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LT14 Western Isles HVDC Link - Post Application Support

Pockmark Cable Routing

Scottish and Southern Energy plc

Assignment Number: A100336-S04
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Pockmark Cable Routing

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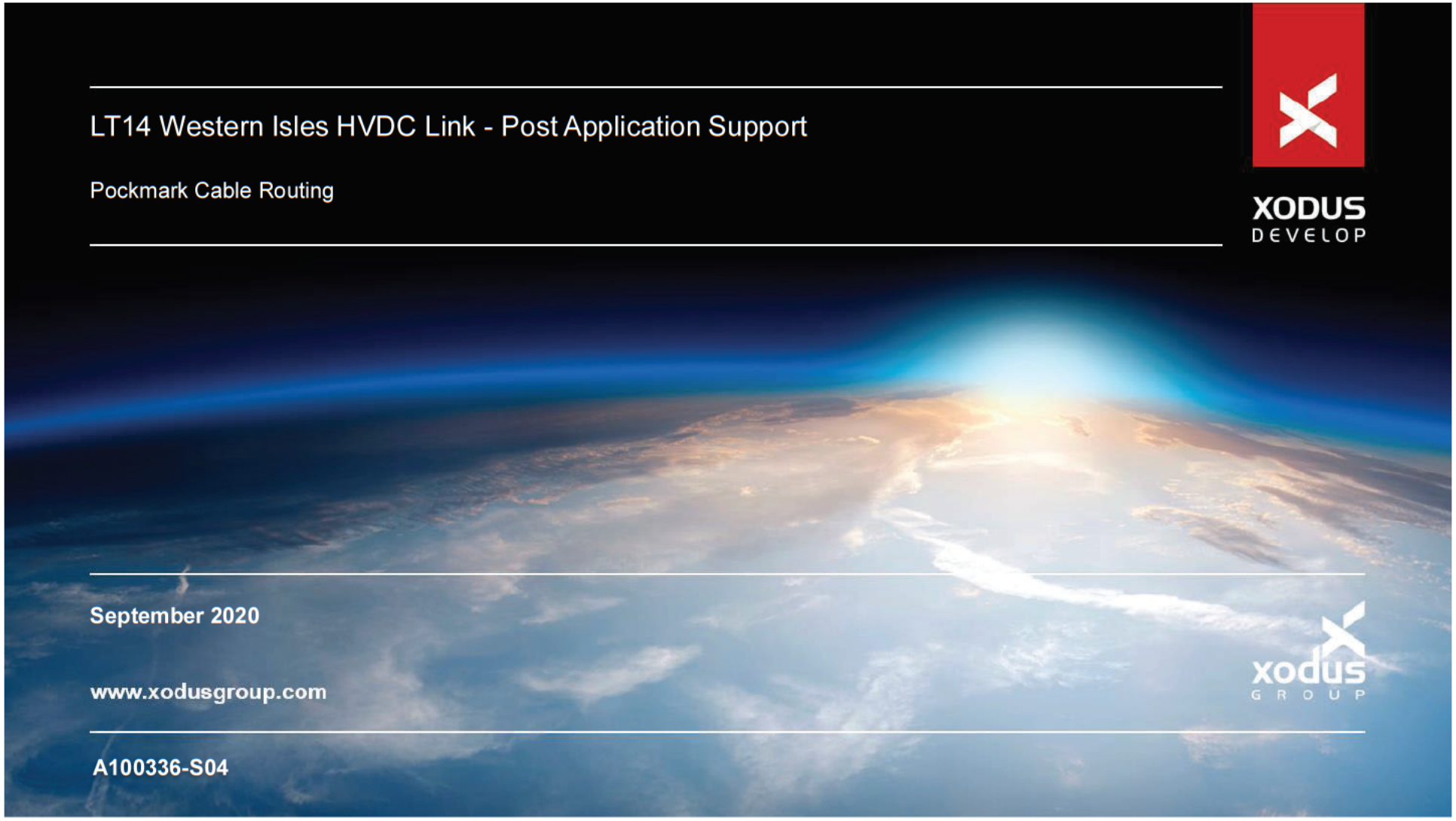

September 2020

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Scope and Approach

- To review the prosed route and propose refinement to avoid pockmarks where possible, utilising:
  - Received Nature Scot and Marine Scotland feedback;
  - Audsley et al. (2019)[1]; and
  - 2m-resolution MBES data of the proposed installation corridor.

- Contracted the British Geological Society to map pockmarks using the semi-automated approach developed by the BGS[2], utilised in Audsley et al. (2019), to providing the following deliverables:
  - Shapefile with the mapping output;
  - Vertices of the proposed cable corridor (Appendix A); and
  - Slidepack documenting the mapping approach and the results obtained (Appendix B).

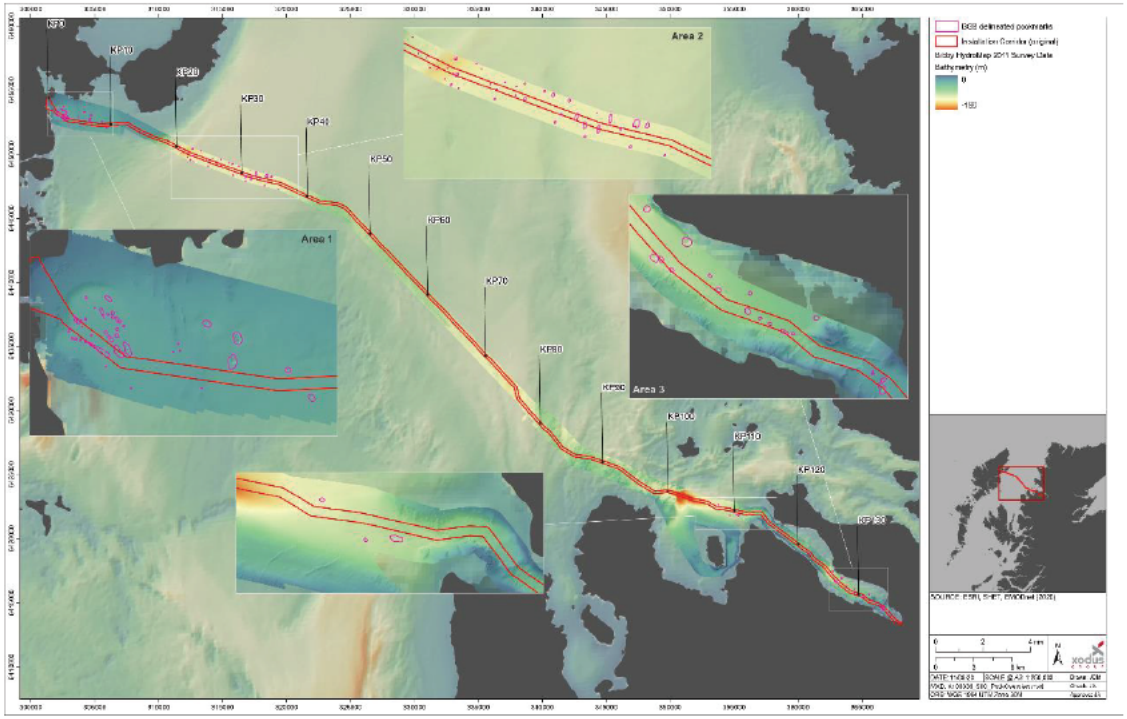
- Xodus review of the BGS shapefile to confirm pockmark detection and identify any requirements for corridor rerouting.

1. Audsley, A., Bradwell, T., Howe, J.A. & Baxter, J.M. (2019) Distribution and classification of pockmarks on the seabed around western Scotland, *Journal of Maps*, 15: 2, 807-817, DOI: 10.1080/17445647.2019.1676320
2. BGS Seabed Mapping Toolbox

Results

Area identification

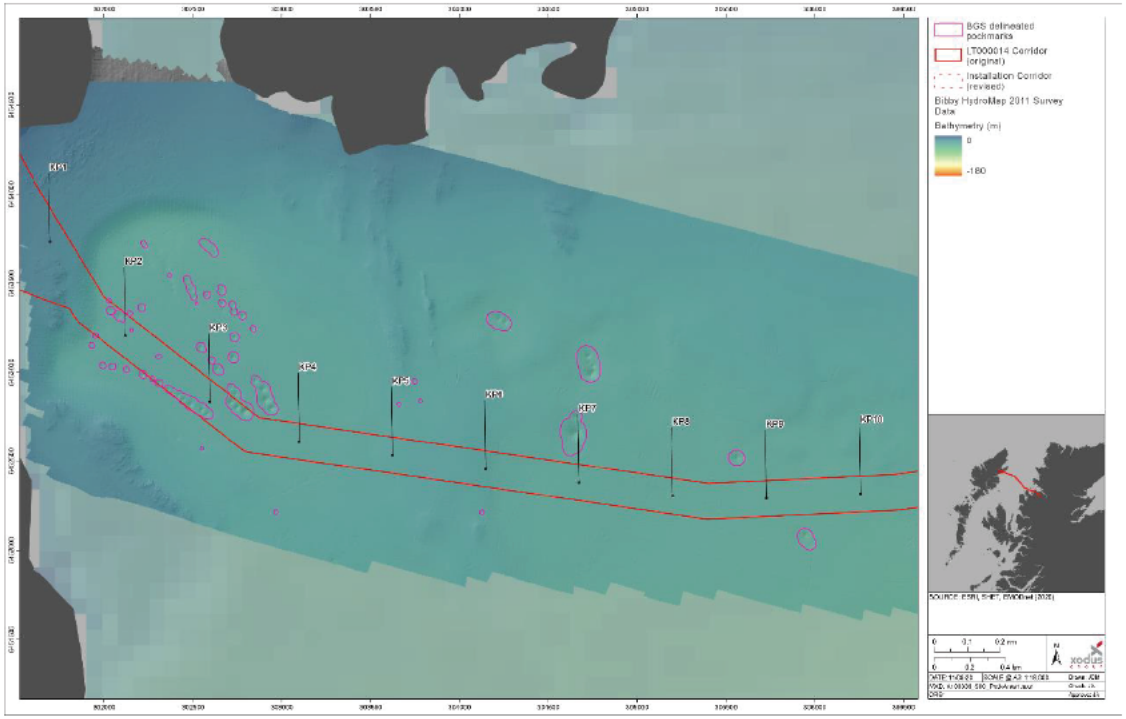
- 107 pockmarks identified
- Reduced pockmark boundaries
- Pockmarks were identified within the cable corridor in 3 areas:
  - Area 1 – Stornoway; ca.KP0-KP10;
  - Area 2 – Mid-line; ca.KP20-KP40; and
  - Area 3 – Little Loch Broom; ca.KP125-KP135
- Pockmarks adjacent to the corridor route were identified on the approach to Little Loch Broom, ca.KP105-KP115 but do not present a routing issue.



