

# Combining varying resolution survey data to produce a robust deep seabed classification

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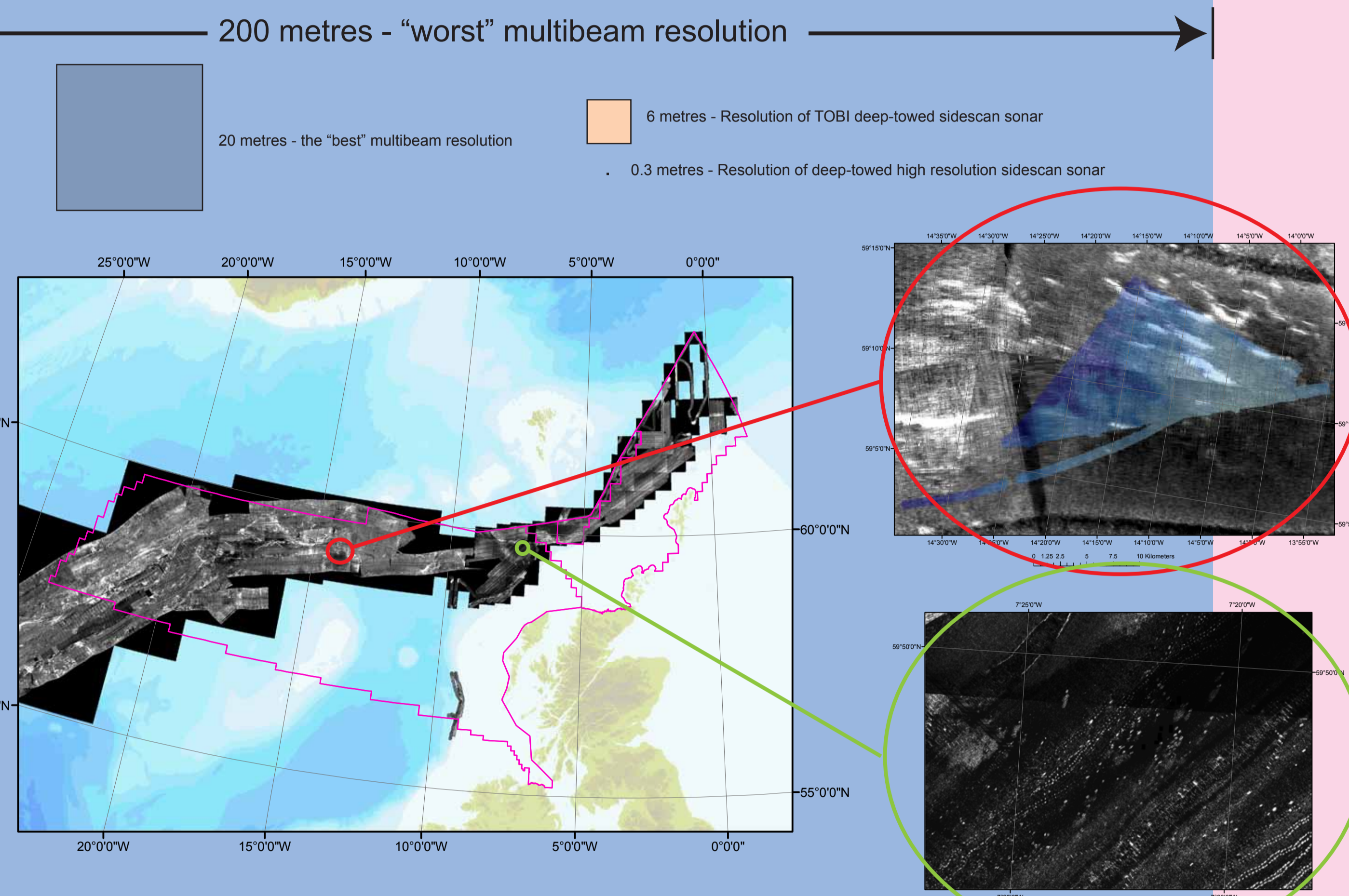
The whole of the United Kingdom's claimed deep water (> 200m) territory in its northwest approaches has been the subject of a broad geology, geomorphology, process and substrate-type seafloor classification. This is a very large area (> 350,000km<sup>2</sup>) that has yet to be fully surveyed to modern standards, however, pressing requirements for marine spatial planning and Marine Protected Area or Marine Conservation Zone selection meant that a pragmatic approach had to be taken and the classification was based upon existing interpreted acoustic and other deep water datasets. Survey data resolution varied from >500m pixels (in GLORIA long range reconnaissance side-scan sonar data) to sub-metre pixels (high resolution deep-towed side-scan sonar). We assigned each different type of data used in the study a "Confidence" that was aligned to a combination of the acoustic resolution, the navigation system accuracy and any ground-truthing. This approach allowed us to produce, at a broad scale, a classification scheme that is, in a similar vein to the current EUNIS scheme, quasi-hierarchical, of significance for benthic ecology, and gives down-stream users and indication of the robustness of the seafloor classification. The product of the work was a 5-layer GIS overview, using "Confidence" (data quality), "Physiography" (primarily to help policy-makers and other non-specialists), "Substrate" (surficial sediment types), "Deposit" (to indicate the genesis of the seabed sediment type, e.g. contourite, debris flow deposit etc.), and "Modifiers" (to indicate how the seabed has been changed by active processes, e.g. iceberg ploughmarks). Expert interpretation of the acoustic data lay behind the identification of each classification unit, with higher resolution data being used, where possible, to guide lower resolution data interpretations. The approach taken, of combining all available data sets without regard to the differing resolutions, and assigning varying levels of confidence to the interpretations from the different data sets, has so far we believe been unique. The classification results have been stored and are displayed as a series of GIS overlays so that end users (planners and policy makers) can view the classified layers and gain an insight into the level of confidence with which the boundaries of, and sub-divisions within individual layers have been defined. Further, use of GIS has allowed for the entire area to be classified without any data gaps so the results can relatively easily be fed into automated 3<sup>rd</sup> party spatial planning software. The results of this project are contributing to the UK Deep-Sea Marine Protected Area Project, aimed at identifying where deep-water MPA's should be placed in order to preserve representation of known biodiversity.

