Royal Netherlands Institute for Sea Research

Using video and still imagery - current status and emerging methods including 3D reconstructions ~~and AUV photo mosaicing~~

Barreyre et al., 2011, G3;
Prados et al., 2011; IEEE (Oceans 2011)

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NIOZ is an institute of the Netherlands Organisation for Scientific Research (NWO)

What do you want ...?

- **Searching**
  - Looking for a specific, localised, habitat
  - Using each transect to refine positioning of the next
  - Use video data to target deployments of physical sampling
- **Exploring**
  - Investigate new areas
  - Perform video observations in contaxt to MB, SSS, ... maps
  - Adapt sampling and further studies based in what is found
- **Mapping**
  - Generate representative data across large areas
  - ... using these to extrapolate to unsampled/unobserved areas

... and what do you need?

- Good camera, under water navigation (USBL, LBL, inertial, DVL) and synchronized between all sub-systems involved (navigation, camera, sensors)
- Online information about where you are at the seafloor in relation to bathymetric, side-scan and other maps
- Capability of logging online what you see in an easy/multi-observe approach

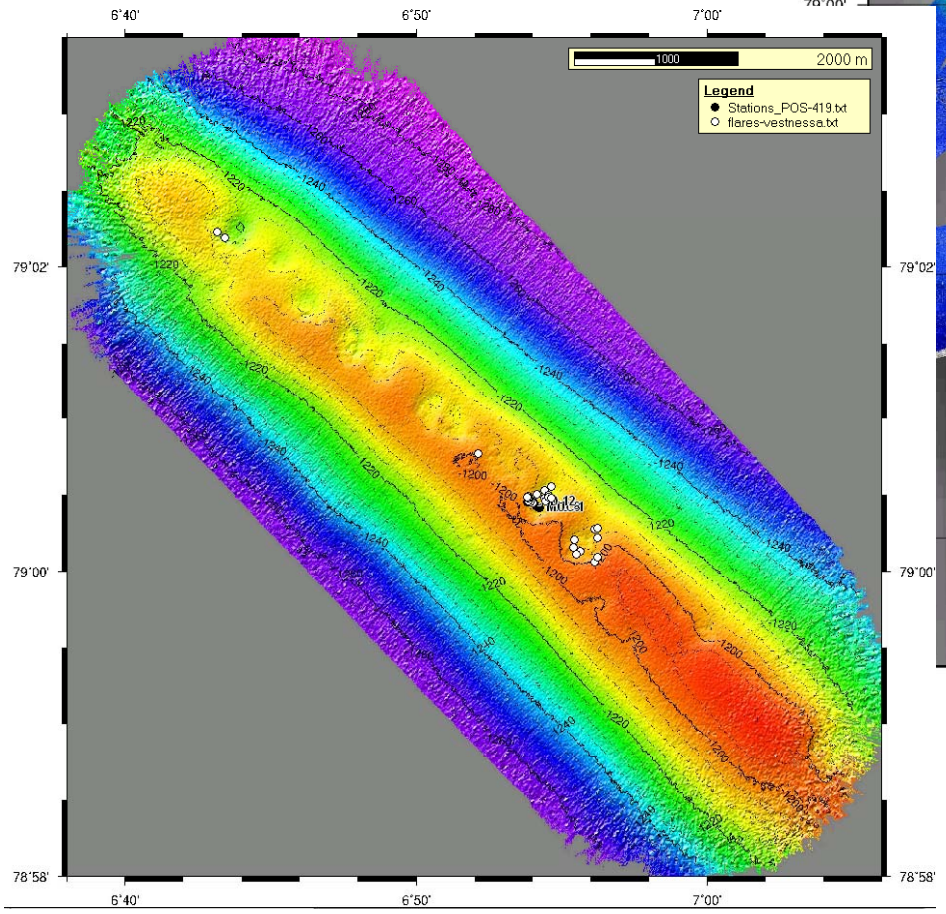
- A unique way of how to describe what you see at the seafloor, substrata, substrate properties and taxa
- Possibility to easily re-investigate geo-referenced video/image data
- Storage in a data base linked to reference data base

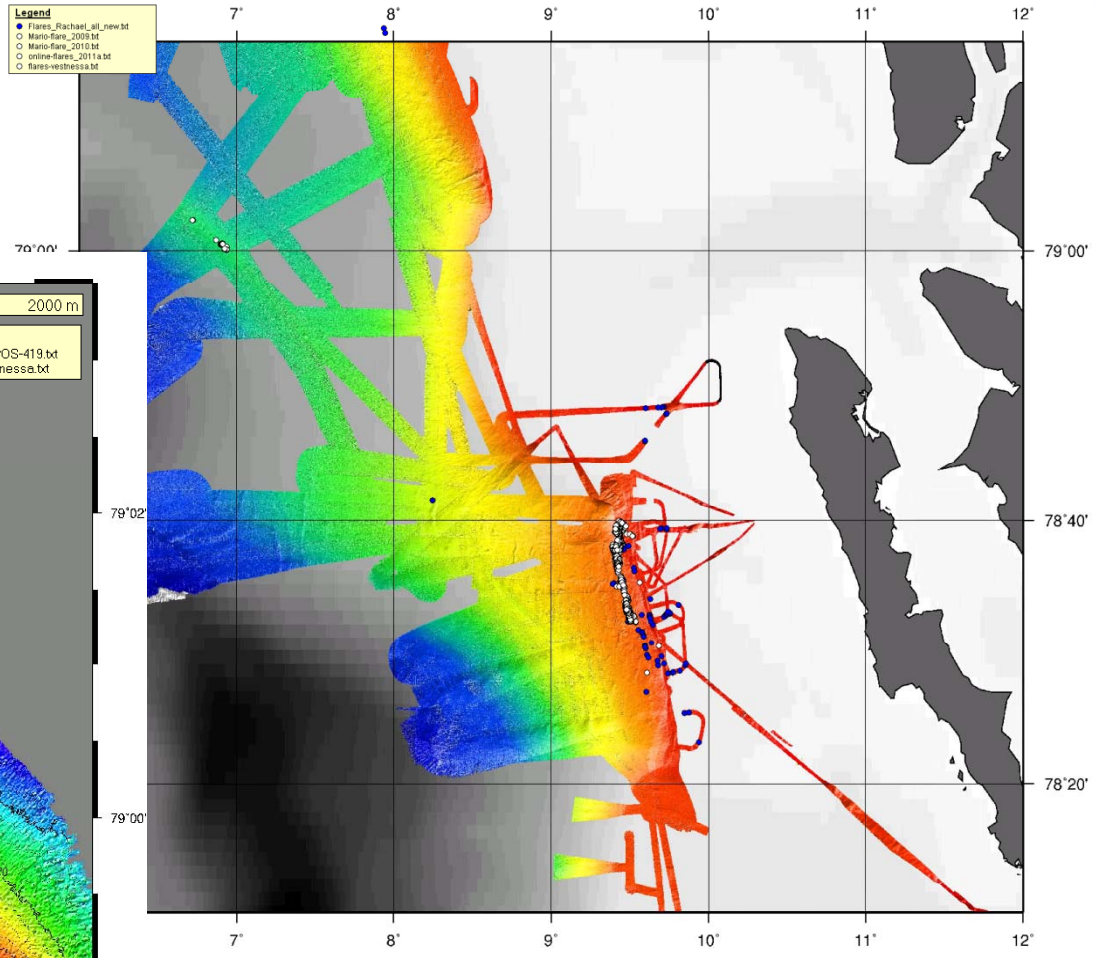
- For detailed observations on local features, high res MB and photogrammetry are possible techniques

Searching

Vestnesa Ridge offshore Svalbard

MB data from S. Bünz; U-Tromsoe

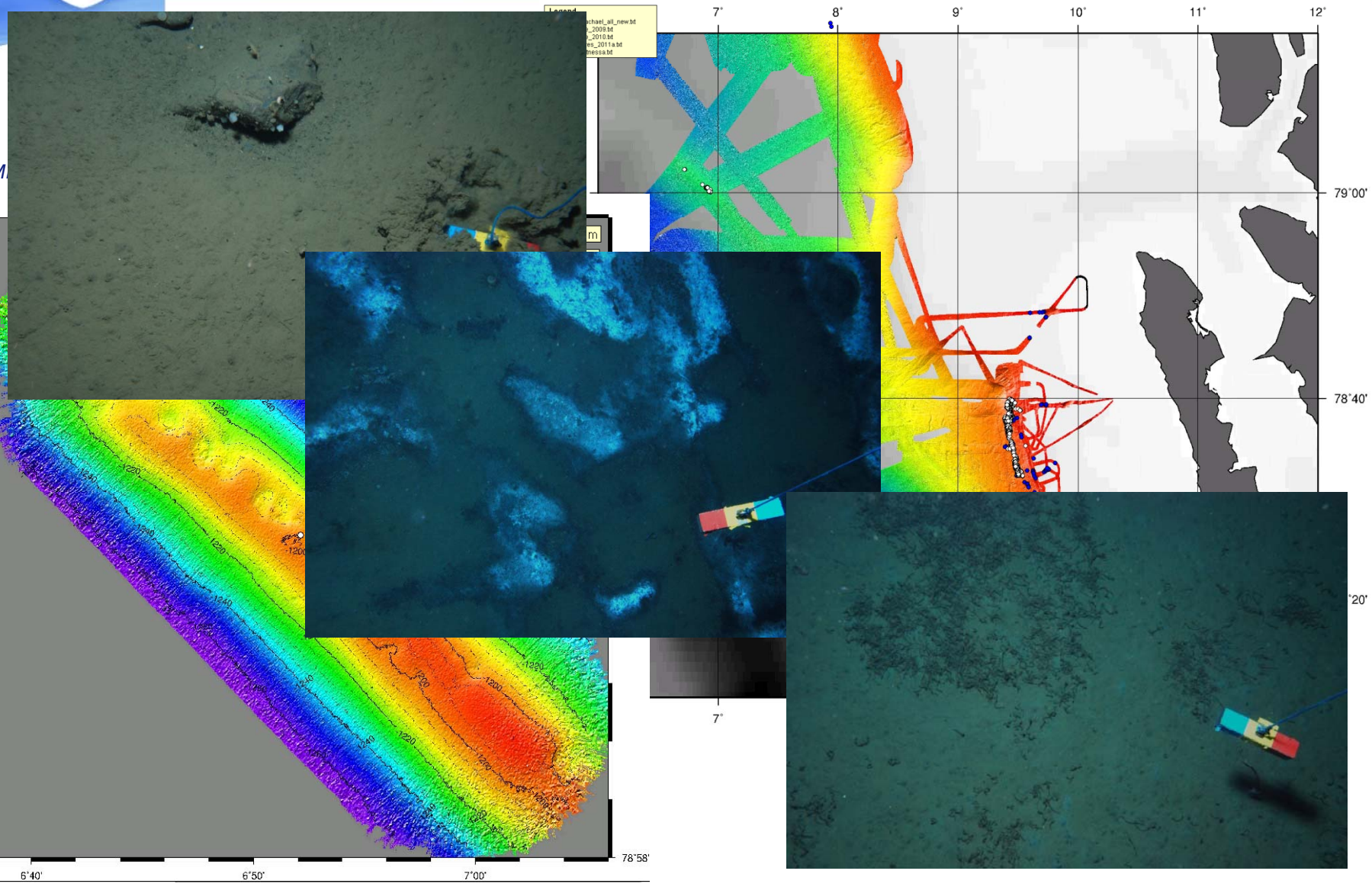




Data compiled from IPY (JR211), GEO3144 and AOEM

Searching

Vestnesa Ridge offshore Svalbard



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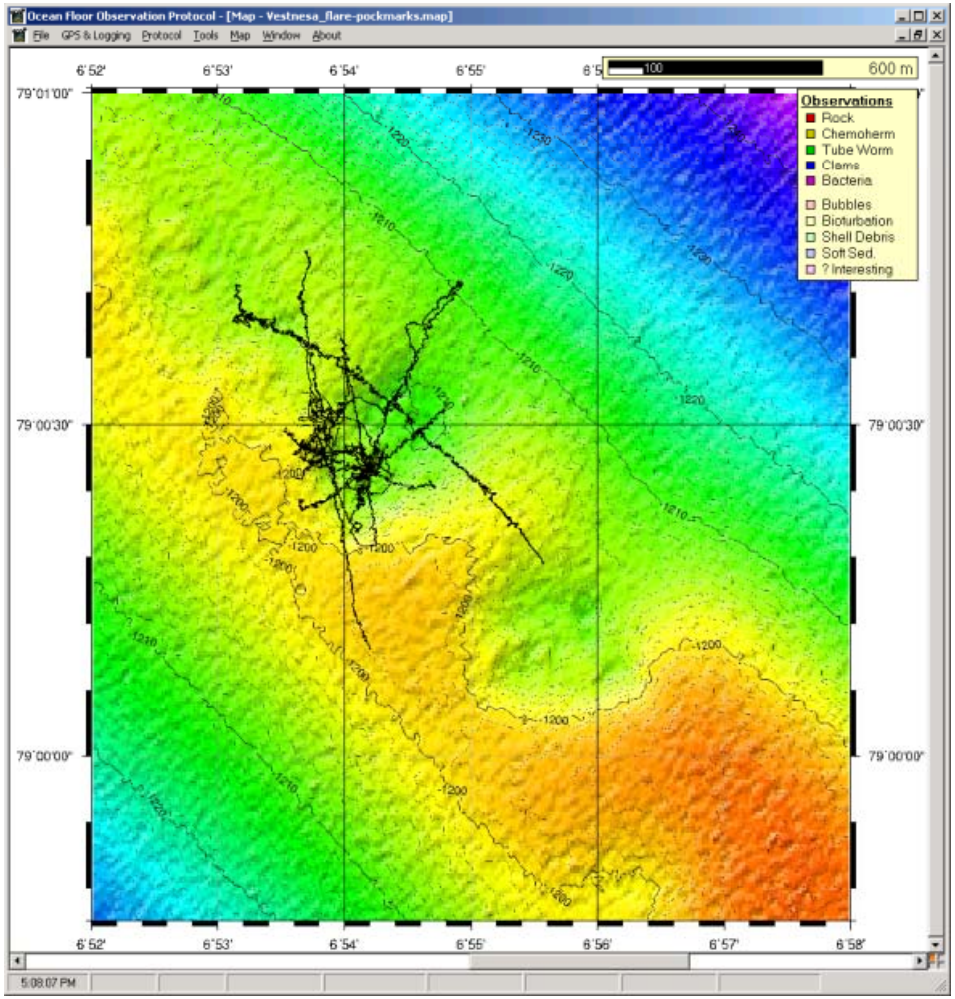

