Mapping gas pockmarks and gas emission off New Zealand: multibeam mapping and acoustic water column imaging

(Schneider von Deimling, Hoffmann)

System installation

The novel 50 kHz multibeam SB3050 manufactured by L-3 ELAC Nautik GmbH was installed on POLARIS II in Portobello near Dunedin on March 8th and 9th. This system uses a Mills-Cross setup of respective 50kHz transmit- and receive-transducers and was mounted via the over-the-side-pole of POLARIS on starboard (FIG. MOUNTING).

Fig. MOUNTING: Picture of the SB3050 mounted via the over-the-side-pole of Polaris II.

The SB3050 is a modern 50 kHz sonar with full WCI and Multi-Ping functionality allowing high survey speeds and full water column scanning and storage capability with maximum range up to 3000 m water depth and a beam resolution of up to 0.5° x 0.5°. Due to the size of the mobile installation a 3°x2° beam setup was chosen.

In single ping mode one transmission cycle is characterized by the formation of three simultaneously yaw and pitch stabilized transmit-sub fans with subsequent roll-stabilization during receive. The center transmit-sub fan has the frequency F1 slightly different from the respective outer sub fans (F2) due to necessary reception signal separation. The system covers a maximum of 140° swath width.

In multi ping mode, two spatially separated acoustic swaths are formed each having three transmit sub-fans having frequencies F3 and F4, respectively. 64 reception staves record the incoming echo signals. The transceiver electronic (SEE37) of the SB3050 then performs A/D conversion of the voltage and reception signal processing of the echo time series for further multibeam processing. 4 PCs (one for each frequency F1-F4) perform real-time hybrid time-delay beam forming to generate up to 191 equi-angle beams (or up to 386 equi-distant beams). On the one hand, the beam formed data were processed in the bottom detection algorithm (BDA) and streamed to the “Operator PC” to display and store bathymetric data in the XSE file format and HYPACK/HYSWEEP. On the other side the uncompressed beam formed data were streamed to the “WCI PC” for each beam to visualize the water column backscattering data over travel time in each direction. Alternatively, raw stave data (not beam formed) can be recorded by the "WCI PC". The amount of stored WCI data depends on the calculated system depth, the manually configured or automatically determined beam spacing and the current pulse length.

For accurate positioning and ship movement measurements two Codaoctopus GPS antennas were installed on top of POLARIS (Fig. SKETCH). Good satellite coverage was given during any course and time. The water resistant Coda Octopus IMU F180R was permanently attached to the transducer head. Using such a setup allowed for lowering the over-the-side-pole without the need of re-calibration for each deployment. The F180 GPS reference ellipsoid was set to WGS84. Roll, pitch and heave data (TSS1) were streamed to the multibeam electronics with 50Hz via serial connection, and the data were time-tagged by the F180 PPS pulse sent to the SB3050 electronic. Moreover heading (NMEA-HDT), positioning values (NMEA-GGA, VTG, ZDA) and keel sound velocity gathered with a Valeport probe were sent to the SB3050. System settings were controlled by the Hydrostar control software (Version 3.5.8) with data storage in XSE format. The data were then further streamed to HYPACK/HYSWEEP, where the angle/travel time data were corrected for sound velocity and ship motion to finally generate georeferenced depth and amplitude soundings (F180 MCOM data were additionally used for the corrections). Later postprocessing was conducted by a combination of HYPACK/HYSWEEP, MBSYSTEMS, QPS-Fledermaus and GMT. Water column traces of all beams were streamed to another PC to visualize water column images (WCI) online with the Hydrostar WCIViewer (WCI files).

Vertical sound speed profiles were derived from Seabird CTD casts and post-processed by SBEProcessing using the sound speed conversion method after DelGrosso.