Results

Area 1 - Stornoway

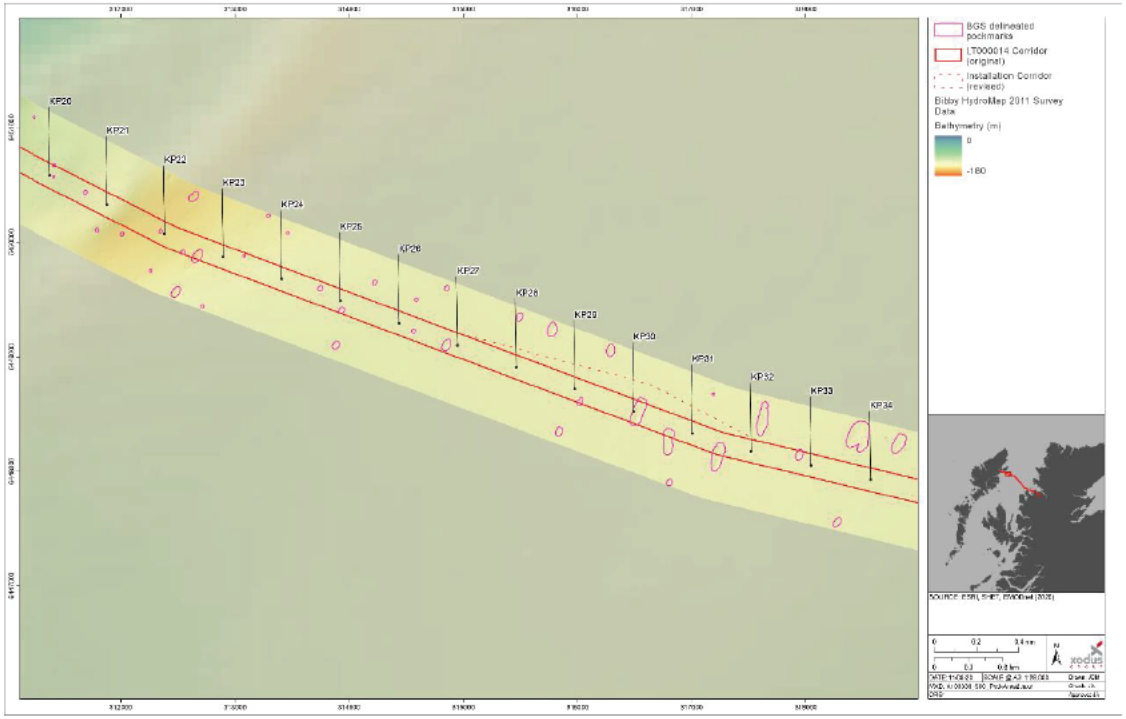
- Numerous pockmarks of various size and morphology were identified intercepting the corridor in Area 1.
- Two adjacent strings of pockmarks at KP 3 present minimum routing gap = ~80m
- Relatively uniform surrounding bathymetry.
- No rerouting to corridor proposed.



Results

Area 2 – Mid-line

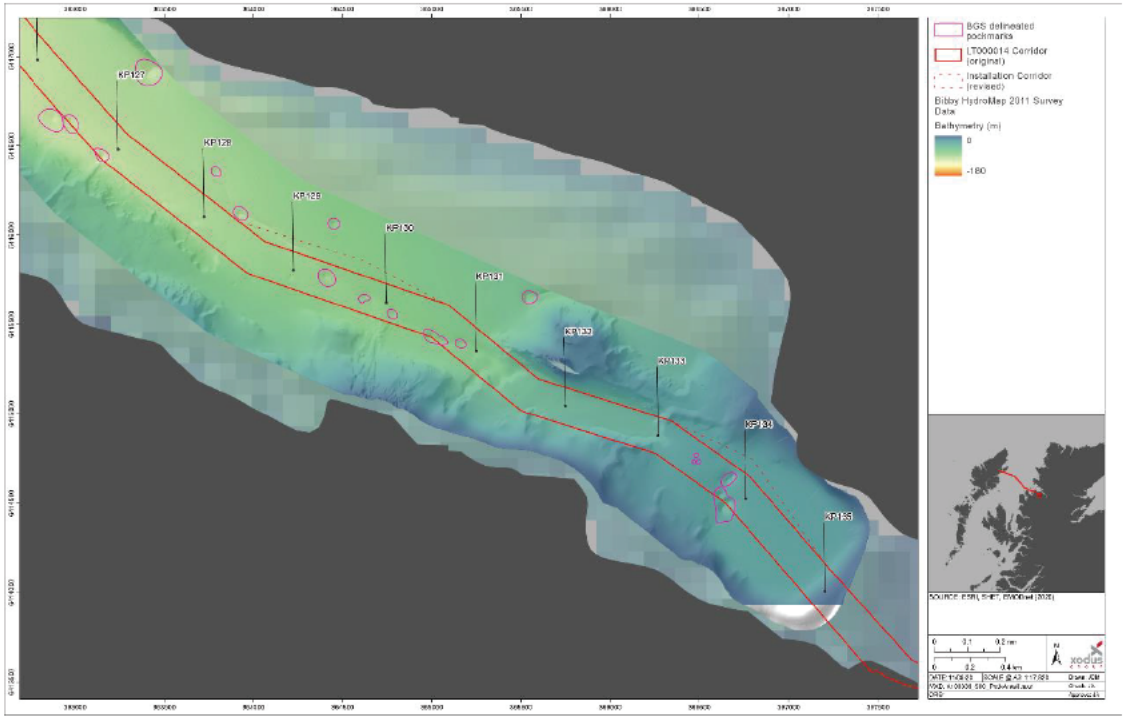
- Numerous pockmarks of various size and morphology were identified intercepting the corridor in Area 2.
- Pockmark spans width of corridor at KP30
  - ~100m length
  - Deepest at southern end
- Suggested re-routing to the north of current corridor to avoid additional external pockmarks to the south



Results

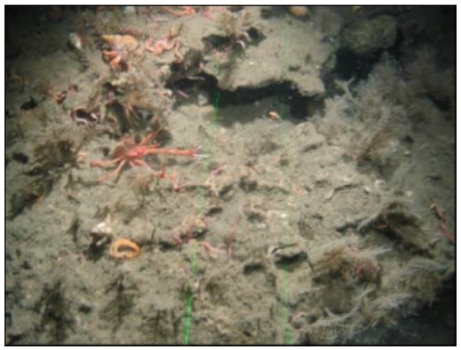
Area 3 – Little Loch Broom

- 12 pockmarks of various size and morphology were identified intercepting the corridor in Area 3.
- Visible gullies along steep southern slope indicating sediment slides/slumps and mass flow processes.
- 3 pockmarks at ~KP129-KP131 present cable routing complexity.
- Proposed rerouting to the north of the corridor between KP128 and KP131 over uniform seabed to avoid complex topography and unstable southern slope.



Discussion
Pockmarks

- Pockmarks are craters in the seabed caused by the release of fluids (gasses and liquids) through the sediment.
- Reviewed Western Isles Connection, Volume 3a – Geophysical Survey Results Report, Bibby HydroMap Project No. 2016-011, September 2016 for evidence of pockmarks rather than other crater/depression type features.
- Identified areas of acoustic blanking in the seismic record along much of the cable corridor, indicating the presence of shallow gas, a causal event of pockmarks.
- Pockmarks can contain the Habitats Directive Annex I protected habitat *Submarine structures made by leaking gases*, characterised by the formation of *methane-derived authigenic carbonate* (MDAC) which in turn provide habitat for complex ecosystems.
- Hard contact within the pockmarks was not detected during the geophysical survey, indicating that MDAC is not present.
- Avoidance of pockmarks recommended due to technical complexities including free-span formation.
- Vertices for the proposed route are provided in Appendix A.



http://www.cpgeoservices.com/operational-photos/

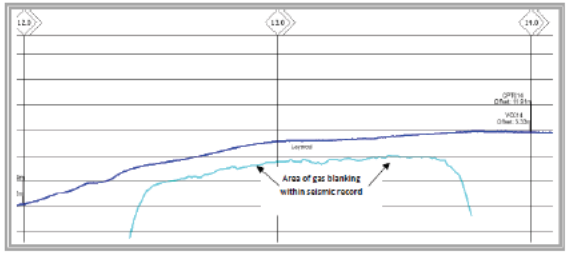


Figure 35: Area of acoustic blanking across route between KP12.50 and KP13.63

Appendix A
Cable corridor vertices

Order	Coordinates for LT14 Western Isles HVDC Link (WGS 84)[1]					
	Degrees, Minutes and Seconds		Degrees and Decimal Minutes		Decimal Degrees	
	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
1	6° 22' 45.336" W	58° 10' 41.772" N	6° 22.756' W	58° 10.696' N	-6.37926	58.17827
2	6° 22' 51.538" W	58° 11' 4.258" N	6° 22.859' W	58° 11.071' N	-6.380983	58.184516
3	6° 22' 40.875" W	58° 11' 9.564" N	6° 22.681' W	58° 11.159' N	-6.378021	58.18599
4	6° 22' 2.408" W	58° 10' 39.269" N	6° 22.040' W	58° 10.654' N	-6.367336	58.177575
5	6° 21' 6.801" W	58° 10' 18.663" N	6° 21.113' W	58° 10.311' N	-6.351889	58.171851
6	6° 18' 31.119" W	58° 10' 10.807" N	6° 18.519' W	58° 10.180' N	-6.308644	58.169669
7	6° 16' 31.623" W	58° 10' 18.416" N	6° 16.527' W	58° 10.307' N	-6.275451	58.171782
8	6° 16' 12.492" W	58° 10' 16.259" N	6° 16.208' W	58° 10.271' N	-6.270137	58.171183
9	6° 15' 6.133" W	58° 9' 58.191" N	6° 15.102' W	58° 9.970' N	-6.251704	58.166164
10	6° 14' 4.596" W	58° 9' 45.444" N	6° 14.077' W	58° 9.757' N	-6.23461	58.162623
11	6° 13' 4.199" W	58° 9' 35.985" N	6° 13.070' W	58° 9.600' N	-6.217833	58.159996
12	6° 11' 11.583" W	58° 9' 9.340" N	6° 11.193' W	58° 9.156' N	-6.186551	58.152595
13	6° 8' 39.775" W	58° 8' 43.421" N	6° 8.663' W	58° 8.724' N	-6.144382	58.145395
14	6° 6' 54.641" W	58° 8' 31.328" N	6° 6.911' W	58° 8.522' N	-6.115178	58.142036
15	6° 5' 55.001" W	58° 8' 16.597" N	6° 5.917' W	58° 8.277' N	-6.098611	58.137943
16	6° 3' 52.091" W	58° 8' 4.163" N	6° 3.868' W	58° 8.069' N	-6.06447	58.13449
17	6° 0' 43.184" W	58° 7' 22.617" N	6° 0.720' W	58° 7.377' N	-6.011995	58.122949
18	5° 59' 17.753" W	58° 7' 19.336" N	5° 59.296' W	58° 7.322' N	-5.988265	58.122038
19	5° 58' 35.993" W	58° 7' 10.469" N	5° 58.600' W	58° 7.174' N	-5.976665	58.119575
20	5° 44' 29.756" W	57° 59' 56.899" N	5° 44.496' W	57° 59.948' N	-5.741599	57.999138
21	5° 44' 12.295" W	57° 59' 26.738" N	5° 44.205' W	57° 59.446' N	-5.736749	57.990761
22	5° 42' 4.424" W	57° 58' 15.759" N	5° 42.074' W	57° 58.263' N	-5.701229	57.971044
23	5° 41' 42.182" W	57° 58' 7.576" N	5° 41.703' W	57° 58.126' N	-5.69505	57.968771
24	5° 41' 5.433" W	57° 57' 47.376" N	5° 41.091' W	57° 57.790' N	-5.684842	57.96316
25	5° 40' 38.567" W	57° 57' 28.498" N	5° 40.643' W	57° 57.475' N	-5.67738	57.957916
26	5° 39' 38.594" W	57° 57' 10.805" N	5° 39.643' W	57° 57.180' N	-5.66072	57.953001
27	5° 38' 21.690" W	57° 57' 6.277" N	5° 38.362' W	57° 57.105' N	-5.639358	57.951744
28	5° 36' 5.494" W	57° 56' 44.168" N	5° 36.092' W	57° 56.736' N	-5.601526	57.945602
29	5° 34' 21.514" W	57° 56' 6.517" N	5° 34.359' W	57° 56.109' N	-5.572643	57.935144
30	5° 33' 11.159" W	57° 55' 45.960" N	5° 33.186' W	57° 55.766' N	-5.5531	57.929433
31	5° 32' 10.593" W	57° 55' 50.327" N	5° 32.177' W	57° 55.839' N	-5.536276	57.930646
32	5° 30' 13.977" W	57° 55' 31.299" N	5° 30.233' W	57° 55.522' N	-5.503882	57.925361
33	5° 28' 57.607" W	57° 55' 24.456" N	5° 28.960' W	57° 55.408' N	-5.482668	57.92346
34	5° 28' 17.797" W	57° 55' 12.809" N	5° 28.297' W	57° 55.213' N	-5.47161	57.920225
35	5° 27' 17.867" W	57° 55' 9.691" N	5° 27.298' W	57° 55.162' N	-5.454963	57.919359
36	5° 25' 42.221" W	57° 54' 59.855" N	5° 25.704' W	57° 54.998' N	-5.428395	57.916626
37	5° 25' 1.901" W	57° 55' 3.503" N	5° 25.032' W	57° 55.058' N	-5.417195	57.91764
38	5° 24' 38.434" W	57° 55' 2.897" N	5° 24.641' W	57° 55.048' N	-5.410676	57.917471
39	5° 23' 58.854" W	57° 54' 37.272" N	5° 23.981' W	57° 54.621' N	-5.399682	57.910353
40	5° 20' 41.009" W	57° 53' 25.886" N	5° 20.683' W	57° 53.431' N	-5.344725	57.890524
41	5° 20' 25.182" W	57° 53' 13.426" N	5° 20.420' W	57° 53.224' N	-5.340328	57.887063
42	5° 19' 28.152" W	57° 52' 52.886" N	5° 19.469' W	57° 52.881' N	-5.324487	57.881357
43	5° 18' 17.228" W	57° 52' 12.072" N	5° 18.287' W	57° 52.201' N	-5.304786	57.87002
44	5° 17' 38.168" W	57° 51' 56.897" N	5° 17.636' W	57° 51.948' N	-5.293936	57.865805
45	5° 16' 54.873" W	57° 51' 50.477" N	5° 16.915' W	57° 51.841' N	-5.281909	57.864021
46	5° 16' 25.233" W	57° 51' 42.819" N	5° 16.421' W	57° 51.714' N	-5.273676	57.861894