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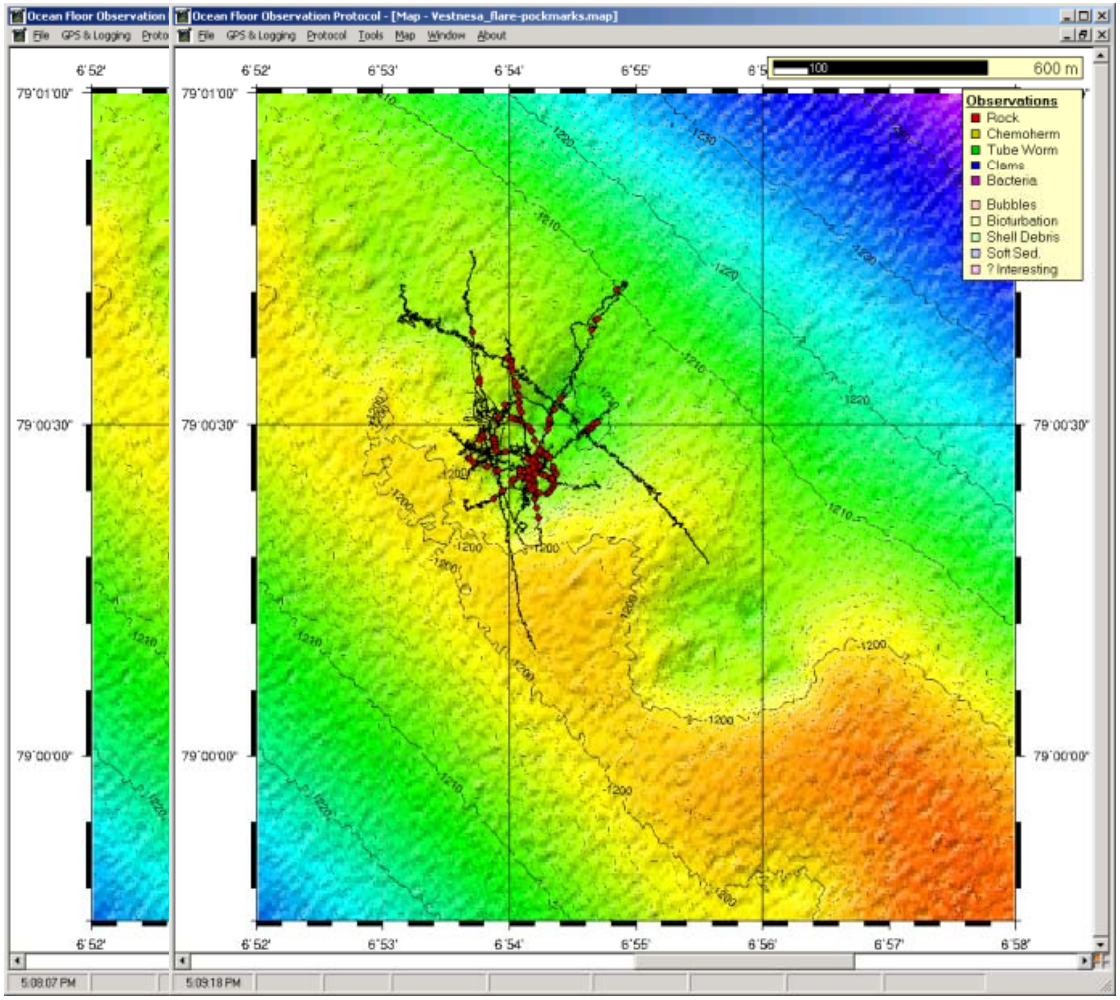

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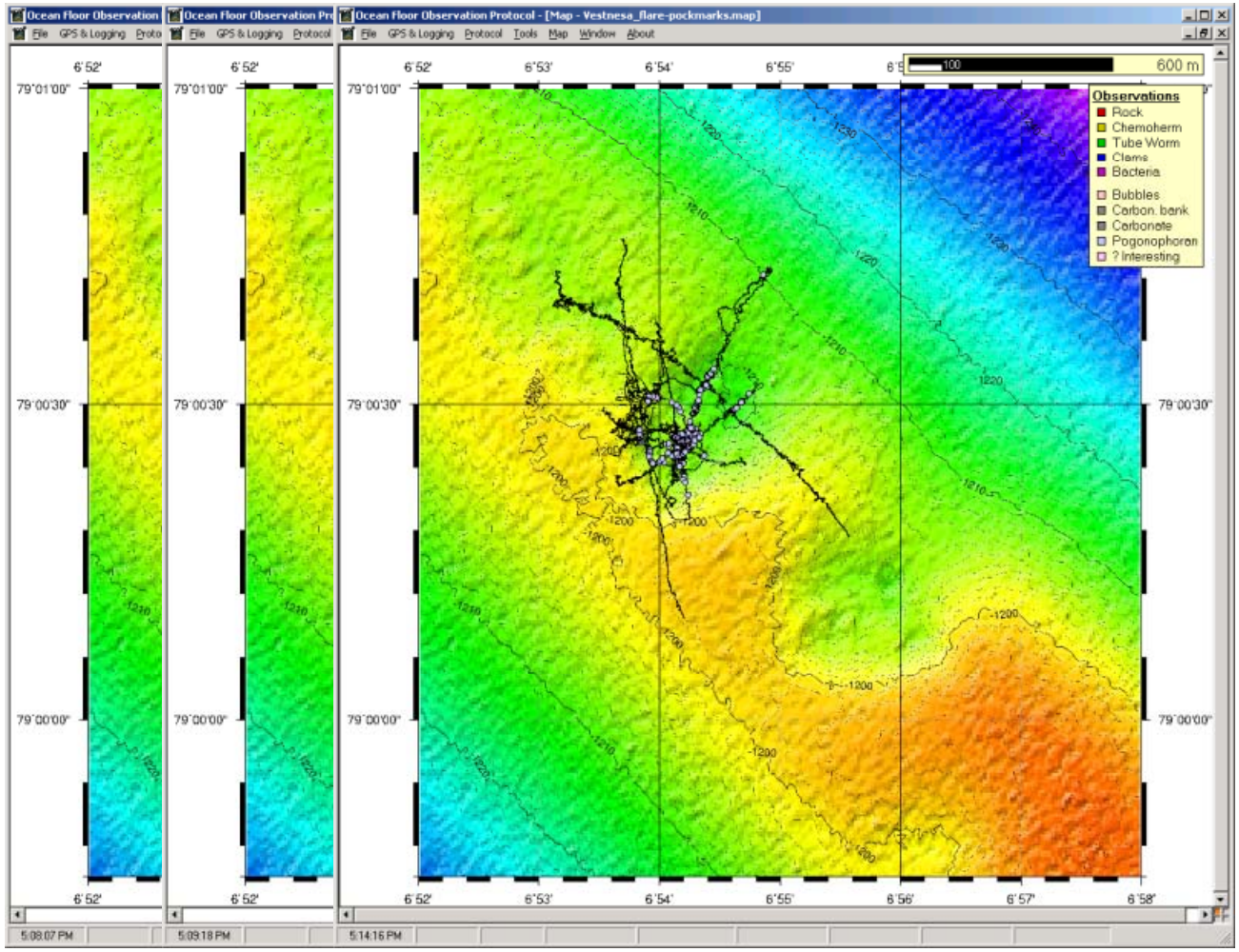

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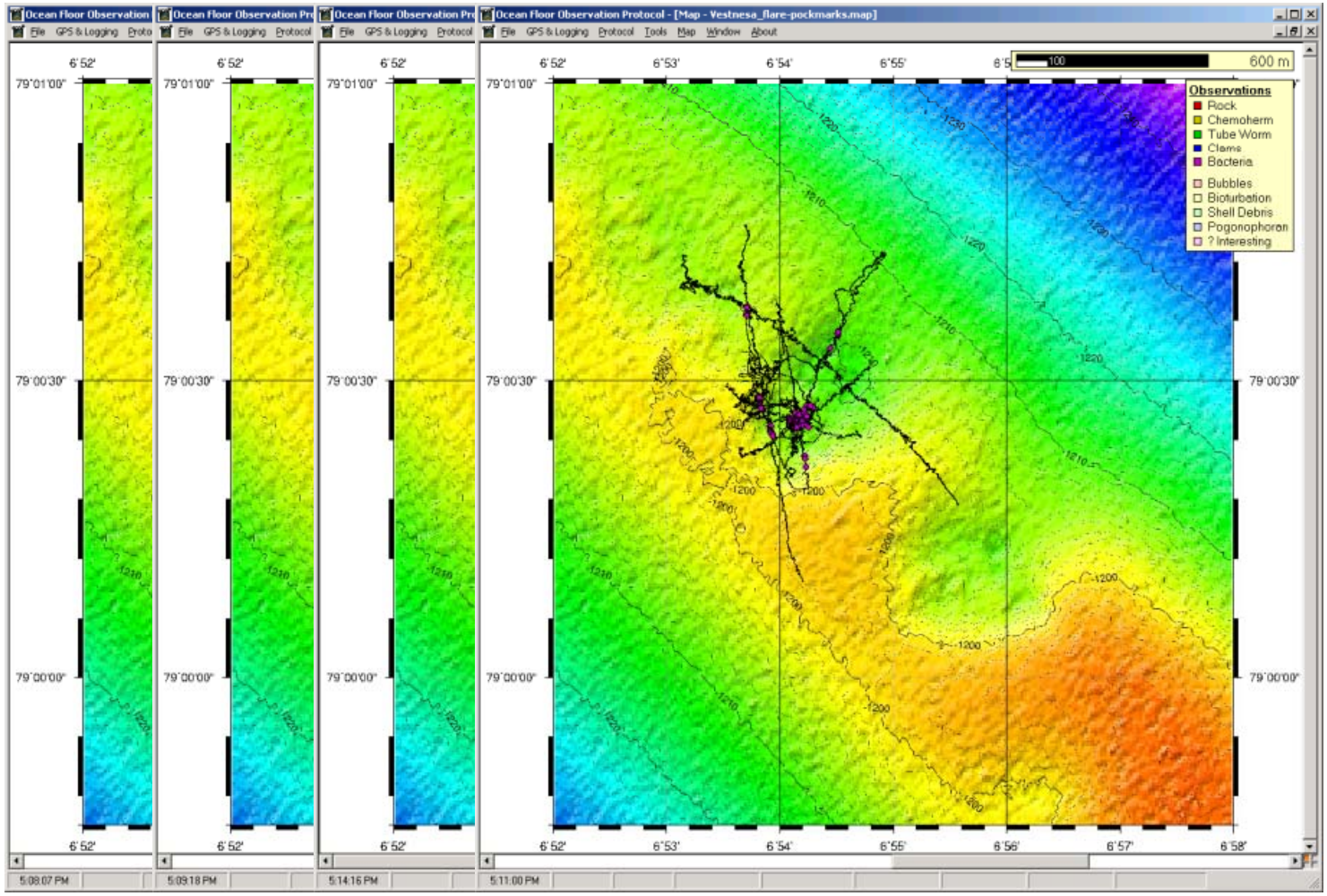

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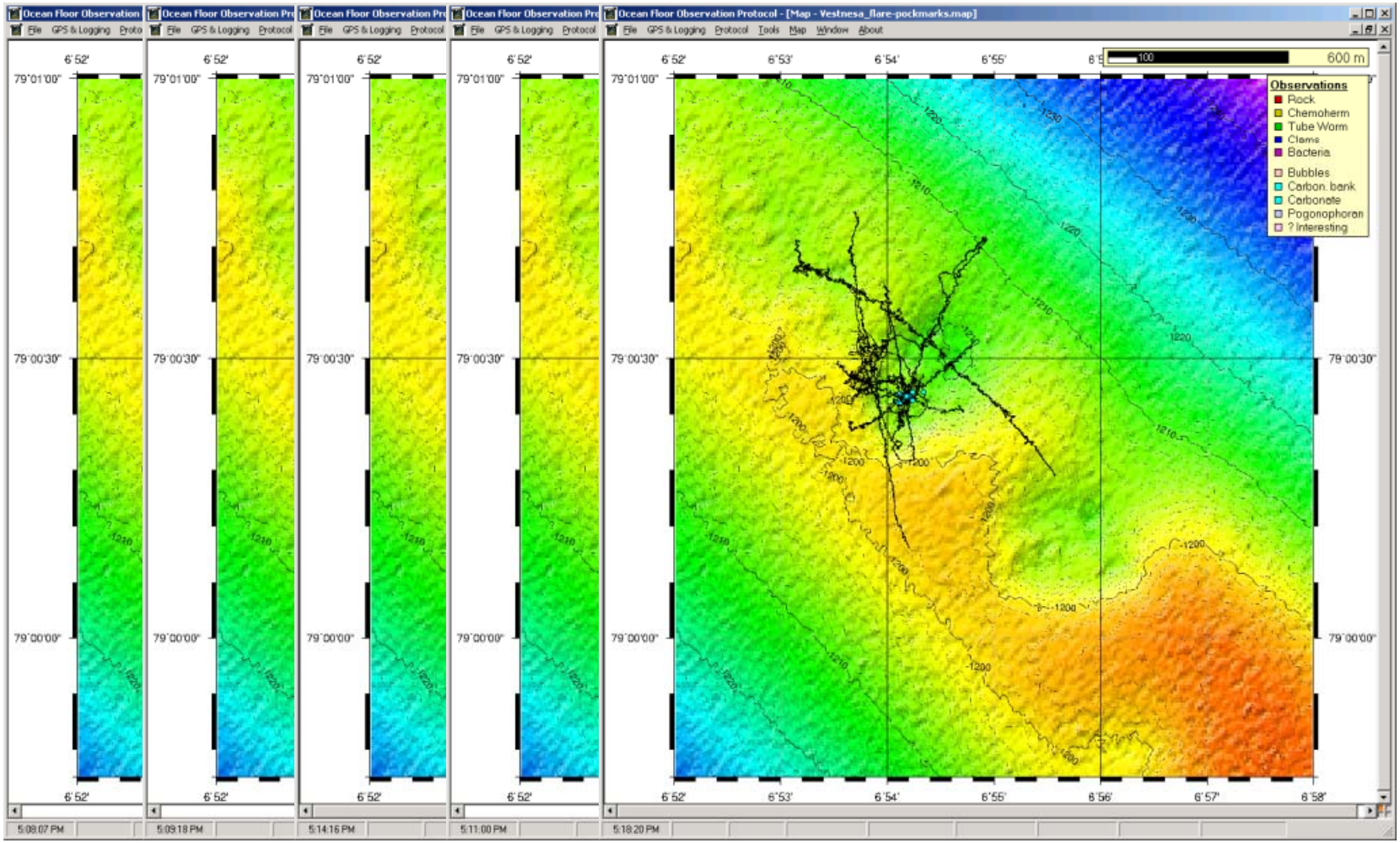