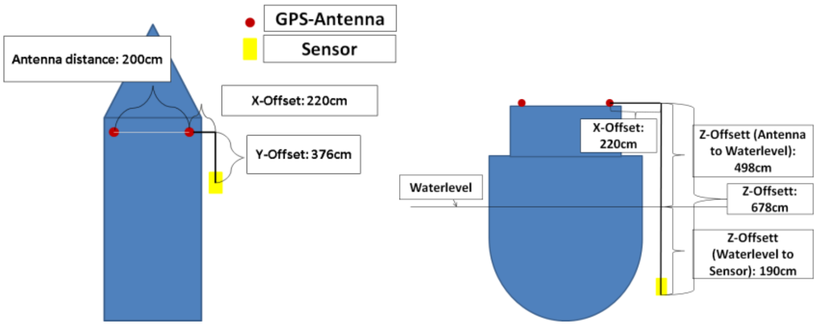

Fig. SKETCH: Measured offsets between MRU, the transducer (both labeled by "Sensor") and the primary (stbd) and secondary (port) GPS-Antenna. All offsets relate to the local origin co-ordinate defined by the MRU position projected onto the water level.

Comment [js1]: show picture of transducer mounted over the side pole

Table 1: F180 corrections provided by dynamic self-calibration after cruising several "8"s

XOFF	YOFF	ZOFF	Motion accuracy	Heading accuracy	GPS accuracy
-2.14	-3.49	-6.85	~0.04°	~0.07°	~0.5m

Goals, System settings, and performance

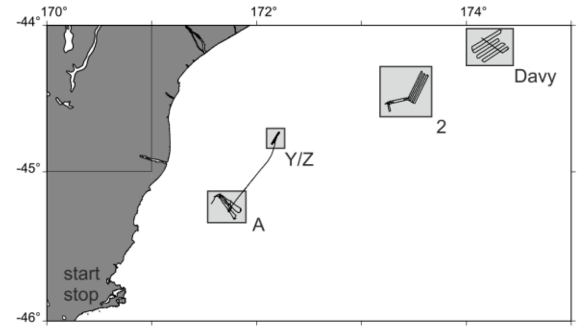

Fig. SURVEYS: Position and tracklines of our four survey areas. During Polaris-XXX

The main goal of the multibeam studies during this cruise was to identify gas seepage as a potential indicator for methane hydrates in the seabed (Haeckel et al., 2004). Thus we concentrated on the detection of gas bubble-mediated echoes in the water column (flares) and suspicious seafloor features such as pockmarks. Prior to this cruise multibeam (EM120) and subbottom profiler (PARASOUND) data gathered during research cruise SO169 (Gohl et al., 2003) have been reviewed to find the most suspicious sites in regard to gas seepage, i.e. shallow gas combined with pockmarks or faults (Fig. PS).

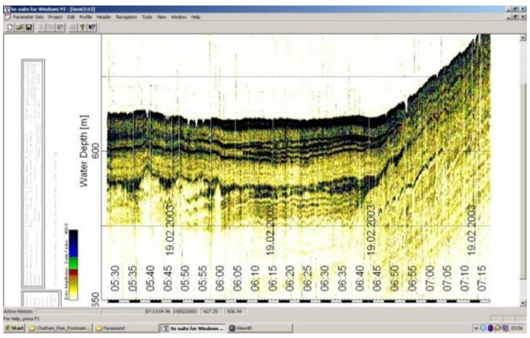

Fig. PS: Parasound record from the SO169 cruise processed with SENT from 2003 showing shallow gas blanking together with seafloor depressions (data courtesy by Brian Davy, GNS).

Seafloor mapping

Ideal operation for recording water column signals required high reception gain settings and low pulse lengths. These settings may have led to confusion of the bottom detection algorithm (over-modulation of echo voltage), i.e. the settings were optimized for enhanced water column inspections for the cost of bathymetric measurement quality. Nevertheless the system performed well and worked reliable throughout the cruise. After the second survey one network card of the survey computer failed and consequently HYPACK/HYSWEEP data storage was not possible any longer.

