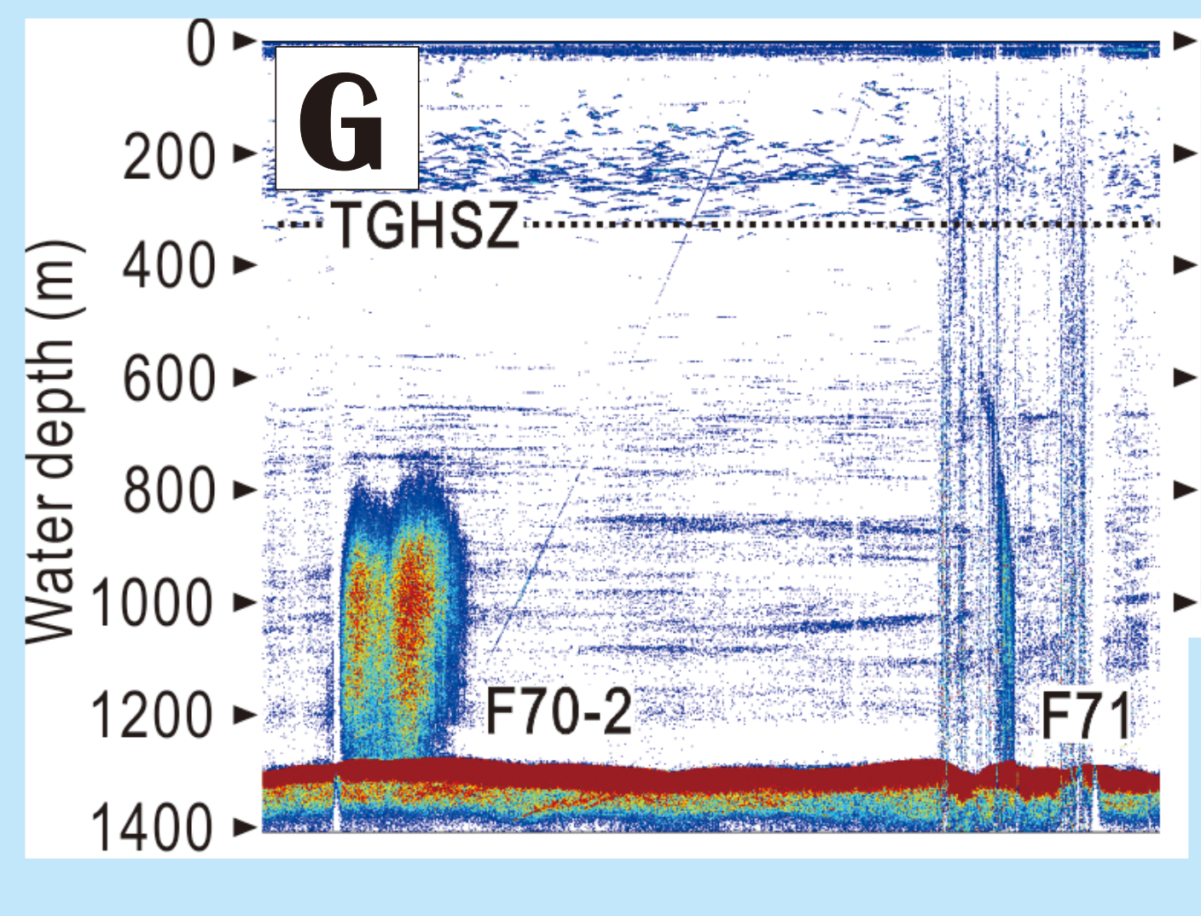
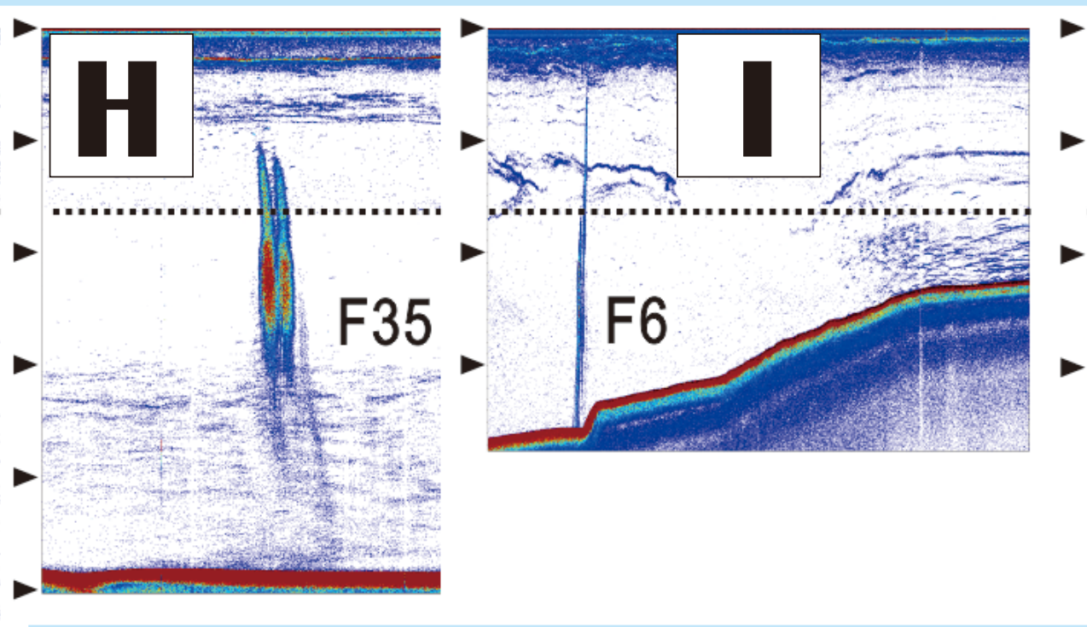