47	5° 15' 54.456" W	57° 51' 30.241" N	5° 15.908' W	57° 51.504' N	-5.265127	57.8584
48	5° 15' 8.353" W	57° 51' 23.294" N	5° 15.139' W	57° 51.388' N	-5.25232	57.856471
49	5° 14' 40.791" W	57° 51' 17.027" N	5° 14.680' W	57° 51.284' N	-5.244664	57.85473
50	5° 13' 44.451" W	57° 50' 41.673" N	5° 13.741' W	57° 50.695' N	-5.229014	57.844909
51	5° 13' 14.251" W	57° 50' 34.376" N	5° 13.238' W	57° 50.573' N	-5.220625	57.842882
52	5° 13' 17.847" W	57° 50' 31.719" N	5° 13.297' W	57° 50.529' N	-5.221624	57.842144
53	5° 13' 58.281" W	57° 50' 39.346" N	5° 13.971' W	57° 50.656' N	-5.232856	57.844263
54	5° 14' 49.404" W	57° 51' 8.910" N	5° 14.823' W	57° 51.149' N	-5.247057	57.852475
55	5° 15' 13.830" W	57° 51' 17.486" N	5° 15.230' W	57° 51.291' N	-5.253842	57.854857
56	5° 15' 59.719" W	57° 51' 24.350" N	5° 15.995' W	57° 51.406' N	-5.266589	57.856764
57	5° 16' 31.312" W	57° 51' 37.171" N	5° 16.522' W	57° 51.620' N	-5.275364	57.860325
58	5° 17' 35.326" W	57° 51' 47.855" N	5° 17.589' W	57° 51.798' N	-5.293146	57.863293
59	5° 18' 25.369" W	57° 52' 7.261" N	5° 18.423' W	57° 52.121' N	-5.307047	57.868684
60	5° 19' 36.124" W	57° 52' 47.951" N	5° 19.602' W	57° 52.799' N	-5.326701	57.879986
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63	5° 24' 6.681" W	57° 54' 32.282" N	5° 24.111' W	57° 54.538' N	-5.401856	57.908967
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65	5° 25' 43.006" W	57° 54' 53.359" N	5° 25.717' W	57° 54.889' N	-5.428613	57.914822
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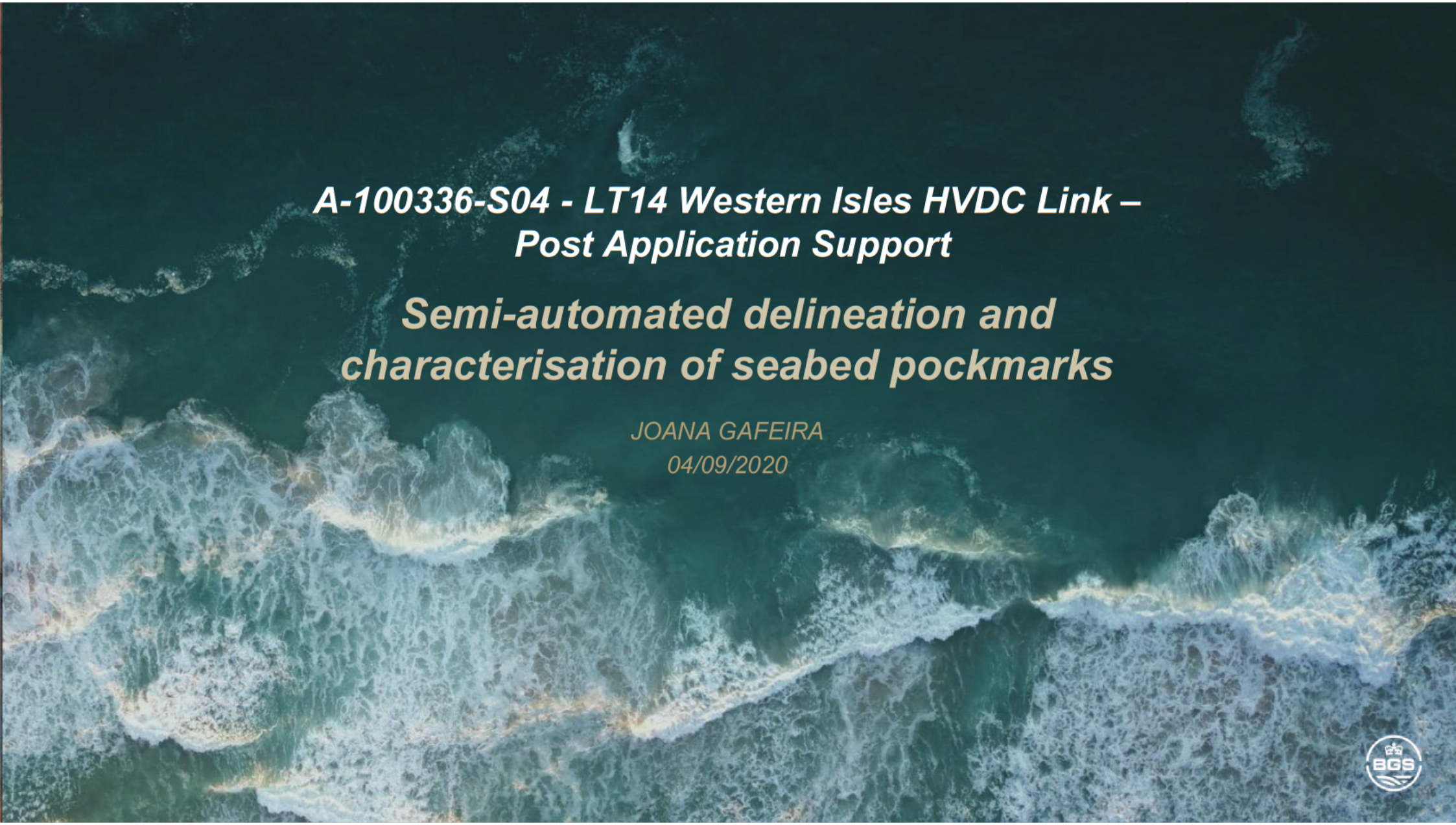
67	5° 28' 20.717" W	57° 55' 6.475" N	5° 28.345' W	57° 55.108' N	-5.472421	57.918465
68	5° 29' 1.633" W	57° 55' 18.306" N	5° 29.027' W	57° 55.305' N	-5.483787	57.921752
69	5° 30' 16.965" W	57° 55' 25.021" N	5° 30.283' W	57° 55.417' N	-5.504712	57.923617
70	5° 32' 11.949" W	57° 55' 43.852" N	5° 32.199' W	57° 55.731' N	-5.536653	57.928848
71	5° 33' 13.887" W	57° 55' 39.486" N	5° 33.231' W	57° 55.658' N	-5.553858	57.927635
72	5° 34' 27.850" W	57° 56' 0.995" N	5° 34.464' W	57° 56.017' N	-5.574403	57.93361
73	5° 36' 10.520" W	57° 56' 38.251" N	5° 36.175' W	57° 56.638' N	-5.602922	57.943958
74	5° 38' 24.483" W	57° 56' 59.979" N	5° 38.408' W	57° 57.000' N	-5.640134	57.949994
75	5° 39' 42.085" W	57° 57' 4.546" N	5° 39.701' W	57° 57.076' N	-5.66169	57.951263
76	5° 40' 46.028" W	57° 57' 23.318" N	5° 40.767' W	57° 57.389' N	-5.679452	57.956477
77	5° 41' 14.438" W	57° 57' 43.026" N	5° 41.241' W	57° 57.717' N	-5.687344	57.961952
78	5° 41' 50.219" W	57° 58' 2.703" N	5° 41.837' W	57° 58.045' N	-5.697283	57.967417
79	5° 42' 12.786" W	57° 58' 11.051" N	5° 42.213' W	57° 58.184' N	-5.703552	57.969736
80	5° 44' 22.445" W	57° 59' 23.035" N	5° 44.374' W	57° 59.384' N	-5.739568	57.989732
81	5° 44' 39.399" W	57° 59' 52.861" N	5° 44.657' W	57° 59.881' N	-5.744278	57.998017
82	5° 58' 42.108" W	58° 7' 4.815" N	5° 58.702' W	58° 7.080' N	-5.978363	58.118004
83	5° 59' 20.177" W	58° 7' 12.967" N	5° 59.336' W	58° 7.216' N	-5.988938	58.120269
84	6° 0' 46.443" W	58° 7' 16.345" N	6° 0.774' W	58° 7.272' N	-6.012901	58.121207
85	6° 3' 55.815" W	58° 7' 57.989" N	6° 3.930' W	58° 7.966' N	-6.065504	58.132775
86	6° 6' 17.797" W	58° 8' 12.426" N	6° 6.297' W	58° 8.207' N	-6.104944	58.136785
87	6° 11' 15.650" W	58° 9' 3.242" N	6° 11.261' W	58° 9.054' N	-6.18768	58.1509
88	6° 13' 8.458" W	58° 9' 29.917" N	6° 13.141' W	58° 9.499' N	-6.219016	58.15831
89	6° 14' 8.816" W	58° 9' 39.376" N	6° 14.147' W	58° 9.656' N	-6.235782	58.160938
90	6° 15' 10.843" W	58° 9' 52.224" N	6° 15.181' W	58° 9.870' N	-6.253012	58.164507
91	6° 16' 16.492" W	58° 10' 10.122" N	6° 16.275' W	58° 10.169' N	-6.271248	58.169478
92	6° 16' 31.270" W	58° 10' 11.931" N	6° 16.521' W	58° 10.199' N	-6.275353	58.169981
93	6° 18' 31.314" W	58° 10' 4.330" N	6° 18.522' W	58° 10.072' N	-6.308698	58.167869
94	6° 21' 10.092" W	58° 10' 12.347" N	6° 21.168' W	58° 10.206' N	-6.352803	58.170096
95	6° 22' 13.965" W	58° 10' 36.755" N	6° 22.233' W	58° 10.613' N	-6.370546	58.176876