Nevertheless all data were stored in parallel in ELAC vendor format XSE (this is also the reason for presenting non-calibrated bathymetry data later in this study).

WCI

Water column imaging and logging was performed during all surveys with reduced ship speed (3-5 kn) to (1) lower pole-vibration and propeller noise (2) reduce surficial bubble entrainment, and (3) not to lose the spatial coherence of rising and current-deflected gas bubbles streams. Multiping mode was chosen for enhanced coverage and the pulse length was preferentially set to the systems minimum value of 0.15 in singleping and 0.4ms in multiping mode. Depending on the water depth, the transmission source level was either reduced to a power of -20dB or 0dB and the reception gain and TVG were correspondingly adapted to visualize features in the water column. The water column data were streamed over a gigabit-ethernet to the WCI computer and stored on a raid 1 connected via E-SATA for better performance. Even though fast ethernet was used for data streaming, the high data rate of ~20MB/s caused significant time latency between echo reception and WCI echogram visualization of approximately 10 seconds. The online time lapse worsened during the cruise, however, this has no implication on the data investigations during postprocessing.

A flare-like systematic artefact appeared on the port side near nadir (Fig. ARTEFACT) and often extended over the entire travel time from the transducer until the end of the recording window. In regard to WCI gas flare detection and respective postprocessing approaches this artefact has to be considered. We speculate that it originates from a real acoustic source on the port side of the transducer (compare Fig. MOUNTING and SKETCH). Given its shape exactly following the beams and the pronounced sub-seabed elevated echoes it can be clearly discriminated against real flares.

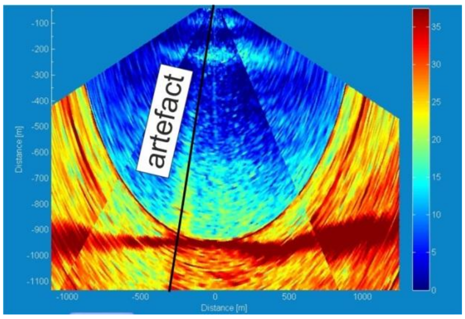

Fig. ARTEFACT: artefact along the near nadir port side beams extending throughout the water column and the sub-seafloor domain.

To test the sensitivity of the system a calibration sphere survey was conducted operated from the rescue boat of Polaris. The -41dB calibration sphere from Biosonic was clearly visible from nadir until the very outer swath at 70° starboard revealing a low signal decay towards the outer swath (Fig. SPHEREa). Given the rough weather conditions such a test could only be conducted in protected regions at shallow water depth up to 30m.

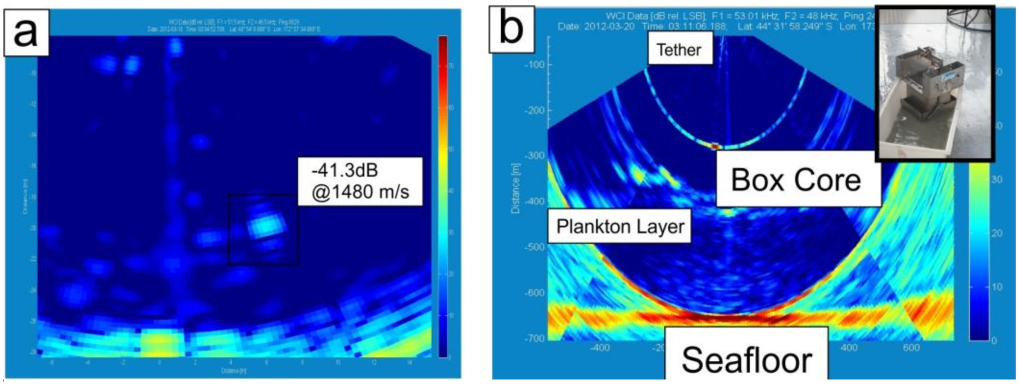

Fig. SPHERE: (a) Reference target backscatter of the calibration sphere with expected target strength of -41.3dB. (b) Backscatter of 30cm diameter Boxcore (inset picture), its respective tether connected to Polaris. Around 400m water depth a prominent scattering layer emerges accompanied by the presence fish.