Fig. F. Water temperature with depth measured three CTD sites.





Figs. G-I. Hydroacoustic profiles with the top of gas hydrate stability zone as a dotted line (TGHSZ). Various shapes of bubble streams (hydrate-coated bubble streams).

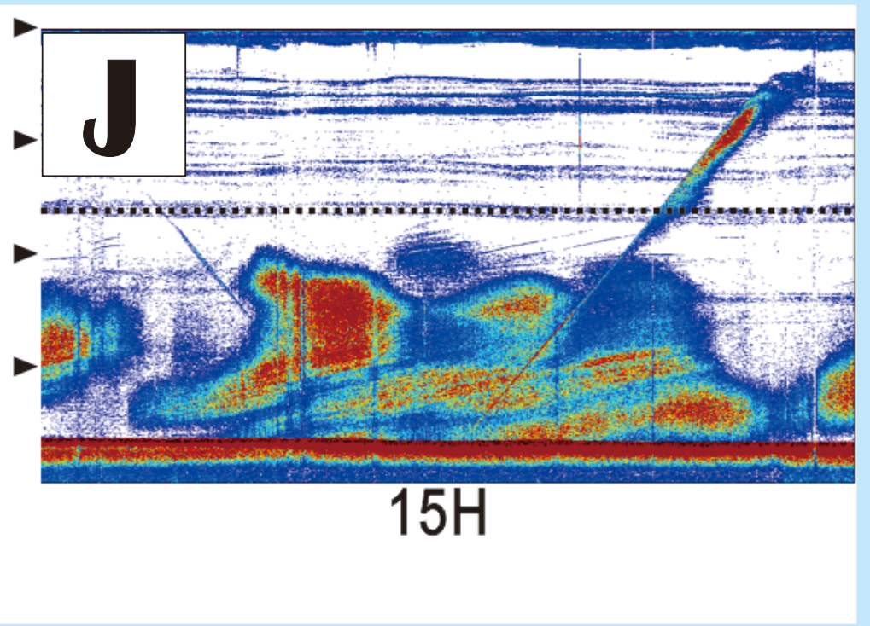
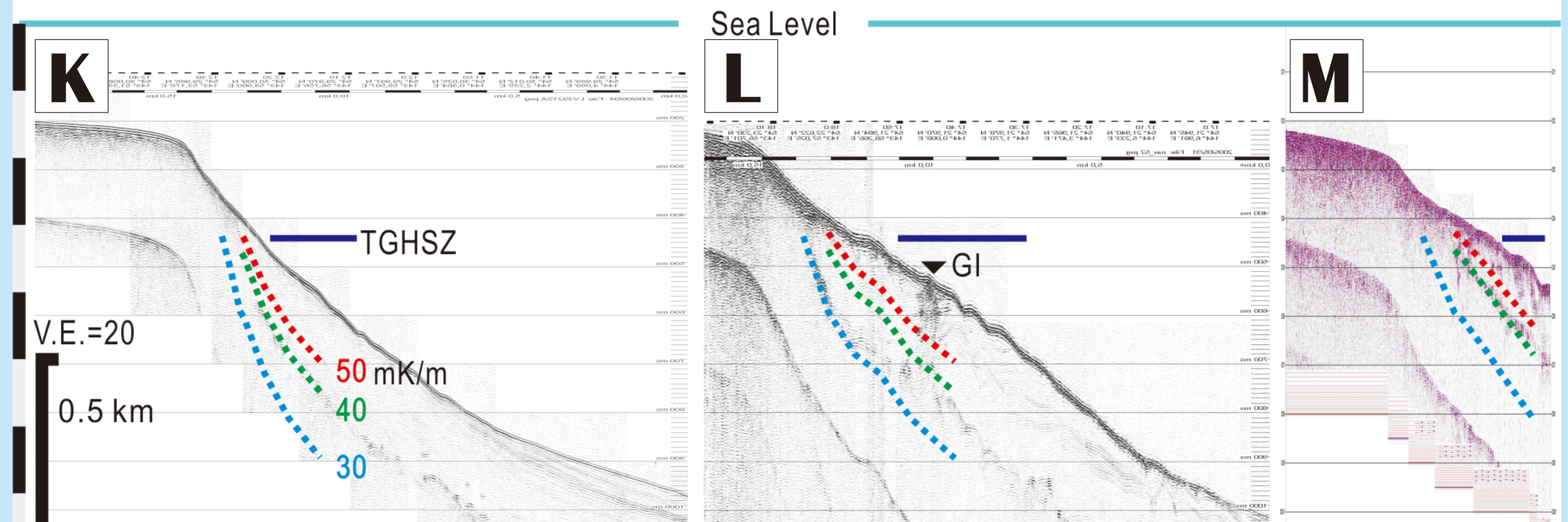
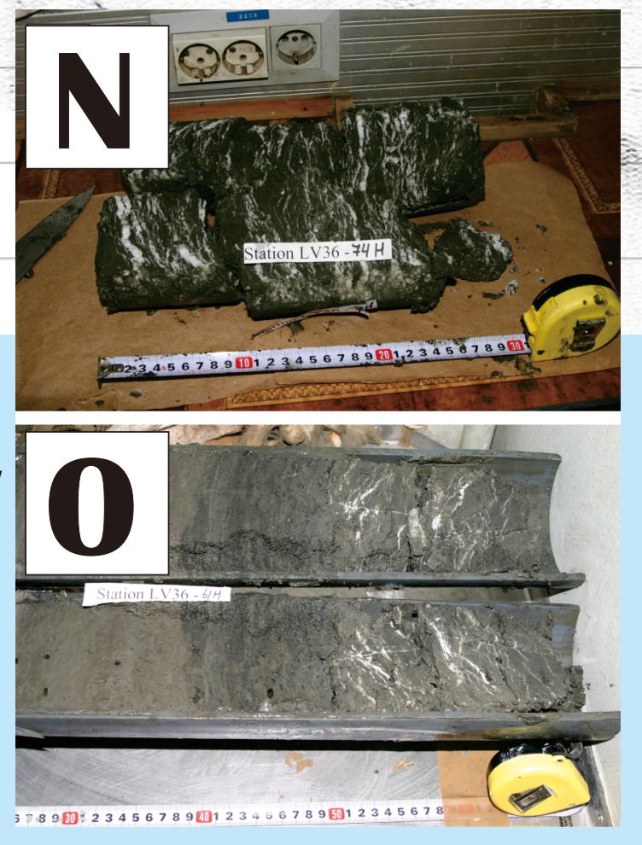


Fig. J. Retrieval of a piston core containing gas hydrate, generating high backscatter above TGHSZ due to dissociation of gas hydrate.



