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Automatic Estimation of the Seafloor Geomorphology of the Santos Basin, Brazil

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Summary

The bathymetry of the Santos Basin, Brazil (figure 1) was mapped using a SeaBeam 2112 (12kHz, 151 beam) Multibeam Echosounder (MBES) aboard the R/V Falcon Explorer. This MBES data was acquired from January-November, 2000, during a high-resolution multi-channel 3D seismic survey, resulting in 380 parallel lines of 90km length, spaced 250m apart (figure 2). A total of approximately 470×10⁶ soundings were gathered by the MBES and recorded for post-processing. The final survey mapped an area of 5,000km² in water depths of 600-2300m. These closely spaced multibeam tracks resulted in an average overlap between swaths of 1000%, thereby ensonifying most areas of the seafloor at least ten times

Data this dense is time consuming and tedious to process by hand, with the added difficulties of operator error and fatigue. However, the density of data makes it ideal for automatic estimation algorithms. We ran all of the MBES accepted soundings through the CUBE algorithm (figure 3), resulting in a DTM at 25m spatial resolution over all of the survey area (figure 4), a process that took approximately seven hours of non-interactive computer time on commodity PC hardware (1.6GHz P4, Firewire disks). Inspection of the first-pass result showed that the algorithm had correctly isolated outlier points (figure 5) and reconstructed the seafloor morphology reliably. Approximately one hour of interactive time was used to clean up some small anomalies in the edge of the data, but otherwise the data was not touched. Human interactive time for a traditional hand-editing approach to this dataset required 15 days of effort, but is equivalent to the CUBE surface (figure 6).

The seafloor morphology of the area includes a set of linear depressions parallel and perpendicular to the shelf-break. These linear depressions are the surface expression of fault planes related to subsurface salt walls (figure 7). In the shallowest part, the detailed bathymetry also shows various pock-marks (350m wide, figure 8) possibly associated with fluid expulsion, while in the deeper portion we observe a small number of larger ones (2500m wide, figure 9) which are clearly inactive as they are partially filled with recent sediments. Some pockmarks are aligned with fault planes, suggesting a preferential pathway for fluid expulsion.