The water column imaging appeared to be sensitive for weak target detection even at larger water depths up to 700 m. Here other features such as a 30cm diameter box core (Fig. SPHEREb inset), fish shoals and /or zooplankton layers clearly appeared as elevated signals thus demonstrating the system sensitivity (Fig. SPHEREb).

Results

Combined bathymetric/WCI surveys have been conducted together with Boomer operation at ships speeds around 3-5 kn. Often, the weather conditions were rough, though the system performed considerably well and was operating well even for roll ship movement up to +-12° and bathymetric features like pockmarks could be detected within an approximately 130° swath at all survey depth (up to 1000m). First inspection of backscatter data did not show any correlation between backscattering strength and pockmark occurrence. However, the data has not been processed yet with more sophisticated approaches like angular range analysis.

Target A

North of the first survey area (Fig. TARGET_A) a roll test was performed in the beginning across a flat seafloor at 130m water depth. Calibration lines for pitch, yaw, and latency corrections could be conducted later across the steep canyon walls recorded in the southwest (Fig. TARGET_A) in deeper water between 800-1000m. The final results of the calibrations values are latency 0, roll -0.15°, pitch -1.1°, and yaw 2° (HYPACK coordinate system).

The gathered bathymetry in Fig. TARGET_A a shows a distinct slope deepening towards southeast. Beginning at 600 m water depth a hummocky elevated area with local depressions extends towards the 800 m contour. Further downslope a few solitary depressions were found. The west of the survey area is cut by one meander belonging to a large canyon with very steep slope at the canyon walls. Another less pronounced erosional channel appears parallel to the northeast of the hummocky area.

Together with the bathymetric measurements this area was surveyed in WCI mode and one flare-like feature could be found (Fig. TARGET_A, b, Fig. WCI_FLARE). It originates from 240m water depth and reveals an enlongated shape of 140m height and 20m width. Its rise height, the vertical/horizontal expansion ratio and a potential current derived deflection towards the portside are characteristic for flares. However, fish shoal scattering can not entirely be excluded as a source of this enhanced backscatter. Especially the time series presentation in Fig. WCI_FLARE reveals some elevated echoes apart from the flare that resemble fish derived echoes. During a subsequent criss-cross survey no elevated water column signals could be detected again. The seafloor backscatter amplitudes are provided for the time where Fig. TARGET_A b was found in Fig. TARGET_A c and no anomalies have been found in the vicinity of the flare feature.