Figs. K-M. Sparker seismic profiles showing clear bottom-simulating reflectors (BSRs). Vertical exaggeration is 20. Dotted curves represent estimated BSRs with geothermal gradients of 30, 40 and 50 mK/m. Horizontal lines indicate the top of gas hydrate stability zone (TGHSZ). Gas hydrate sample at GI (reverse triangle)



Figs. N-O. Gas hydrate samples from a sediment core. **N** from Dungeon and **O** from Gisella gas seep structures are retrieved at water depths are 385 and 390 mbsl, respectively.

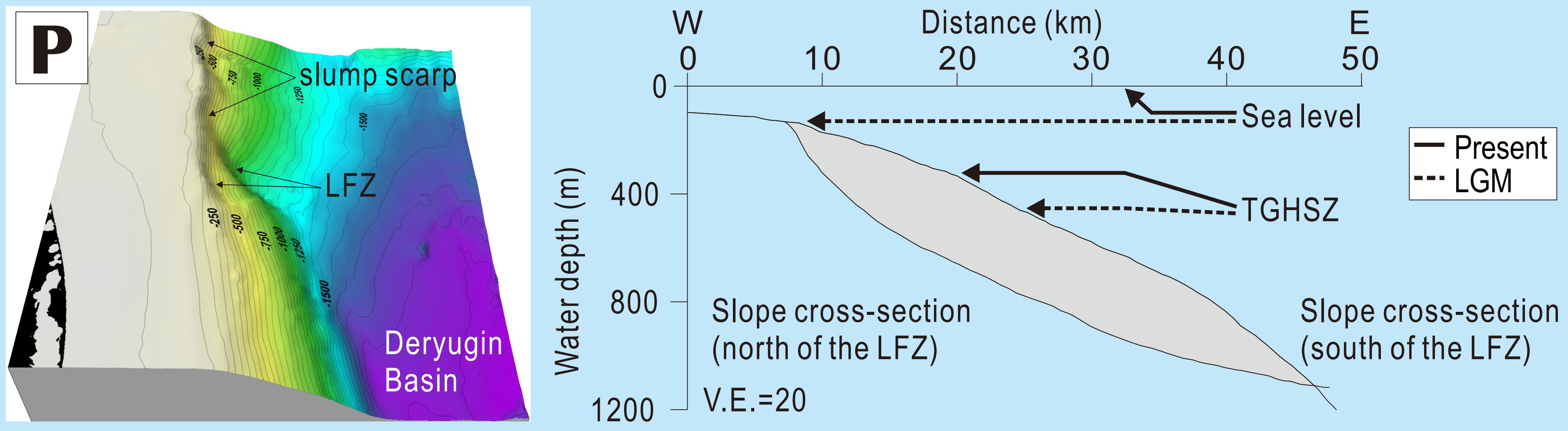


Fig. P. The comparison of the slope between the continental margin to the north and south of the Lavrentyev Fault Zone (LFZ) (modified from Wong et al., 2003). (left) 3-dimensional aerial view. See Slump scarp develops along contour lines 250-300 mbsl. (right) Sea level and the top of gas hydrate stability zone (TGHSZ) are represented for present-day (solid lines) and the Last Glacial Maximum (LGM; dotted lines)