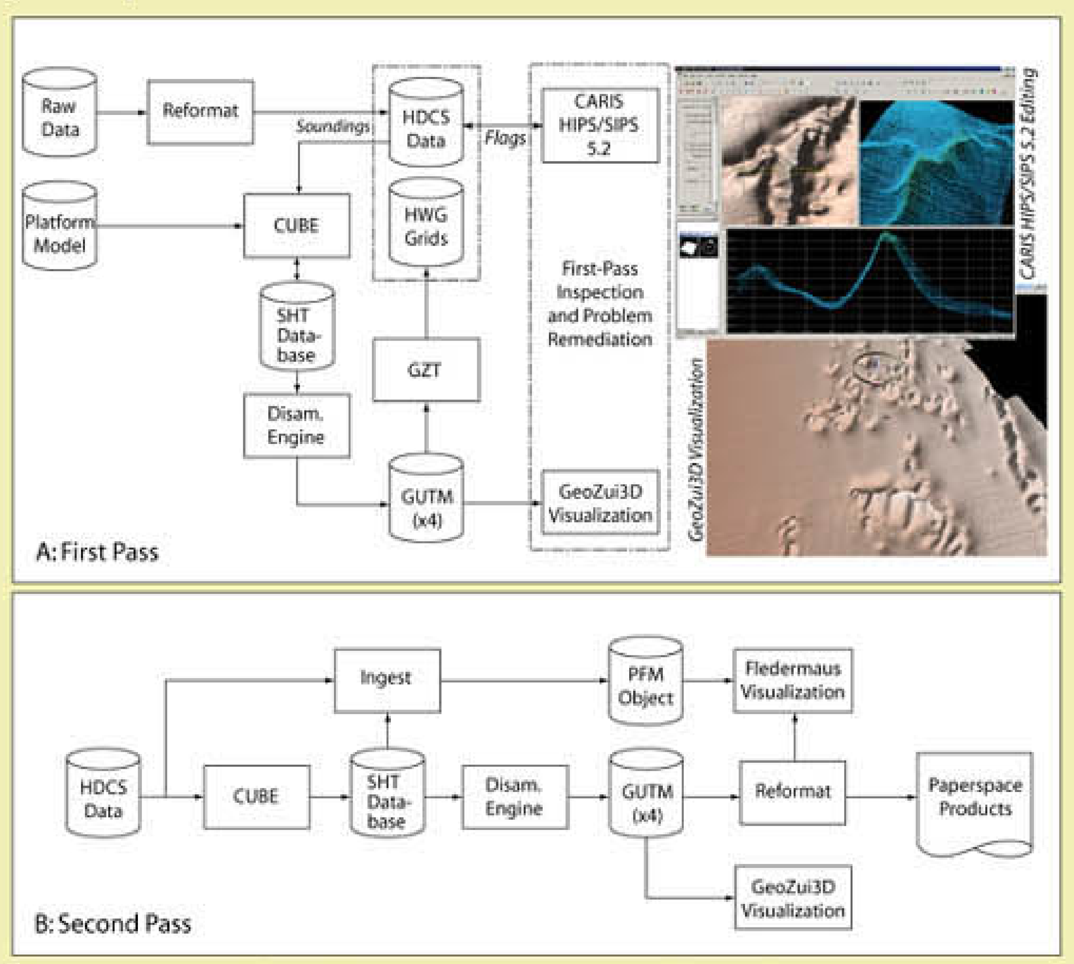

Figure 3: CUBE Flow Diagram. CUBE is conducted in two passes - the first to locate and remediate any problems that CUBE cannot resolve itself, the second to make final products in various forms.

Figure 1: Location map. The study area is located at the southeast part of the Brazilian continental slope, approximately 150km south of Rio de Janeiro, between the isobaths of 600 and 2300m. The surveyed area is part of the Santos Basin, the largest offshore Brazilian basin.

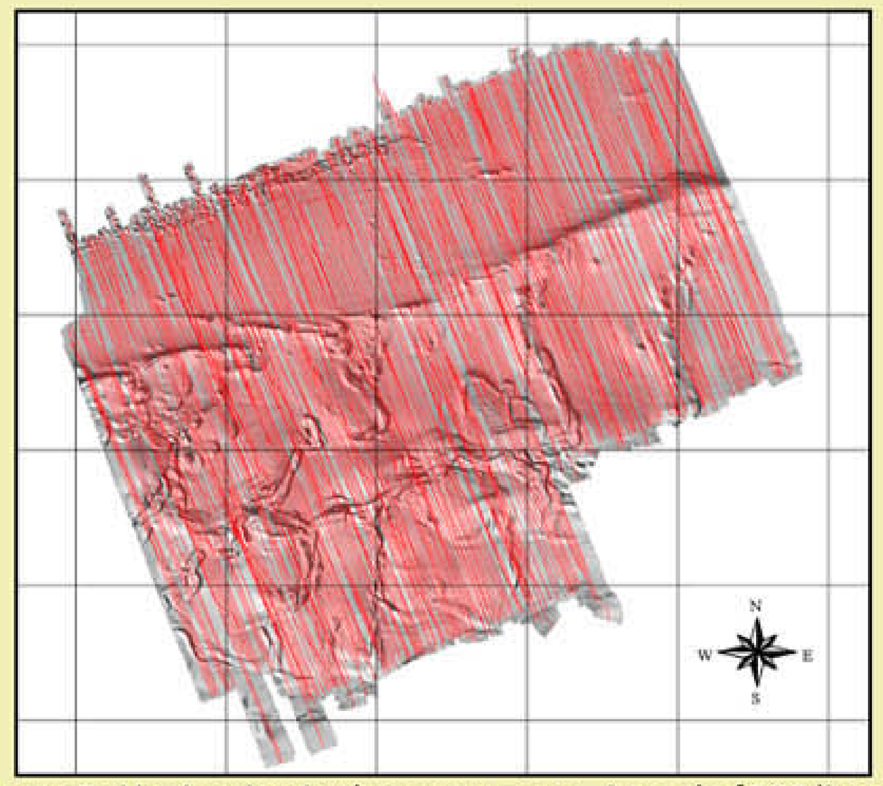

Figure 2: Navigation in the survey area. A total of 380 lines were collected, each approximately 90 km long, covering an area of 5,000km² Note that the spacing between adjacent lines is only 250m, thereby ensonifying most areas of the seafloor at least ten times.