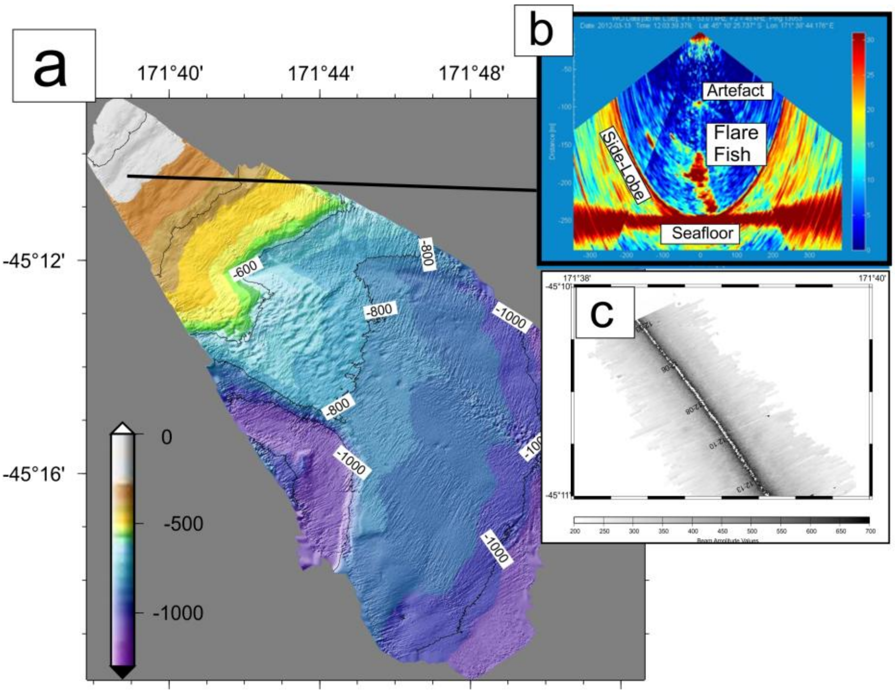

Fig. TARGET_A: (a) Bathymetric chart (Mercator, WGS 84) of survey area A. (b) flare-like feature rising ~100m (c) backscatter start of flare survey line around 12:04 o clock UTC.

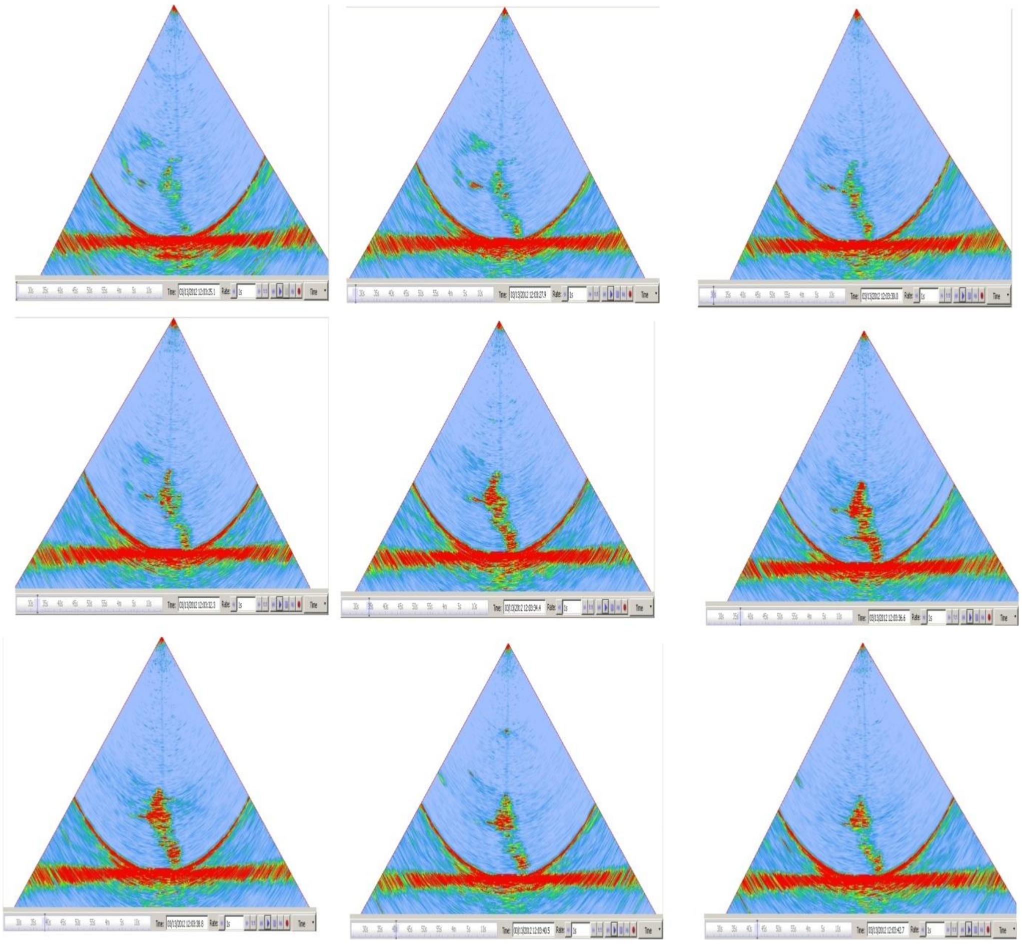

Fig WCI_FLARE.: Time series of 9 pings (14 seconds) at the flare site showing the WCI succession from upper left to lower right corner. Distance travelled between those pings comprises ~20m.