## Data Types and Resolution Issues

There are huge variations in the operating frequencies of the acoustic imaging systems utilised in the classification. The GLORIA sonar data has an operating frequency of 6.5kHz and the digital mosaicing techniques used for that data give pixels that vary in size from 175 x 45 to 657 x 45m (dependant upon slant range and survey speed). The TOBI system is a deep-towed side-scan system that is "flown" at a more-or-less constant height above the seabed and therefore has a fixed resolution of 6m pixels. The footprint of the various multibeam imagery systems used, of course varies with water-depth, and for this classification the spatial resolution of the grid-nodes varies from 200m to <20m. The highest resolution sonar data used in this classification study was a 500kHz deep-towed side-scan, with a sub-metre resolution.

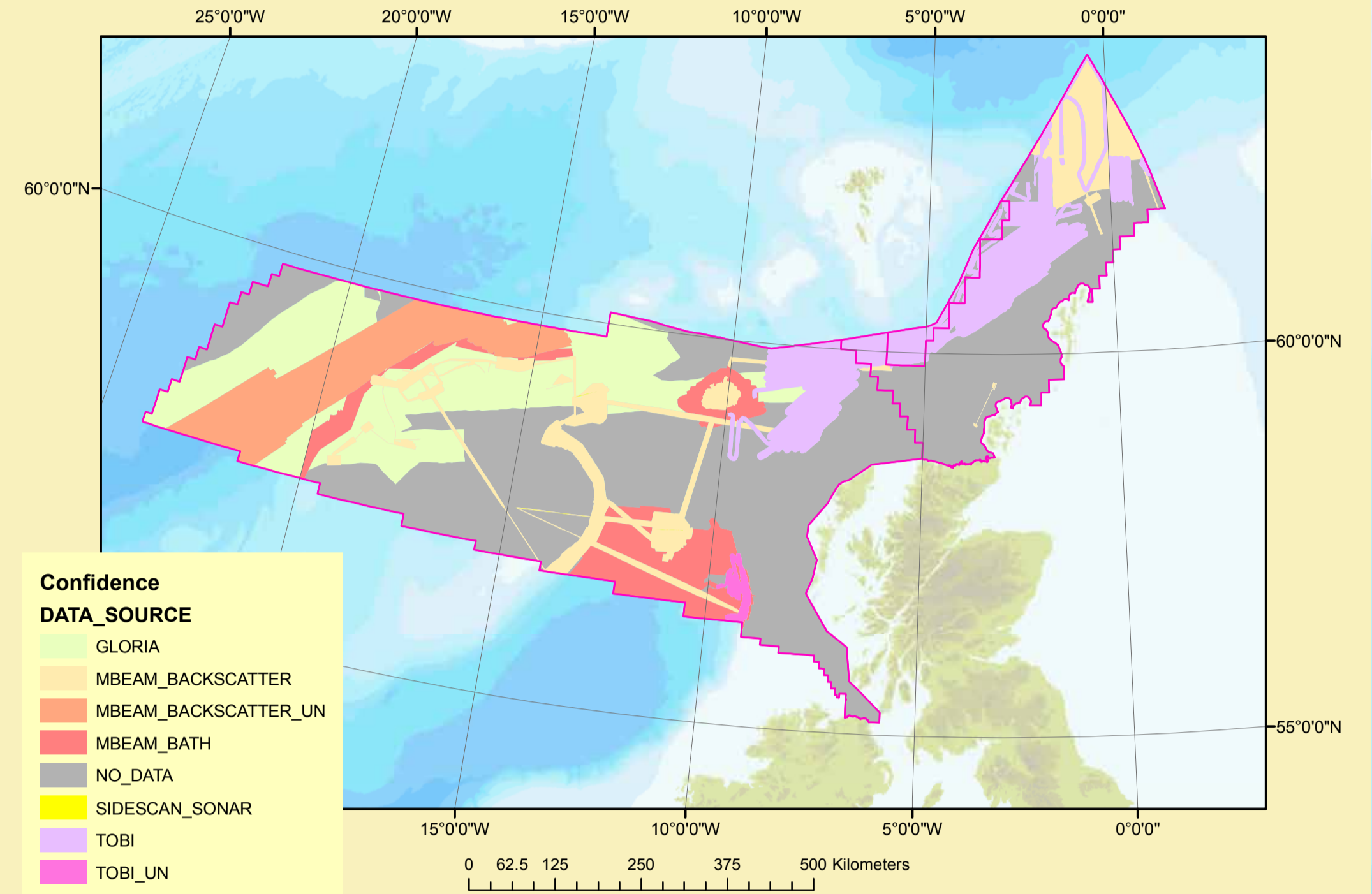
To show the relative variation in spatial resolution, the large pink square behind this text represents the approximate footprint of one average (250m square) GLORIA pixel, the blue boxes represent the best (20m resolution) and the worst (200m resolution) multibeam data, the orange is the TOBI pixel size and the tiny black square corresponds to the deep-towed 500kHz sonar pixels.

250 metres - "best" GLORIA resolution



## Initial Classification

The first task was to assemble all available existing acoustic imaging data. There were four major acoustic imagery data types – GLORIA long range, low resolution side-scan sonar, TOBI medium-high resolution side-scan sonar, multi-beam bathymetry, which transit water depths from the continental shelf edge (< 200m) to over 3,000m, and finally high resolution side-scan sonar.