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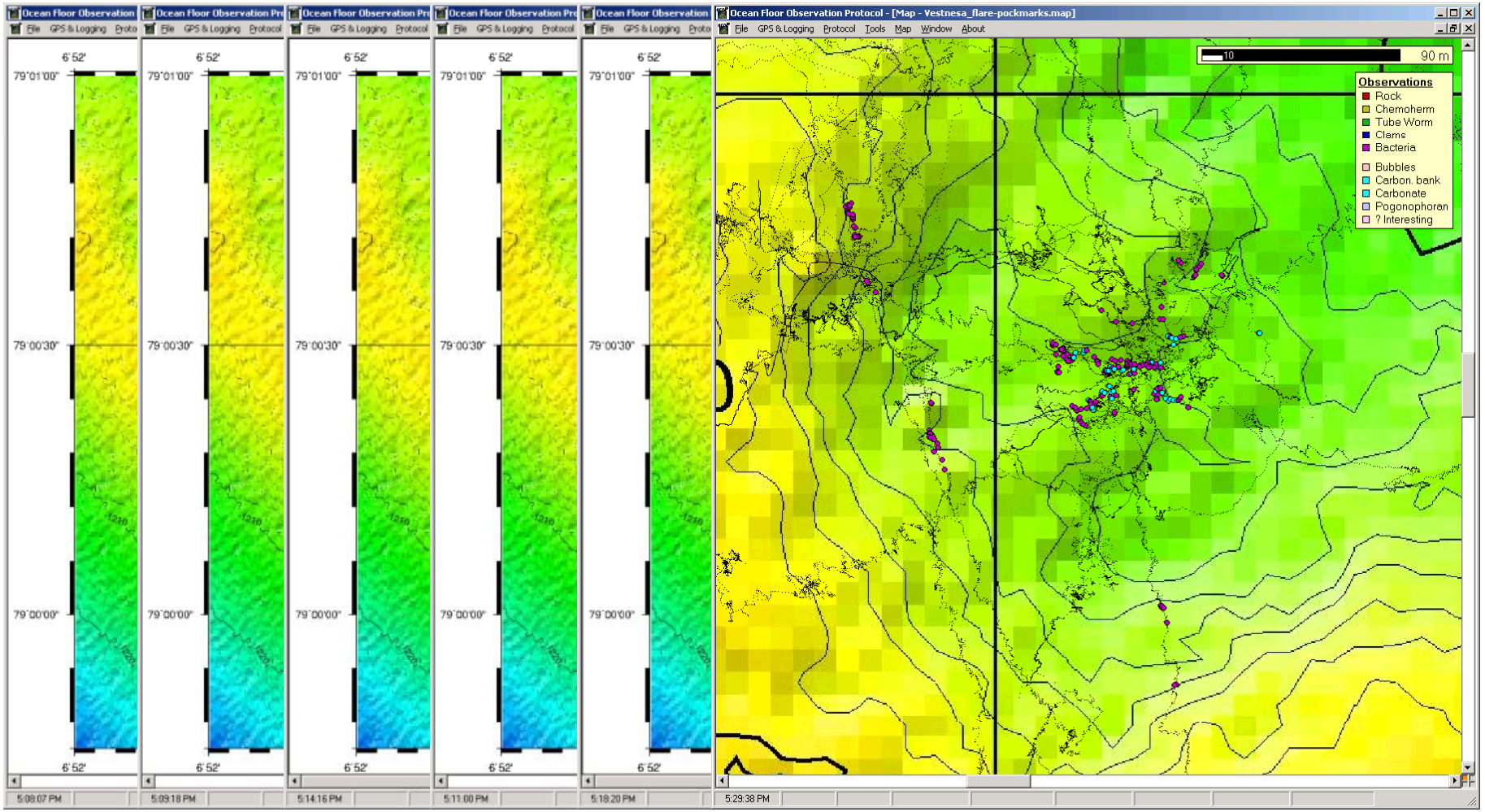
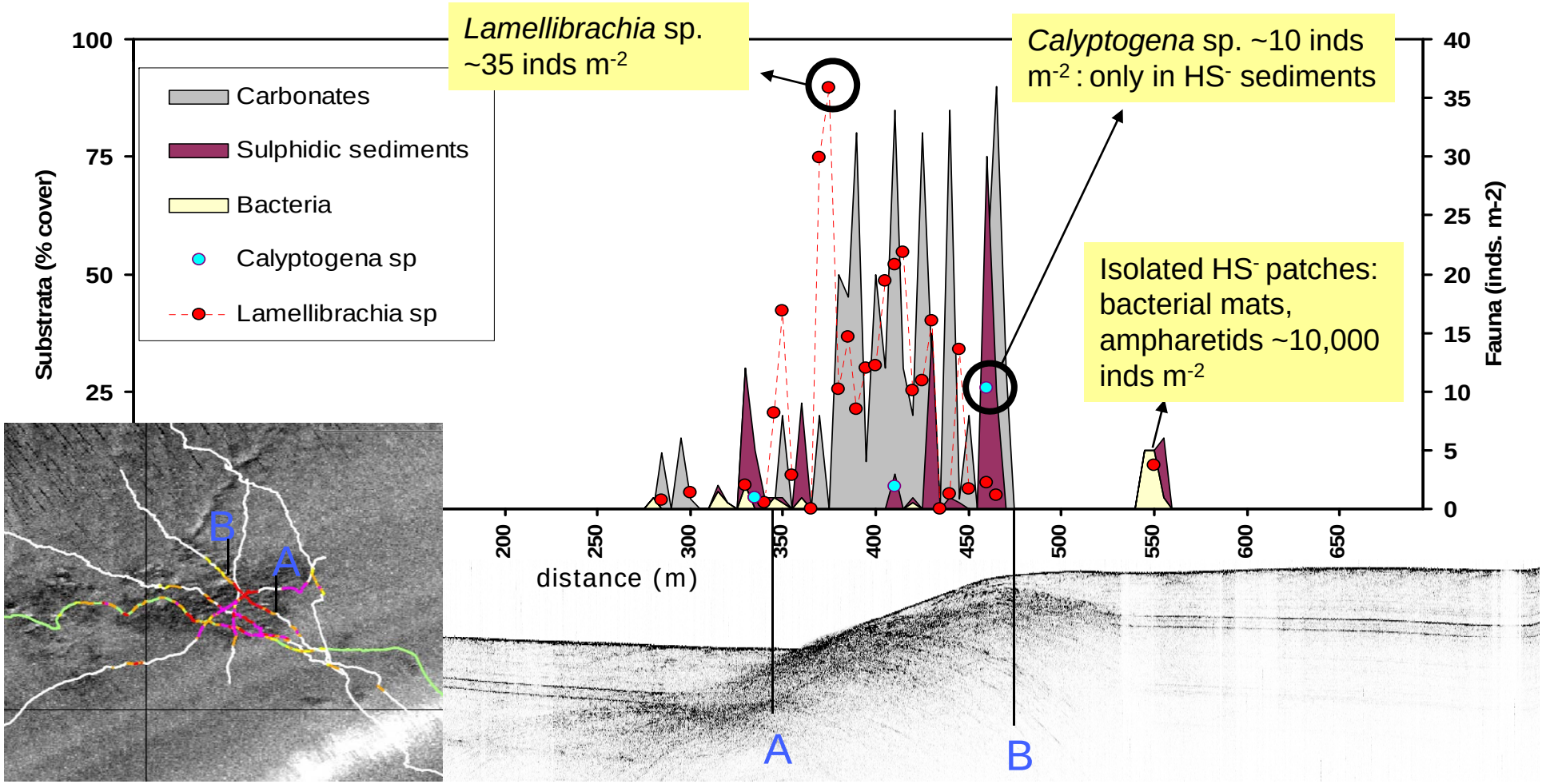
Vestnesa Ridge offshore Svalbard



Exploring

Opouawe Bank offshore New Zealand

- Video analysis to define habitat extent
- detailed still image analysis focused on seep habitat to quantify fauna and substrates



Importance of good online mapping

„you are halfway there“

- **Good online mapping enables**
  - A quick assessment of different habitats
  - Highlights areas of specific interest
  - Provides an immediate data base for reports and later work

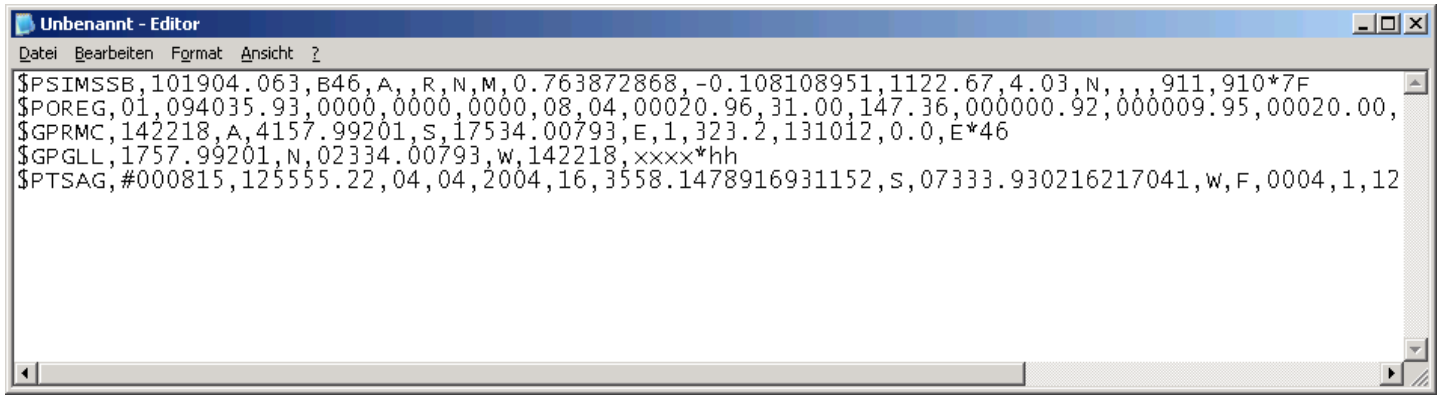
„As you are watching anyway, log as much as you can“

- **Requirements:**
  - Navigation and online annotation software (ideally in one package)
  - Skilled personnel, trained in biological and geological observations
  - Ideally multi-observer logging capabilities
  - Standardized logging of key observations *„via mouse click“*
  - Generic data output useable in other software applications

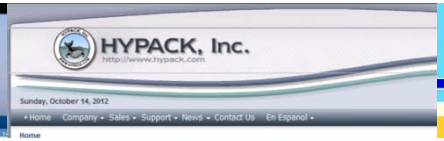
Navigation and annotation software

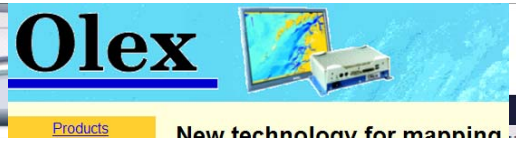
Knowing where you are, logging what you see

- **Navigation software** (your choice)
  - Different (commercial/non-commercial) software packages can read a broad range of navigation strings (GAPS/Posidonia, OreTrackPoint, HiPAP, Sonardyne, ...)



  - OLEX (3D), OziExplorer, GlobalMapper, Hypack, SIS, PDS2000, QINSy, ESRI-GIS, OFOP, MIMOSA, Fledermaus (3D), ...