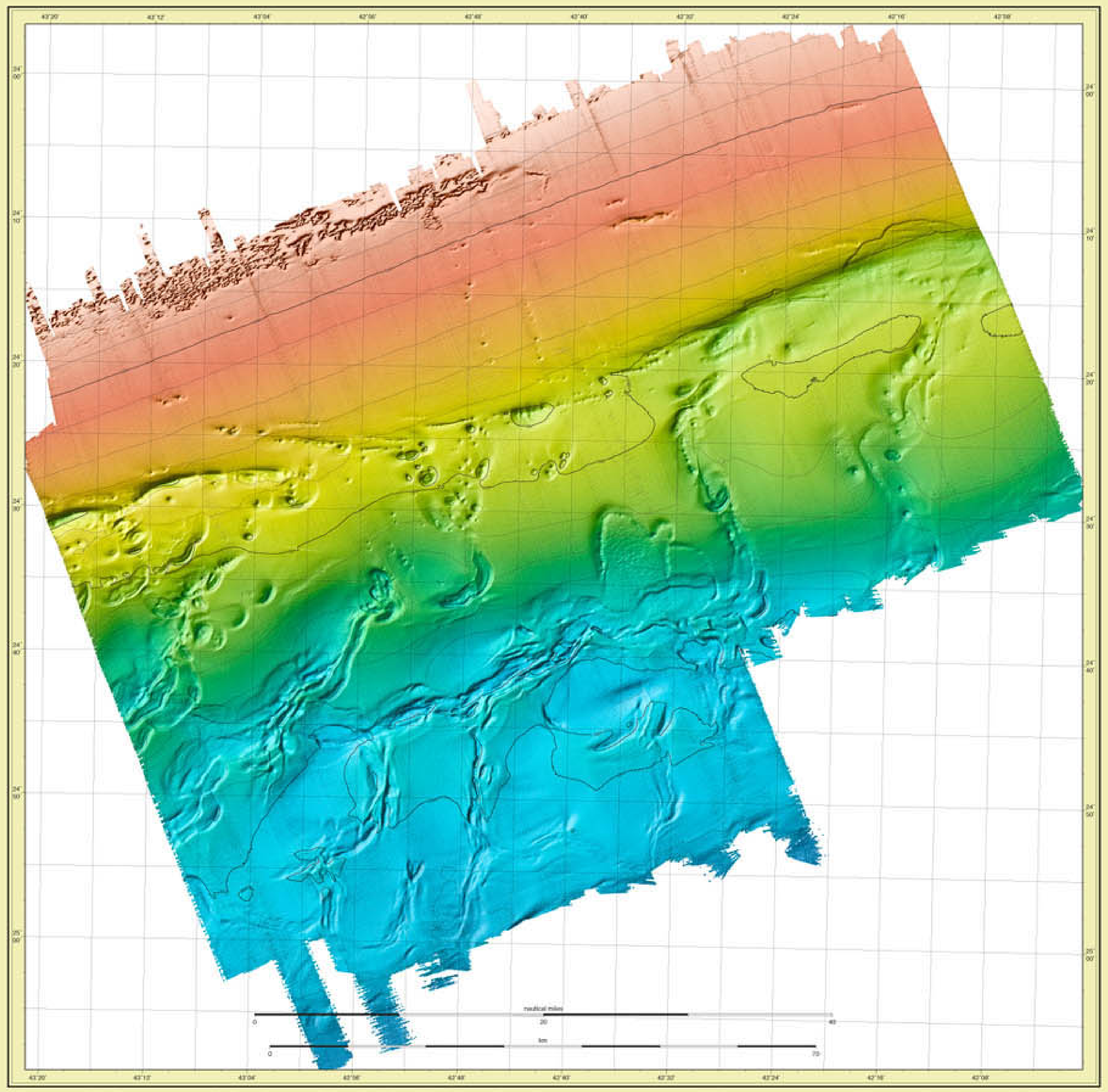

Figure 4: Bathymetry of the Santos Basin, Brazil. The data here was processed from raw soundings using CUBE. The non-interactive assimilation time for all of the data (470 million soundings total, 235 million marked active by sonar operator) is approximately seven hours on a commodity PC; operator interactive time is approximately one hour. Processing by hand took approximately 15 days of interactive time. Projection: UTM Zone 23S, WGS-84 Datum.