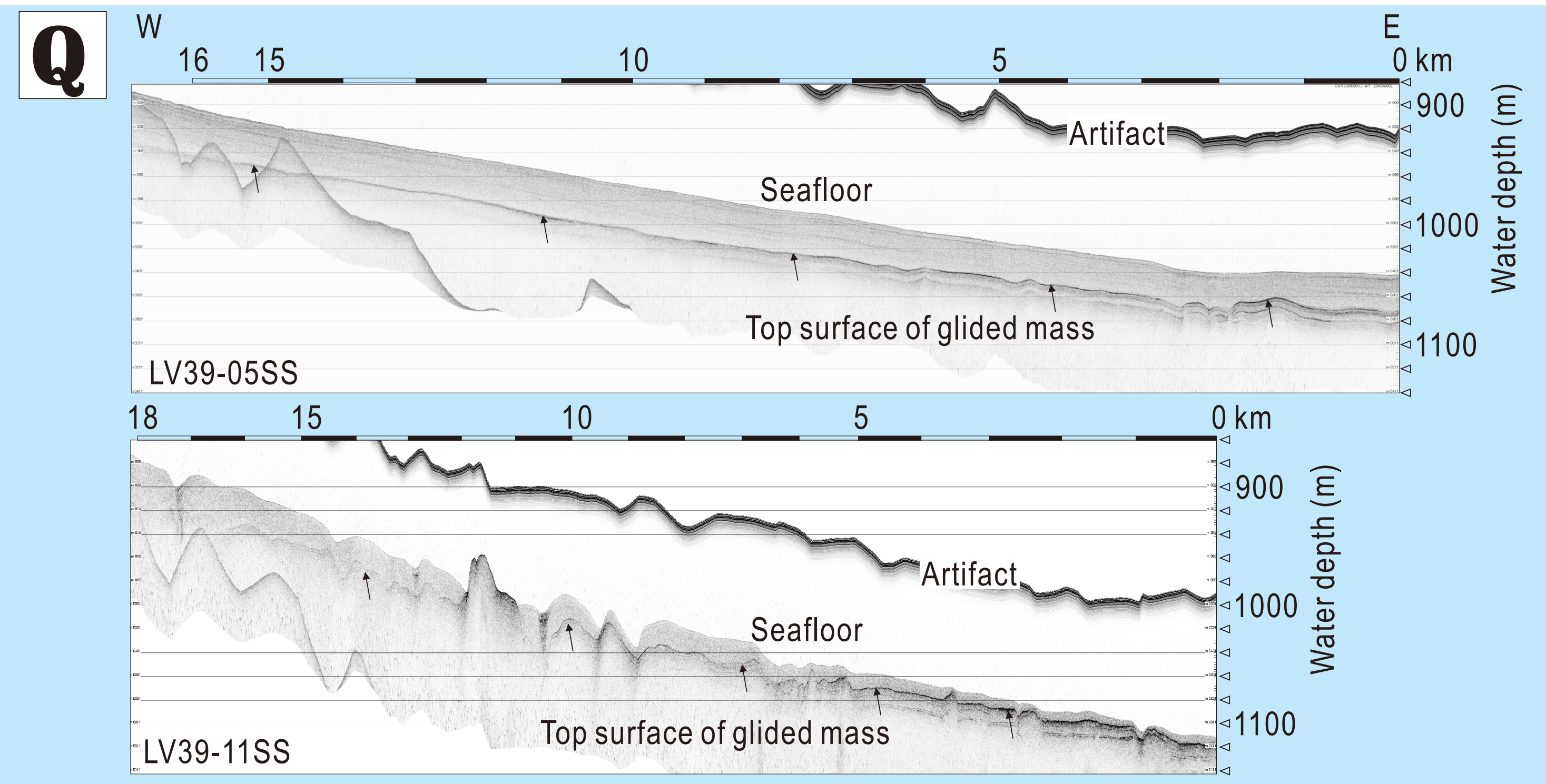


Fig. Q. Subbottom profiles showing a clear top surface of glided mass (arrows) at ~10-40 meters below the seafloor. The more deformed the less reflectors below the top surface of glided mass could be distinguished. Thickness of hemipelagite over the top surface is variable due to irregularity of the glided mass top surface: (top) rather constant at area with the flat top surface, and (bottom) thin or absent over highs/bumps as well as thinning-away offshore. When considering variable sedimentation rate in this region (40~100 cm/kys; Biebow et al., 2003; Gorbarenko et al., 2010), the age of the mass wasting is 50-20 ka.

