British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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Department for Environment Food and Rural Affairs

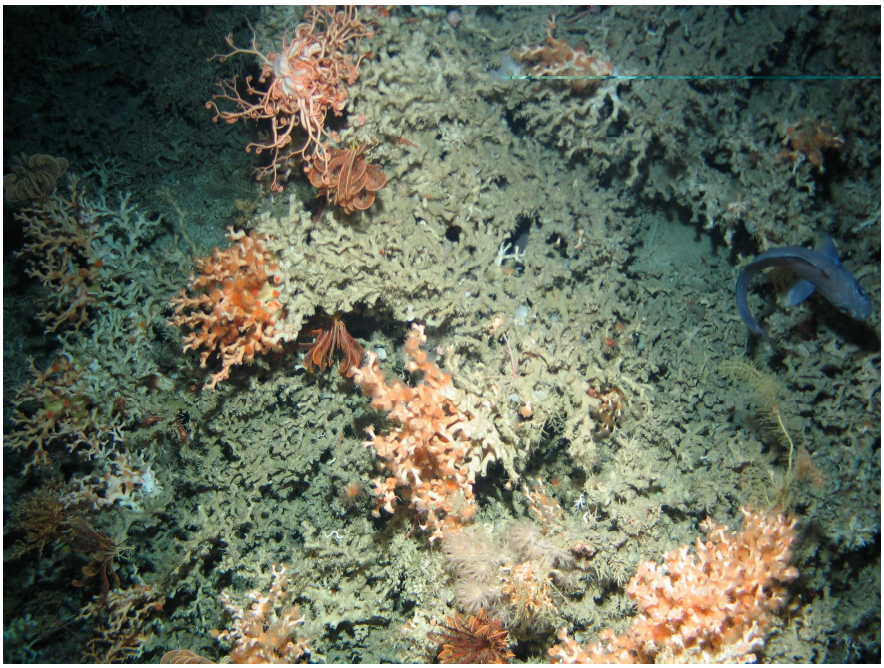
Habitat investigations within the SEA7 and SEA4 areas of the UK continental shelf

(Hatton Bank, Rosemary Bank, Wyville Thomson Ridge and Faroe–Shetland Channel)

Marine, Coastal and Hydrocarbon

Programme Commissioned Report

CR/07/051 N



BRITISH GEOLOGICAL SURVEY

MARINE, COASTAL AND HYDROCARBON PROGRAMME

COMMISSIONED REPORT CR/07/051 N

Keywords

acoustic backscatter, multibeam, bathymetry, Hatton Bank, Lyonesse, Rosemary Bank, Wyville Thomson Ridge, Faroe–Shetland Channel, cold water coral, SEA4, SEA7, seamount, conservation.

Front cover

Biogenic reef on Hatton Bank comprising a framework of both live and dead *Lophelia pertusa* with a diverse range of other corals.

Bibliographical reference

STEWART, H A, AND DAVIES, J S. 2007. Habitat investigations within the SEA7 and SEA4 areas of the UK continental shelf (Hatton Bank, Rosemary Bank, Wyville Thomson Ridge and Faroe–Shetland Channel). *British Geological Survey Commissioned Report*, CR/07/051. 85pp.

Habitat investigations within the SEA7 and SEA4 areas of the UK continental shelf

(Hatton Bank, Rosemary Bank, Wyville Thomson Ridge and Faroe–Shetland Channel)

H A Stewart[1] and J S Davies[2]

[1] British Geological Survey
Murchison House
West Mains Road
Edinburgh, EH9 3LA
hast@bgs.ac.uk
+44 (0)131 650 0259

[2] Marine Biology and Ecology Research Centre
University of Plymouth
Davy Building
Drake Circus
Plymouth, PL4 8AA
jaime.davies@plymouth.ac.uk
+44 (0)1752 232642

Edinburgh British Geological Survey 2007

BRITISH GEOLOGICAL SURVEY

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British Geological Survey offices

Keyworth, Nottingham NG12 5GG

☎ 0115-936 3241 Fax 0115-936 3488
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.geologyshop.com

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e-mail: scotsales@bgs.ac.uk

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Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF

☎ 028-9038 8462 Fax 028-9038 8461

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

☎ 01491-838800 Fax 01491-692345

Columbus House, Greenmeadow Springs, Tongwynlais, Cardiff, CF15 7NE

☎ 029–2052 1962 Fax 029–2052 1963

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Foreword

This cruise report summarises operations onboard the *M/V Franklin* during cruise 0306 on behalf of the Department of Trade and Industry Strategic Environmental Assessment 7 and the Joint Nature Conservation Committee. The survey took place between the 24th August and the 13th September 2006 surveying targets on Hatton Bank, Rosemary Bank, Wyville Thomson Ridge and the Faroe–Shetland Channel. Multibeam and photographic techniques were employed to image and map the sea bed.

Acknowledgements

We would like to thank the officers and crew of the *M/V Franklin* for their accommodation and welcome onboard and to extend our gratitude to the surveyors from Marin Mätteknik AB for their professionalism and expertise. We would also like to thank Quentin Huggett and Sally Marine at Geotek Ltd for their management, support and advice during this cruise.

Funding Acknowledgement

This project was funded as part of the UK Department of Trade and Industry's offshore energy Strategic Environmental Assessment (SEA) programme. The SEA programme is funded and managed by the DTI and coordinated on their behalf by Geotek Ltd and Hartley Anderson Ltd. Additional funds for SEA surveys in 2006 were provided by the Department for Environment, Food and Rural Affairs (Defra).

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The aims of the *M/V Franklin* 0306 Cruise were to acquire high resolution multibeam, sidescan sonar and camera data over four areas of interest: Hatton Bank, Rosemary Bank, Wyville Thomson Ridge and the eastern flank of the Faroe–Shetland Channel. These four sites were chosen based on the remit of the Department of Trade and Industry (DTI) Strategic Environmental Assessment (SEA) area 7 (Figure 1) and the requirements of the Joint Nature and Conservation Committee (JNCC) for the assessment of potential Special Areas of Conservation (SAC) under the EC Habitats and Birds Directive (Annex 1).

The work programme was highly successful with multibeam data and photographic "ground truthing" acquired at all the primary sites. The data revealed the presence of highly diverse biogenic reef present on numerous pinnacles on Hatton Bank, examples of which have never previously been recorded west of Rockall Bank (Roberts *et al.*, 2005). Extensive rocky reef was imaged on the Wyville Thomson Ridge, comprising areas of bedrock outcrop and coarse gravel with associated fauna proven during camera operations. Areas of rippled sea bed were observed on Rosemary Bank and Hatton Bank and iceberg ploughmarks were identified on Rosemary Bank and Wyville Thomson Ridge. Survey in the Faroe–Shetland Channel targeted known down-slope sediment transport channels previously identified through studies funded by the Western Frontiers Association (Bulat and Long, 2001).

Preliminary observations and interpretation of the data acquired during the course of this survey suggest that there are several sites which comply with EC Habitats and Birds Directive (Annex 1) as sites of conservation and steps should be taken to ensure their protection. Specifically, the areas of biogenic reef discovered on Hatton Bank and rocky reef on Wyville Thomson Ridge are primary sites for conservation. This is important especially with reference to the Wyville Thomson Ridge where several instances of anthropogenic debris were observed. Accurate mapping and recording of the area to the north and west of Scotland is important in balancing environmental protection and sustainable development with activities such as oil and gas exploration and exploitation, fishing, trawling and alternative energy programmes.

1 Introduction

The objectives of the *M/V Franklin* 0306 cruise were to collect high-resolution bathymetry and backscatter data over targets of interest (Figure 2) within the SEA7 (West of the Outer Hebrides) and SEA4 (West of Shetland) areas (Figure 1). These targets of interest were selected to fulfil the requirements of both the Department of Trade and Industry (DTI) Strategic Environmental Assessment (SEA) and the Joint Nature and Conservation Committee (JNCC). The work programme examines areas which have potential for conservation under the EC Habitats and Birds Directive (Annex 1, Figure 3) (Johnston *et al.*, 2002) and to balance environmental protection and sustainable development with programmes and activities such as oil and gas exploration and exploitation.

Hatton Bank is an elongate, relatively shallow bathymetric high located on the western edge of the Rockall Plateau. The western margin descends into the Iceland Basin and the eastern edge into the Hatton Basin, sometimes referred to as the Hatton–Rockall Basin. Rockall Bank forms a relatively flat plateau orientated southwest–northeast. The Rockall Trough is located to the east of Rockall Bank where water depths increase to between 1500 and 2000 m. There are three seamounts located in the Rockall Trough from south to north: Hebrides Terrace, Anton Dohrn and Rosemary Bank (Figure 2). This report is only concerned with Rosemary Bank, a broadly domal and elongate seamount with a diameter of 70km. The summit of Rosemary Bank is around 500m below sea level and boasts the presence of a number of pinnacles that stand up to 180m in height above the surrounding sea floor with the shallowest point at 316m water depth. To the south of Rosemary Bank a deep moat has been eroded around the seamount with water depths in excess of 2200m. To the northeast of Rosemary Bank the Wyville Thomson Ridge forms part of the Greenland–Scotland Ridge that extends from East Greenland to Scotland. The Wyville Thomson Ridge forms a narrow north-westerly trending topographic barrier between the Faroe–Shetland Channel and the Rockall Trough. The Wyville Thomson Ridge forms a barrier to deep water flow both northerly, flowing from the Rockall Trough and southerly, from the Faroe–Shetland Channel. Both bedrock and extensive gravel fields are present on the Wyville Thomson Ridge as a result of this varying oceanographic regime.

The first target of the cruise was to add an extra line of data to the Lyonesse volcanic centre on which multibeam and photographic data had been previously collected by the *M/V Franklin* 0206 cruise (Jacobs and Howell, 2006). Lyonesse centre, located on the eastern flank of Hatton Bank, has been identified by the JNCC as a potential deep-water reef habitat (Johnston *et al.*, 2002). The volcanic rocks of Lyonesse protrude through the younger Cenozoic sediments to form a series of peaks at sea bed (Hitchen, 2004). The additional line of data helps to better define the extent of the low structural dome of the centre.

The main area of survey was on the southern end of Hatton Bank, located to west of Lyonesse. Using existing knowledge, the programme of work in this area aimed at determining the precise shape and dimensions of biogenic and rock reef habitats in the southern Hatton Bank area. The ridges and mounds imaged previously on Hatton Bank are thought to bear a strong resemblance to features reported in the Porcupine Seabight (ICES WGDEC Report, 2005) that have proven to be bioclastic accumulations sustained by the growth of cold water corals (Masson *et al.*, 2003). The mounds on Hatton Bank are more likely to have a structural/tectonic origin resulting on upstanding features that have been opportunistically exploited by biogenic reef building fauna. Using existing data collected by the British Geological Survey (BGS) and the National Oceanography Centre, Southampton three target areas on Hatton Bank were selected for survey during this cruise.

Rosemary Bank, located in the northern Rockall Trough, is located 305km west of Cape Wrath on the UK mainland. Although Rosemary Bank is entirely covered in high-resolution

bathymetry data (Howe *et al.*, 2006), no backscatter data or photographic "ground truthing" currently exists. During the course of this cruise high-resolution bathymetry, backscatter and photographic data was collected to complement the existing multibeam dataset. Volcanic parasitic cones, mobile sedimentary bedforms, terraced flanks, iceberg ploughmarks and the moat surrounding the seamount have been studied along with their associated biological communities.

Near the end of operations the focus moved to SEA area 4 (Figure 1), an area located in the Faroe–Shetland Channel where straight sea bed channels feed sediment down-slope to fans located at the slope break between the West Shetland Slope and the floor of the Faroe–Shetland Channel. The channels are located on a broad structural anticline and modern topographic ridge and are partly underpinned by glacigenic debris flows of the Foula Apron (Bulat and Long, 2001).

2 Equipment

2.1 VESSEL

Name:	M/V Franklin	Port of Registry:	Gothenburg, Sweden
Length:	55.6 m	Beam:	11.99 m
Draught:	3.8 m	Freeboard:	2.5 m
Gross Tons:	1179	Net Tons:	353
Owner:	Shipriders AB		
	Nya Varvet Byggnad 84 Nya Varvet Byggnad 84		
	426 71 Vastra Frolunda		
	SWEDEN		
	Tel: +46 31 695280		

2.2 NAVIGATION

Vessel navigation is by DGPS using the ARON 2000 system, a navigation system developed by Marin Mätteknik AB as the primary system. All data acquisition systems took their time stamp from this navigation signal ensuring seamless positioning of every type of data collected during the cruise. The navigation system has an accuracy of better than 0.5m, exceeding requirements for this survey. The positional data was run through navigation logging and display software, with continuous QC checks being run during each watch.

The USBL navigation system is based upon the French-designed GAPS (Global Acoustic Positioning System). The system is fully integrated into the primary DGPS and has proved reliable, giving accurate fixes.

2.3 MULTIBEAM ECHO SOUNDER EM1002

The EM1002 system is designed for high-resolution sea bed mapping in water depths of less than 1000 m. The system operates at a frequency of 95 kHz and precise phase and amplitude detection provide accuracy in a variety of survey conditions and water depths. 100% data coverage was achieved through 650m line spacing on Hatton Bank and 500m line spacing on the other survey areas. Line spacing was reduced in order to optimise the backscatter data. Processing was carried out onboard and a variety of output formats was produced including the processed xyz files, ArcGIS files, Geotiffs and Fledermaus files.

2.4 SEATRONICS DROP FRAME CAMERA

The SEATRONICS drop frame system was deployed from the starboard side of the vessel. The system comprised a 5 mega pixel Kongsberg and Imenco digital stills camera, and an integrated DTS 6000 digital video telemetry system. Both video and stills cameras were mounted at an oblique angle to the sea bed to aid in species identification. Sensors monitored depth, altitude and temperature, and a USBL beacon provided exceptionally accurate position data.

3 Survey Overview

3.1 SURVEY PLAN

This survey was jointly funded by the DTI and the JNCC. Its objectives are to collect high-resolution bathymetry and backscatter data over targets of interest within the SEA7 (West of the Outer Hebrides) and SEA4 (West of Shetland) areas. The targets have been selected to fulfill requirements for both the Department of Trade and Industry (DTI) Strategic Environmental Assessment (SEA) and the Joint Nature and Conservation Committee (JNCC). The areas examined have potential for conservation under the EC Habitats and Birds Directive (Annex 1) (Johnston *et al.*, 2002) and aim to balance environmental protection and sustainable development with programmes and activities such as oil and gas exploration and development.

A list of personnel onboard for the duration of the survey are listed in Appendix 1. The British Geological Survey led team operations for this cruise and the University of Plymouth provided biological expertise. The Joint Nature Conservation Committee representative was primarily participating as an observer, however, the individual's biological expertise was a welcome asset to the cruise especially in light of the diverse biogenic reef structures identified during the course of operations.