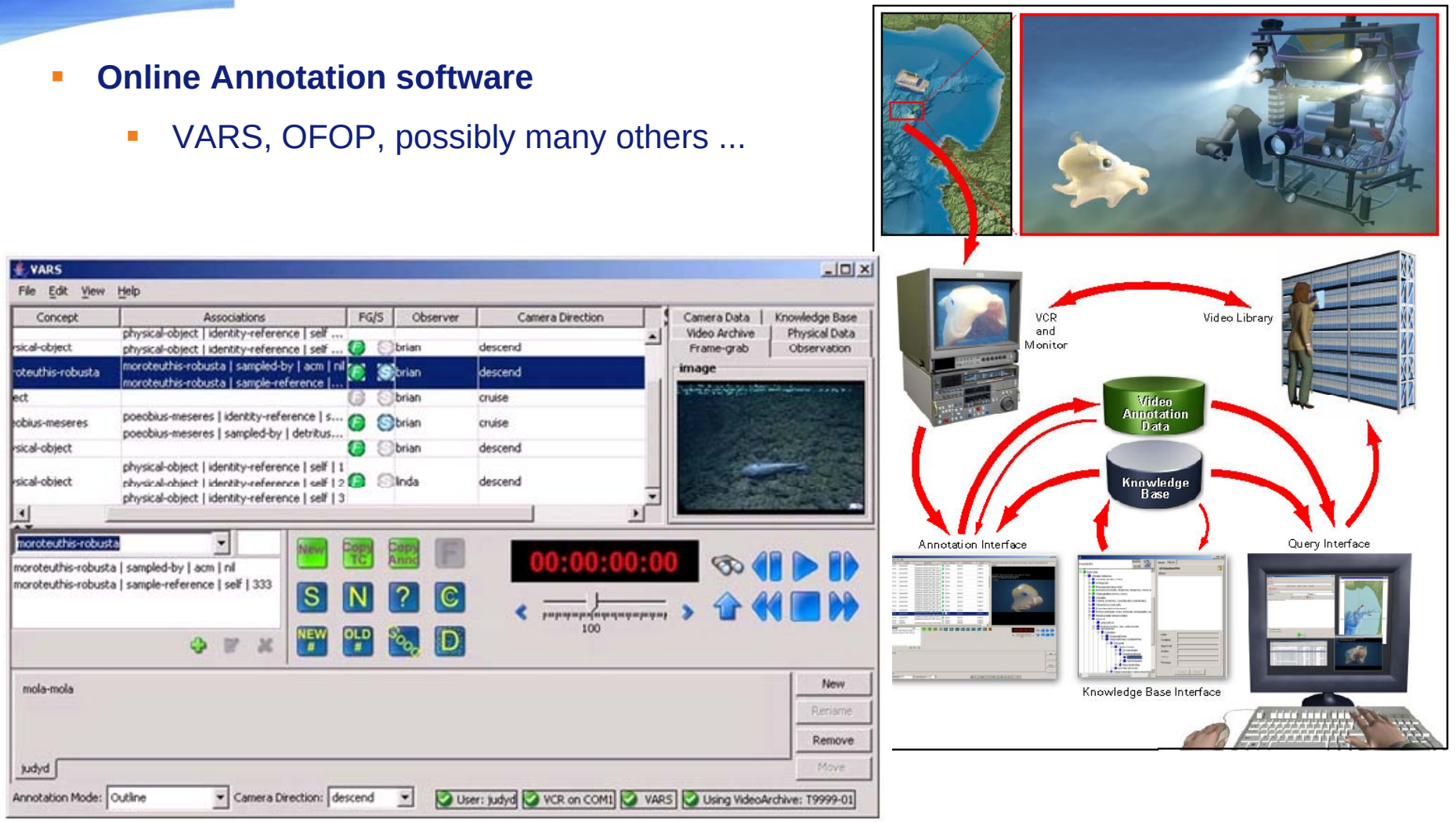




Navigation and annotation software

Knowing where you are, logging what you see

- **Online Annotation software**
  - VARS, OFOP, possibly many others ...



Video Annotation and Reference System (VARS; MBARI); Java based, freely available

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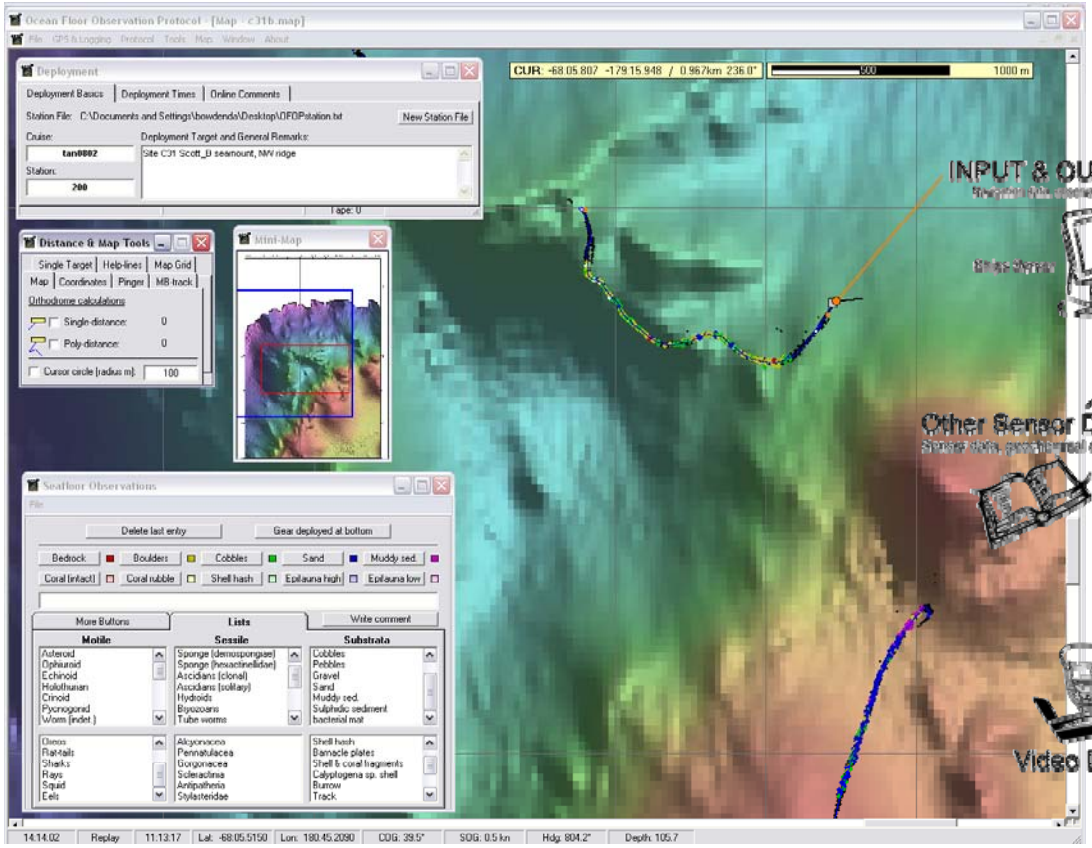
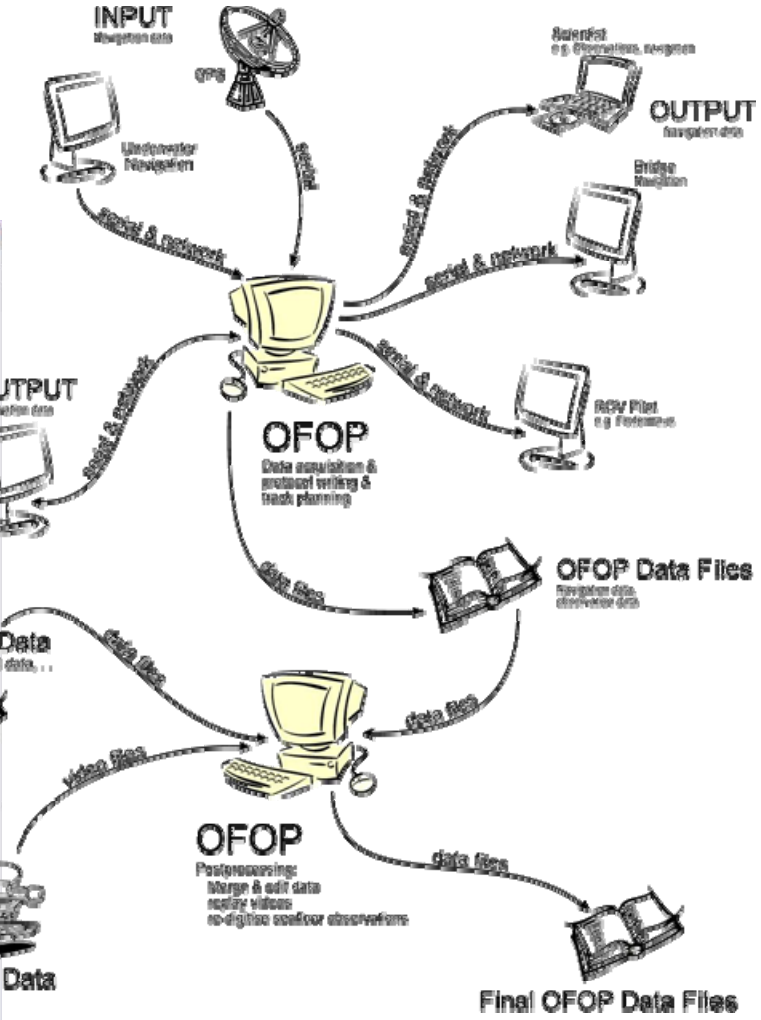


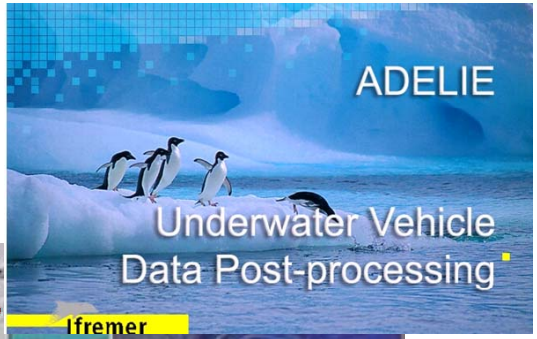


Ocean Floor Observation Protocol (OFOP; Greinert); not freely available (demo at: http://ofop.texel.com)

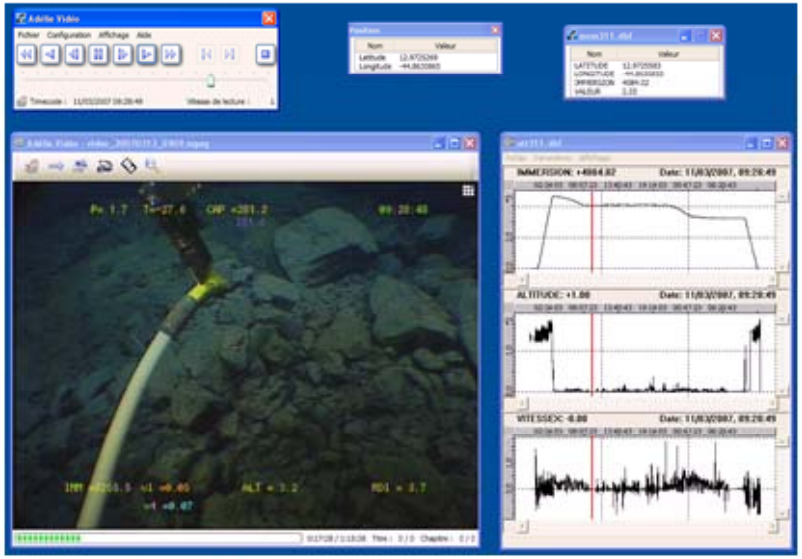
Navigation and annotation software

Knowing where you are, logging what you see

- **Post-processing annotation/mapping software**
  - VARS, OFOP, Adelie, ...



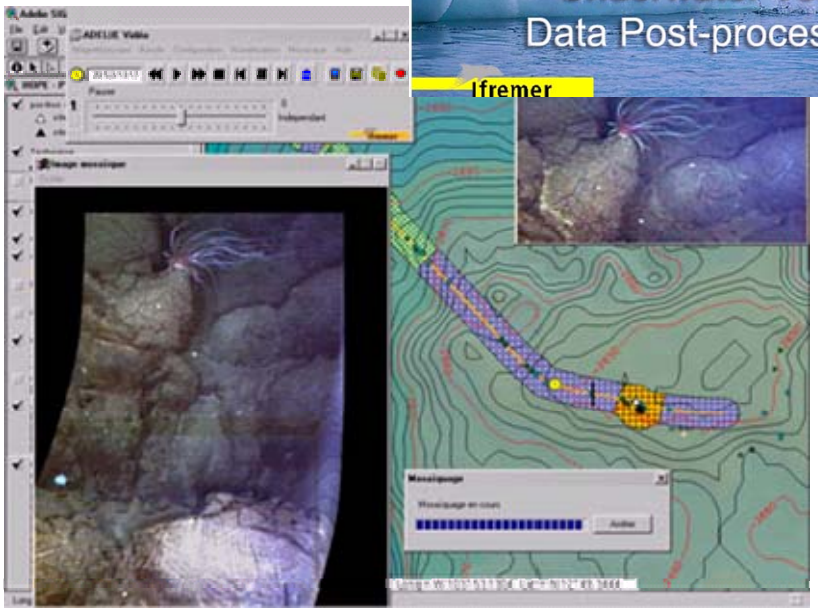
ADELIE Video :



Video Recorder control software which can :

- synchronise up to 3 tapes with the dive data,
- capture new video still images and sequences,
- create video tape summaries automatically,

ADELIE GIS :



based on ArcMap, with this tool, you can:

- display layered thematic fields,
- display in the background sea bed map and imagery produced by CARAIBES,
- filter and smooth vehicle navigation,
- have direct access to pictures,
- localize the video in real time,
- interactively create a sea bed characterisation,
- etc.

• merge other data e.g. from sensors

Adelie (IFREMER); not freely available

Be congruent in annotating (still images)

Unique description of taxa, substrates , features, ...