1.
Landward boundaries of the survey corridor are defined by Mean High Water Springs (MHWS)
Longitude and latitude coordinates are provided in WGS 1984 CRS (EPSG: 4326)

Appendix B

Semi-automated delineation and characterisation of seabed pockmarks - BGS



A-100336-S04 - LT14 Western Isles HVDC Link – Post Application Support

Semi-automated delineation and characterisation of seabed pockmarks

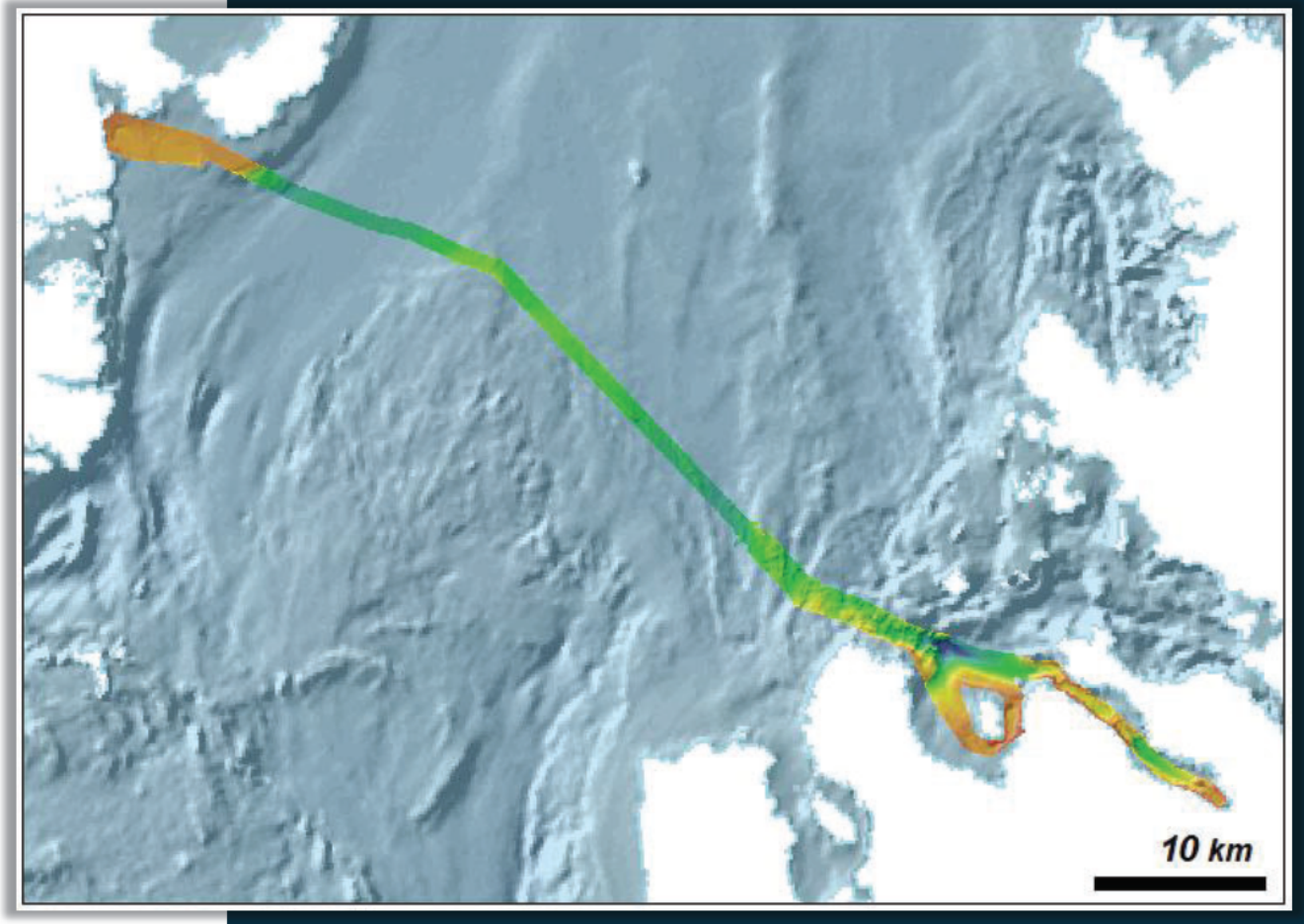
JOANA GAFEIRA

04/09/2020

SCOPE OF THE WORK

Mapping pockmarks in 2 m resolution MB dataset acquired by Xodus Group (2011_011_DTM_Merged_W84UTM30N).

- Visual analysis of data
- Identify areas of interest
- Definition of mapping thresholds
- Running automatic mapping using the BGS Seabed Mapping Toolbox
- Assessment of the results
- Reporting



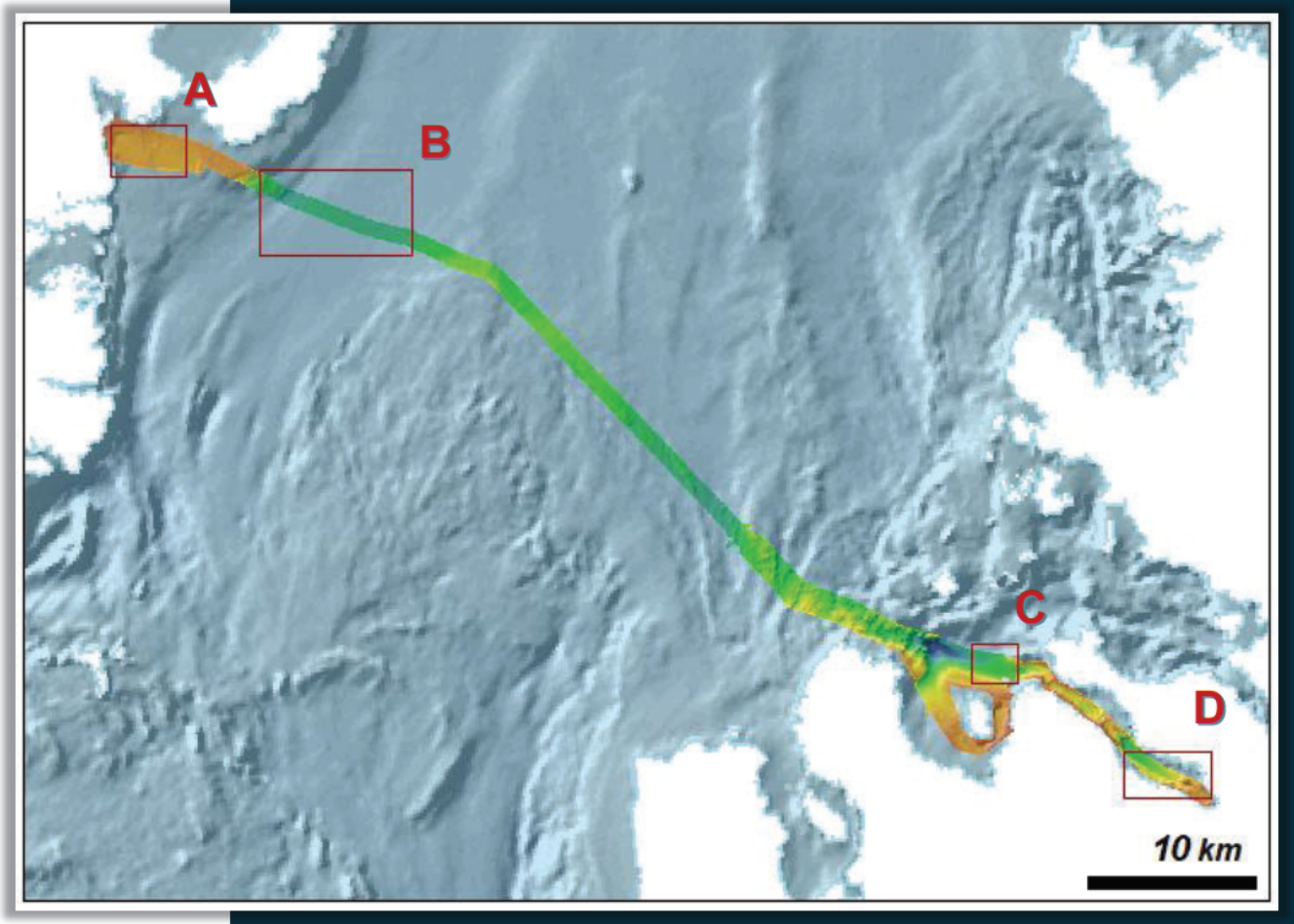
AREAS WITH POCKMARKS

Pockmarks at seabed were found in 4 areas.

The dataset was clipped to focus in areas of known pockmarks.

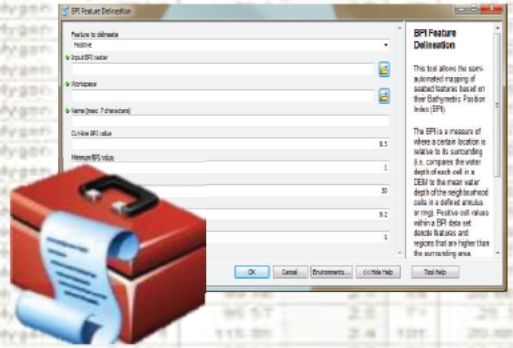
A total of 107 were mapped using the BGS Seabed Mapping Toolbox.