Operations were divided between the following areas of interest: the southern end of Hatton Bank within the UK designated area, Rosemary Bank, a section of the Wyville Thomson Ridge and an area of down-slope sea-bed channels in the Faroe-Shetland Channel. Figure 2 shows the location of the areas surveyed and Table 1 the rationale behind their selection. A list of camera transects carried out is given in Appendix 2.

Table 1 – Summary of rationale behind site selection for survey 0306.

Area	Aims
Lyonesse Igneous Centre	To add one more line of data to this area which was surveyed during cruise 0206 (Jacobs and Howell, 2006).
Hatton Bank south box 1	Chosen to determine the location, distribution, shape and dimensions of Annex 1 reef habitats. Site specifically chosen to encompass a potential reef (reference number R0212) identified by the JNCC and an area of potential rock outcrop identified on existing GLORIA data.
Hatton Bank south box 2	Chosen to determine the location, distribution, shape and dimensions of Annex 1 reef habitats. Site specifically chosen to encompass an area of mounds identified in existing BGS seismic data, located on the sea bed surface and buried. This area also lies within a potential reef (reference number R0216) identified by the JNCC.
Hatton Bank south box 3	Chosen to determine the location, distribution, shape and dimensions of Annex 1 reef habitats. Site chosen based on existing data that suggested the presence of a highly variable sea bed in the area, with potential rock outcrop.
Rosemary Bank 1	This area was selected to collect data to complement an existing multibeam dataset collected during 2005. The survey area centres on a series of pinnacles on the seamount top which are

	separated by a relatively flat section of sea bed.
Rosemary Bank 2	This area was selected to collect data to complement an existing multibeam dataset collected during 2005. The survey area lies in a deeper section of the seamount top with an undulating topography and a sea-bed terrace.
Rosemary Bank 3	This area was selected to collect data to complement an existing multibeam dataset collected during 2005. The target includes a terrace identified in the existing data that may host a different fauna than the central survey area.
Wyville Thomson Ridge	The aim of survey in this small area was to confirm whether potential reef habitat could be located in an area of the ridge partially protected from deep-sea trawlers.
Faroe–Shetland Channel	This area of survey aims at examining straight downslope sea-bed channels that feed sediment down-slope to fans located at the slope break between the West Shetland Slope and the floor of the Faroe–Shetland Channel.

3.2 SUMMARY OF DAILY OPERATIONS

Please note that all times are quoted in BST unless otherwise stated.

Thursday 24th August (*Day 236*)

Whilst alongside, a safety briefing and tour of the vessel was held. The vessel sailed from Stornoway at 14:00 and transit was made to a test area at 58˚ 16.98'N, 6˚04.66'W. Arrived on site at 16:00 and began testing side scan sonar and Seatronics camera equipment.

Friday 25th August (*Day 237*)

Departed test site in the Minch at 02:00 en route to the start of the first survey line which abuts the Lyonesse survey completed during the Franklin 0206 Cruise. The start of survey line will add one extra line of data to be added to the present coverage heading west. Transit time was extended slightly due to adverse weather.

Saturday 26th August (*Day 238*)

Arrived on site at Lyonesse igneous centre at 07:45. Westerly winds 20-25 knots, moderate sea state. SVP carried out when arrived on site, SVP recovered at 08:40. Start of line at Lyonesse at 08:45. The Lyonesse line and transit line between Lyonesse and Hatton Bank south box 1 (along section of BGS seismic line 00/01-29) were completed by 15:40. Survey started in Hatton Bank south box 1.

Sunday 27th August (*Day 239*)

Continued survey in Hatton Bank south box 1. Weather has deteriorated since arrival on site. 25-30knot westerly wind with frequent 35 knot gusts, 2-4m waves and a significant swell. Bathymetric data remains good, however the backscatter data has being affected by the adverse weather conditions. Vessel speed slowed from 7 to 4 knots in order to improve data quality.

Monday 28th August (*Day 240*)

Completed multibeam coverage of Hatton Bank south box 1 at approximately 01:30, transit to area 2. Arrived on site at Hatton Bank south box 2 at 04:30 and carried out an SVP, survey commenced after recovered of the SVP. Current weather 35-40 knot westerly winds, 3.5-4m waves, vessel speed 4 knots increasing to 5 knots. First look at data gathered in Hatton Bank south box 1. Bathymetry shows relatively flat lying sea bed to the north east of the area surveyed with a significant ridge which is orientated approximately SSW-NNE which separates

this relatively flat area, with an approximate water depth of 830m, from a bathymetric low in the SW of the survey area (approximate water depth of 900m). The ridge is approximately 20-30m in height and 3 pinnacles can be observed in the data. Identified location of 4 camera transects in Hatton Bank south box 1 in preparation for improved weather conditions forecast for the 29th and 30th August. Continuing multibeam survey in Hatton Bank south box 2.

Tuesday 29th August (*Day 241*)

Weather improved sufficiently to proceed with camera transects in Hatton Bank south box 1. The wind dropped to between 10 and 15 knots and the wave height reduced to approximately 1.5m and was forecast to continue to drop throughout the day. Temporarily halted operations in Hatton Bank south box 2 at approximately 09:30 before transiting to the start of the first camera transect in Hatton Bank south box 1. Began camera operations at 12:47 (GMT, as used for camera and video footage) and completed 5 camera transects. Camera operations were completed by 23:10 (BST, 22:10 GMT).

Transects over an area of a change in backscatter response and a circular hollow revealed fairly uniform sedimentological and biological assemblages and associations (fine to coarse sand with an abundance of *ophiuroids*). Other fauna present included xenophyophores, echinoids and a few rat-tails.

However, the first and second pinnacles showed up the presence of a major biogenic reef. Rough estimates suggest continuous reef covered 1800m^2, with additional areas of patch reef covering at least the same area again. The reef consisted of a scleractinian framework (*Lophelia pertusa*) as well as a mixture of other coral groups. Coral observed included: scleractinians (*Lophelia pertusa*, *Madrepora oculata* and solitary cup corals), with several antipatharians (*Stichopathes sp, Leiopathes sp*) and gorgonians (*Callogorgia sp*). Other dominant fauna included crinoids, fish and crustaceans. Corals were observed as being up to and occasionally more than 2m in height, possibly indicating a mature reef. The ridge transect located just south of the first and second pinnacles showed a sand rich substrate with coarser sediment patches, again with abundant *ophiuroids* present. This transect crossed the flanks of the third pinnacle which is less prominent than the first two to the north showed the presence of corals in more of a "patch reef" environment.

At the end of camera operations the vessel proceeded back to Hatton Bank south box 2 in order to continue the multibeam survey.

Wednesday 30th August (*Day 242*)

Continuing operations in the Hatton Bank south box 2. Initial processing of data gathered before suspension of activities (to carry out camera work in area 1) shows the complex topography of the sea bed. A number of slightly elongated hollows, varying in depth from 25 to 40m, are orientated in three roughly E-W lines. These hollows are encompassed in an area of low backscatter, which may indicate slightly coarser sediment or indeed outcrop within the depressions. Multibeam collection was completed in the area by 18:00 and 4 camera transects have been chosen based on the processed bathymetric and backscatter data. Deteriorating weather caused by a low pressure system located to the south of our current position means that camera work cannot be carried out at this time. Therefore we shall continue multibeam data acquisition in Hatton Bank south box 3. Operations in box 3 were started by 19:30.

Thursday 31st August (*Day 243*)

Multibeam data collection continued in Hatton Bank south box 3, the southern most of the survey areas. By early evening the weather conditions had eased sufficiently to allow camera operations to start in survey Box 2. Multibeam survey was halted in Box 3 and the vessel arrived on site for the first camera transect by 19:55. Two camera transects were completed before the weather deteriorated, halting camera operations. Camera work ceased at 22:50 (GMT) and the vessel returned to Hatton Bank south box 3 to continue multibeam data collection.

The two sites visited revealed diverse coral reefs with abundant sponges and tall sea fans, which were more abundant than observations made at the three pinnacles in Box 1 revealed. The fauna observed at these locations are on the whole different from that observed before. Interestingly, basket sponges (probably *Gorgonocephalus sp.*) and many more fish species were observed at these two locations. The biogenic reefs consisted of a *Lophelia pertusa* framework with a diverse range of other corals, including: other scleractinians (*Madrepora oculata*, solitary corals (probably *Caryophyllia sp.*)); a number of bamboo corals (probably *Acanella sp., Isidella sp.* and *Keratoisis sp.*); antipatharians (*Stichopathes sp.*) and a possible encrusting octocoral growing on the *Lophelia*. Other fauna that was characteristic of this habitat were bryozoan, fish, soft corals, crinoids (at least 2 species), sponges (including *Aphrocallistes* glass sponges) hydroids, ascidians and echoinds (*Echinus sp*). The reef was bordered by patch reef with less abundant but similar fauna as to that found on the reef. The winch driver observed that the current seems a lot stronger at this location than observed at the three pinnacles, as it can be felt tugging at the camera frame at/near sea bed. Cobbles and boulders observed appear basic in composition. Away from the pinnacles where these transects started, "patch reef" seems to extend for some distance on the surrounding, relatively flat lying, sea bed. Again this was not observed at the three pinnacles (Box 1) where the coral reef was restricted to the topographic highs. More sponges are observed on the surrounding sea bed coinciding with occurrences of cobbles/boulders on coarse sand, and no rock outcrop is visible. Where cobbles/boulders are absent, the sea bed generally comprises medium- to coarse-grained sand with stalked crinoids.

On completion of the two camera transects it was decided to return to Hatton Bank south box 3 to complete multibeam acquisition as the next weather window is not forecast until Saturday 2nd September.

Friday 1st September (*Day 244*)

Multibeam data acquisition continues in Box 3. The weather deteriorated significantly during the early hours of the morning resulting in a confused sea state and winds in excess of 35 knots. Data collection suffered as a result so we reduced the line spacing to 550m to improve data quality. During the day the wind decreased steadily and the wave height followed suit although the wave height in early afternoon remained in excess of 3m.

A preliminary overview of the multibeam data collected in this area reveals a gently sloping sea bed with no obvious features of interest.

Saturday 2nd September (*Day 245*)

Multibeam data collection in Box 3 was completed by 07:00. Weather improved allowing camera work to resume in Box 2. Arrived on site at circular hollow transect at approx 08:20.

HS3_3 circular hollow transect revealed a highly rippled sea bed comprising medium- to coarse-grained sand and occasional cobbles/pebbles. This continues down into the hollow and a change is not observed until the sea bed begins to rise as the far edge of the hollow is reached. Little epifauna was evident within the sand habitat, cobbles, boulders and possible bedrock can be observed at the lip of the hollow with abundant erect sponges and encrusting fauna. Cobbles, boulders (and bedrock) appear basaltic in composition.

HS3_4 transect begins at the base of a set of terraces in the west section of the multibeam area. At the base of the terraces in water depths of approximately 950m sponges are found anchored to ?basaltic boulders. As the transect continues east the sea bed comprises generally coarse sand. As the first scarp/terrace is crossed an outcrop of bedrock in excess of 4-5m in height is crossed which hosts encrusting fauna, sponges (cup and unidentified), solitary cup corals (*Caryophyllia sp*) and boulders can be observed. The slope angle here is in excess of 30˚. On top of slope, where sea bed levels out, bedrock is still visible beneath a thin covering of sand for a short distance. Continuing east along fairly uniform sea bed, coarse sediment with varying degrees of gravel/biogenic debris and encrusting fauna can be seen. An area of sponges (cup and

unidentified), solitary cup corals (*Caryophyllia sp.*) and boulders can be observed coinciding with crossing the upper scarp/terrace but unfortunately no bedrock outcrop is visible.

HS3_5 transect on an elevated area of topography in NE of area. Medium- coarse- grained sand encountered with many *ophiuroids*. This continues over most of the transect but is interrupted by patches of sandy gravel and cobbles. During the course of this transect three small areas of coral are observed, coinciding with areas of increased cobble occurrence. Coral rubble areas consisted of some live gorgonians (including bamboo corals) and antipatharians, including *Stichopathes sp.*, possibly *Bathypathes sp.* Additionally *ophiuroids* are very abundance throughout the sand habitat.

The camera transects are completed by 16:00, and the vessel begins transit to Rosemary Bank. Transit should take between 20 and 24 hours.

Sunday 3rd September (*Day 246*)

Continuing transit to Rosemary Bank, estimated time of arrival 13:35. Arrived on site at Rosemary Bank by 14:00 and the side scan sonar is deployed by 15:30 for calibration and checks. Following successful checks on the data the vessel heads for the start of the first line. Unfortunately very soon into the first line the winch malfunctions and the line must be aborted while the vessel turns south towards deep water.

The winch fault cannot be fixed before consultation with SEATRONICS engineers in Aberdeen. The winch was able to recover the 1400m cable and tow fish currently out after tension was taken off the cable by slowing be vessel to <3knots.

Monday 4th September (*Day 247*)

Fish recovered and GAPS switched off by 00:35. Decided to return to the start of the first line and continue with multibeam data acquisition. Collecting high quality backscatter data in lieu of side scan sonar data will aid in camera site identification.

Tuesday 5th September (*Day 248*)

Continuing multibeam survey on the top of Rosemary Bank (Rosemary 1). The area of survey currently centres on a group of pinnacles located centrally on the bank top. Good weather conditions result in high quality back scatter data to aid camera site selection. Survey area complete by 19:30. Survey begins on a second site on Rosemary Bank (Rosemary 2) slightly to the southwest of the first area surveyed in 650-980m water depth by 20:00. 12 camera sites for Rosemary 1 have been chosen from the bathymetry and backscatter data. It is predicted that camera work will take place tomorrow as the weather forecast indicates that the current period of good weather is set to continue until the weekend.

Wednesday 6th September (*Day 249*)

Continuing multibeam survey in the Rosemary 2 area. This area of survey is located to the south west of Rosemary 1 in 650-980m water depth. The multibeam survey was completed by 20:30 and the vessel has begun transit to the first of 12 camera transects in the Rosemary 1 area. Camera operations had begun by 23:00. Provisionally, 3 sites for sampling have also been selected (predicted to be collected on Thursday 7th September). It is predicted that camera work in the Rosemary 1 and 2 areas will be completed by 21:00 on Thursday 7th September.

The first transect up the northern slope of a ridge, visible in the northeastern area of Rosemary 1, revealed a sea bed comprising predominantly gravely sand with abundant cidaris. Small areas on the upper and lower slopes of the ridges also include cobbles and boulders which host *Psolus sp.* and occasional sponges and anemones. On the mid-upper slope an area of bedrock outcrop is visible. This appears to be basaltic in composition. Camera operations at this transect were completed by 00:03, and the vessel proceeded to transit to the next camera site.

Thursday 7th September (*Day 250*)

Continuing camera operations on Rosemary Bank. Camera work on the pinnacles reveal a dominantly gravely sea bed with cobbles, boulders and bedrock outcrop in places. In some areas shelly debris makes a significant contribution to the gravel fraction. Areas of relatively flat sea bed located between individual pinnacles and covering a larger area of the sea bed comprise predominantly sandy gravel and gravely sand with occasional areas of cobbles and boulders which correspond with the presence of criss-crossing linear features visible on the bathymetry and backscatter data.