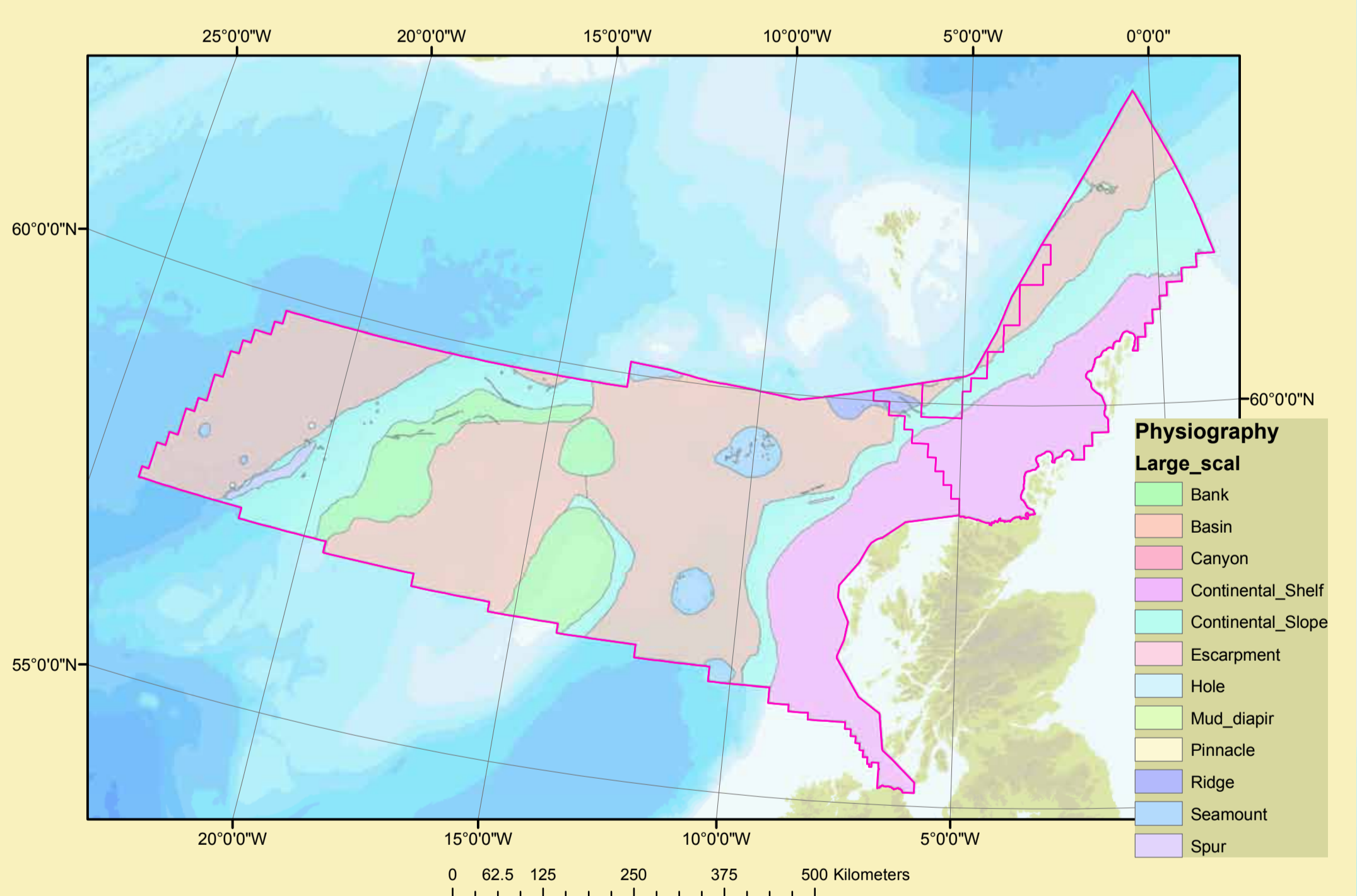
Above, the various areas and types of acoustic imagery are displayed, further sub-divided according to whether or not the survey imagery was then subject to ground truthing studies (note the areas that have high resolution side-scan sonar are too small to be represented at the scale of this map). The brighter colours (above) are the surveys where no specific ground-truth operations were undertaken, the areas outlined in pastel shades have significant ground truth studies which include still photographs, video transects and sampling. Each of these seabed imaging systems was then given a subjective ranking or "Confidence" in the interpretations of a number of different properties of the seabed (see more below). The highest resolution data was assigned the highest confidence level, followed by areas of slightly lower resolution (TOBI) that had been ground truthed, then areas of TOBI without directed ground truthing studies, then to the various multibeam surveys (that may or may not have had directed ground truth studies), and finally the GLORIA side-scan. Where no primary data at all were available (in the off-shelf environment), then this was given the very lowest Confidence level and only the gross morphological features were interpreted unless other features (e.g. polygonal faults in the Rockall-Haton Basin) were clearly depth-dependant and could therefore be reasonably implied.