This toolbox overcomes the subjectivity intrinsic to manual delineation of pockmarks and is also more effective. It also provides an efficient geomorphologic characterisation of the vast number of features.

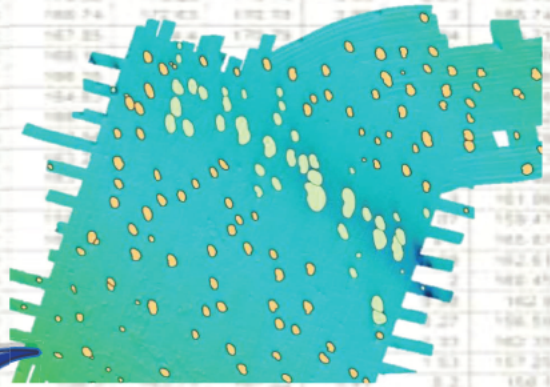


BGS Seabed Mapping Toolbox

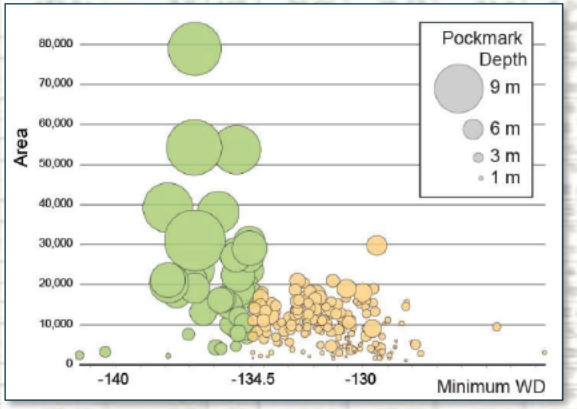
It is a ArcGIS-based Toolbox that allows the semi-automatic:



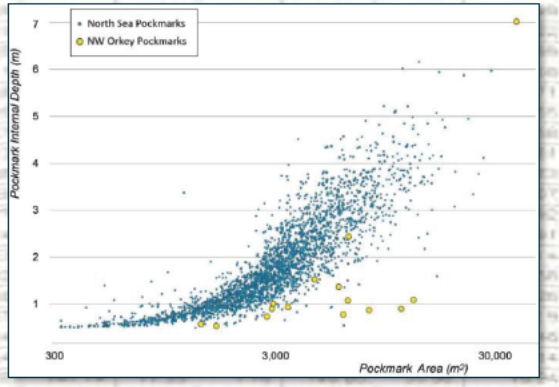
Delineation



Characterization



Comparison



BGS Seabed Mapping Toolbox

UPSTREAM TOOLS

- Create Fishnet – *Standard ArcGIS tool*
- **Filter-based** - *Clip raster to preserve only areas of topographic changes*
- Focal Statistics – *Standard ArcGIS tool*

- **FEATURE DELINEATION [BATHY]** *Used in this work*

  Delineation of confined topographic anomalies based on the DTM

- **FEATURE DELINEATION [DERIVED]**

  Delineation of confined anomalies based on a derived layer (e.g. BPI)

- **FEATURE DESCRIPTION [SHORT]** *Used in this work*

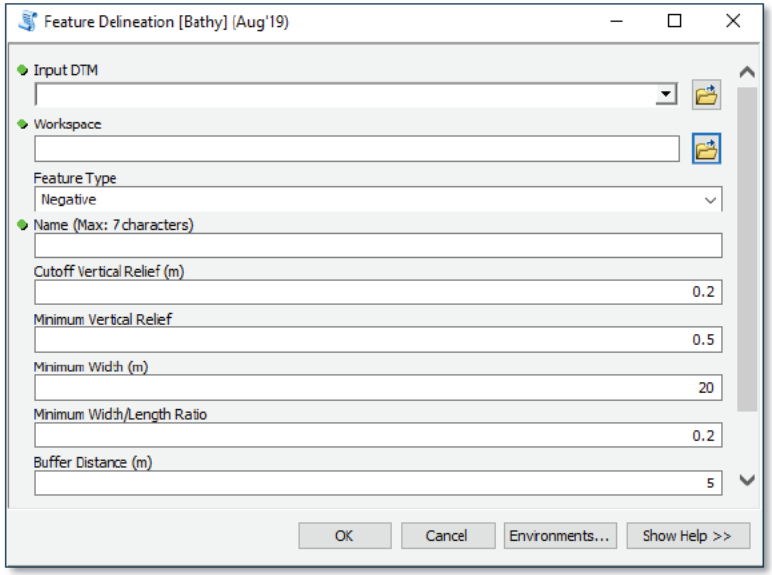
  Brief characterization of the features' morphometrics

- **FEATURE DESCRIPTION [FULL]**

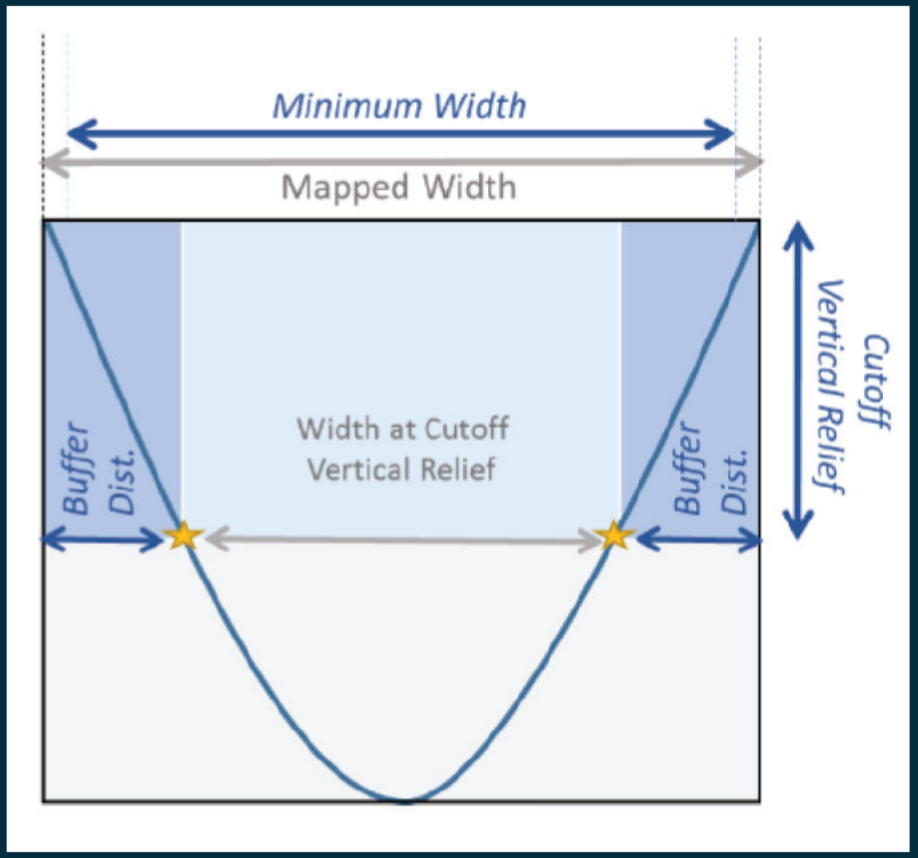
  Complete characterization of the features' morphometrics

FEATURE DELINEATION [BATHY]

This tool allows the semi-automated delineation of confined features directly from the bathymetric data. Five values have to be defined, these are the *Cut-off Vertical Relief*, *Minimum Vertical Relief*, *Minimum Width, Minimum Width/Length Ratio* and Buffer Distance.



Although the threshold values are set independently, there is a certain degree of “interaction”.



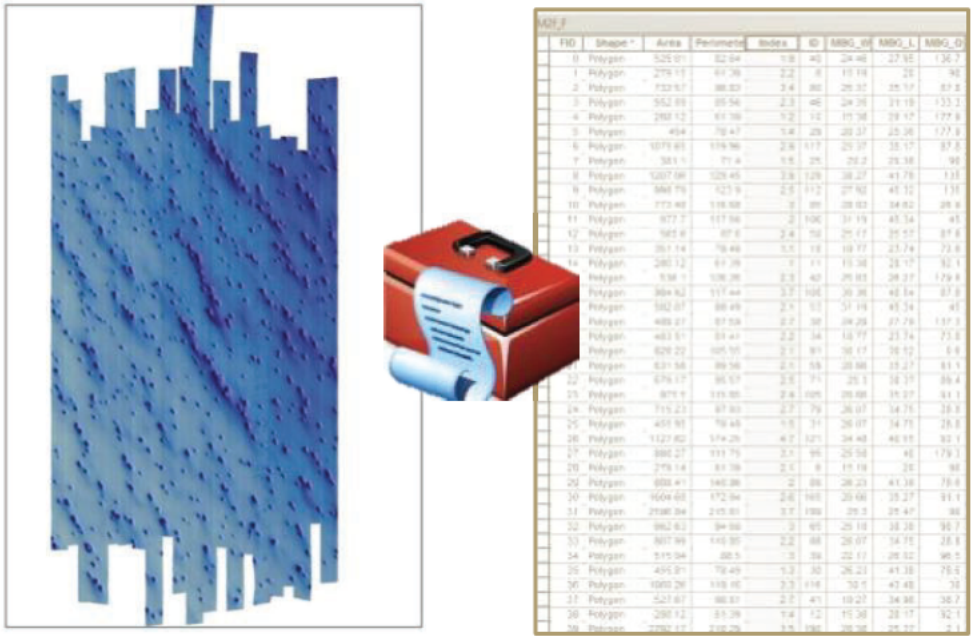
FEATURE DELINEATION [BATHY]

Thresholds used during the mapping.

Name	Description	Value Used
Cut-off Vertical Relief :	*The Cut-off Vertical Relief defines the contour line that will be used to delineate the features. This threshold is set in meters.*	***0.15***
Minimum Vertical Relief:	*Only features with a vertical relief greater to Minimum Vertical Relief value will be mapped. This threshold is set in meters.*	***0.15***
Minimum Width:	*Only features with width greater the Minimum Width value will be mapped. This threshold is set in meters.*	***20***
Minimum Size Ratio:	*The Minimum Width/Length Ratio threshold allows to exclude features based on their shape. It should be noticed that the Minimum Width/Length Ratio does not have units and that it uses the values obtained using the Minimum Bounding Geometry.*	***0.2***
Buffer Distance:	*The Buffer Distance should reflect approximately the distance, in plan view, from the initial contour line delineated based on the Cut-off Vertical Relief to the actual rim of the feature. This threshold is set in meters*	***7.5***

FEATURE DESCRIPTION [SHORT]

The outputs of this tool are a shapefile of polygons that delineate the mapped features and a text file with information relative to the script, input DTM and parameters used. The output shapefile will have the name defined by the user and the text file will have the "_Info" suffix.