Disappointingly Rosemary Bank was not as diverse as Hatton Bank appeared to be. Abundant *Cidaris cidaris* were present and many fish species such as blue mouth red fish and chimera. However the diversity of coral species as seen previously on Hatton Bank were absent. Occasional communities of coral corresponded to areas of bedrock scarps up to 6m in height and areas of boulders and cobbles. Many sponges, anemones and encrusting fauna were also identified, although again not in significant numbers.

We took the opportunity to send the camera down into the moat surrounding Rosemary Bank to the south. Water depths at this location were around 2200 m. The sea bed was highly variable, ranging from gravely sand with occasional boulders to boulders on bedrock. Areas of rippled sand were also identified on the camera footage. *Ophiura lymani*, encrusting sponges, annelid worms, echinoids and numerous fish were observed, comprising a very different fauna to that previously seen this cruise.

Friday 8th September (*Day 251*)

Began multibeam data collection in the Rosemary 3 area. Completed survey and spent 3-4 hours deploying and recovering the camera winch due to a fault winding the winch back on following the deep camera dive to the moat surrounding Rosemary Bank. While this was happening the Rosemary 3 data was processed and 2 camera transects were chosen. The camera transects in a trench located at the base of a terrace and down part of the terrace slope were completed by 16:45. The camera was recovered and the vessel began transit to Ullapool where we will collect a new 3000 m winch from SEATRONICS.

Saturday 9th September (*Day 252*)

Arrival in Ullapool at 10:00. SEATRONICS engineers onboard to fit the winch from 22:00 to 23:00.

Sunday 10th September (*Day 253*)

Departed Ullapool at 02:30 and commenced transit to the next area of survey located on the Wyville Thomson Ridge. Arrived on site at the Wyville Thomson Ridge by 13:00, carried out a SVP and commenced multibeam survey on the Wyville Thomson Ridge by 13:45. An approximate 2.5 knot surface/near surface current is experienced during survey operations which does influence the vessel's heading but is not a problem for data acquisition. However, this will need to be taken into consideration for potential camera operations.

Monday 11th September (*Day 254*)

Problems encountered with the Gyro, probably related to a power cut the ship experienced on the evening of Monday 4th September. Gyro engineer recommended a restart of the Gyro which was carried out at 08:00. It took approximately 2-3 hours for the Gyro to come back on line following the restart. That time was spent processing the multibeam data collected in the Wyville Thomson Ridge area and identifying two camera transects.

Interestingly the data showed what appear to be iceberg ploughmarks on the top of the ridge and several breaks in the slope down into an incision between the West Shetland Shelf / Hebridean Shelf and the Wyville Thomson Ridge, the area targeted for survey. The camera work reveals a gravely sea bed with abundant cobbles and boulders which host several encrusting fauna,

sponges, anemones and small soft corals. Slightly larger corals (mainly *Madrepora oculata*) were observed in the deeper areas of the slope. Several examples of fishing ropes and cable were observed on the upper slopes (water depths between 460 and 560 m).

Camera work was completed by 17:30 and the vessel began transit to site in the Faroe–Shetland Channel.

Tuesday 12th September (*Day 255*)

Arrived on site approx 03:40 and began multibeam data acquisition following carrying out a SVP. Multibeam data acquisition was completed by 10:30 and the sidescan sonar was deployed. The sidescan sonar was tested and discovered a problem with the winch and transponder. Time spent trying to rectify this problem before recovering the sidescan in order to change to the responder. Unfortunately these problems have meant that no sidescan sonar data acquisition could take place. Time is spent trying to ensure that sidescan operations can be undertaken on the next cruise. Additional multibeam data has been acquired over the down-slope channels and the sediment lobes on the upper slope.

Wednesday 13th September (*Day 256*)

Operations in the survey area were completed by 01:35, the vessel began transit to Lerwick, Shetland Isles. The vessel docked in Lerwick at 10:50. Following the handover meeting between the scientists and surveyors of cruise 0306 and 0406, survey operations were then completed.

4 Observations and Preliminary Interpretations

The following chapter describes the initial interpretations and biological observations made during operations for cruise 0306. Each section describes the general morphology and geology of individual survey areas followed by a more detailed assessment of camera and video transects and their interpretation in terms of the geology and biology. Exceptions to this format are the Lyonesse igneous centre and Hatton Bank south box 3 where no camera operations took place.

4.1 LYONESSE IGNEOUS CENTRE AND TRANSIT LINE TO HATTON BANK SOUTH BOX 1

Lyonesse is centred on 57º58'N, 17º40'W and forms part of the south-eastern end of Hatton Bank, marked by a bulge in the bathymetry. As described in Jacobs and Howell (2006) the igneous centre forms a gentle dome crowned by numerous pinnacles which stand 100-140m above the surrounding sea floor. As described in the 0206 cruise report (Jacobs and Howell, 2006) the pinnacles/mounds located on the top of Lyonesse vary in diameter between 1 and 5 km and are slightly elongated in an east-west direction. The additional line of data, collected as part of this cruise, extends the current data coverage to the south (Figure 4). The bathymetric data shows water depths increasing to the south, west and east, coinciding with the slopes of the domed igneous centre. As shown by the combined image, the sea bed is relatively featureless in the west of the area, continuing along the transit line heading towards Hatton Bank south box 1.

Existing work by the British Geological Survey suggest that the Lyonesse volcanic centre, along with Sandarro, are latest Paleocene to earliest Eocene in age (Hitchen, 2004). The low volcanic dome is covered by a thin veneer of younger Cenozoic sediments through which igneous rocks outcrop, forming the pinnacles identified during the 0206 and 0306 multibeam surveys. Lyonesse, along with other large igneous centres in the Hatton–Rockall area, are responsible for erupting the widespread Palaeogene basalt found throughout the area.

No additional camera work on Lyonesse was carried out during the course of the 0306 survey. Please consult Jacobs and Howell (2006) for an overview of the biological observations from the Lyonesse igneous centre obtained during the 0206 survey.

4.2 HATTON BANK SOUTH BOX 1

The sea floor in Hatton Bank south box 1 comprises three distinct areas (Figure 5). The northeast of the survey area comprises relatively flat lying sea bed ranging in depth from 835-840m, deepening towards the southwest. The southwest of the survey area forms a distinctive area of low bathymetry where a maximum water depth of 900m is achieved in two circular hollows. The surrounding sea floor in this south-western area ranges in depth between 900 and 885 m.

The most interesting feature in the survey area is that of a ridge which effectively separates the relatively flat lying north-eastern and south-western areas. The ridge is approximately 5.5km in length, 1.5km in width, 20m in height and orientated NNW-SSE (58º01.46'N, 18º48.32'W; 58º04.16'N, 18º45.30'W). The bathymetric data shows that three distinct pinnacles or mounds exist on top of the ridge (58º03.99'N, 18º45.52'W; 58º03.79'N, 18º46.06'W; 58º02.96'N, 18º46.55'W). The northern most two pinnacles stand approximately 35m above the height of the ridge (Figure 5). The southern most pinnacle stands approximately 20m above the ridge. At the northern end of the ridge a slight dip in the sea floor separates this ridge from a broad bathymetric high to the northwest approximately 20 km in width and length.

4.2.1 Geology

Camera transects within this area revealed a sea bed comprising mainly medium- to coarse-grained sand with an increasing percentage of gravel found on top of the ridge and on the slopes of the pinnacles. Cobbles and pebbles observed on the video and photographs appear basaltic in composition and are probably derived locally from the underlying bedrock. On the slopes of the pinnacles, the gravel element of the sea-bed sediments was composed of biogenic material derived from the biogenic reefs located on the pinnacles (Figure 6). Camera transect HS2_1, in the northeast of the area was chosen based on the acoustic backscatter response (Figure 7). The transect aimed to determine whether there was a change in sea-bed composition which was reflected in the backscatter response. The data revealed the area to comprise muddy sand with no significant change in sea-bed composition. The reason for the change in acoustic response may be related to a change in orientation in ripples on the sea bed, although this cannot be either confirmed or rejected using the data available.

Disappointingly, no bedrock outcrop was discernable from the camera transects in the area. The acoustic backscatter response implied that the pinnacles and ridge comprised bedrock at sea bed. However, transect HS2_2 crossing the northern most pinnacle, HS2_3 over the ridge and HS2_4 over the middle pinnacle, failed to image bedrock at sea bed. The high acoustic backscatter response may be due to the presence of biogenic reef coupled with the probable occurrence of bedrock beneath a thin veneer of medium- to coarse- grained sandy sediment on the three pinnacles (Figure 8). As an additional note in support of this, it is suggested the biogenic reef would most likely be anchored to a hard substrate such as bedrock, rather than unconsolidated sediment.

Widespread Palaeogene lavas cover much of the Hatton Bank area, although several areas have been mapped which are devoid of lava (window). Seismic data present over these basalt-free areas image dipping seismic reflectors indicative of sedimentary strata, suggested to be Upper Paleozoic–Mesozoic in age (Hitchen, 2004). Currently, there are no known basalt-free areas coinciding with the Hatton Bank south box 1 survey area. Existing seismic data show the presence of basalts at sea bed extruded from either local volcanic centres such as Lyonesse or the incipient spreading axis to the west. Therefore it is suggested here that Hatton Bank south box 1 comprises basalt beneath a thin veneer of sediments with the pinnacles comprising coral communities anchored to basaltic bedrock (Figure 9).

4.2.2 Biology

HS_2_1

The target was an area with a change in backscatter response (box 1). The tow revealed one continuous habitat of medium muddy sand, with bioturbation seen throughout (urchin tracks and large U-shaped depressions). The transect began on a slightly rippled sea bed, and as the transect neared the end there was an increase in ripple intensity. The faunistic assemblage was generally consistent throughout; with an abundance of xenophyophores and small ophiuroids (sp 1). Other fauna regularly encountered were echinoids (3 species) and fish: *Chimera monstrosa*, grenadiers (probably *Coryphaenoides rupestris*) and eel-like fish (possibly *Lycodonus flagellicauda*). (Figure 10).

HS_2_2

The target was the Northern pinnacle (box 1), with an approximate elevation of 35m above the ridge (the ridge sits 20m above sea bed). The video track began at the base of the pinnacle with an area of medium-grained sand substrate with few conspicuous epifauna other than small ophiuroids (sp 1). The substrate then gradually changed to coarser-grained sand with organic debris, and abundance of epifauna increased with the presence of xenophyophores and fish: grenadiers (probably *Coryphaenoides rupestris*) and eel-like fish (possibly *Lycodonus flagellicauda*). The camera then passed over a brief area of pebbles and cobbles with biogenic

debris, covering approximately 20% of the sea bed. Little epifauna were observed within this area, with the exception of a few anemones and a large unidentified coral (possibly a Stylasterid). As the camera continued it encounters a medium- to coarse-grained sand substrate with some biogenic debris coverage. Conspicuous epifauna included xenophyophores, unidentified fish (due to camera elevation) and a few cup corals (*Caryophyllia sp.*). The sand gradually became more gravely before changing into a biogenic gravel (predominantly coral) habitat, covering approximately 75% of the sea bed, with little visible epifauna. As the camera continued up the flanks of the pinnacle it crossed a brief cobbled area covering approximately 25% of the sea bed with lumps of the scleractinian coral *Lophelia pertusa* visible, although little other epifauna were observed. As the camera proceeded along the tow, the cobbled area graduated into an area of coral rubble with some cobbles and biogenic gravel, covering between 50 and 80% of the sea bed; conspicuous fauna observed were fish. As the camera neared the summit of the pinnacle a biogenic reef, with a typical dead *Lophelia* framework (50-100% coverage) edge was evident, which also had live *Lophelia pertusa*, gorgonians, crinoids and hydroids. As the camera transversed the reef, the framework became a more structured reef (covering 100%) with a diverse assemblage of corals, crinoids, echinoids and other fauna. In addition to the *Lophelia pertusa* framework, the reef consisted of a diverse mixture of corals (live): scleractinians (*Madrepora oculata and cup corals - Caryophyllia spp.)*; gorgonians, including Bamboo corals (probably *Keratoisis sp.*); soft corals; corkscrew-shaped antipatharian coral (*Stichopathes sp.*) and a purple encrusting octocoral were abundant on the *Lophelia*. Other conspicuous fauna were asteroids (*Peltaster placenta* and *Henricia sp.)* pencil urchins (*Cidaris cidaris*), ascidians, *Galathea sp.*, sponges (blue encrusting sponges and globose sponges) and fish (although unidentified due to difficultly with observation). Other less frequently observed fauna included antipatharians (possibly *Parantipathes sp.*). The reef continued as the camera transverse the edge of the pinnacle summit and on down the pinnacle flanks. As the camera continued to descend down the flank of the pinnacle, *Lophelia* framework with a rubble boarder was encountered again, covering between 80 and 100% of the sea bed. Conspicuous fauna included live and dead *L. pertusa*, live *M. oculata*, hydroids, sponges, solitary corals and occasional fish. The rubble graduated into an area of biogenic gravel (coral fragments) with a coverage of between 30-60% of the sea bed. Little epifauna were visible, only a few cup corals (*Caryophyllia sp.*) and fish were observed. The habitat then changed into a brief cobbles area with 5-10% coverage, with some epifauna attached to the cobbles (predominantly *Caryophyllia sp.*) and fish. As the camera progressed to the end of the transect, off the pinnacle flanks on to the moderately flat-lying surrounding sea bed the cobbles become more frequent with pebbles (40% coverage), but little epifauna were visible. Tow track with representative habitat images: HS_2_2 017, HS_2_2 023, HS_2_2 030, HS_2_2 048 HS_2_2 087, HS_2_2 093 (Figure 11).

HS2-3

The target was a ridge south of the 3rd pinnacle (box 1). The transect began on a slightly rippled coarse sand substrate. Fauna frequently observed throughout were fish: grenadiers (probably *Coryphaenoides rupestris*), eel-like fish (possibly *Lycodonus flagellicauda*) and unidentified fish; small ophiuroids (sp 1) and polychaetes. The pencil urchin (*Cidaris cidaris)* and the holothurian *Stichopus tremulus* were occasionally observed. After the camera traversed the long sand habitat it passed over a cobbles (5% coverage) habitat characterised by fish: eel-like (possibly *Lycodonus flagellicauda*), *Lepidon sp.* and other unidentified fish. Subsequently, another sand habitat was encountered, with little epifauna other than xenophyophores and the occasional pencil urchin (*Cidaris cidaris)*, holothurians (*Stichopus tremulus)* and fish. As the transect progressed along the ridge toward the pinnacle, areas of patch coral rubble with intermittent sand were present until the end of the transect. The rubble areas consisted of dead *L. pertusa* covering between 10-60% of the sea bed. These areas were characterised by live corals (including *M. oculata*) crinoids, fish and occasional echinoids. The intermittent coarse-grained sand areas were characterised by eel-like fish (possibly *Lycodonus flagellicauda)* occasional

holothurians (*Stichopus tremulus)* pencil urchins (*Cidaris cidaris)* and xenophyophores. (Figure 12).