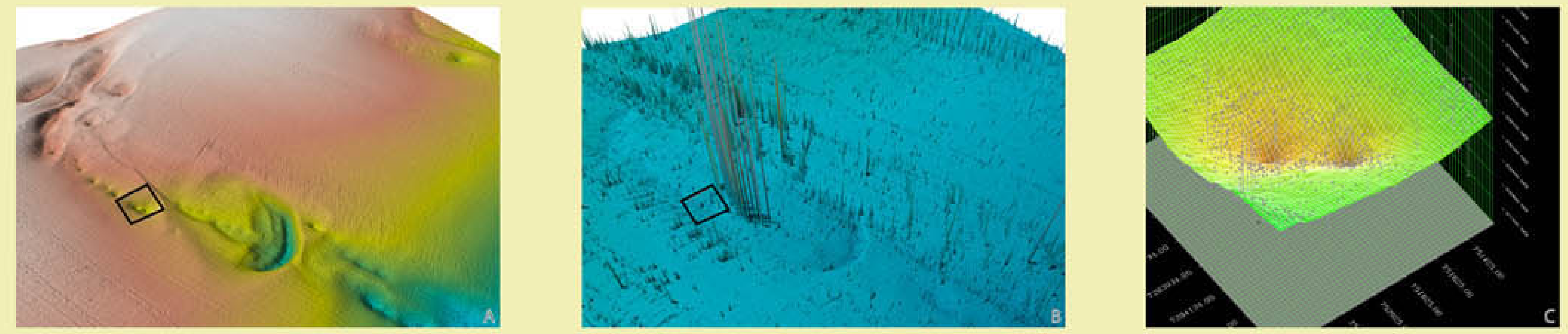

Figure 5: CUBE output surfaces. (a) The 'best depth' estimate surface, with no interventions; (b) Filtered shoal biased binned surface from the same viewpoint; (c) Marked area, showing data (cubes with stalks vertically to surface) and CUBE estimated depth surface. Since CUBE is able to determine which data are consistent (given the estimated accuracy), outliers are aggregated into a separate depth hypothesis, and do not corrupt the primary estimate. After data assimilation, one depth estimate is chosen at each node, completely eliminating any other noise.

Figure 6: Comparison of surfaces. CUBE's surface estimate closely matches the hand-generated surface (A), and where there are significant differences (B: differences color-coded over CUBE's depth estimate), they typically indicate an outlier remaining in the hand-cleaned dataset (C). The red-white transition is at 2.3% of water depth, approximately the limit for IHO S-44 Order 3 survey (for depths over 200m).