Attributes:

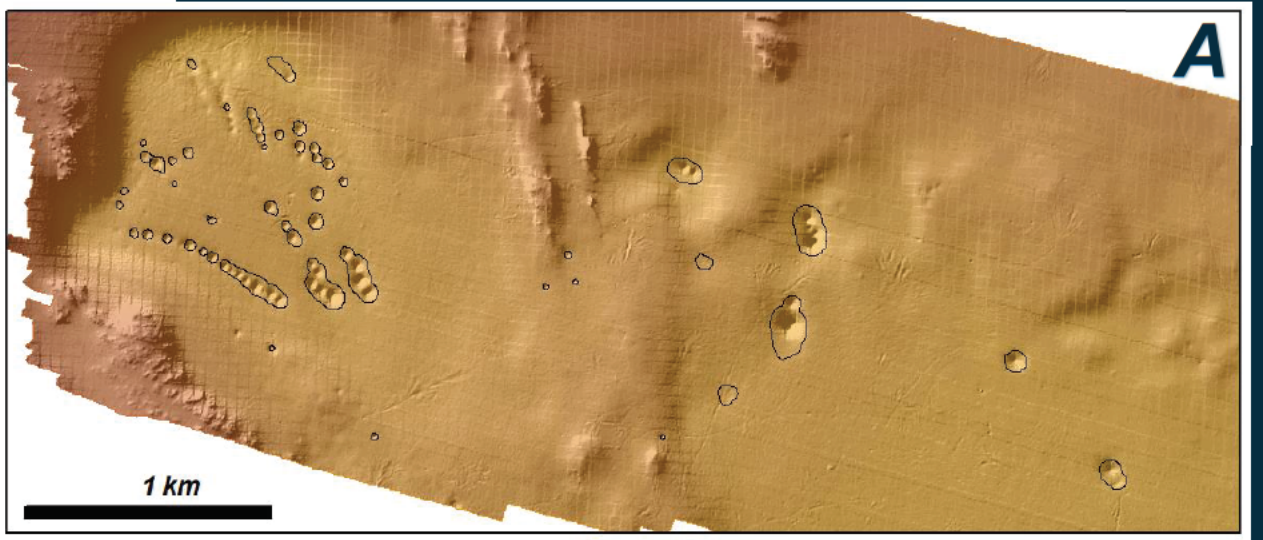
Twelve morphological characteristics are captured in the table of attributes of the output shapefile, allowing the statistically analysis of these features.

The attribute table contains the following fields:
1) Area, 2) Perimeter, 3) VRelief,
4) MBG_Width, 5) MBG_Length, 6) MBG_Orient,
7) MBG_W_L,
8) MinWD, 9) MaxWD, 10) MeanWD,
11) MaxSlope and 12) MeanSlope.

The Area and Perimeter describe the geometry of each delineated feature and the VRelief provides their vertical relief. The MBG_Width, MBG_Length, MBG_Orient describe the MBG envelope that contains each delineated feature. The MBG_W_L describes the MBG envelope aspect ratio. The MinWD, MaxWD and MeanWD capture the feature water depth range. The MaxSlope and MeanSlope describe the maximum and the mean slope of each feature.

Area A

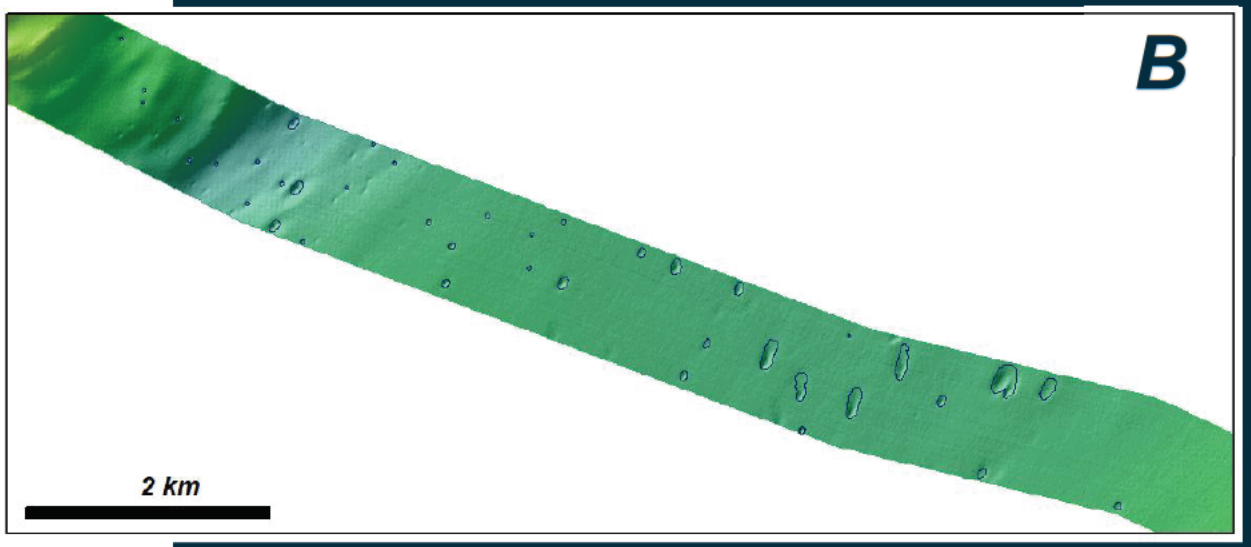
- The script mapped 45 depressions deeper than 15 cm
- 4 of these depressions correspond to pockmark chains (*i.e.* a sequence of pockmarks that are connected due to its geographic proximity). The longest of the pockmark chains is comprised of 7 individual pockmarks.
- In the central zone of the area A, there is 3 pairs of pockmarks that are joined delineated.
- At least 9 potential pockmarks were not delineated using the chosen thresholds.



	Min	Mean	Max
Area (m^2)	208.3	4031	27505
Vertical Relief (m)	0.19	1.98	6.11
Width (m)	20	47.97	147.8

Area B

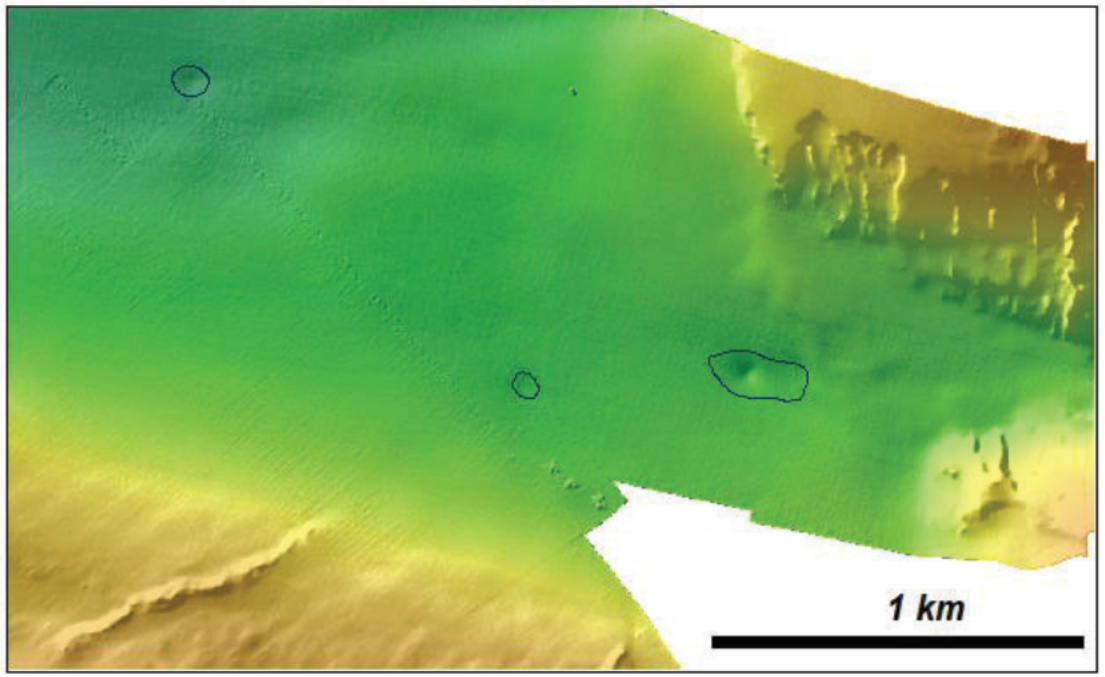
- The script mapped 40 depressions deeper than 15 cm
- At least 12 potential pockmarks were not delineated using the chosen thresholds.
- These features, mainly located in the deepest area, could potentially be mapped by changing the threshold used. However, that would have implications to the other areas with more complex topography and more frequent artefacts.



	Min	Mean	Max
Area (m^2)	376	5325	38961
Vertical Relief (m)	0.16	0.58	1.73
Width (m)	20.7	52.7	193.5

Area C

- The script mapped 3 depressions deeper than 15 cm
- The biggest of the three pockmarks in this area provides a good example of the difficulty to define the edge of pockmarks. It can be consider that the area of this feature is being overestimated by delineating it based on 15 cm below surrounding seabed. In case, a higher *Cut-off Vertical Relief* could provide an more accurate delineation.

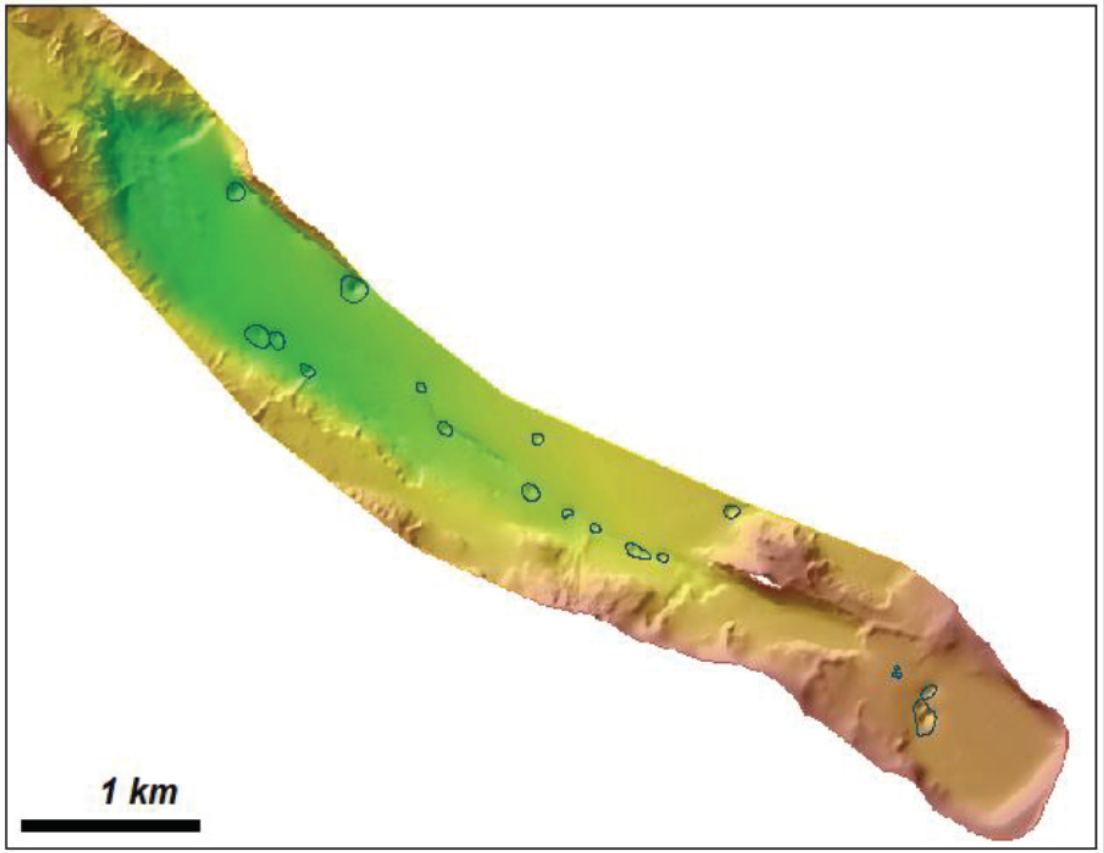


	Min	Mean	Max
Area (m^2)	3575	12063	26356
Vertical Relief (m)	0.45	1.54	3.25
Width (m)	59.7	87.8	123.7