Target Y/Z

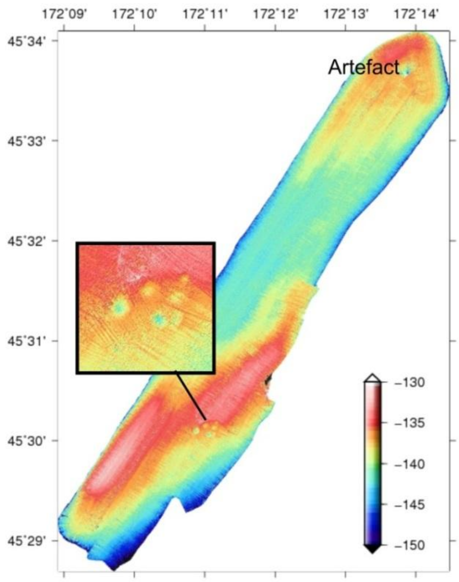

Fig. Y/Z: Bathymetric chart (Mercator, WGS 84) of survey area Y/Z. Inset shows a closeup of discovered pockmarks.

After a one day port call we returned to survey area Y in shallow water depth of around 135m. The swell picked up giving rise to very pronounced ship movement with roll values exceeding 20° deteriorating the data quality. Moreover the CTD broke and no adequate sound velocity profile could be generated at this site. Even though valuable results could be acquired after intense data cleaning. This included application of a maximum depth filter to (1) suppress the erroneous sound velocity up-bending towards the outer swath and (2) to better visualize pockmarks. A strong heave artefact is present in the data. A future post-processing of the heave might be applied to compensate this error. Generally the area is characterized by two 10m high ridges one in the north and one in the south. At the southern edge of the southern ridge six depressions of several meters depth show up in the bathymetric chart (Fig. Y/Z). Those correspond to a phase shift and a depression in the seafloor found beforehand in seismic records (courtesy of Brian Davy) and thus we interpret those depressions as pockmarks; no respective backscatter anomalies were found at those pockmarks sites in the multibeam data.

Comment [js2]: Boomer data?

Target 2

Target area 2 is characterized by average water depths around 650 m slightly deepening to the southeast. The seafloor is covered with hundreds of pockmarks of various scales ranging between only tens to hundreds of meter in diameter and with depths near the detection limit (3m) and 70 m depth (Fig. TARGET_2a). During the transit towards target area 2 a pronounced pockmark was found having smaller pockmarks inside a larger one – a potential indication of ongoing pockmark activity (Fig. TARGET_2b). A vague striking direction from SW-NE and S-N is visible in the very northern and very southern part of Fig. TARGET_2, respectively.