## Data Interpretation and Resolution Issues

The interpretations of the different resolution data layers were enhanced where possible by using the interpretations from higher resolution data where they overlapped or were adjacent to lower resolution data. See above for an example where EM1002 multibeam data, here shown as a semi-transparent layer, overlay the GLORIA survey data (red circle). The small scoured deeps in the bathymetry are imaged in the GLORIA data, or at least the walls of the scours are imaged and represented as areas of high acoustic backscatter. In fact in this example the EM1002 multibeam (here shown as depths) was also processed to show backscatter imagery and was also subject to ground-truth photographic surveys (still and video). Note the difference of the scale bars between the upper in-set figure (multibeam on GLORIA) and the lower (TOBI 30kHz side-scan sonar, circled in green). The features imaged on the TOBI data are the DARWIN MOUNDS, sand volcanoes with colonies of *Lophelia pertusa* and (typically down-current) prominent on the sonar imagery, highly backscattering "tails". These mounds are typically 5m high and ~100m across so given the resolutions of the survey systems, it would be impossible to "see" these features in GLORIA sidescan data and also the multibeam backscatter.

## Large-Scale Classification

The largest-scale classification we determined was in the Physiography layer. However whether this is a truly meaningful sub-division in terms of seabed ecology is doubtful, depth and water temperature are probably far more important, but here we are producing something that will be used by both scientists and policy makers, and we felt it important that easily understandable geomorphological features were identified.