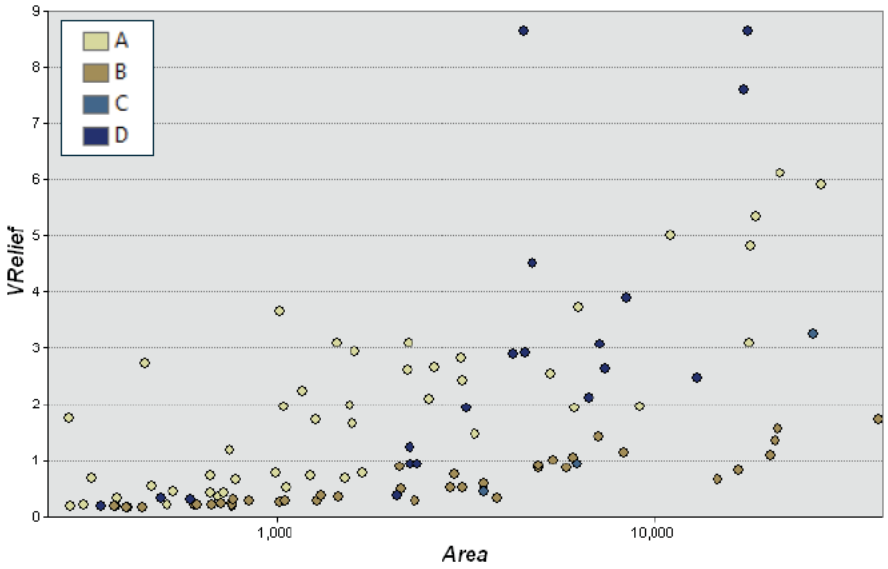
Area D

- The script mapped 19 depressions deeper than 15 cm
- Only a few potential small pockmarks were not delineated using the chosen thresholds.
- The biggest feature delineated in this area is comprised of two joined pockmarks. For the purpose of the mapping (*i.e.* delineating areas of seabed modify by processes associated with fluid flow) its correct to delineate as one complex feature. However, if the intent would be to localize points of potential seepage, this feature would have to be split.

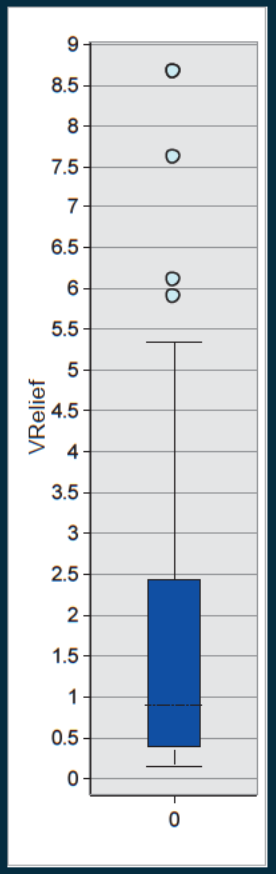
	Min	Mean	Max
Area (m^2)	343	5748	17606
Vertical Relief (m)	0.19	2.92	8.65
Width (m)	20	67	137

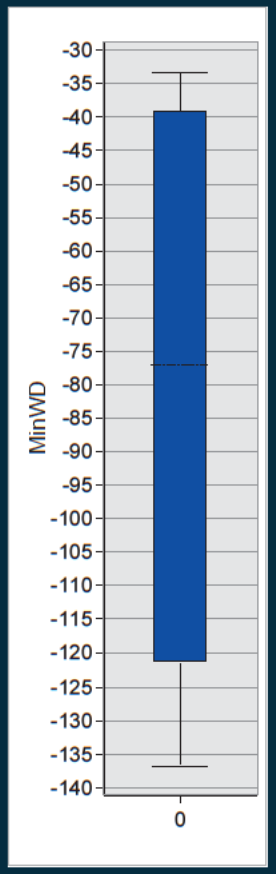


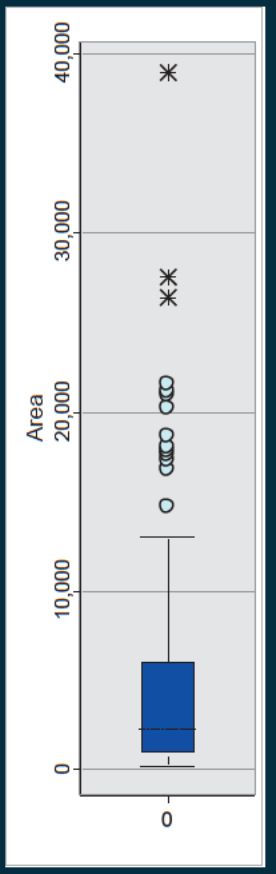
All areas



	Min	Mean	Max
Area (m^2)	208	5035	38961
Vertical Relief (m)	0.16	1.62	8.65
Width (m)	20	67	137

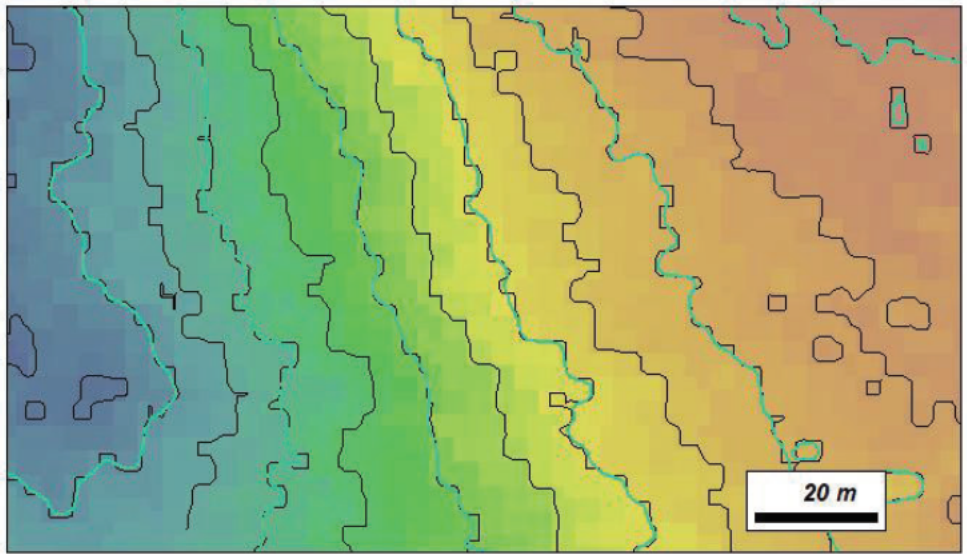






NOTES

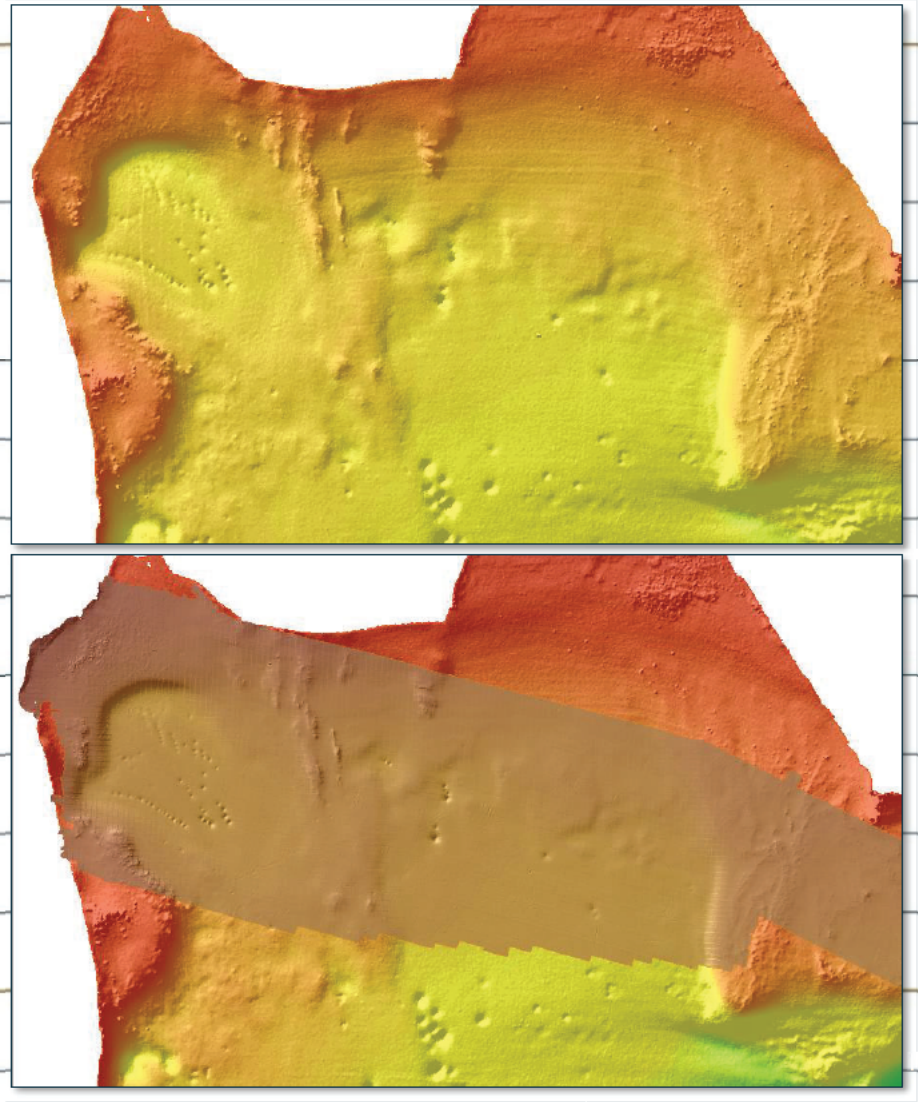
- *The cell size was impacting on the geometry of the delineation with the marked steeps - Black Contour Lines.*
- *To minimize that effect the delineation was based on a smoothed and resampled (cell size =1m) raster - Blue Contour Lines*



- *However, the characteristics of the pockmarks (e.g. Vertical relief) were extracted directly from the raster provided at 2 m resolution.*