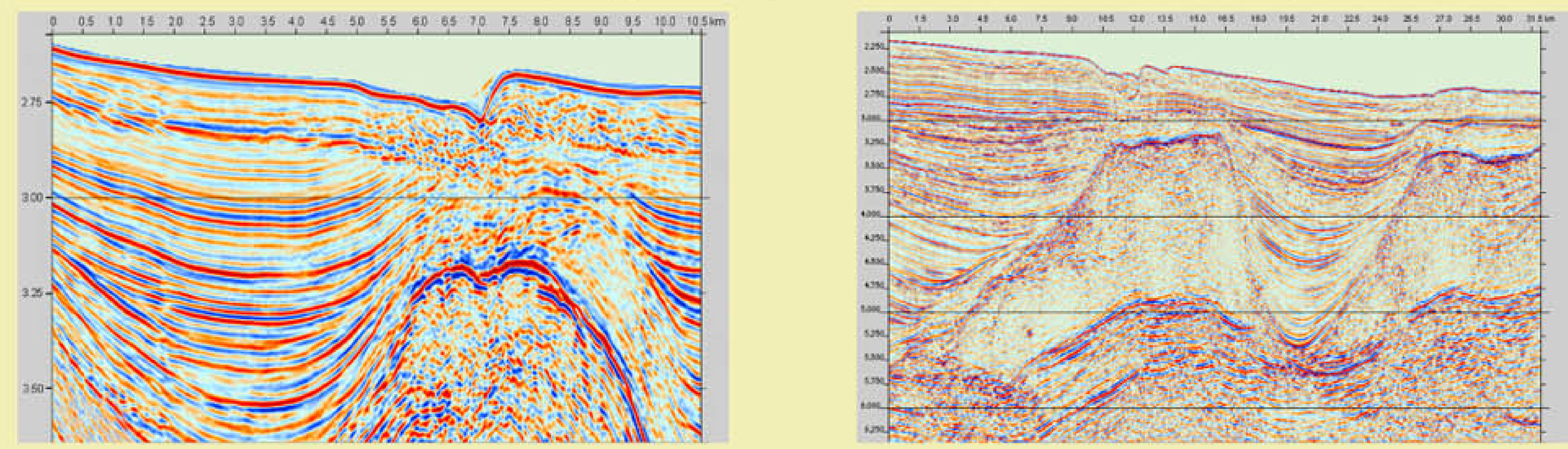

Figure 7: Two parallel NW-SE Multichannel seismic reflection profiles showing salt walls, which delimit tertiary sedimentary basins. These subsurface salt walls are associated with fault planes that reach the ocean floor. Note vertical scale is in seconds of two-way travel time.