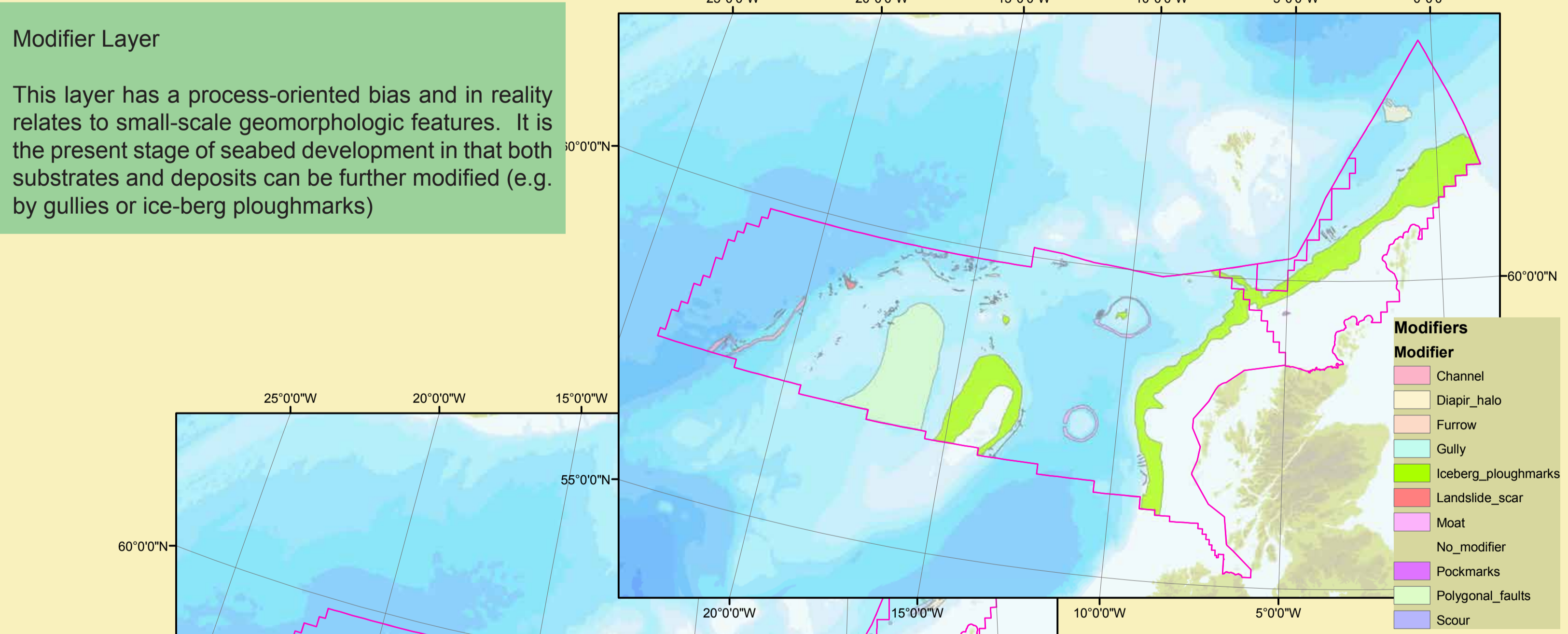


## Detailed Classification Scheme

The overall classification scheme was designed to be quasi-hierarchical and, where possible to align itself with the existing EUNIS classification scheme and be ecologically meaningful. Thus we developed three additional layers to those described above (see left).

### Modifier Layer

This layer has a process-oriented bias and in reality relates to small-scale geomorphologic features. It is the present stage of seabed development in that both substrates and deposits can be further modified (e.g. by gullies or ice-berg ploughmarks)