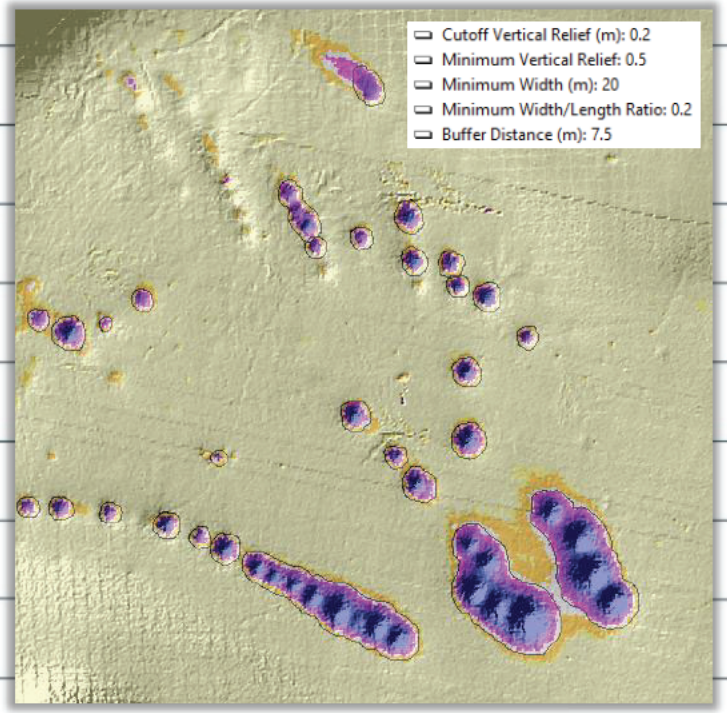
Possible further work

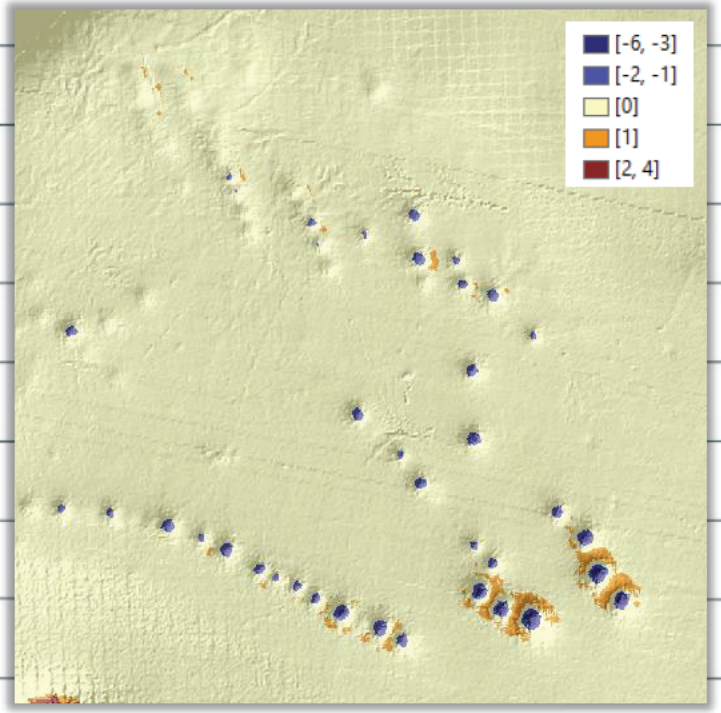
- *The 2 m resolution dataset offers a visible improvement to the publicly available datasets .*
- *However it would be relevant to quantify the improvement by running the same approach to the previous dataset and assess the difference particularly on:*
  - *number of features mapped*
  - *the vertical relief measured*



Possible further work

Use a BTM derived layer to delineate the individual seepage point.





References

Related work using the same toolbox

Geomorphometric characterization of pockmarks by using a GIS-based semi-automated toolbox
Geosciences 8.5: 154, 2018

Using novel mapping tools to predict the small scale spatial distribution of cold-water coral framework in the Mingulay Reef Complex (Outer Hebrides, Scotland)
Coral Reefs 36, 255–268, 2017

Geological Investigation of Pockmarks in the Braemar Pockmarks SCI and Surrounding Area
Joint Nature Conservation Committee, 2015

Geological Investigation of Pockmarks in the Scanner Pockmark SCI Area
Joint Nature Conservation Committee, 2015

Semi-automated characterisation of seabed pockmarks in the central North Sea
Near Surface Geophysics 10(4):303 – 314, 2012

emi-automated characterisation of seabed pockmarks
the central North Sea

Gafeira*, D. Long and D. Diaz-Doce

sh Geological Survey, West Mains Road, Edinburgh EH9 3LA, UK

ived May 2012, revision accepted May 2012

ABSTRACT

Pockmarks are indicators of focused fluid seepage, most notably gas such as methane, and can oc in vast numbers in many marine and even in lacustrine environments. The presence and distribu of pockmarks need to be considered in the development of any infrastructure at the seaf However, manual mapping of these features can be extremely time-consuming and it is inaptic subjective.

An extensive area in the central North Sea, where the seabed comprises a thick sequence of m sand/sandy muds of the late glacial Witch Ground Formation, shows numerous inactive pockma typically 20-100 m in diameter and 3-4 m deep. Within this area a few larger, active pockmarks, 50 diameter and up to 17 m deep are known. Modern site investigations in this area regularly incl multibeam sonar mapping, a technique that collects large volumes of bathymetric data that can used to produce digital depth models of the seafloor with sufficient resolution to characterize i vidual pockmarks.

This paper presents a semi-automated method to recognize, spatially delineate and characte morphometrically pockmarks at the seabed. The method comprises two scripts, Pockmark Morp and Pockmark Characterization , that allow the systematic application of a sequence of well defi tools available within the ESRI ArcGIS toolbox. Almost 4150 pockmarks were mapped apply this method to 18 selected site surveys across the central North Sea. The mapping and morpho ric characterization of such vast number of pockmarks allows the identification of certain fac reflecting the hydrodynamic regime, whereas the pockmarks density and spatial distribution app to be attributable to differences in shallow gas availability and deeper geology controlling f migration pathways.

RODUCTION

marks were first reported by King and Maclean (1970) off- e Nova Scotia, Canada. They suggested that gas and/or water the underlying bedrock was released in sufficient quantities ot fine grained material into suspension where it can drift r from venting point thereby forming a void or pockmark in seabed sediments. Since then pockmarks have been found in lakes and estuaries, on open shelves and in deep oceans. hin the UK, pockmarks were first discovered in 1970 by a rig survey in the Forties Field in the North Sea. This area, the h Ground Basin, is the primary location of pockmarks on UK continental shelf (Hovland and Judd 1988). As well as g identified on the surface, buried pockmarks close to seabed also been noted in the Witch Ground area. It is thought that varied pockmarks formed during a short period of increased mark eruption frequency around 15,000 years ago, coincid- with a rapid rise in marine temperatures (Long 1992).

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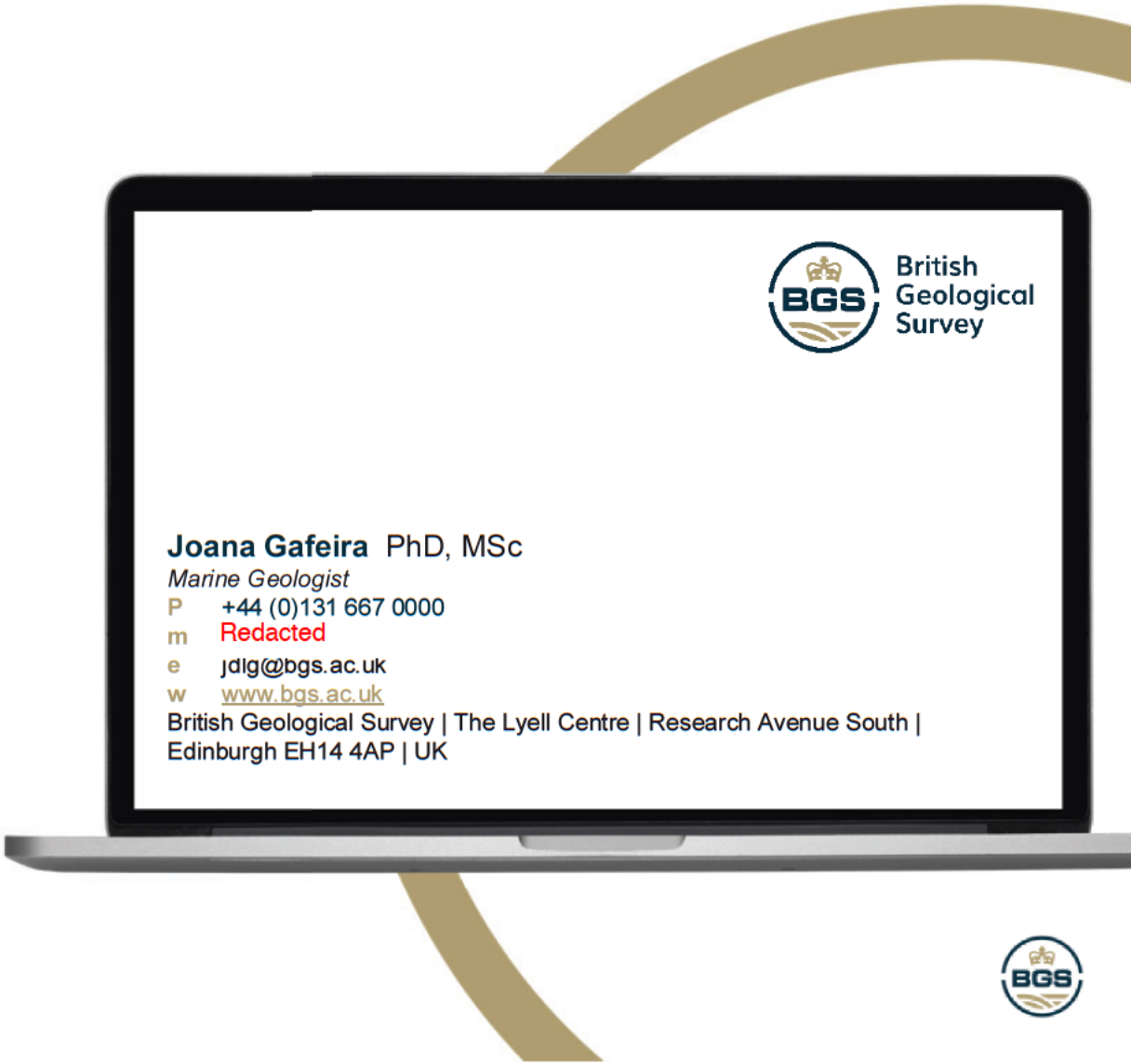
Pockmarks within the UK are typically 100 m diameter a few metres deep and are usually restricted to muddy sedime Only a few are larger with diameters greater than 250 m depths greater than 10 m. These larger pockmarks show sign active gas seepage such as bubbles in the water column ab and acoustic blanking below in seismic profiles. They often show evidence of carbonate cementation of the seafloor (Hovl and Judd 1988) which can create a distinct seabed habitat some have been nominated for protection under the Europ Habitats Directive (JNCC 2011). These carbonates, metha derived authigenic carbonate (MDAC) are formed when meth is oxidized anaerobically by a microbial consortium of arch and sulphate reducing bacteria (Boetius et al. 2000). Grain the normal seafloor sediments are bound by carbonate cem (typically $CaCO_3$) where the carbon is derived from the methe

POCKMARK MAPPING

Profiling data such as echosounder or high resolution seis (chirp, boomer and sparker) will display pockmarks on the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