HS2-4

The target was the summit of a pinnacle (box 1). The transect began on the summit of the pinnacle where biogenic reef (coral) covering 100% of the sea bed with a high elevation was encountered. The reef consisted of a *L. pertusa* framework (mostly dead) with a diverse assemblage of other corals, including: scleractinians (*M. oculata* and solitary corals); antipatharians, including corkscrew-shaped antipatharian coral *(Stichopathes sp.*); gorgonians (*Callogorgia sp.*); and a purple octocoral encrusting the *Lophelia*. Other conspicuous fauna included crinoids (sp 1) bryozoan, ascidians, *Porania sp.* and occasional fish. As the camera progressed down the flanks of the pinnacle on to relatively flat sea bed, the framework became less elevated and with slightly less coverage (80-95%) until it graduated into distinctive rubble (50-85%), with little visible epifauna. As the camera traversed the rubble area, it gradually became sparser (10-30%) but the faunal assemblage changed: there were live corals within the rubble, including *L. pertusa*, *M. oculata*, solitary corals, gorgonians (probably *Callogorgia sp.*) and antipatharians (*Leiopathes sp.*). The glass sponge *Aphrocallistes sp.* was also frequently observed. As the camera neared the end of the transect, the rubble changed into a broad stone habitat (5-30%), with both boulder/cobbles and pebbles on sand habitat. Typical epifauna included encrusting fauna and fish, although not highly abundant. Towards the end of the transect there were corals attached to the rocks and burrowing ophiuroids. (Figure 13).

HS2-5

The target was a hollow in box 1. The video track showed a continuous coarse-grained sand substrate habitat with gravel in areas. As the camera traversed the area, ophiuroids (sp 1) were abundant throughout, and other fauna occasionally observed were echinoids (*Echinus sp.)* fish (*Molva sp.*, *Lepidon sp.* and possibly *Lycodonus flagellicauda*) and holothurians (*Stichopus tremulus).* (Figure 14).

4.3 HATTON BANK SOUTH BOX 2

Overall, the entire area covered by multibeam area box 2 shows a general increase in water depth from northeast (around 800m) to the south (910m) and west (950m) (Figure 15). This sloping topography is punctuated by a number of pinnacles which are restricted to the northern third of the survey area and a number of bathymetric depressions located in the central section of the area. The multibeam data implies that the southern section of the area is morphologically featureless.

The most interesting features identified in the multibeam data include a number of pinnacles, for example located 57º53.33'N, 18º59.86'W and 57º51.03'N, 19º40.09'W (Figure 16 and 17), a series of hollows varying in depth between 5 and 20 m below the surrounding sea bed and terraces located in the west of the area surveyed which combined have a vertical height of over 30m (Figure 18).

Acoustic backscatter data in box 2 shows a higher backscatter response coinciding with the location of pinnacles and mounds on the sea bed and the edges of bathymetric hollows (Figure 19). The backscatter response implies that bedrock is either present at or near sea bed. A generally high backscatter area covers the central section of box 2 implying that slightly coarser sediment is present there compared to that of the north-eastern and south-western areas.

4.3.1 Geology

In the northern section of the survey area the sea-bed sediments comprise coarse-grained sand with patches of pebbles, cobbles and occasional boulders. The composition of these appears basaltic which is probably derived locally from underlying basaltic bedrock. In the vicinity of

the cobble and boulder patches, biogenic gravel contributes a significant percentage to the generally sandy sea-bed sediment.

As described in survey area box 1, the acoustic backscatter response in the vicinity of the pinnacles implies the presence of bedrock at sea bed. Again, no bedrock outcrop was seen in the camera data in the vicinity of the pinnacles. The pinnacles host biogenic reef where coarse sediment and biogenic detritus can be seen pooled between the biogenic reef fauna. However, the high occurrence of boulders and cobbles in the vicinity of the pinnacles, coupled with their apparent basaltic composition, inferred local origin and existing seismic interpretation in the area suggests that basalt is present beneath a thin veneer of sea-bed sediments.

Bedrock is however imaged in camera transect HS3_4, where outcrop coincides with the lowermost scarp. Bedrock is seen to form a wall in excess of 4m in height, resulting in the significant sea-bed feature seen in the bathymetric data (Figure 20). East of this feature in an area of abundant bathymetric depressions, rippled sea-bed sediment is observed on the surrounding sea floor (Figure 21). It is inferred here that these sediment bedforms are currently active due to strong currents experienced tugging at the camera frame during operations. On the edges of the depressions, an increase in cobbles and boulders can be observed and rock outcrop on the 'lip' of the depression (Figure 21). Unfortunately, due to encrusting fauna, it is difficult to determine the composition of the clasts and rock outcrop.

A known 'window' in the extensive Palaeogene basalt flows lies under the westernmost section of this area of multibeam (Figure 15). Where the basalts are absent either due to non-emplacement or consequent erosion, BGS seismic data image dipping reflectors considered to be Upper Palaeozoic–Mesozoic titled sedimentary rocks (Hitchen, 2004 and references therein; Stewart *et al.*, 2006). BGS boreholes 99/1 and 99/2A are located approximately 1.5km to the west of the Hatton Bank south box 2 area and have proved mid-Cretaceous mudstone (Albian) and terrestrially derived sandstones (Albian) respectively (Hitchen, 2004) (Figure 15).

4.3.2 Biology

HS3-1

The target was the northern most pinnacle in box 2. The transect began near the summit of the pinnacle, with a biogenic reef (coral) covering between 80 and 100% of the sea bed. The reef consisted of both dead and live *Lophelia pertusa* framework with a diverse range of other corals, including: other scleractinians, *Madrepora oculata* and cup corals (probably *Caryophyllia sp.*); a number of bamboo corals (probably *Acanella sp.*, *Isidella sp.* and *Keratoisis sp.*); corkscrew-shaped antipatharian corals (*Stichopathes sp.*) and possibly *Parantipathes sp.*; soft corals and a purple encrusting octocoral. Other fauna included basket stars (probably *Gorgonocephalus sp.*) bryozoan, fish (*Lepidon sp.* and *Sebastes sp.*) crinoids (at least 2 species) sponges (including the glass sponge *Aphrocallistes sp.*) hydroids, ascidians and echinoids (*Echinus sp.*). As the transect progressed down the pinnacle flanks towards the topographic low, patch coral rubble/framework was present, with less abundant but similar fauna as to that found on the reef. The rubble graduated into biogenic debris, with abundant ascidians, xenophyophores and sponges. As the flat area was traversed, the biogenic debris gave way to an area of mixed rock substrate (cobbles, pebbles and occasional boulders) with biogenic gravel infill. Epifauna were not highly abundant, with only a few species of anemones and erect sponges attached to the rocks. (Figure 22).

HS3-2

The target was a pinnacle in box two. The tow was spilt into two, the first (HS_3_2a) was an identification run on the summit of the pinnacle where the ship was stationary to allow slow movement of the camera, thus allowing better quality images that may aid in the identification. Once the identification run was complete the transect commenced from the summit of the pinnacle (HS_3_2b) to the base.

The transect (HS_3_2b) began on the summit of the pinnacle with mostly dead *Lophelia pertusa* framework with areas of rubble, and unlike the other pinnacle the coral is more low lying. Despite this, there was 100% coverage of the sea bed and a diverse array of organisms present. Conspicuous species included crinoids (sp 1) echinoids, pencil urchins (*Cidaris cidaris*) fish (*Lepidon sp.*) and corals: soft corals, scleractinians (possibly *Flabellum sp* and *Madrepora oculata*) and bamboo corals. As the traverse descended the flanks of the pinnacle towards the topographic low, the coral framework became sparser (50% coverage) with sand patches. Although fauna were less abundant within this area, still a diverse range of organisms were present. These included: corals, antipatharians (*Stichopathes sp.*) scleractinians (*Madrepora oculata*) soft corals and bamboo corals; fish (*Lepidon sp.*); ascidians, crinoids (sp 1) and the sea star *Porania sp.* As the camera continued down the flanks, the rubble gradually gave way to more distinctive patch rubble with biogenic material present. Fauna were less abundant, with the glass sponge (*Aphrocallistes sp.*) ascidians and cup corals (*Caryophyllia sp.*) dominating. As the tow neared the end (a far distance from the pinnacle) the habitat became a coarse gravel/biogenic substrate with very little visible epifauna. (Figure 23).

HS3-3

The target was a circular depression that was highlighted on the multibeam in box 2 (for location see Figure 21). The tow began on flat sea bed of rippled medium-grained sand with detritus substrate; little epifauna were visible within this habitat. As the traverse descended into the hollow, the habitat remained continuous until the base where the substrate became coarser-grained with biogenic material and graduated into a pebble habitat. This habitat was very different to that of the other habitats, with an abundance of pebbles, detritus and biogenic material. There appears to be numerous tube worms (possibly sabellids) present, as well cup corals (*Caryophyllia sp.*). As the traverse progressed out of the base of the hollow, the pebble habitat became for gravely until it gave way to a mixed rock substrate of boulders and cobbles on gravely coarse-grained sand. Conspicuous fauna were anemones (*Phelliactis sp.*) cup corals (*Caryophyllia sp.*) erect sponges and squat lobsters. As the camera neared the end of the tow (out of the hollow and onto flat sea bed) a substrate of medium-grained sand with detritus was present with very little epifauna apparent. (Figure 24).

HS3-4

The target was the terraces (scarps) of the western area of box 2. The transect began with a coarse, gravely sand area with pebbles. Fauna included abundant polychaetes and solitary corals. As the camera continued along the tow, a brief bedrock outcrop is encountered with a higher abundance of fauna, including cup corals (*Caryophyllia sp.*) and cup sponges (*Axinella sp.*). Towards the end of the transect, the habitat changed to medium-grained sand substrate with an abundance of polychaetes (sabellids), and other less abundant fauna (solitary corals, anemones and xenophyophores). (Figure 20).

HS3-5

The target was the within the northern area of box 2, this was a random tracks to see if there were any other habitats within this area. The tow began on an area of slight topographic high. Two distinct habitats were present: medium- to coarse-grained sand and coral rubble (10-30% cover). The tow began with a sand habitat which then had intermittent rubble and sand habitats throughout. Fauna present within the sand habitat were ophiuroids (sp 1) while those observed from the rubble habitat were: corals (*Stichopathes sp., Madrepora oculata* and soft corals) crinoids, pencil urchin (*Cidaris cidaris*) and glass sponges (*Aphrocallistes sp.*). (Figure 25).

4.4 HATTON BANK SOUTH BOX 3

Multibeam data collected in this area reveal a sea bed sloping gently from northeast to southwest, with water depths ranging from 865m to 930m (Figure 26). Unfortunately no

morphological features of particular interest were resolved in this area even though existing data suggested that the sea bed in this area was morphologically variable. However, the head of a channel or possible canyon was imaged in the far south of the area. The small section imaged extends from 57º31.13'N, 19º18.26'W to the southern edge of the dataset and is 25-30m in deep (Figure 27). Due to the increasing water depths and the limitations of the multibeam system onboard, the distance that this feature extends down-slope into water depths in excess of 1000m could not be determined.

Based on the multibeam data and the corresponding backscatter data, which revealed little of interest, it was decided not to carry out camera operations in this area at this time.

4.5 ROSEMARY BANK 1

The area surveyed covers a section of the top of Rosemary Bank and includes a series of pinnacles up to ~180m in height above the surrounding sea bed. The survey covers an area approximately 100km^2 and ranges from 322m water depth on the crest of the pinnacles to 520m depth in the south west of Rosemary area 1 (Figure 28).

The bathymetric data in this area reveals 6 large pinnacles, the largest of which is 180m in height. The pinnacles are separated into two groups located in the east and west of the area surveyed separated by a relatively flat sea bed 9-12km in width. The bathymetric data reveals a number of features including iceberg ploughmarks and current scour features located in the central flat lying area (Figure 29) and megaripples which can be identified on the video collected during transect RB1_8. The iceberg ploughmarks are imaged exceptionally well in the backscatter data collected (Figure 30).

4.5.1 Geology

Rosemary Bank is a seamount located in the northern Rockall Trough (Figure 2). Published data suggests that the volcanic centre was active 70 Ma (late Cretaceous; Hitchen *et al.*, 1997), and magnetic data suggests that the pinnacles represent later stages of activity (Hitchen *et al.*, 1997). The main period of volcanic activity was between 62–53 Ma (Hitchen *et al.*, 1997) although volcanism may have continued episodically on Rosemary Bank until about 42Ma (late mid-Eocene; O'Connor *et al.*, 2000; Howe *et al*, 2006).

The entire summit of the seamount is covered in medium- to coarse- grained sediment with areas of gravel, cobbles and boulders in areas of iceberg ploughmarks. Bedrock crops out at sea bed in areas of the flanks and crests of the pinnacles (Figure 31). The seamount is thought to comprise primarily basalt with localised occurrences of phono-tephrite lavas and potassium rich tuffs (Figure 32 and 33; Stoker, 1995). Strong sea-bed currents forced around the pinnacles have resulted in areas of sediment waves, or megaripples, visible on the video and camera data (observed on transect RB1_8, Figure 34).

The iceberg ploughmarks are best imaged in the backscatter dataset (Figure 30). The backscatter response indicates a change between relatively high and low levels implying a change from harder to softer substrates as the area of iceberg ploughmarks are crossed. The overall backscatter response reveals a series of criss-crossing eroded scars approximately 80-150m in width and up to 1.5km in length. Video data suggests that the change in backscatter response recorded may be related to changes from sandy gravel strips to areas of gravel and cobbles. Iceberg ploughmarks are formed by the bottom of detached sections of ice-sheet or glaciers carving patterns onto the sea bed which reflect the direction of ocean currents. Over time, bottom current activity winnows the sediment, resulting in a complex pattern of gravel, which form berms at the edges of the ploughmarks, and finer-grained sediment in the centre of the trough.

4.5.2 Biology

RB1-1

The target was a change in topography, a ridge of 40m elevation from the sea bed. The transect began on an area of flat sea bed which consisted of a coarse gravely sand with pebbles habitat (with an approximate coverage of 20-25%). The conspicuous fauna were pencil urchins (*Cidaris cidaris*) - which were abundant throughout the tow. As the video progressed up the slope of the ridge the substrate changes to a brief cobbles and pebbles area, still with *C. cidaris*, but also with anemones (*Phelliactis sp.*) and fish present. As the video continued to proceed up the slope of the ridge, an area of bedrock (basaltic) was observed – but with little epifauna visible. After the brief bedrock habitat, the substrate changed back to intermittent areas of pebbles with cobbles, and coarse-grained sand with pebbles, both with coverage of between 30-60%. Conspicuous fauna of these areas included *Cidaris* (both habitats) and *Phelliactis sp., Psolus sp.* and sponges within the cobble habitat. The transect ended at the top of the ridge with a coarse-grained sand with pebbles area, again with abundant *C. cidaris*.