- **NICAMS,** to extract data from still images consistently and repeatable we needed
  - A uniform data structure
    - To get away from the multiple Excel file syndrom
  - A means of audit
    - To ensure consistency of descriptions and measurements between analysts and analyses
    - all ROIs, measurements, and identifications stored in db
  - A single source for taxon hierarchies and substrata descriptions
    - To get away from typos, synonyms, and *“that blobby thing with purple feet”*
    - *ITIS Species 2000* taxon data as taxonomy table in db

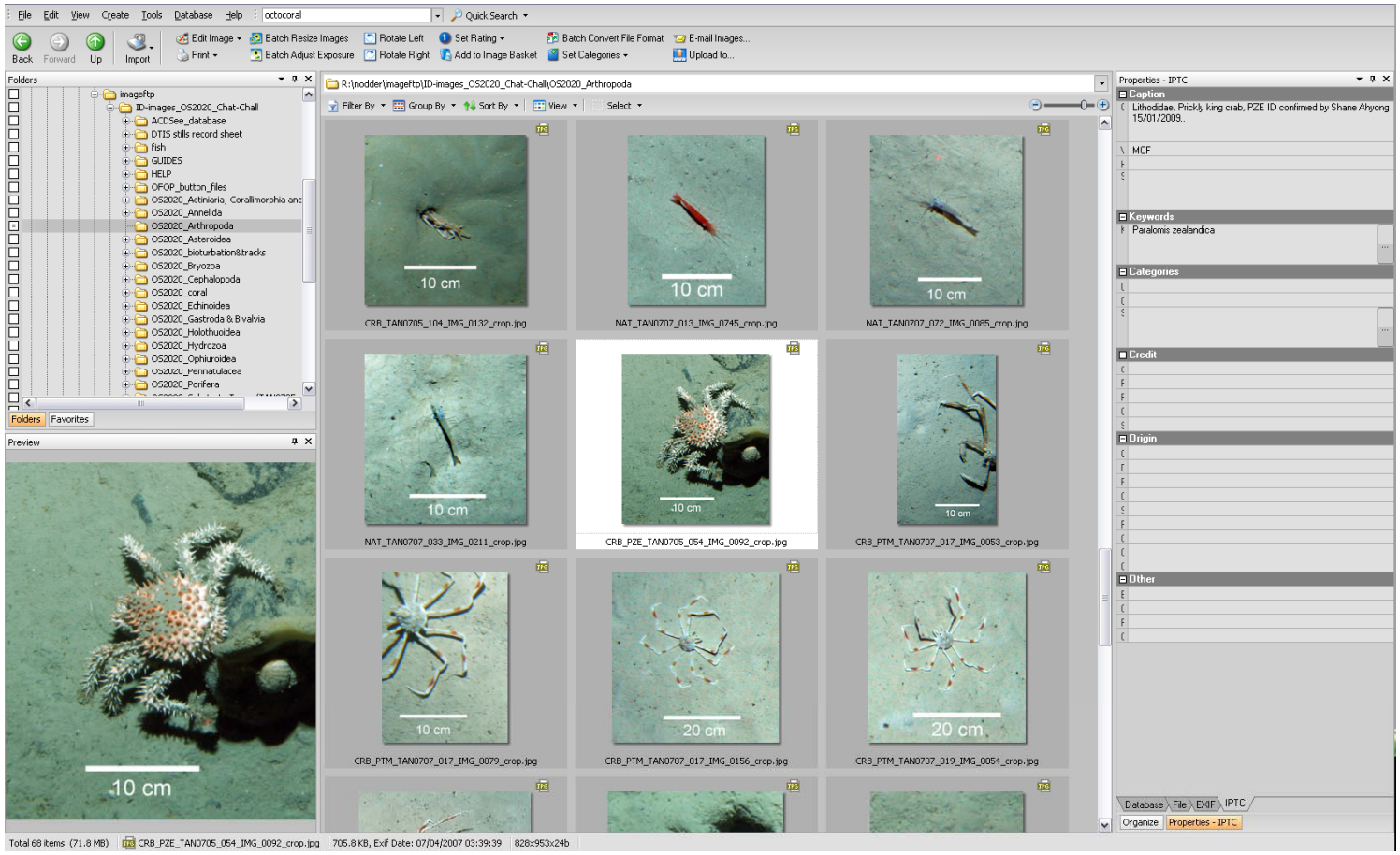
NIWA Image CApture & Management System

Be congruent in annotating (still images)

Unique description of taxa, substrates , features, ...

NICAMS library of reference images

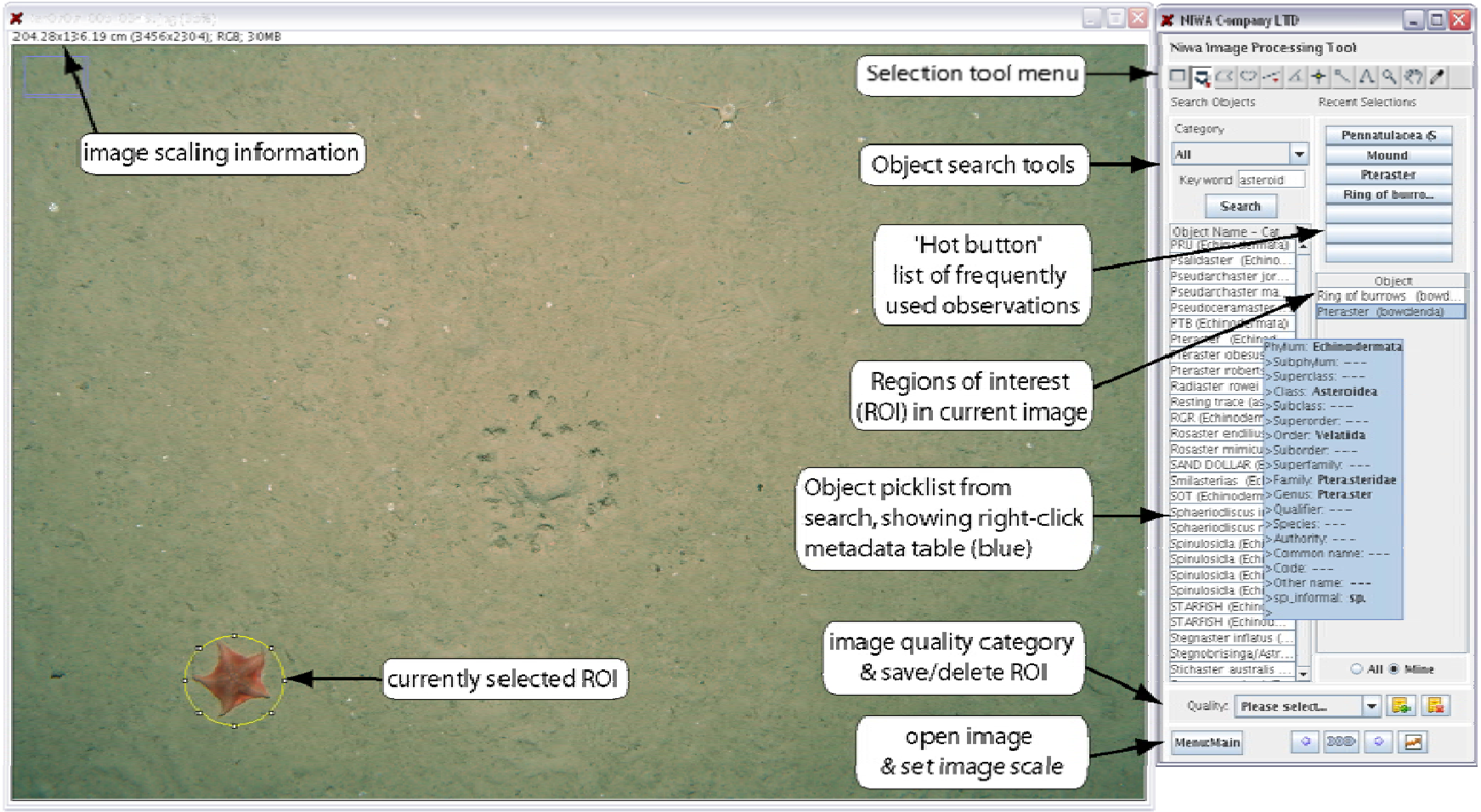
- Seabed images colour-corrected, cropped, & scaled
- Images identified by specialist taxonomists (NIWA and world)



Be congruent in annotating (still images)

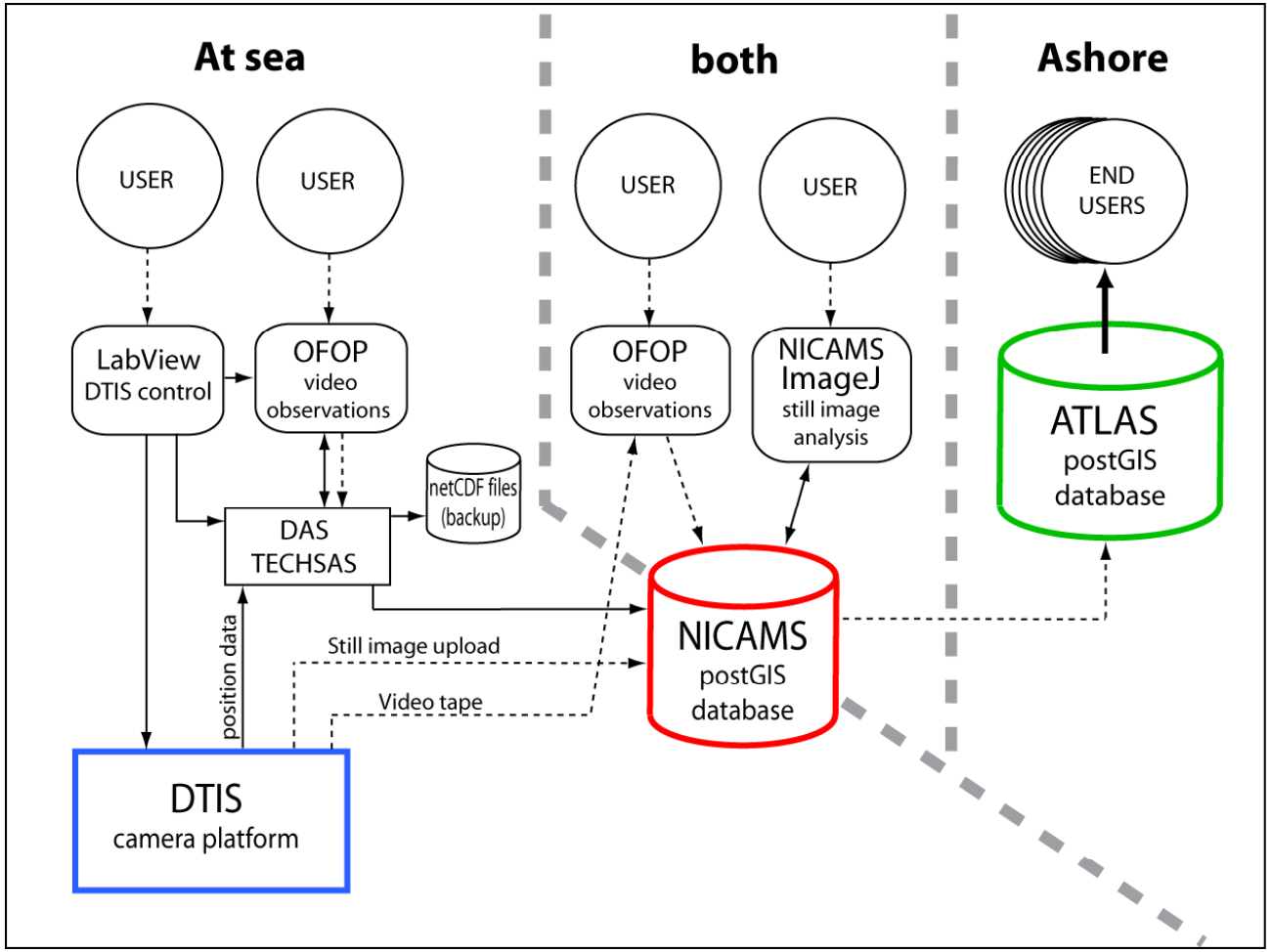
Unique description of taxa, substrates , features, ...