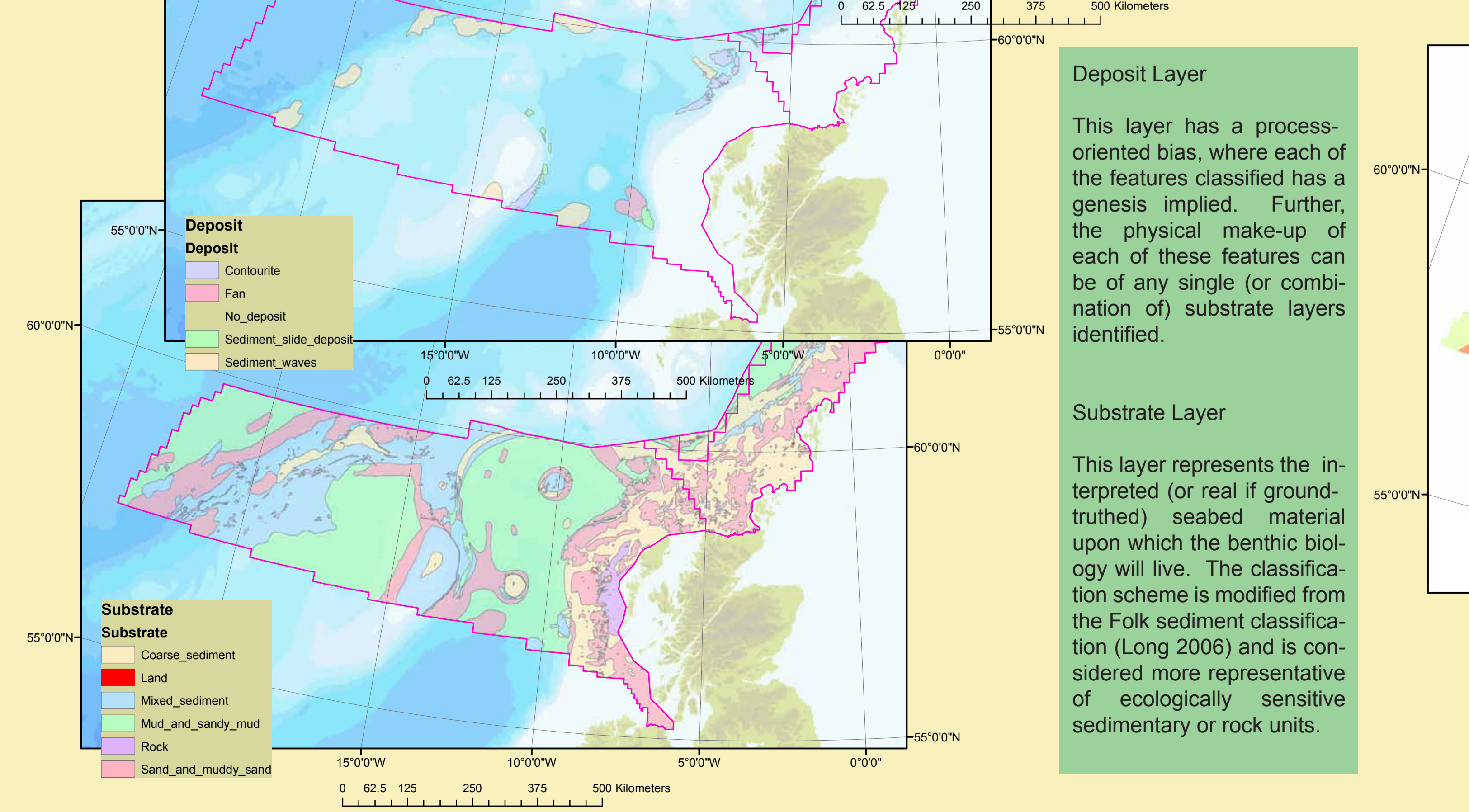


### Deposit Layer

This layer has a process-oriented bias, where each of the features classified has a genesis implied. Further, the physical make-up of each of these features can be of any single (or combination) of substrate layers identified.