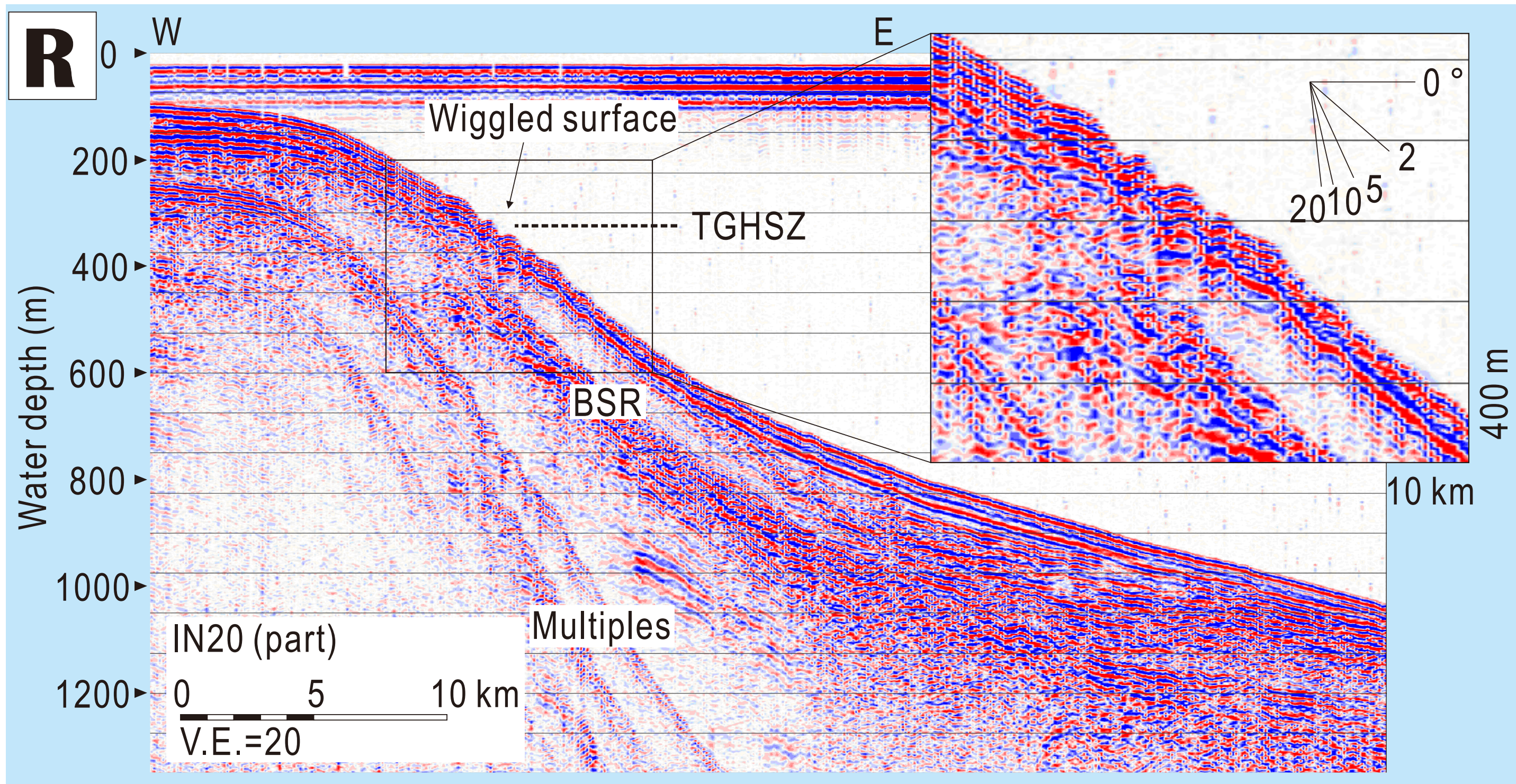
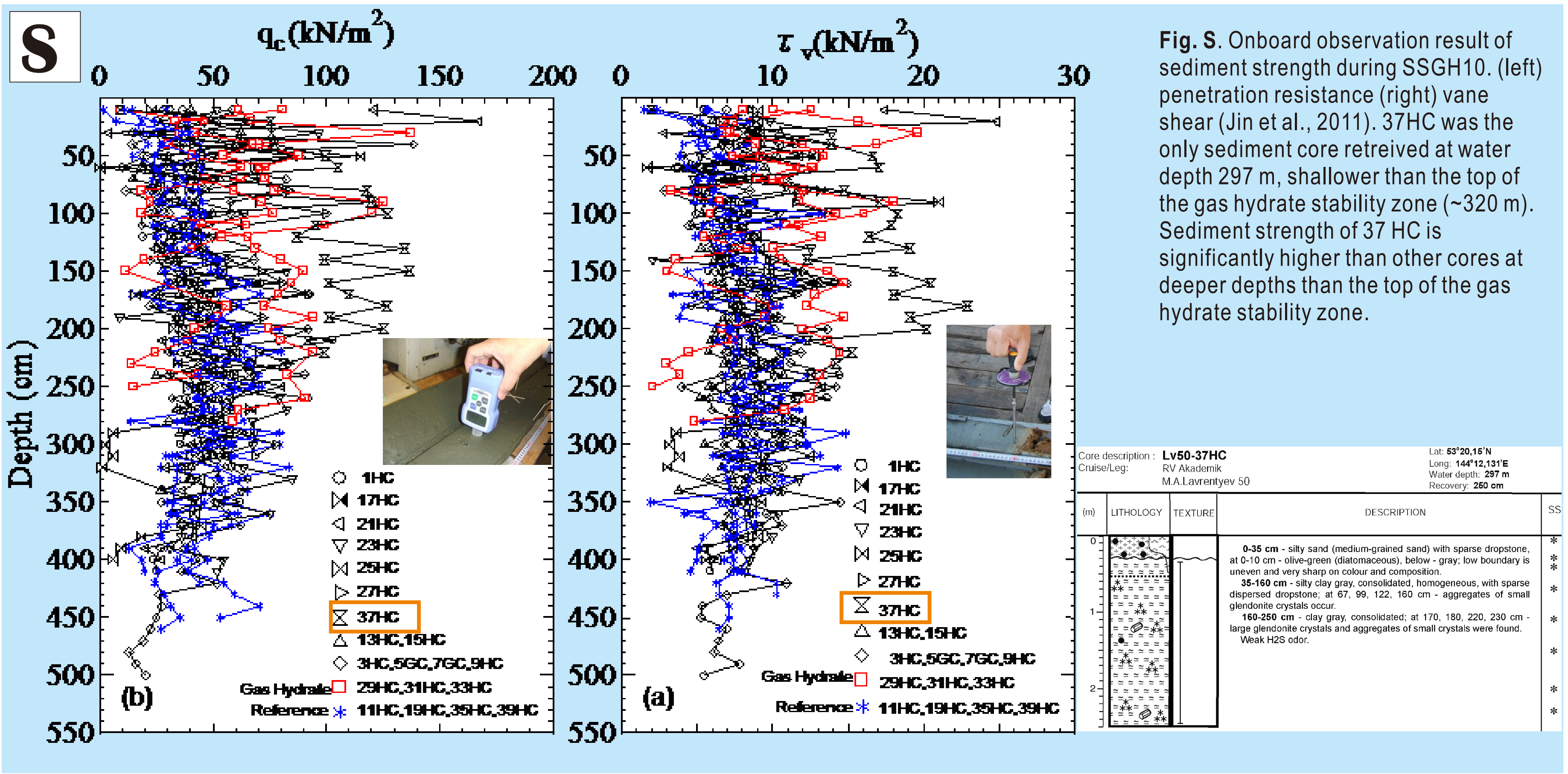


Fig. R. The wiggled surface as shown in the sparker seismic profile. The location of the wiggled surface roughly agrees with the top of gas hydrate stability zone (TGHSZ). Inset is a blow-up image of the box. Careful interpretation of seismic data on the wiggled area may suggest that the surface does not have a current origin: 1) no change in seabed reflector amplitudes compared with one in non-wiggled area (Berndt et al., 2006), and 2) steep (>15 °) angle between the boundary of undulation and reflector of undulation (Berndt et al., 2006; Hill et al., 1982).



Core description : **Lv50-37HC**
Cruise/Leg: RV Akademik M.A.Lavrentyev 50
Lat: **53°20,15'N**
Long: **144°12,131'E**
Water depth: **297 m**
Recovery: **260 cm**

Fig. S. Onboard observation result of sediment strength during SSGH10. (left) penetration resistance (right) vane shear (Jin et al., 2011). 37HC was the only sediment core retreived at water depth 297 m, shallower than the top of the gas hydrate stability zone (~320 m). Sediment strength of 37 HC is significantly higher than other cores at deeper depths than the top of the gas hydrate stability zone.

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Acknowledgment

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