NICAMS image annotation



NIWA‘s workflow from seabed to analysis

- Video and still images capture at sea
- Recording of real-time observations
- Post-voyage analyses of video and stills
- Database storage of all images and related data for access by analysts and end-users



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- Video and still images capture at sea
- Recording of real-time observations
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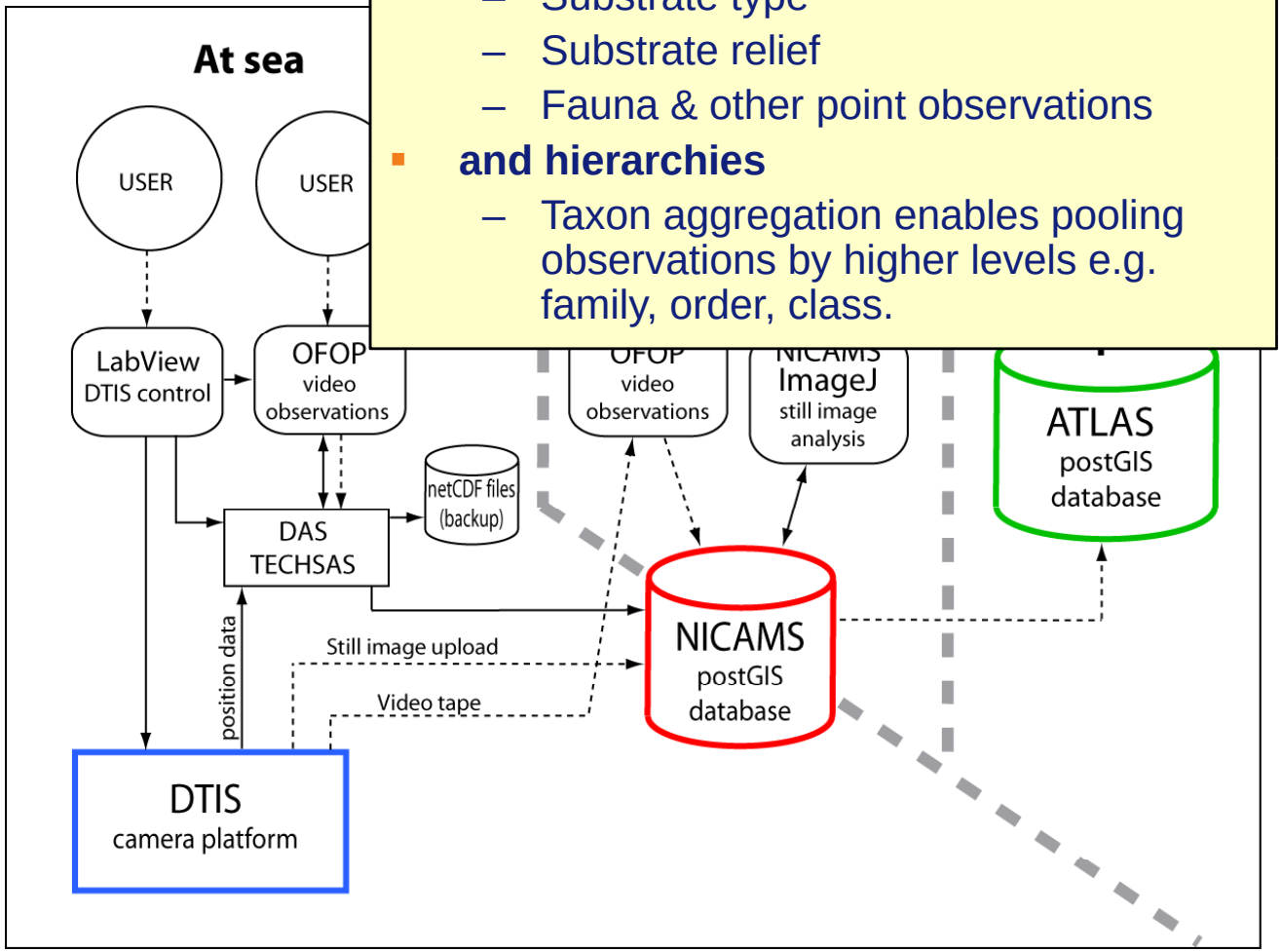
- Database storage of all images and related data for access by analysts and end-users

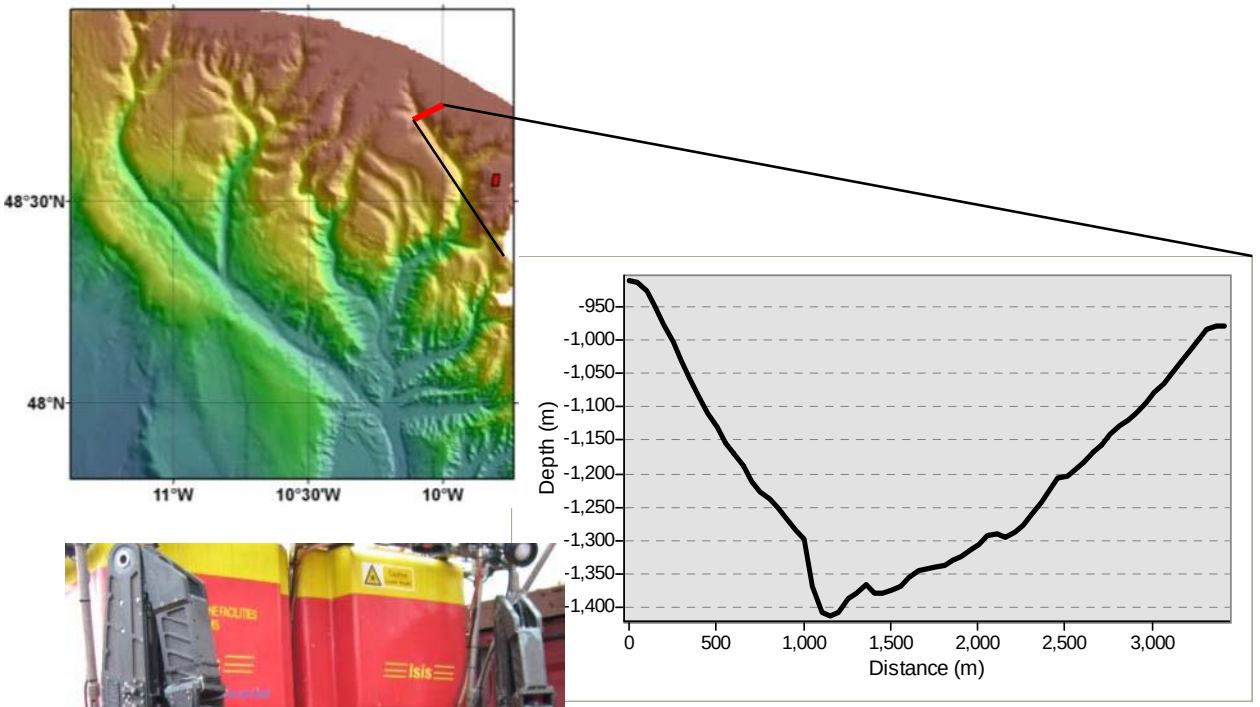
- **Observations in categories**
  - Substrate type
  - Substrate relief
  - Fauna & other point observations
- **and hierarchies**
  - Taxon aggregation enables pooling observations by higher levels e.g. family, order, class.

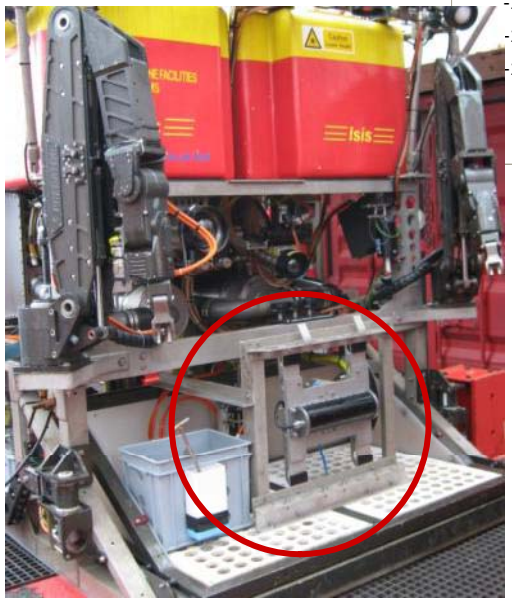


3D Habitat mapping

the multibeam way

- Mapping of deep-sea **cliffs** and **overhangs** using underwater vehicles (AUV/ROV) in ‘sideways’ or ‘front-looking’ mode
- **Visualisation** through point-cloud models and voxel-based TINs (Triangulated Irregular Networks)
- Derivation of **3D habitat heterogeneity** measures





SM2000 multibeam on front of ISIS

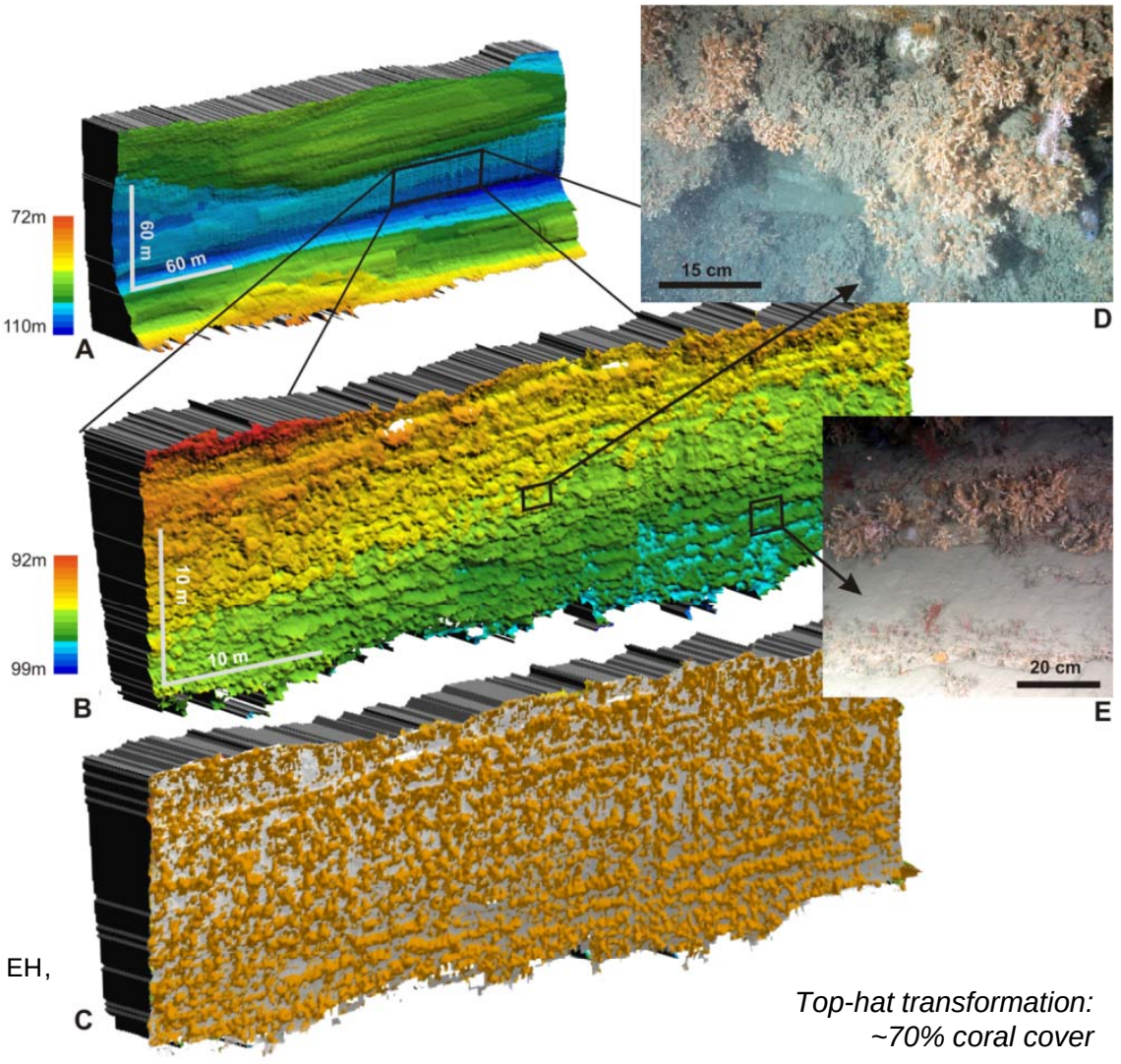
Surveys at 4 different distances from cliff

3D Habitat mapping

the multibeam way

ROV at 30 m
50 cm pixel

ROV at 7m
10 cm pixel



Top-hat transformation:
~70% coral cover

No morphological exaggeration

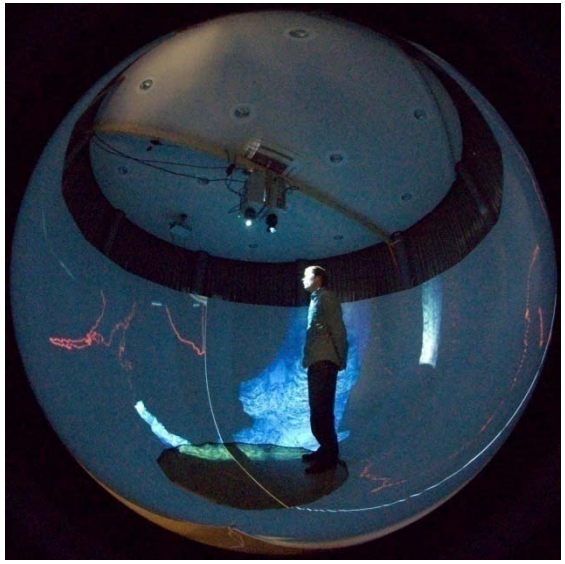
See: Huvenne VAI, Tyler PA, Masson DG, Fisher EH, Hauton C, et al. (2011) A Picture on the Wall: Innovative Mapping Reveals Cold-Water Coral Refuge in Submarine Canyon. PLoS ONE 6(12): e28755. doi:10.1371/journal.pone.0028755

3D Video mapping

Photogrammetry / Immersive video, advantanges and restrictions

- **Immersive Video -> Photogrammetry**
  - enable to experience the environment as we are used to (in 3D and in front of us)
  - allows revisiting sites for different purposes
  - enables measurements that can otherwise not be done (bedding, tectonic, ...)