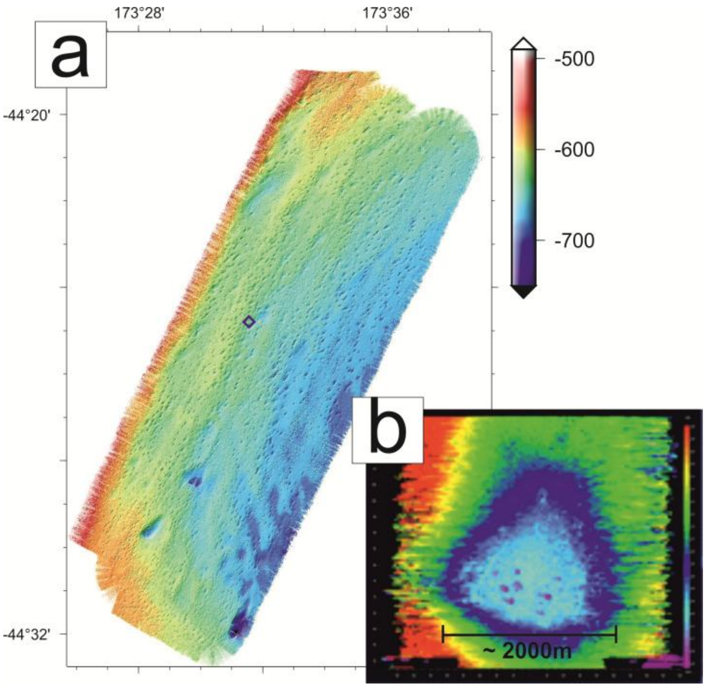

Fig. TARGET_2: (a) Heavily pockmarked area around survey target 2. The first survey line in the northwest of the map (Mercator, WGS 84) was not yet corrected for sound velocity profile giving rise to distinct up-bending towards the outer swath (red soundings). Diamond marks target 2. (b) unreferenced screenshot of the bathymetry during the transit towards TARGET_2a showing a 2km diameter pockmark with smaller pockmarks inside.

Davy site

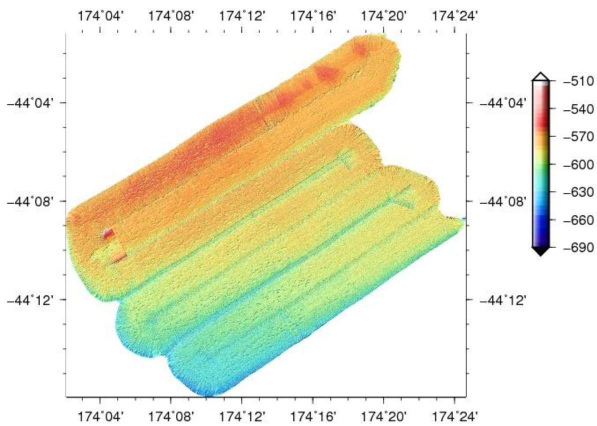

Fig. DAVY: Uncorrected bathymetric data (Mercator, WGS 84) around the site discovered in Davy et al. (2010). In the western part a strong artifact appears in the data.

Given the shallow gas indications in Davy et al. (2010) a survey was planned in the vicinity. Even though hundreds of pockmarks were detected no gas escape in the form of hydroacoustic flares was observed. After one computer network card was not operating correctly anymore, data could not be stored by HYPACK/HYSWEEP any longer. For hitherto unknown reason application of the Roll, Pitch and YAW offsets by MBSYSTEM fails and thus uncorrected bathymetry is presented (Fig. DAVY). The general appearance of this survey area is flat with a gentle slope deepening towards the southeast. Pockmarks are uniformly distributed concentrating around 600m water depth. We attribute this odd occurrence to angle dependent resolution issues (higher resolution at nadir).

Conclusion

Prior to this cruise areas were defined as 'suspicious' in regard to gas escape on a basis of BSR findings in seismic records, shallow gas blanking effects in subbottom data, and the occurrence of gas escapement seafloor features such as pockmarks. During our cruise a vast amount of previously known and newly discovered pockmarks were surveyed during an overall of 385nm of survey lines (92 hours). A broad swath of at least 120° was used all the time and the system demonstrated to perform well in regard to resolving small scatterers like gas bubbles in the water column. Though, only one potential flare was found (Fig. TARGET_A) during online inspection. More gas flares might be identified after detailed review of all stored WCI data. So far no seafloor backscatter anomalies were found neither in the vicinity of the pockmarks nor elsewhere. Thus, very shallow gas occurrences <2mbsf in soft sediment are excluded to occur because they would have been detected as high backscatter features on the seafloor. However, Backscatter has not been inspected in detail and further angular versus range analysis is suggested to constrain more information between areas with and without pockmarks. Overall we conclude that gas escape in the surveyed areas do not play a major role, at least not during this period of time.

Literature

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