RB1-2

The target was a scour (2m change in height) within the sea bed. The transect began with a medium-grained sand substrate with little epifauna other than the pencil urchin *Cidaris cidaris* and occasional *Chimera sp*. As the video progressed along the tow, a possible iceberg ploughmark was apparent, where the substrate changed to a boulders with cobbles (20-40%) on medium-grained sand habitat, with conspicuous fauna including *Psolus sp., Cidaris, Phelliactis sp.,* sponges and the blue-mouth redfish (*Helicolenus dactylopterus*). As the video crossed the ploughmark, medium-grained sand with occasional pebbles were observed, with conspicuous fauna including cup corals (probably *Caryophyllia sp.*) and abundant *Cidaris*. The camera continued to traverse the ploughmark until reaching the final habitat of the tow – medium-grained sand with abundant *Cidaris*. Other less abundant fauna includes fish and cup corals (probably *Caryophyllia sp.*).

RB1-3

The target was a pinnacle, the transect was split into three due to the sheer size of the pinnacle.

RB1-3a

The target was the summit of pinnacle 1. The transect began with a mixed substrate habitat of well rounded cobbles, pebbles and biogenic material with a coverage of approximately 80%. There were little epifauna, with the exception of occasional *Chimera monstrosa*, squat lobsters and echinoids. As the video continued along the summit, boulders appeared amongst the mixed substrate, with sponges attached to the boulders. The transect continued with mixed pebbles and cobble substrate with little epifauna until the end.

RB1-3b

The target was the upper slope of the western flank of pinnacle 1. The transect began with a coarse-grained sand with gravel and pebbles habitat. There were few conspicuous fauna, although there were an abundance of sea pens present throughout the tow. As the video continued down the flank, a brief area of cobbles was encountered which graduated into a boulder habitat; again little epifauna other than fish were seen. The transect ended with a pebble (80% coverage) with sand habitat, with little epifauna.

RB1-3c

The target was the lower slope of pinnacle 1. The transect began with a coarse gravel and pebbles habitat with a coverage of between 50-80%. Occasional boulders were also present. Little epifauna were visible; *Cidaris cidaris* and *Chimera monstrosa* were the most frequently observed fauna. As the video transversed the slope, it encountered a mixed substrate habitat

comprising boulders with cobbles and pebbles, with small sponges and little other fauna. The tow continues onto a pebbles area with few visible epifauna.

RB1-4

The target was a probable iceberg ploughmark. The transect began on a medium-grained sand and pebbles habitat with little epifauna other than *Cidaris cidaris* and *Chimera monstrosa* (which were abundant throughout the sand habitats of the tow). As the camera crossed the ploughmark, the substrate changed to a cobbles (30%) area, with abundant *Phelliactis sp.* attached. As the camera continued along the ploughmark, another sand habitat with occasional pebbles and abundant *C. cidaris* was encountered. As the video continued to cross the ploughmark, another mixed substrate area of boulders/cobbles with abundant *Phelliactis sp.* was observed. The video then crossed two more intermittent mixed substrate areas of boulders and cobbles. Sand areas were dominated by *C. cidaris* and the mixed substrate by *Phelliactis sp.* and *Psolus sp*.

RB1_5

The target was a change in backscatter. The transect began with an area of medium-grained sand substrate, conspicuous fauna included *Cidaris cidaris* and Caryophyllids, with occasional fish. As the video progressed along the transect, a broad mixed rock substrate area was encountered, ranging from pebbles to boulders. Conspicuous fauna within this habitat were the holothurian *Psolus sp.* attached to the rocks and *C. cidaris* on the sea bed. The transect continue into another medium-grained sand habitat with an abundance of *C. cidaris* and some Caryophyllids.

RB1_6

The target was a pinnacle, the transect began at the top of the pinnacle where bedrock crops out at sea bed. A number of sand patches were present on the bedrock which had very little visible epifauna. This habitat graduated into an area of pebbles and cobbles (almost 100% coverage) with little epifauna. As the video continued down the flanks of the pinnacle, a steep bedrock outcrop was encountered, and dominant fauna included *C. cidaris*, echinoids and *Helicolenus dactylopterus*. This area then graduates into a large mixed rock area with pebbles and cobbles predominantly, but also with patches of bedrock. This area was characterised by *Cidaris cidaris* and echinoids. The remaining tow had intermittent areas of pebble substrate and area of mixed rock (pebbles-boulders). Typical fauna of both substrate types were the echinoid *Cidaris cidaris* and the holothurian *Psolus sp*.

RB1_7

The target was a hollow on the northwest flank of pinnacle 2. The transect began with an abundant pebble substrate with little epifauna other than echinoid (including *Cidaris cidaris*) and blue-mouth redfish (*Helicolenus dactylopterus*). As the camera traversed the hollow, a steep bedrock outcrop with boulders was visible. Epifauna were not particularly abundant, although a large gorgonian, possible stylasterids and pennatulids were present. As the traverse moved up the steep ledge, the bedrock gave way to boulders with patches of bedrock. Conspicuous fauna were *Psolus sp.* and encrusting fauna. The remaining transect consists of intermittent mixed substrate of cobble and boulders bordered with abundant pebbles with sand. The first substrate had an abundance of *Psolus sp.* and occasional *Helicolenus dactylopterus*, whereas the latter generally had little epifauna with the exception of *Cidaris cidaris* and echinoids. As the transect neared the end, prominent mega-ripples with abundant pebbles were apparent.

RB1_8

The target was an area between two pinnacles. The transect began with an area of abundant pebbles (50%) with some biogenic material. Fauna observed throughout the tow were *Psolus sp.* and *Cidaris cidaris*. The substrate graduated into pebbles (10%) with biogenic material, with dominant fauna including *C. cidaris* and Caryophyllids. As the video continued along the transect an area of directional mega-ripples composed of pebbles was apparent. This habitat had little epifauna present. The substrate then continued to change to a broader pebble and cobbles

habitat, with slight sand ripples with an abundance of *Psolus sp.*, *C. cidaris* and the biscuit urchin *Echinus acutus*. Finally, the transect finished with another mega-ripple habitat (with pebbles), characterised by biscuit urchins.

RB1_9

The target was the top of a pinnacle, the transect began with an area of abundant pebbles (80%) with biogenic material. Little epifauna were visible with the exception of the echinoid *Cidaris cidaris*. As the transect continued, the substrate changed to less coverage of mixed cobbles and pebbles, again characterised by *Cidaris*, but also by an unidentified echinoid. As the video continued it passed another abundant pebbles habitat (100%) with typical *C. cidaris* and other echinoid species. The substrate graded into another mixed pebbles and cobbles area before reaching a mixed boulders and cobbles area, with 70-100% coverage and *C. cidaris* and *Helicolenus dactylopterus* present. The end of the tow sees a bedrock outcrop (60%) with little fauna before the final habitat: mixed pebbles and cobbles area (80-100), with typical *C. cidaris* and *Helicolenus dactylopterus*.

RB1_10

The target was a small pinnacle, beginning with bedrock substrate with biogenic in-fill (100%). Conspicuous fauna were barnacles, asteroids, holothurians (*Psolus sp.*) pencil urchins (*Cidaris cidaris*), corals (*Madrepora oculata*), and fish (*Chimera sp*). As the traverse continued, the bedrock gave way to a mixed boulder, cobbles and pebbles substrate, with 20-45% coverage. Typical fauna were holothurians (*Psolus sp.)* echinoids (*Echinus sp.*) blue-mouth redfish (*Helicolenus dactylopterus*) and ling (*Molva sp.*). As the video continued to the end of the transect a pebbles substrate (30% cover) was encountered, although with little epifauna. (Figure 35).

4.6 ROSEMARY BANK 2

The area surveyed is located slightly to the southwest of Rosemary Bank 1 covering an area 10.6km by 10.7km and ranging in water depth from 950m to 570m (Figure 28). The area covered images an area of the terraced slope of Rosemary Bank. These terraces are backed by scarps of around 130m in height and extend laterally along the south-western flank of the seamount.

4.6.1 Geology

The second area surveyed on Rosemary Bank Figure 36 comprises a relatively flat lying upper section with one pinnacle that stands 130m above the surrounding sea bed. A terrace is present in the west of the area 130m in height. The area to the west of the escarpment descends to a depth of 950m. The two camera transects carried out in this area start on the flat upper area, and travel down the terrace into deeper water. Both camera transects reveal the upper flat lying area to comprise sand with gravel made of both lithic and biogenic fragments. The proportion of gravel increases as the terrace is descended with cobbles and pebble sized clasts becoming more abundant. Bedrock is visible at sea bed near the end of each transect, coinciding with a break in slope near the base of the ‘step’. The deep water area at the far west of the area surveyed is characterised by rippled, sand dominated sea-bed sediments.

4.6.2 Biology

RB2_1

The target was a north facing slope on a terrace in box 2. The tow began with an area of mixed cobbles and pebbles, with coverage of between 50-80%. Fauna were not highly abundant, although a few decapods, holothurians (*Psolus sp.*), crinoids and encrusting fauna (blue

encrusting sponge) were observed. As the transect continued down the slope, boulders became more frequent. Fauna within this mixed substrate were encrusting organisms, cup sponges, anemones, corals (*Madrepora oculata*, *Plibothrus sp*, soft coral and what maybe bamboo coral) and fish (*Lepidon sp.*). As the camera continued to the end of the tow, a pebble habitat was encountered, with distinctive ripples and little epifauna. (Figure 37).

RB2_2

The target was a gully. The transect began with an abundant pebbles covered area (95%). Typical fauna included fish (eel-like, possibly *Lycodonus flagellicauda*), red echinoids and blue encrusting sponge. As the video passed through the gully, the proportion of pebbles increased with cobbles appearing; conspicuous fauna included encrusting sponges, holothurians (*Psolus sp.*) fish (unidentified) and corals (*Stichopathes sp.*, *Lophelia pertusa*, *Madrepora oculata* and solitary corals*)*. As the tow continued another pebble habitat was present, with the same fauna as the previous pebble habitat. A brief bedrock outcrop habitat was then encountered with mostly (although not highly abundant) corals: the corkscrew-shaped antipatharian (*Stichopathes sp*) *Lophelia pertusa* and an unidentified gorgonian. As the end of the tow was reached, the final habitat encountered was a pebble substrate with very little visible epifauna. (Figure 38).

4.7 ROSEMARY BANK 3

The area surveyed is located on the northwestern flanks of Rosemary Bank, covering an area approximately 4km by 6.5km and ranging in water depth from 820m to 980m (Figure 28). Like Rosemary Bank 2, the area covered images an area of the terraced slope of Rosemary Bank. The terrace imaged is backed by a scarp 120m in height.

4.7.1 Geology

Like area Rosemary 2, the sea bed generally comprises medium- to coarse- grained sand with an increasing proportion of gravel of comprising various lithologies as water depth increases. Transect RB3_2 reveals the sea bed to comprise sand and gravel streaks <0.5m in width in shallower water, with more gravel appearing as the end of the transect is neared (Figure 39). Sand and gravel are also present in the trench which is approximately 1.4km in width and has probably been excavated by bottom-currents. A ‘lip’ is present in the trench, comprising >10m outcrop of bedrock, probably volcanic in composition.

4.7.2 Biology

RB3_1

The quality of some of the habitat images is poor due to the topography and thus difficulty landing the camera.

The target was a trench in box 3, the transect began on the ridge where a mixed rock substrate of cobbles, pebbles and gravel was found. Epifauna were not highly abundant, although some anemones and encrusting sponges were evident. As the camera proceeded towards the edge of the ridge a brief bedrock outcrops with mixed rock substrate (boulders and cobbles) was present - with encrusting fauna. As the camera continued down the trench, an abundant pebbles habitat (90% cover) was encountered with little epifauna were visible. Towards the end of the tow the substrate graduated to the same habitat as that at the beginning (cobbles and pebbles) with some encrusting fauna and sea stars present. (Figure 40).

RB3_2

The target was a slope, the transect began at the slope edge with a mixed rock substrate (cobbles and pebbles). Directional ripples (pebbles) were dominant, indicating the presence of a strong current. Fauna present were, abundant ophiuroids (sp 1) and encrusting fauna on the cobbles.

As the camera descended the slope, the same habitat was observed, although the rock substrate was less abundant and the ripples were sand rather than pebbles, little visible epifauna other than the fish *Lepidon sp.* were observed. At the base of the slope few cobbles were present, it was predominantly abundant pebbles (90% cover); ophiuroids (sp 1) were abundant in this habitat. (Figure 41).

4.8 WYVILLE THOMSON RIDGE

The Wyville Thomson Ridge separates the Faroe–Shetland Channel to the northeast from the Rockall Trough to the south (Figure 2). The Wyville Thomson Ridge is a mid-Cenozoic inversion structure (Johnson *et al.*, 2005) that forms an oceanographic barrier, for example by forcing southwestwards flowing currents from the Faroe–Shetland Channel northwest into the Faroe Bank Channel (Boldreel *et al.*, 1998). Restrictions to current flow result in locally strong currents that re-work and re-distribute the sea-bed sediments.

As discussed previously, the area has experienced a number of glaciations. Although the Wyville Thomson Ridge, like Rosemary Bank, has not hosted an ice sheet, it has experienced intensive erosion from icebergs. These iceberg ploughmarks are clearly visible in Figure 42). The sea bed of the Wyville Thomson Ridge is predominantly composed of cobbles and boulders, both derived locally from the underlying basalt and deposited by the icebergs, and biogenic gravel derived locally from coral reef.

4.8.1 Geology

Both camera tows carried out during the 0306 survey (Figure 43) revealed the sea bed to comprise predominantly basaltic pebbles and cobbles with the occasional boulder sized clast. Occasionally a clast of a different composition was identified, although there is no way of identifying the exact composition using the remote camera (Figure 44). Basaltic bedrock is also encountered.

Biogenic gravel infill's the rough sea bed in places. The biogenic material is likely to have been derived locally from coral reef, however, there was no evidence of an existing "live" coral reef observed at this location. The amount of biogenic material visible suggests that at a significant coral reef existed previously in the area and re-working of the dead material by locally strong currents has resulted in the biogenic gravel observed.

Anthropogenic debris was identified on both camera transects (Figure 43). Although anecdotal evidence suggests that little fishing activity is carried out in this area, the presence of various ropes and cables suggests the reason this area is avoided is due to the high chance of equipment loss. Camera operations were ceased in this area due to concern over safety of the camera if it were to become tangled in the cable and rope debris.