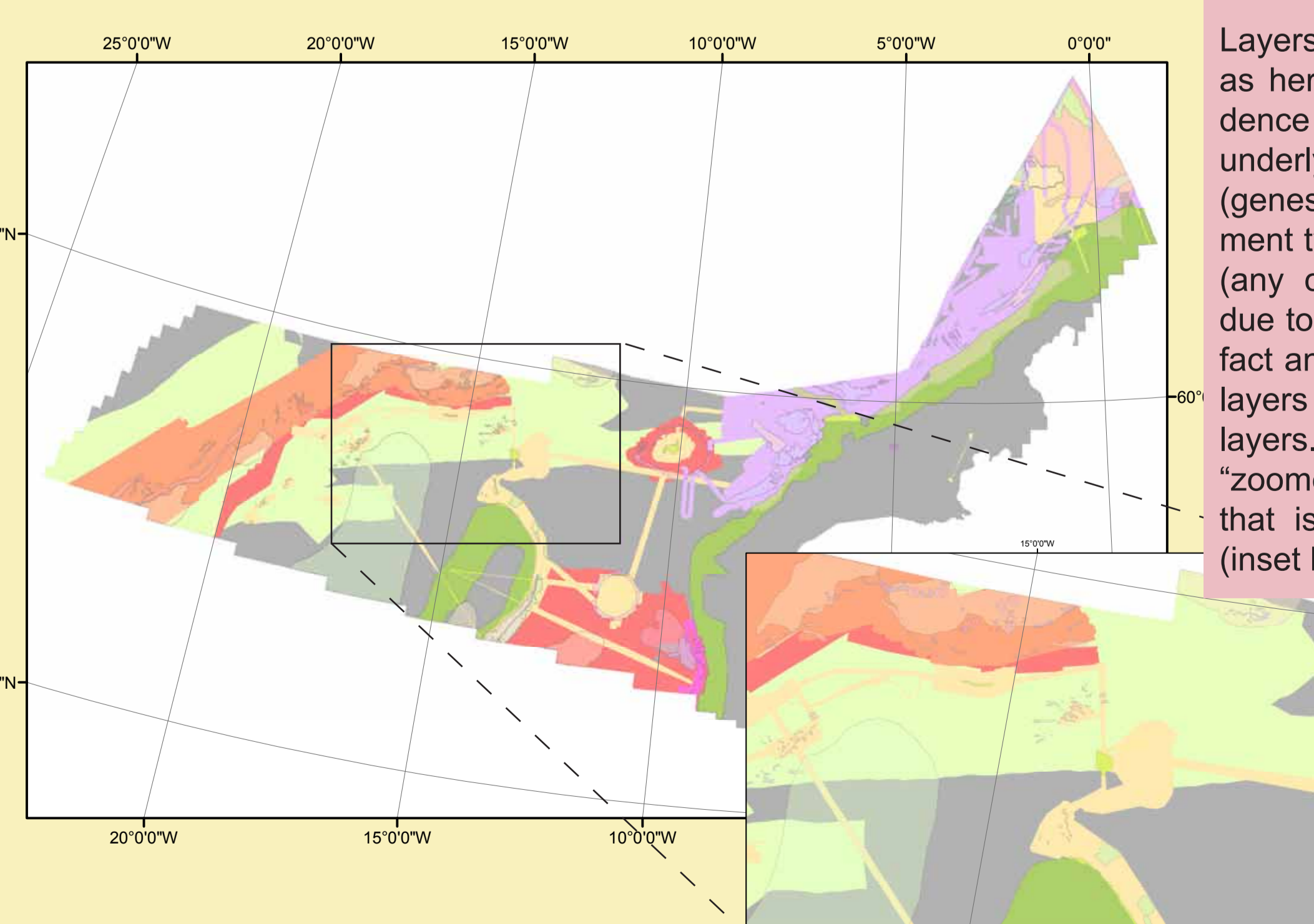
### Substrate Layer

This layer represents the interpreted (or real if ground-truthed) seabed material upon which the benthic biology will live. The classification scheme is modified from the Folk sediment classification (Long 2006) and is considered more representative of ecologically sensitive sedimentary or rock units.



## Results

Layers can be superimposed, as here (left), to show confidence (data type and quality) underlying both the Deposit (genesis of the seabed sediment type) and Modifier layer (any change in the seabed due to active processes), or in fact any other combination of layers including 3<sup>rd</sup> party layers. The GIS can easily be "zoomed in" to show detail that is lost at larger scales (inset below left).



## References

EUNIS <http://eunis.eea.europa.eu>  
 Masson, D.G., Bett, B.J., Billett, D.S.M., Jacobs, C.L., Wheeler, A.J., Wynn, R.B., 2003. The origin of deep-water, coral topped mounds in the northern Rockall Trough, Northeast Atlantic. *Marine Geology* 194 (3-4), 159-180.  
 Long D 2006 BGS Detailed explanation of the seabed sediment modified FOLK classification. see web page <http://www.searchmesh.net/PDF/BGS%20detailed%20explanation%20of%20seabed%20sediment%20modified%20folk%20classification.pdf>