  - needs extreme accurate underwater positioning and motion measurements
  - needs very good camera systems
  - needs careful post-processing and computer power



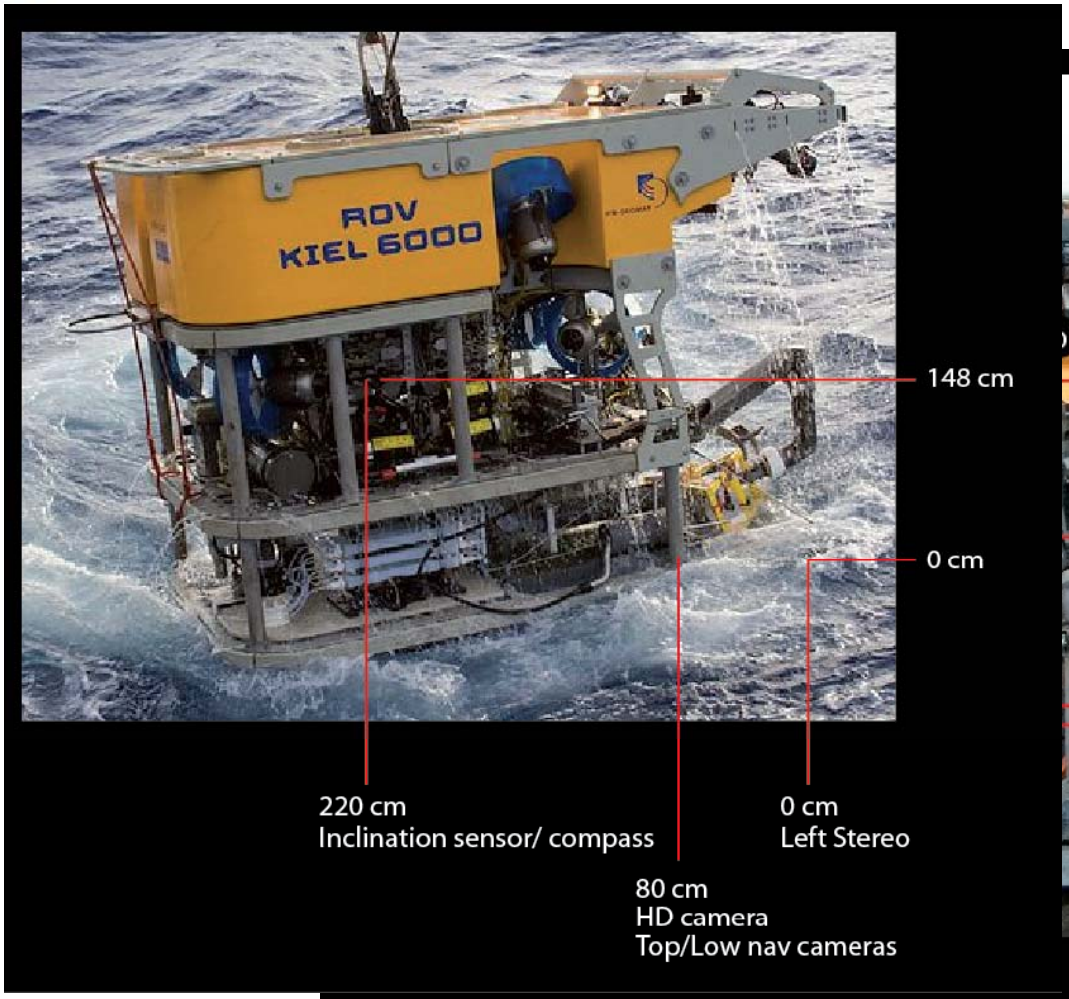
3D Video mapping

Photogrammetry

data: Arbeitsgruppe für Maritime und Limnische Archäologie (AMLA), Kiel, 2011

3D Video mapping

Acquisition



3D Video mapping

General workflow

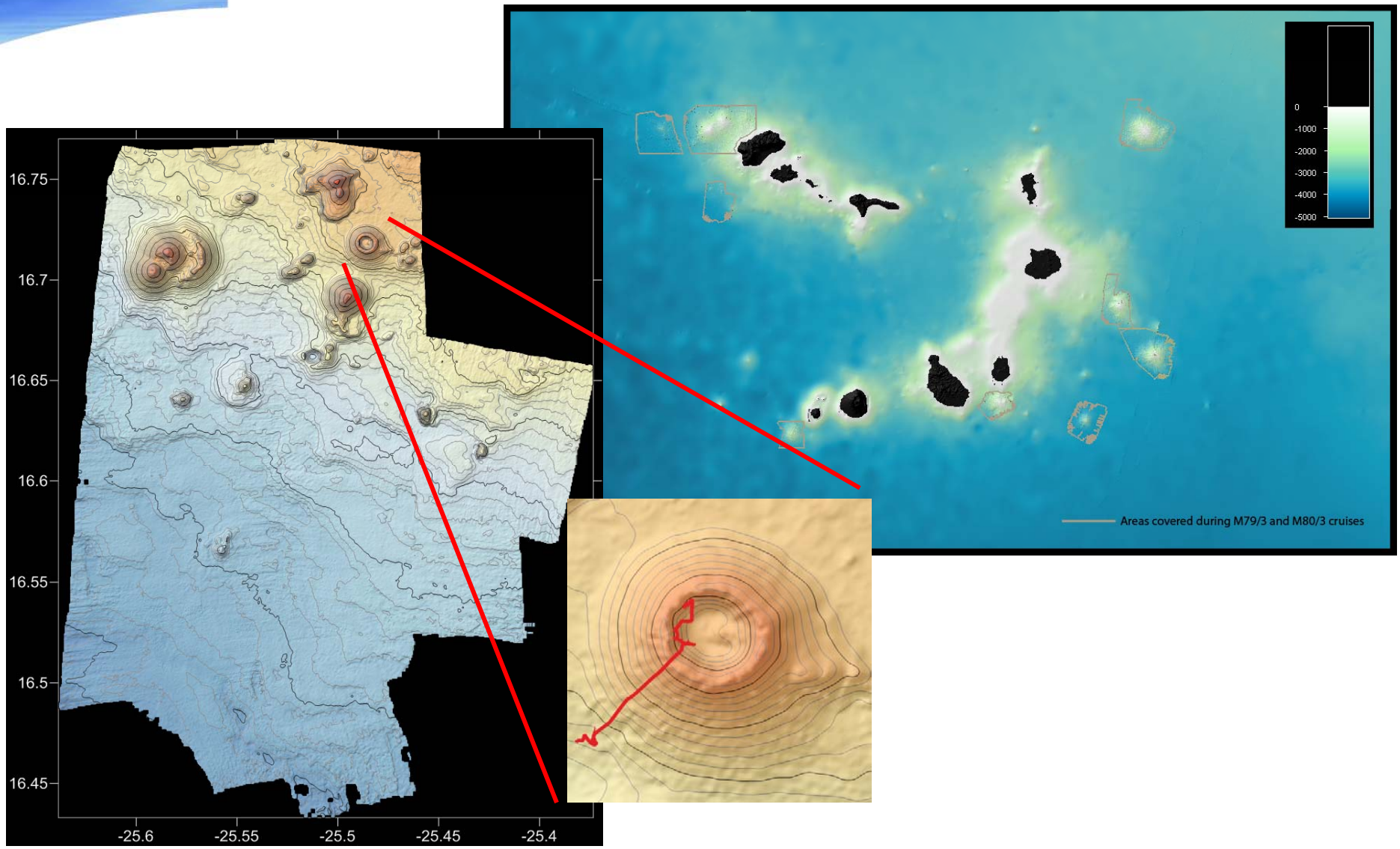
- Use of commercial software products linked by their existing interfaces and some custom written import and export scripts
- Videos preprocessed using Adobe Suite
- Use of aerial photogrammetry software to reconstruct the 3D geometry:

1. Synthesize ROV track by blending USBL and DVL
2. Feature matching of landmarks among the images (u, v coordinates)
3. Calculate the 3D positions of corresponding points in space along with the camera position for each image
4. Reconstruction dense point cloud for each pixel (or sub-sampled value) based on camera positions
5. Editing of point cloud and Poisson surface reconstruction -> the model
6. Texturing the model by re-projecting images onto the model
7. Rigid, 7 parameter geo-referencing of the model according to ROV track or landmarks of known coordinates (i.e., AUV map)
8. Nonlinear optimization of the point cloud may require mesh recalculation
9. Model exported in various formats to Autodesk 3dsMax
10. Perform measurements and export of measured data

See: Kwasnitschka et al. Doing Fieldwork on the Seafloor: Photogrammetric Techniques to yield 3D visual models from ROV video. Computers & Geosciences; accepted.

3D Video mapping

Example from Charles Darwin Seamounts (Cape Verde)



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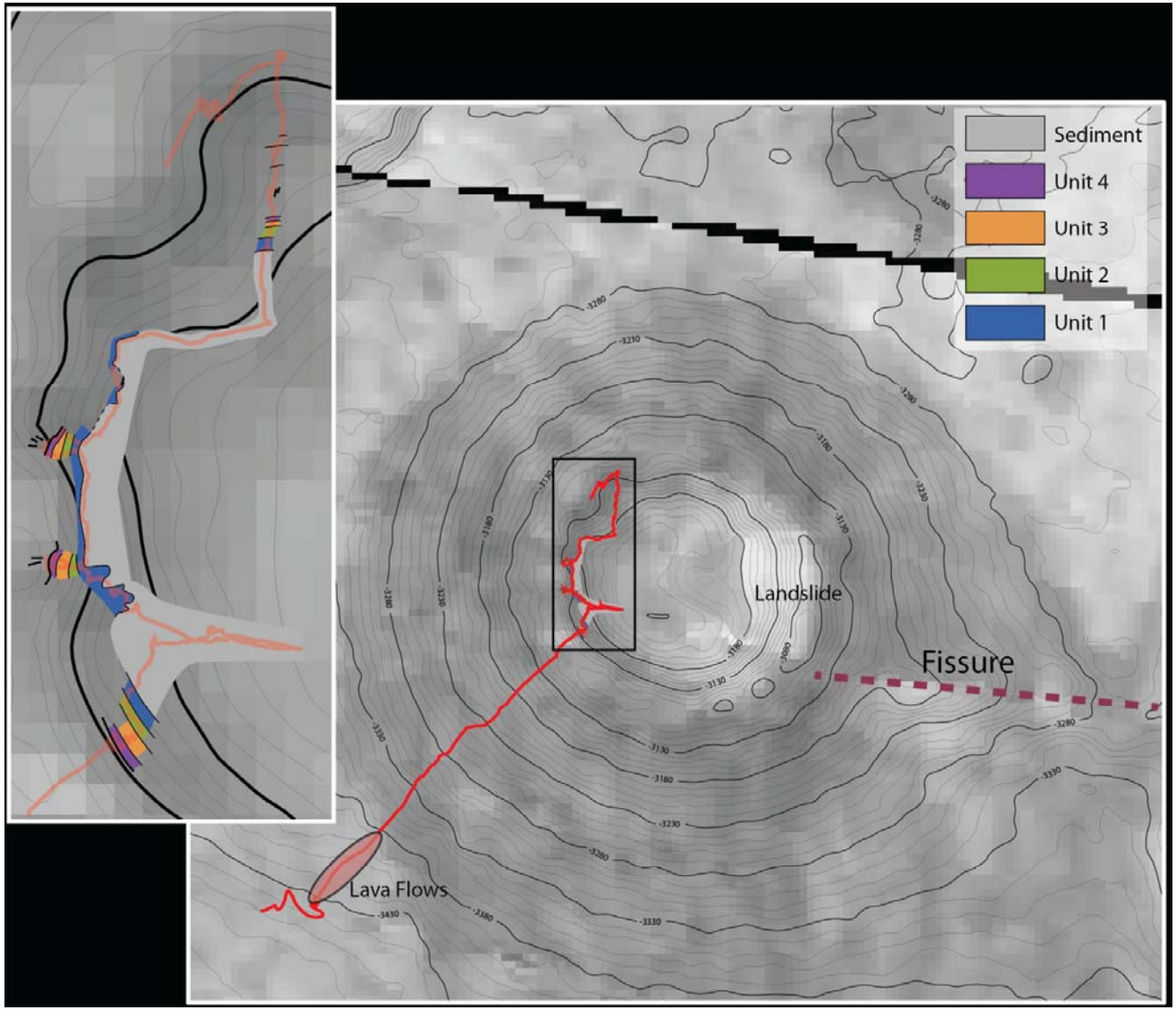

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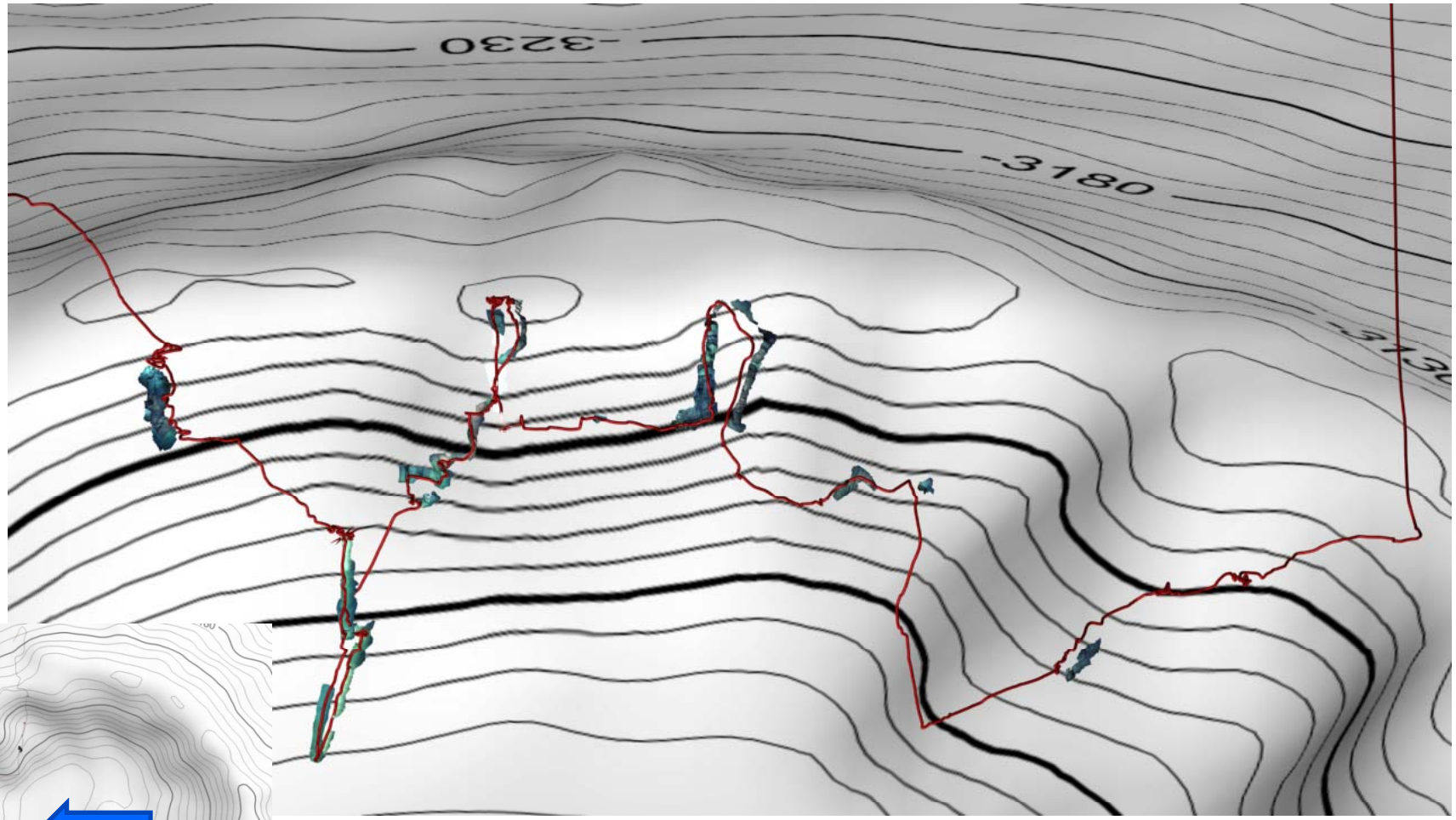