4.8.2 Biology

WTR1_1

The target was the upper slope of a crevice. One continuous habitat of mixed rock substrate with boulders, cobbles and biogenic/ gravel infill (total coverage of 100%) occurred. Bedrock may also be present, although visibility is poor in places due to the speed of the camera – thus this is uncertain. Throughout the tow, the habitat did not significantly change, and for the most part the same was true of the faunistic assemblage. Dominant fauna were encrusting and erect sponges, hydroids, pencil urchins (*Cidaris cidaris*), anemones (possibly *Bolocera sp.*) squat lobsters and fish, including blue-mouth redfish (*Helicolenus dactylopterus*) and ling (*Molva spp.*). Stylasterids (*Plibothrus sp.*) and soft corals (*Capnella glomerata*) and were also abundant. (Figure 45).

WTR1_2

The target was the lower slope of a crevice. The tow began on an area of bedrock outcrop with cobbles. Conspicuous fauna observed were corals, including scleractinians (*Lophelia pertusa* and *Madrepora oculata*) soft coral (*Capnella glomerata*) and stylasterids (*Plibothrus sp.*). Other fauna present were squat lobsters, pencil urchins (*Cidaris cidaris*), encrusting sponges, and anemones (*Phelliactis sp.*). As the tow descended the slope of the crevice, the substrate changed to a mixed rock area with pebbles, cobbles and the occasional boulder s(75-100% cover). Epifauna included, pencil urchins (*Cidaris cidaris*) globose and encrusting sponges, anemones (*Phelliactis sp.* and unidentified) fish (*Lepidon sp.*) and corals (*L. pertusa* and *M. oculata*). (Figure 46).

4.9 FAROE–SHETLAND CHANNEL

An area 28km by 35.5km was surveyed as part of this survey operation. The area comprised a number of gullies running downslope starting in around 500m water depth Figure 47. Associated debris fans located at the base of the gullies are present at around 1000m depth. The gullies and fans are interpreted as being the products of high-energy mass flow and are restricted to this part of the Faroe–Shetland Channel (Bulat and Long, 2005). Previous images of the gullies and associated fans have been produced from 3D seismic data (Bulat and Long, 2001; 2005). The gullies are 25km in length and are up to 200m in width. Further work is necessary to determine whether these features are currently active or are relic features from a time when sea level was lower and the sediment source closer.

Iceberg ploughmarks can be identified in water depths <500m. Iceberg ploughmarks have been formed by icebergs colliding with the shelf margin and often comprise coarse sediments such as gravels, although no photographic ‘ground-truthing’ has been carried out during this survey due to time restraints. Sites were identified to be revisited during survey 0406.

5 Conclusions

Hatton Bank

The superficial sediments of the Hatton Bank South area are predominantly coarse grained sediments such as sands and gravels. The gravel often contains a significant biogenic component derived locally from coral reef located on isolated pinnacles in the area. Individual reef colonies may be separated by many kilometres of relatively barren sea bed.

Outcrops of bedrock mainly found on pinnacles on Hatton Bank provide a substrate for coral reef. The reef comprises a framework of both dead and live *Lophelia pertusa* with a diverse range of other corals, including: other scleractinians, *Madrepora oculata* and cup corals. Other fauna such as sponges, basket stars and fish are common on the colonised pinnacles.

The area of circular depressions identified in Hatton Bank south box 2 may represent an area of ?Upper Palaeozoic–Mesozoic sedimentary rock which contains a large number of igneous intrusions. Basalt underlies much of the sea bed to the northeast of box 2, box 1 and half of box 3.

Rosemary Bank

Pinnacles that stand up to 180m above the surrounding sea bed crown the summit of Rosemary Bank located in the northern Rockall Trough. Bedrock can be identified on video data collected over the summits of the pinnacles. Rosemary Bank is a seamount which was formed in the Late Cretaceous, although volcanic activity probably lasted into the late mid-Eocene.

Rosemary Bank has a terraced slope identified during this survey in water depths of between 750 and 1000 m. The terraces observed are well defined and are backed by scarps 120 to 130 m in height.

Relatively clean rippled sand is present at the base of the scarps extending onto the indicative of strong current activity around the flanks of Rosemary Bank. Areas of bedrock outcrop have also been observed near the base of the scarps.

Wyville Thomson Ridge

Iceberg ploughmarks are common on the summit of Rosemary Bank, the Wyville Thomson Ridge and in water depths <500m in the Faroe–Shetland Channel.

Extensive gravel, cobble and boulder fields are present on the Wyville Thomson Ridge. Strong currents are suggested to have winnowed the finer sediment fraction from the area. Biogenic debris is observed on the camera data, indicative of a once extensive coral community that has died and been re-worked into the sea bed sediment.

Anthropogenic debris was identified on transects WTR1_1 and WTR1_2. Although anecdotal evidence suggests that little fishing activity is carried out in this area, the presence of various ropes and cables suggests the reason this area is avoided is due to the high chance of equipment loss.

Faroe–Shetland Channel

Downslope linear gullies running perpendicular to slope in the Faroe–Shetland Channel were identified in multibeam data. Unfortunately due to limitations in the multibeam system onboard data could only be collected in <1000m of water. As a result of this the associated debris fans located at the base of the gullies in water depths >1000m could not be investigated. Therefore comparison with images from the same area derived from 3D seismic data cannot be fully undertaken.

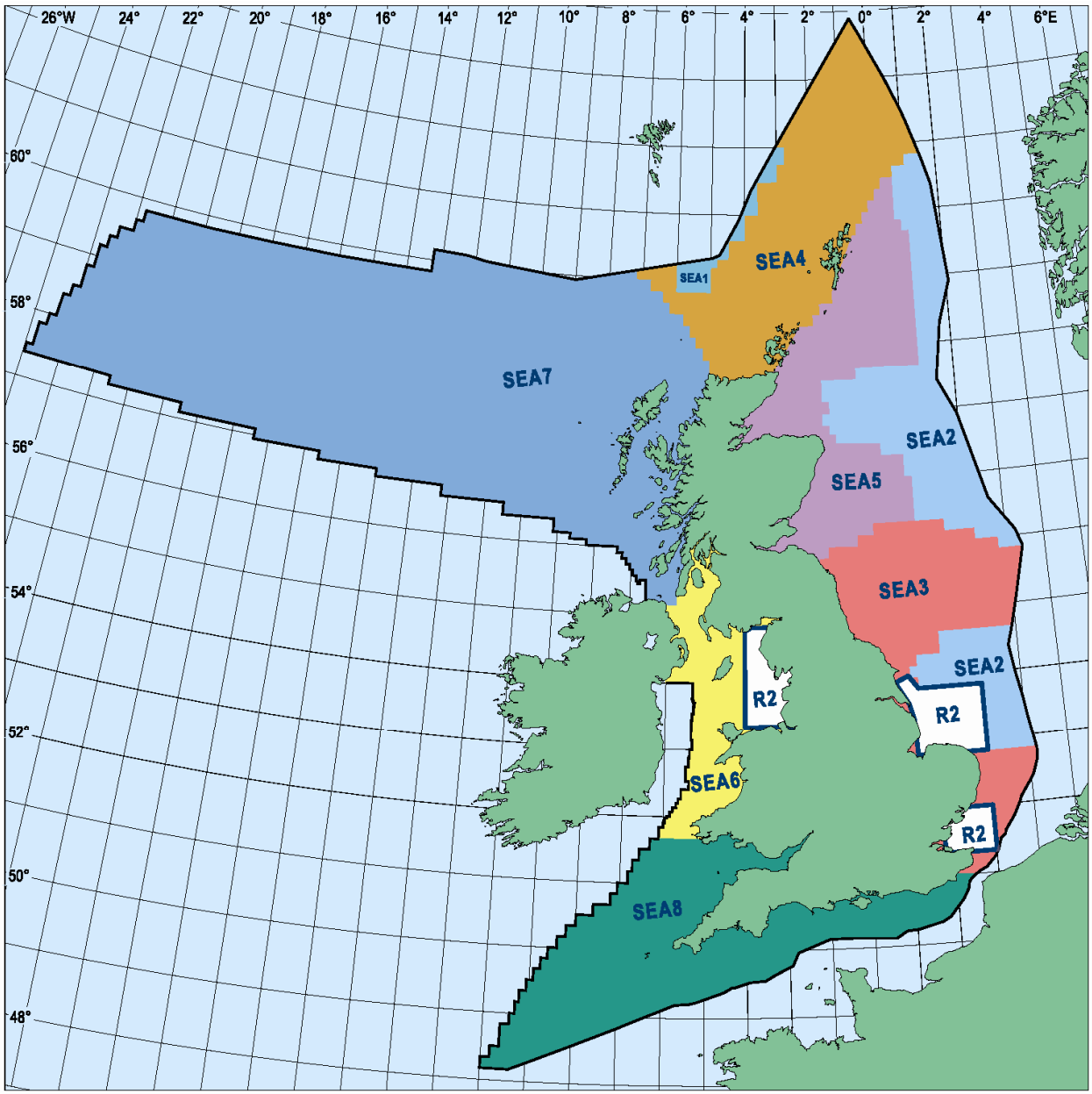

Figure 1. Strategic Environmental Assessment (SEA) area 7 located to the west of Scotland and SEA area 4 located to the north and west of Shetland.

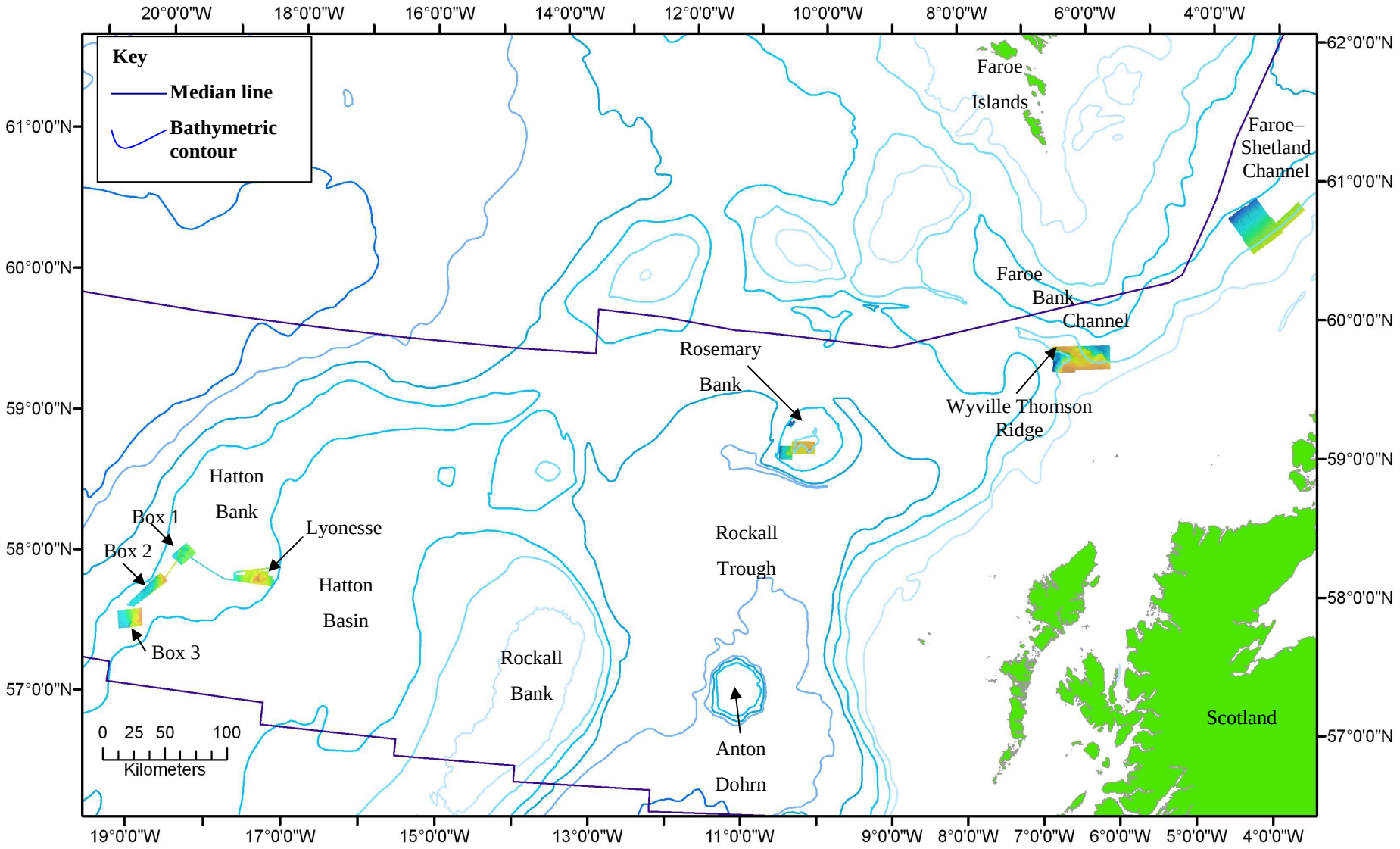

Figure 2. Location of the areas surveyed during the course of cruise 0306. The main bathymetric features are labelled.

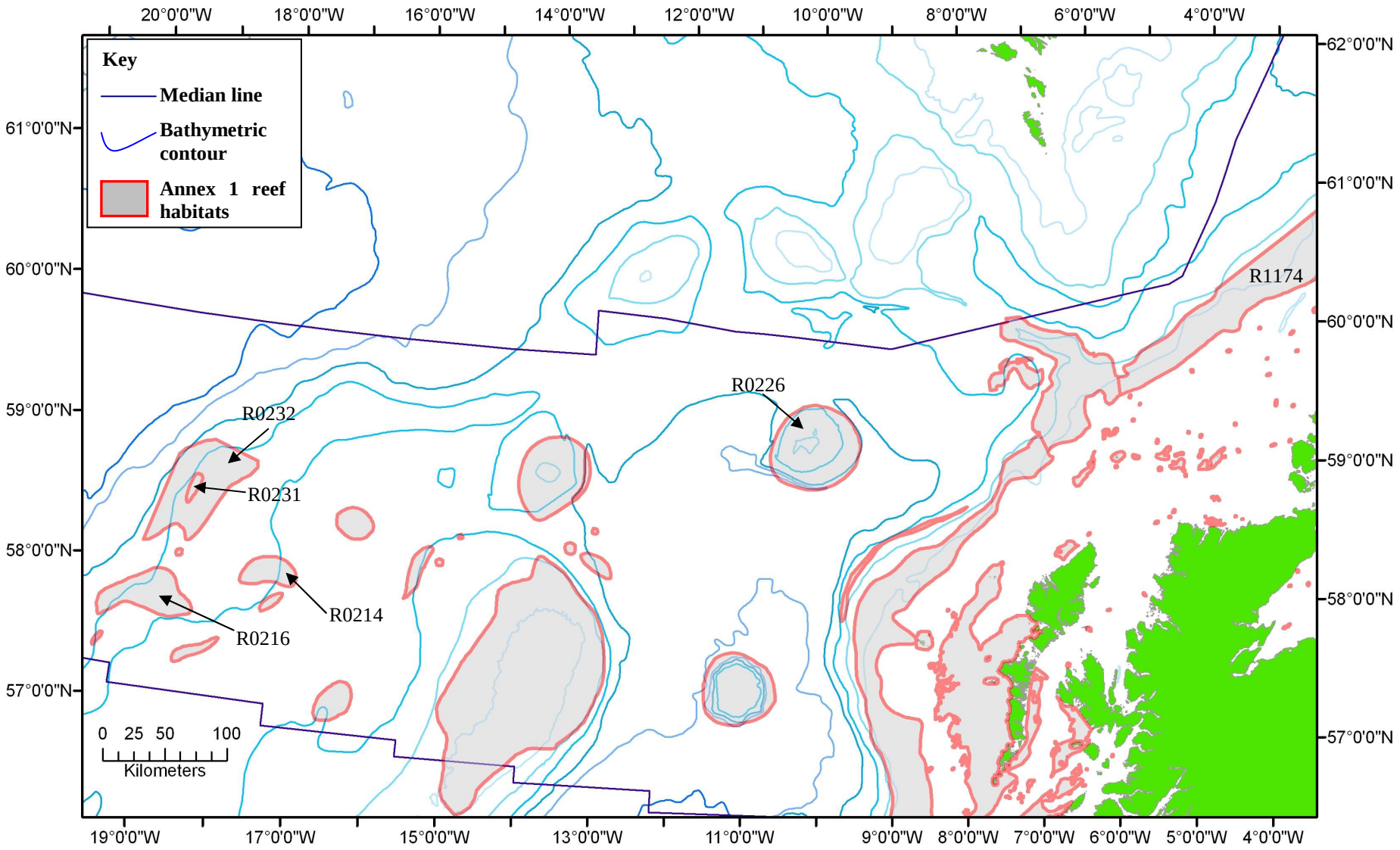

Figure 3. Location of JNCC Annex 1 reef habitats in the survey area. Areas of particular relevance to the survey are labelled; note that the area over the Wyville Thomson Ridge does not have an ID code.