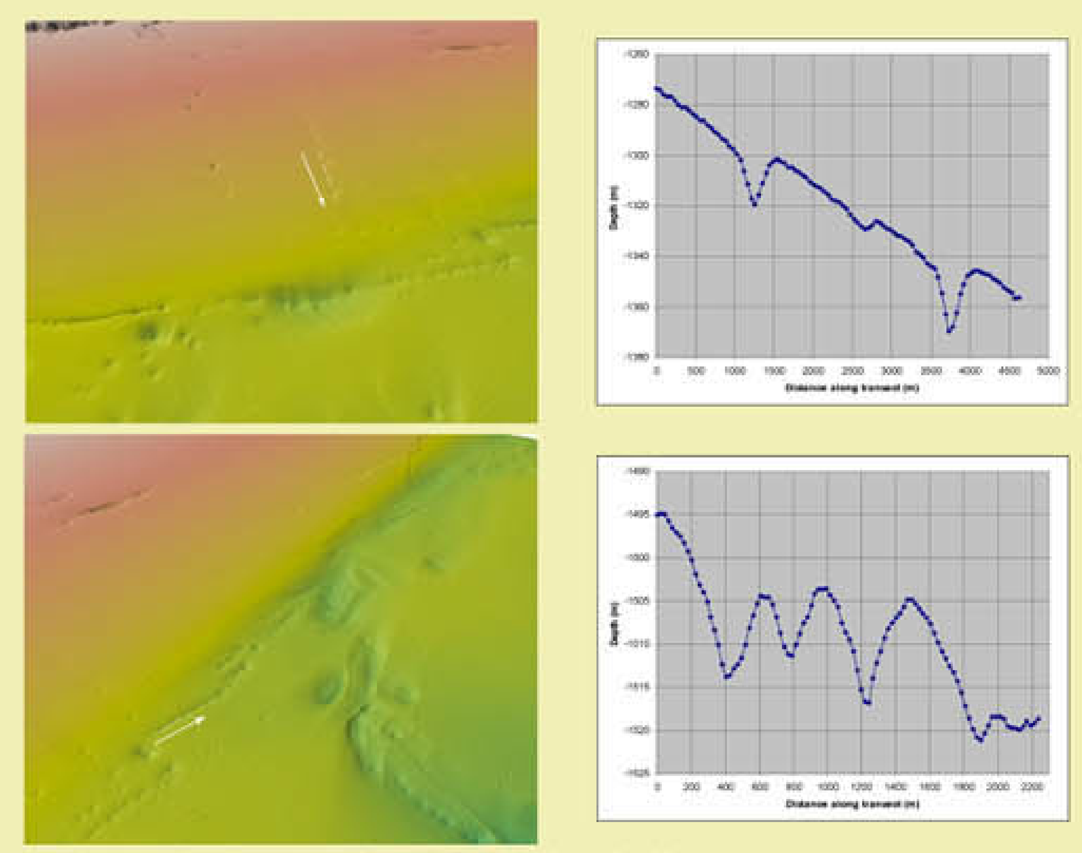

Figure 8: Shallow Pockmarks. In the shallow regions, numerous small pockmarks following linear trends parallel and perpendicular to the shelf break are observed. These may be linked to fluid expulsion along sub-surface salt walls.

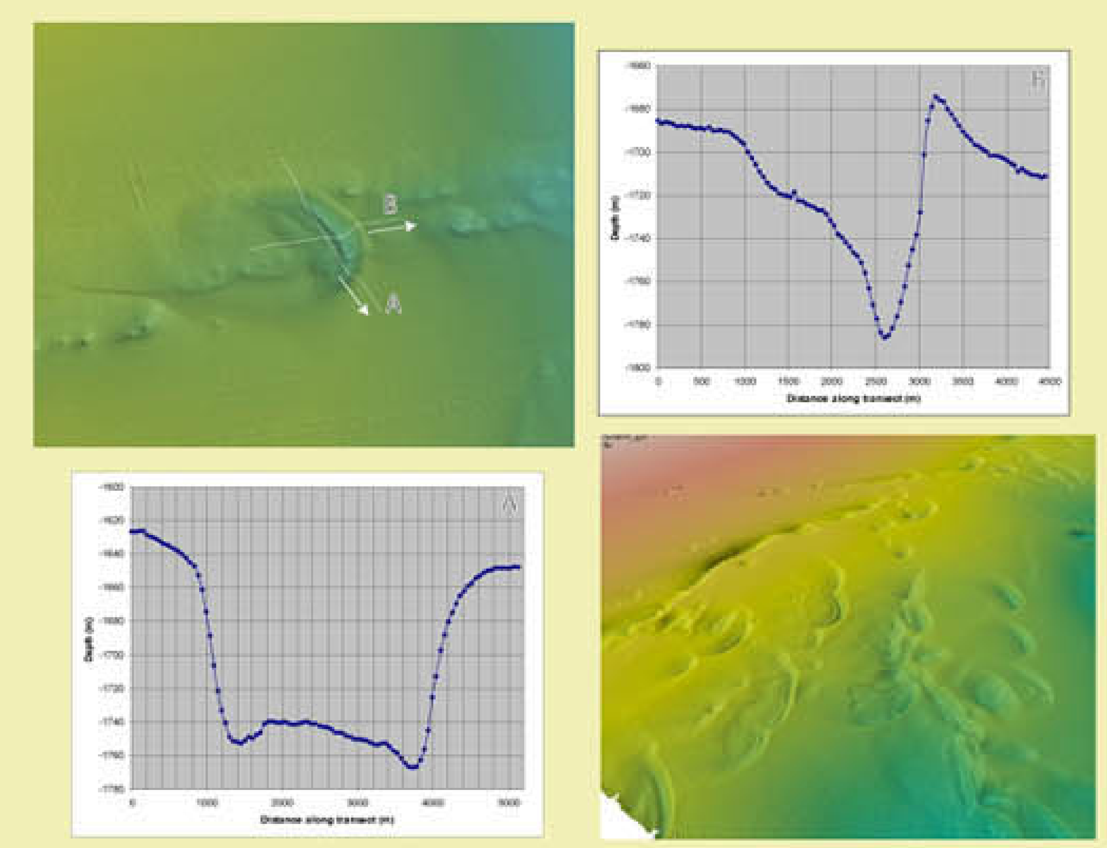

Figure 9: Deep Pockmarks. Significant asymmetry in pock-mark morphology indicate that they are much older. Typical sizes are on the order of 2-3km, although fewer are observed.