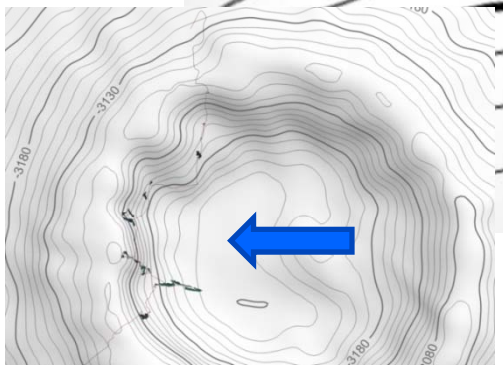

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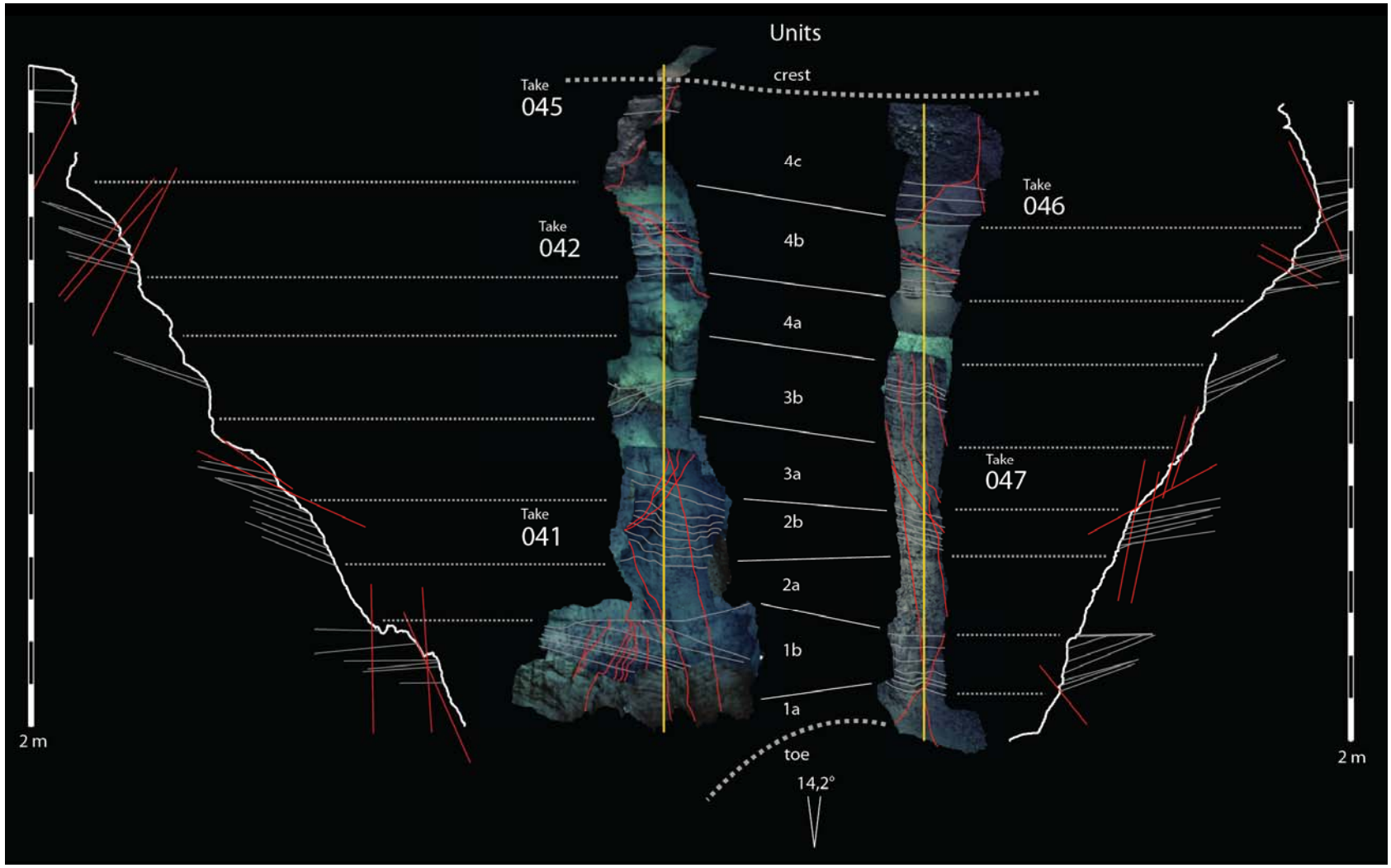

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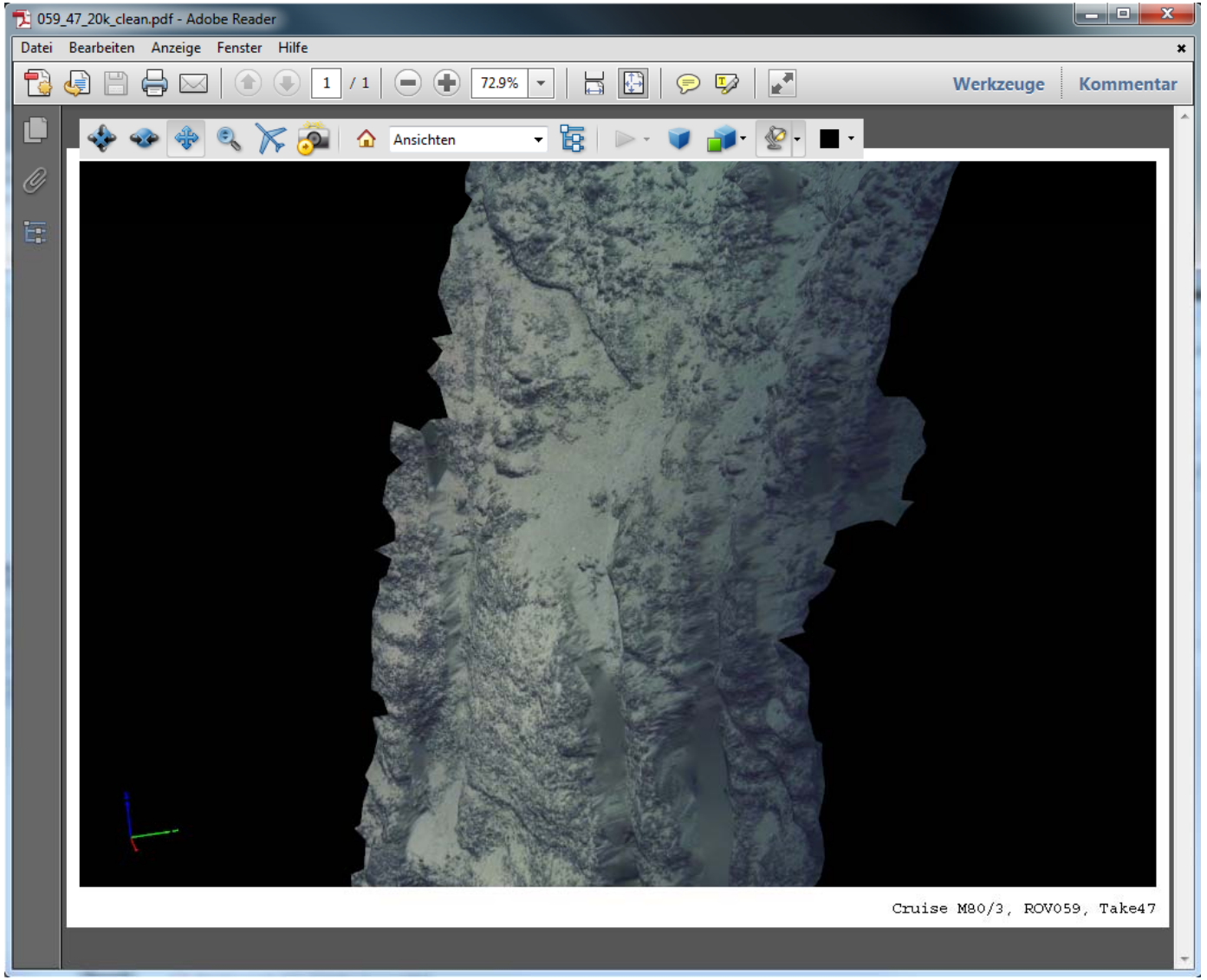
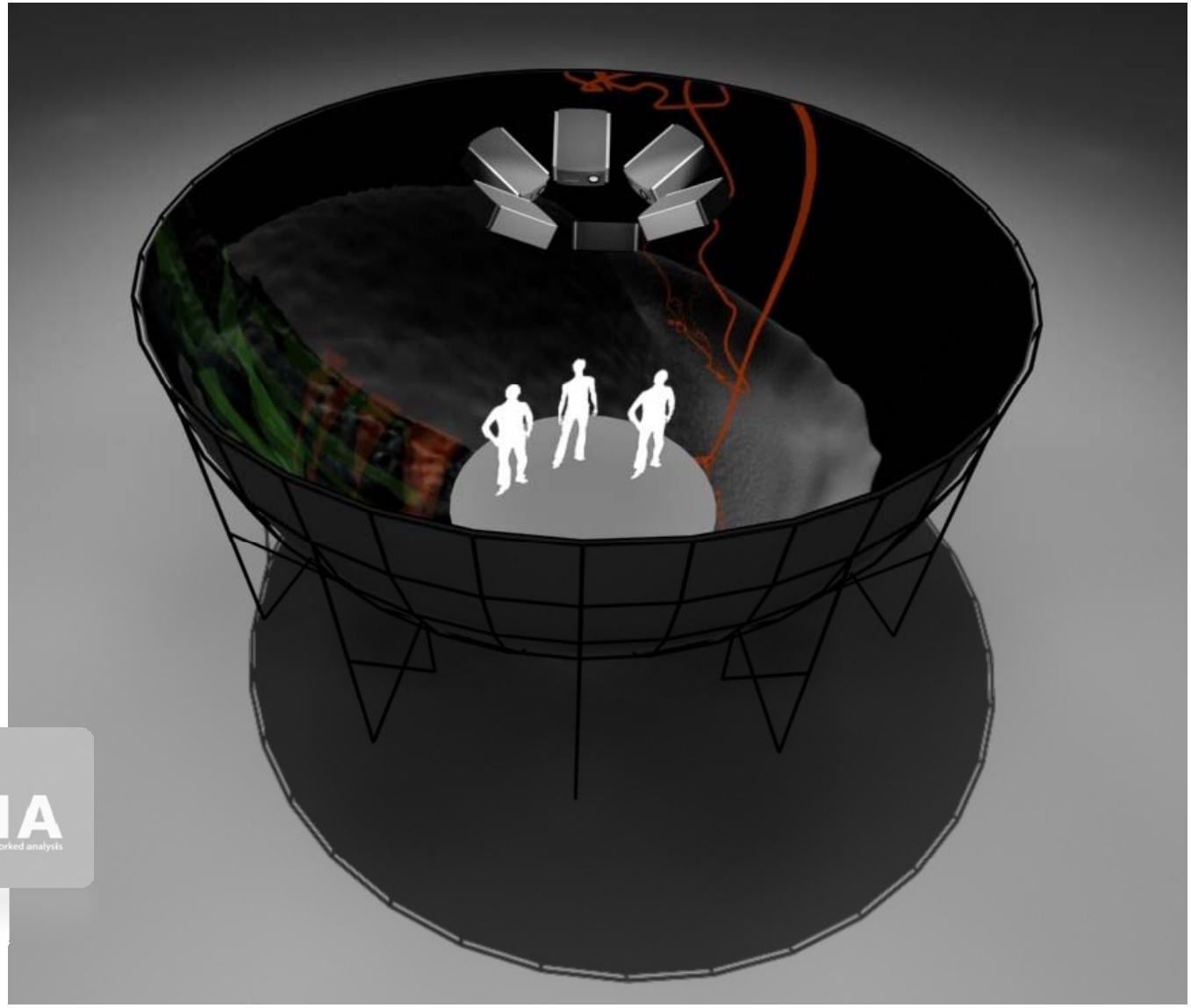


- Measuring faults and bedding

3D Video mapping

Next Steps at GEOMAR

- Standardize processing routines
- Extend 3D video capabilities by establishing the ARENA Laboratory



ARENA
artificial research environment for networked analysis

Conclusion & Outlook

- **Online and post video mapping of what you see at the seafloor is possible**, you have to:
  - be disciplined in data archiving
  - be congruent with seafloor descriptions and taxonomy
  - setup data bases that allow iterative and repeated input of observations

- **Automated image recognition** should be perused but most likely will never replace the trained scientist
- Very high res. **3D seafloor imaging using MB and photogrammetry** is possible and will become a common tool for ‚small scaled' very detailed observations used in nested habitat mapping extrapolation efforts.
- **International standards** how to ‚call things' with unique numerical identifiers are desirable, but new publications