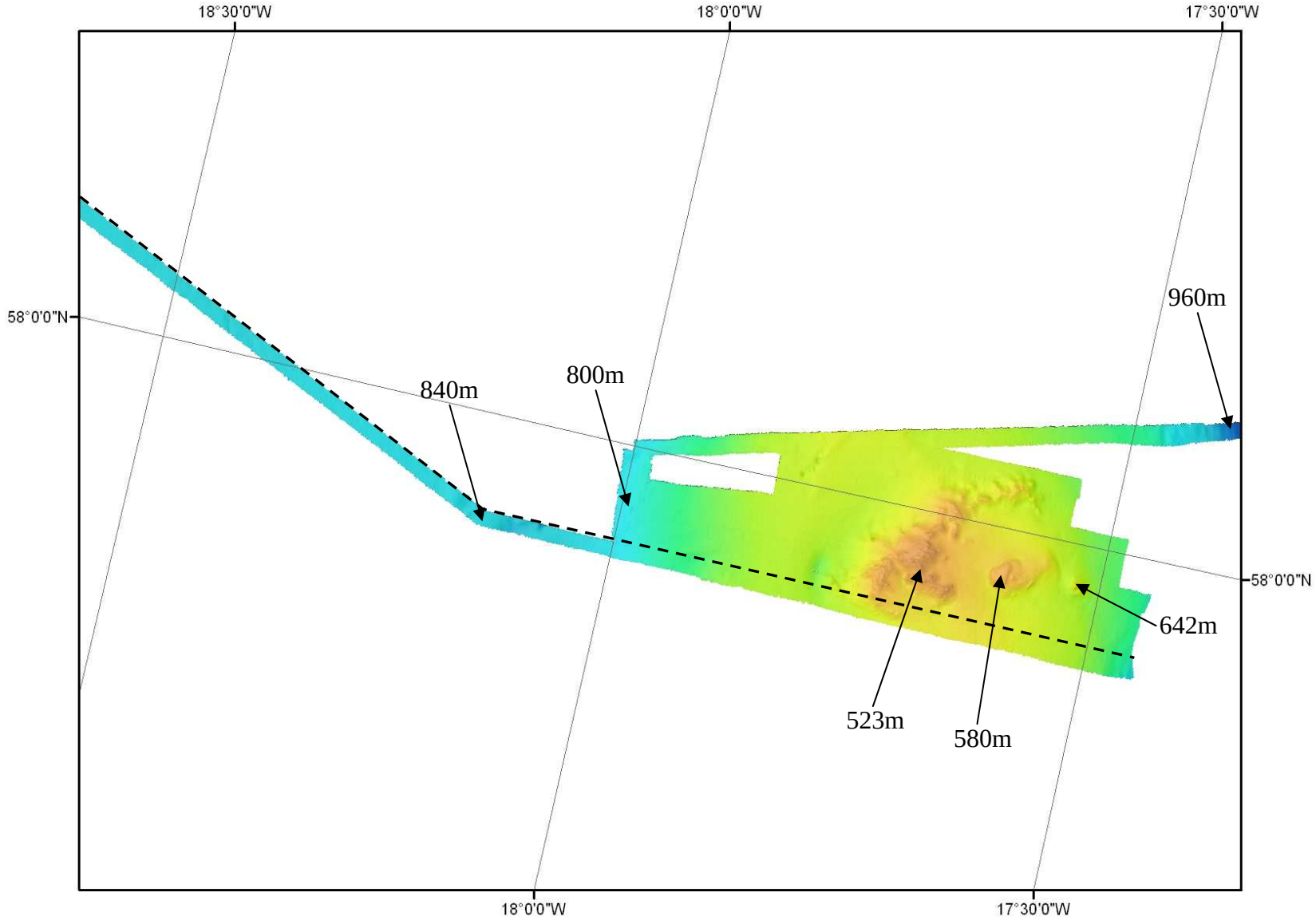

Figure 4. Multibeam bathymetry data collected over Lyonesse igneous centre during SEA7 cruise 0206 and 0306. The area to the south of the dashed line was collected during the 0306 survey, the area to the north was collected during the 0206 survey (Jacobs and Howell, 2006).

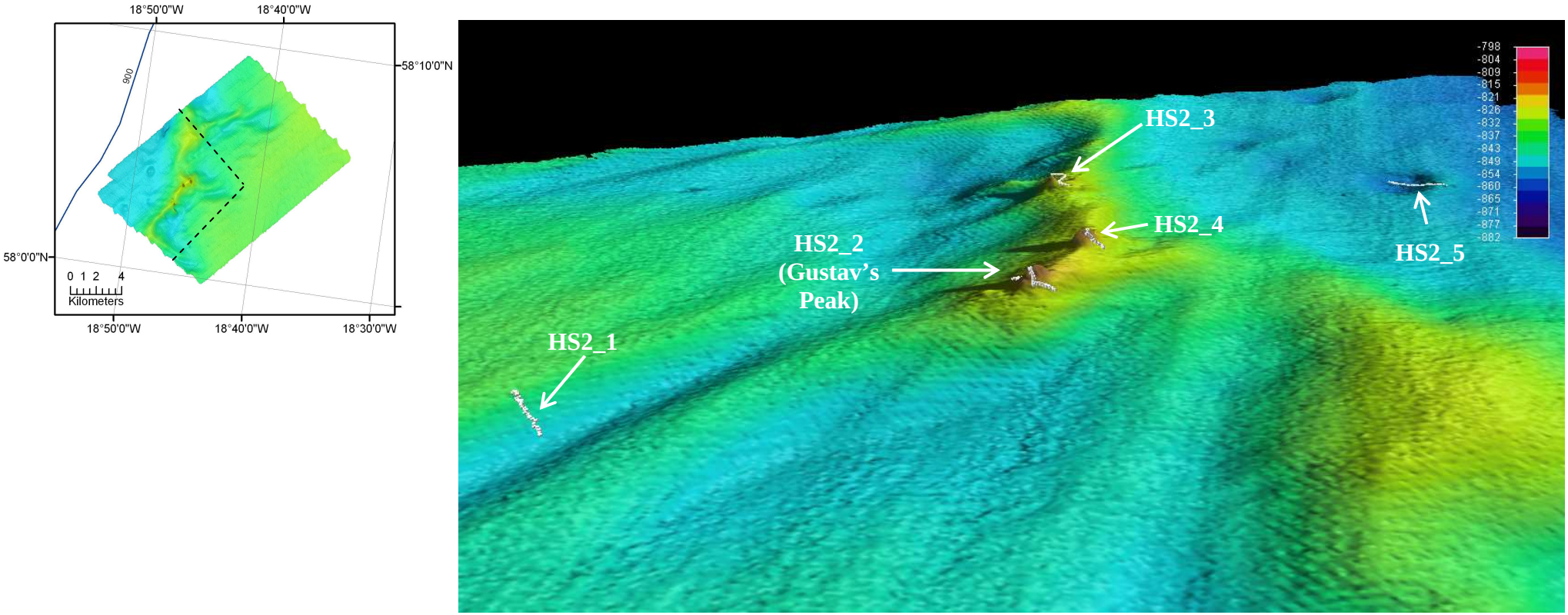

Figure 5. Multibeam bathymetry data collected over Hatton Bank south box 1 with camera transects. The perspective view looks southwest along the ridge, for location please see the inset map (area covered by figure indicated by the dashed line). The three pinnacles are 795, 800 and 810 m below sea level, decreasing in height towards the southwest. The hollow over which transect HS2_5 was collected is 15m in depth. The broad bathymetric high in the bottom right of the image is 826m at its shallowest.

Figure 6. Image HS2_2_045 showing biogenic gravel derived locally from coral reef. For location of photograph see Figure 11.

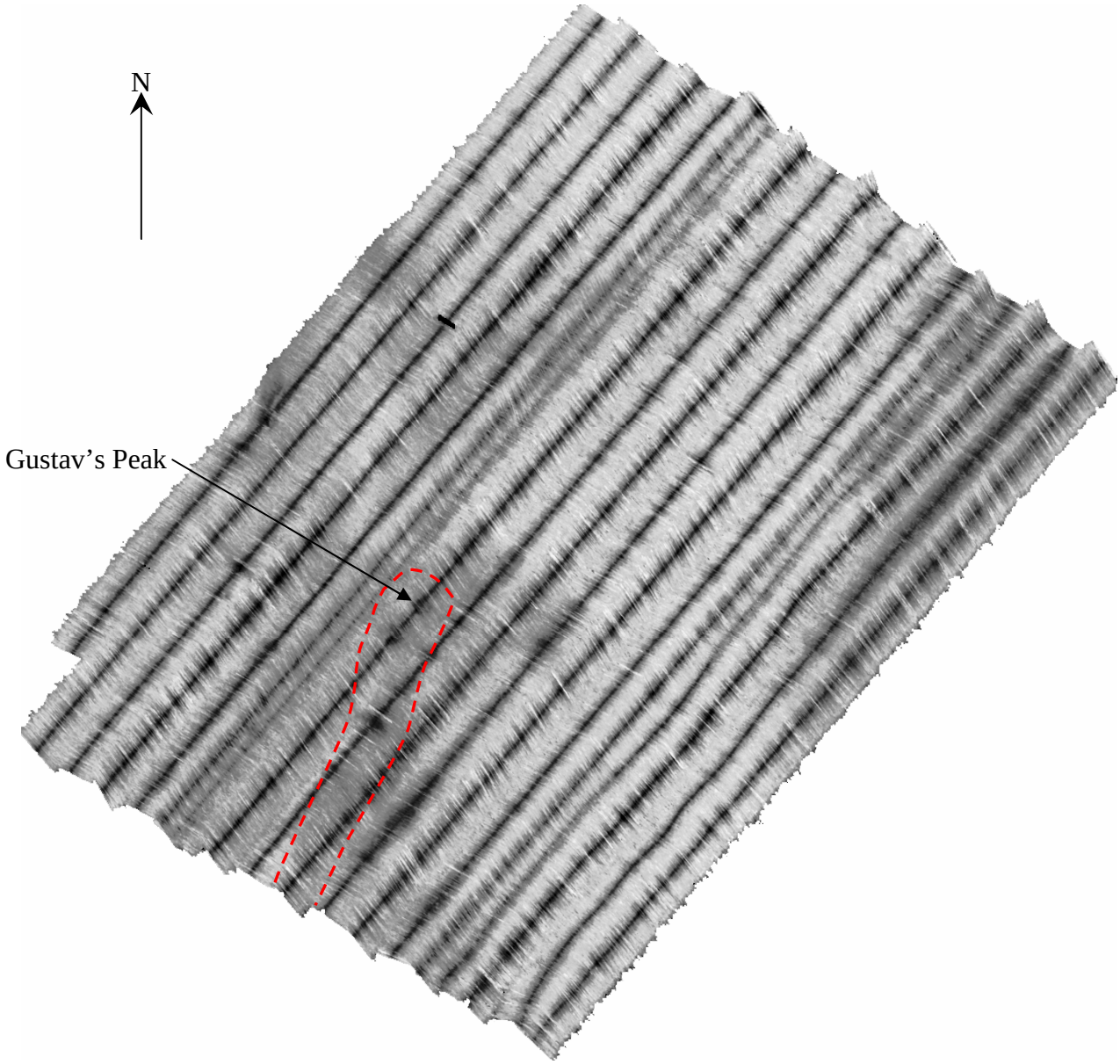

Figure 7. Backscatter image of Hatton Bank south box 1, the location of the ridge is outlined by the red dashed line. Note the change in backscatter response, from light to dark, in the vicinity of the ridge indicating a change from the softer muddy sands of the surrounding sea bed to the hard biogenic reef structure located on the ridge. The change in backscatter response in the northeast of the area surveyed may be due to a change in sediment ripple direction rather than a change in sea bed composition. The dark stripes orientated northeast-southwest are track-line artefacts, spaced at ~650m intervals.

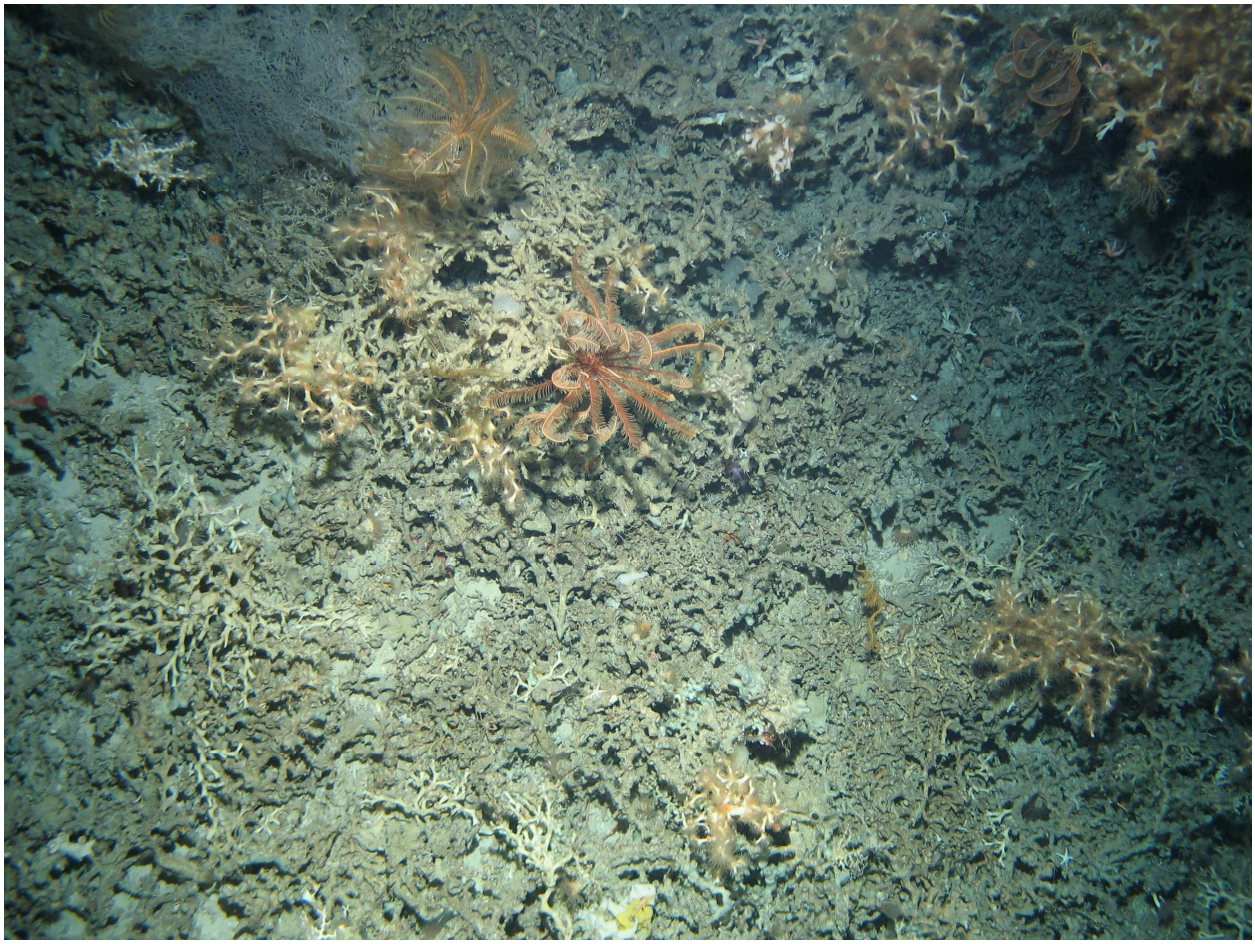

Figure 8. Image HS2_4_024 illustrating the presence of medium- to coarse- grained sand trapped within the reef structure. It is suggested that the reef is anchored to a hard substrate beneath a thin veneer of sediment rather than unconsolidated sediment. For location please see Figure 13.

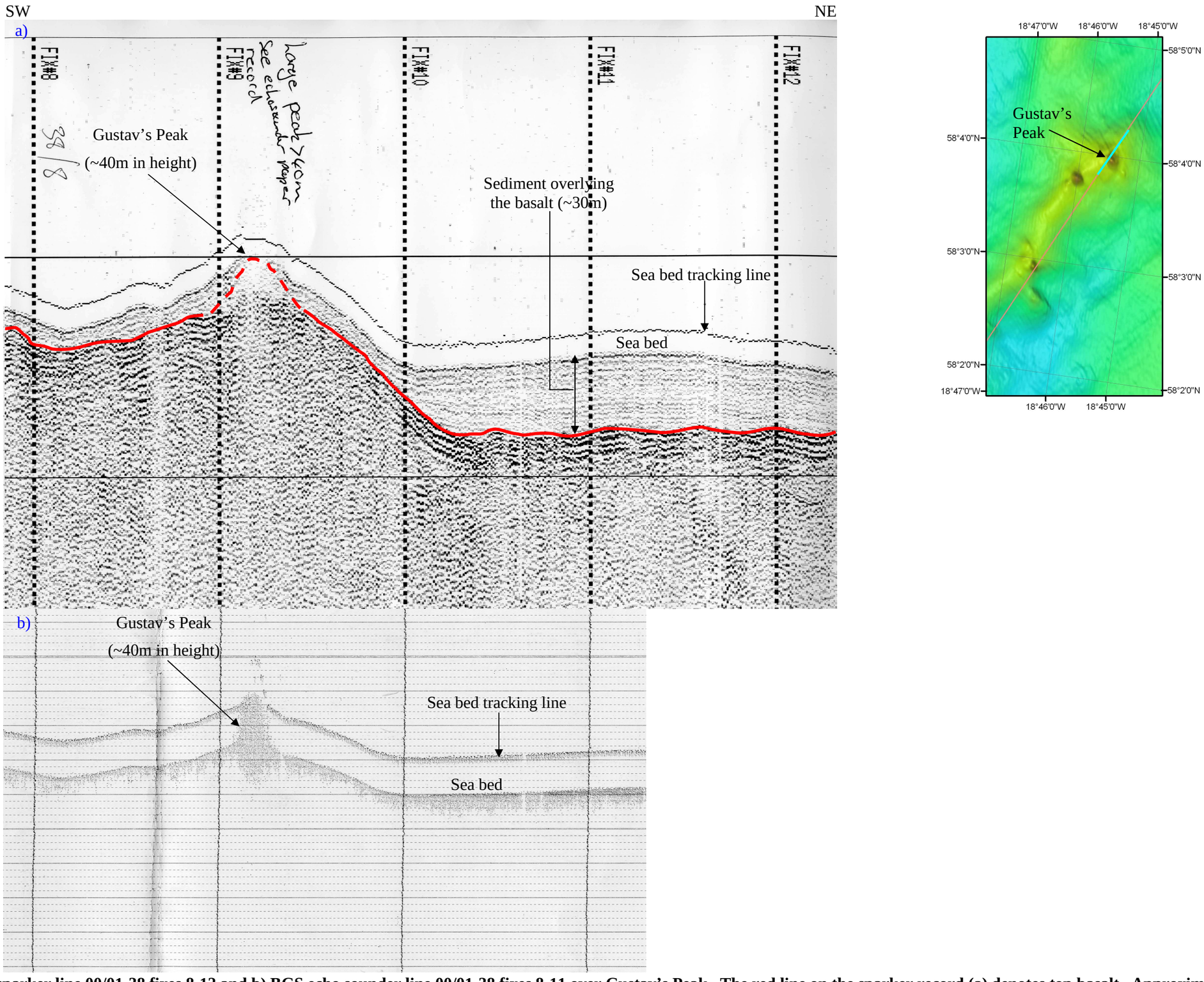

Figure 9. a) BGS sparker line 00/01-38 fixes 8-12 and b) BGS echo sounder line 00/01-38 fixes 8-11 over Gustav's Peak. The red line on the sparker record (a) denotes top basalt. Approximately 30m of sediment can be seen to overlie the basalt to the northeast, with approximately 10m of sediment present over the peak itself although basalt may be present at sea bed. Please see the inset map for the location of the seismic line (bright blue).

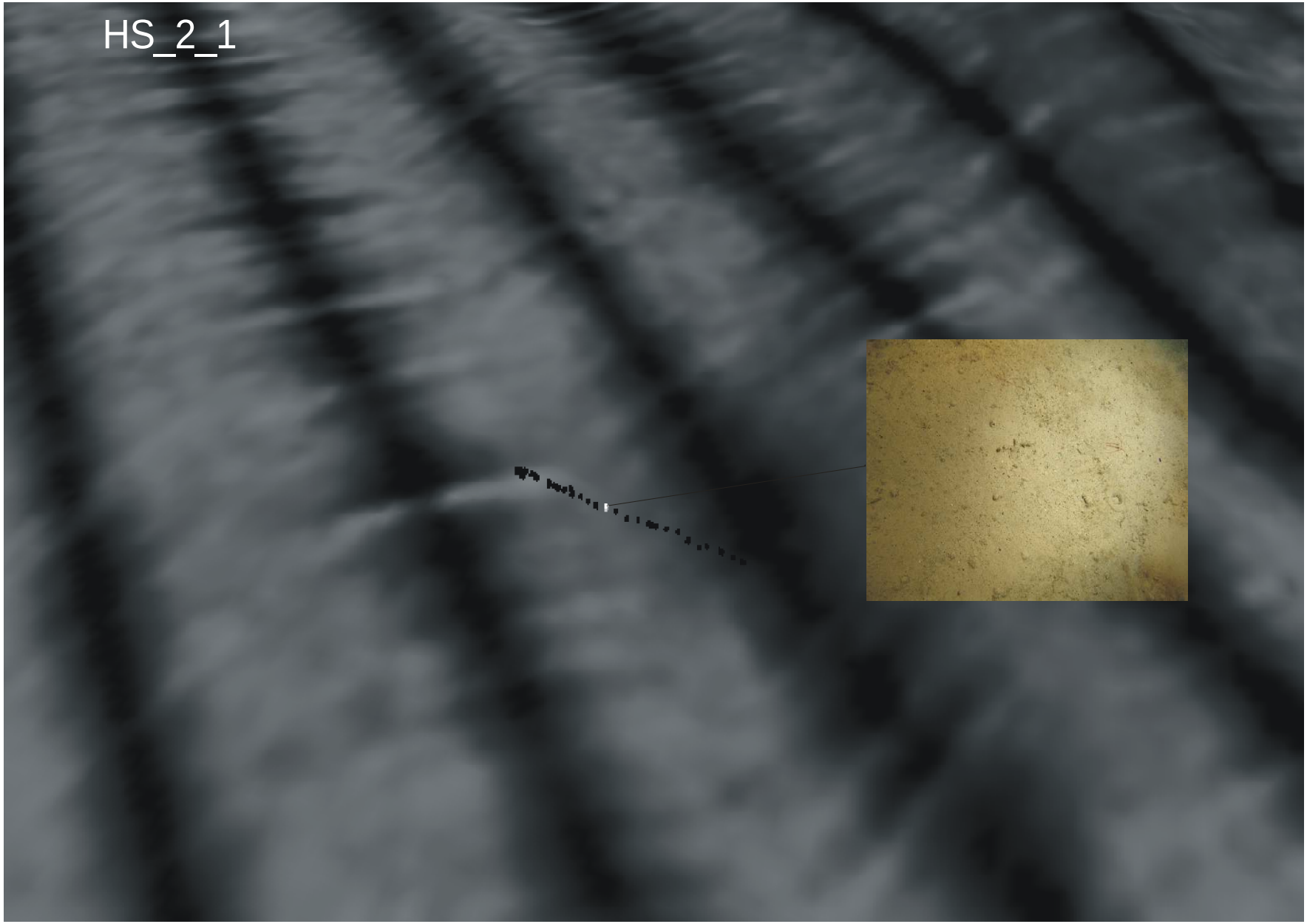

Figure 10. Camera tow of HS_2_1.

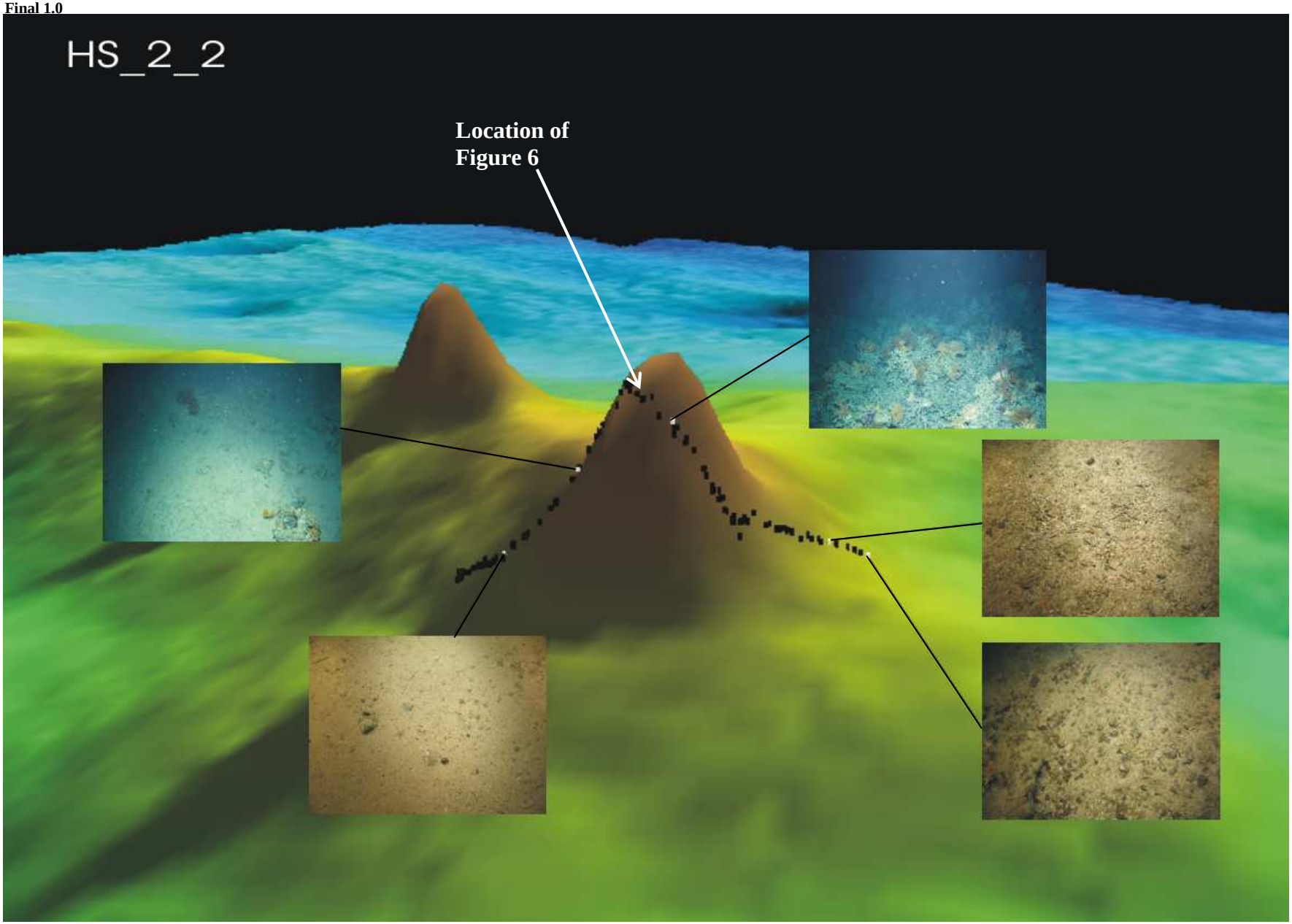

Figure 11. 3D image looking south showing Gustav's Peak with the location of the camera transect draped on top. Selected images show the change in habitat observed. This tow revealed a biogenic reef with a typical reef fringe on the peak of the pinnacle.

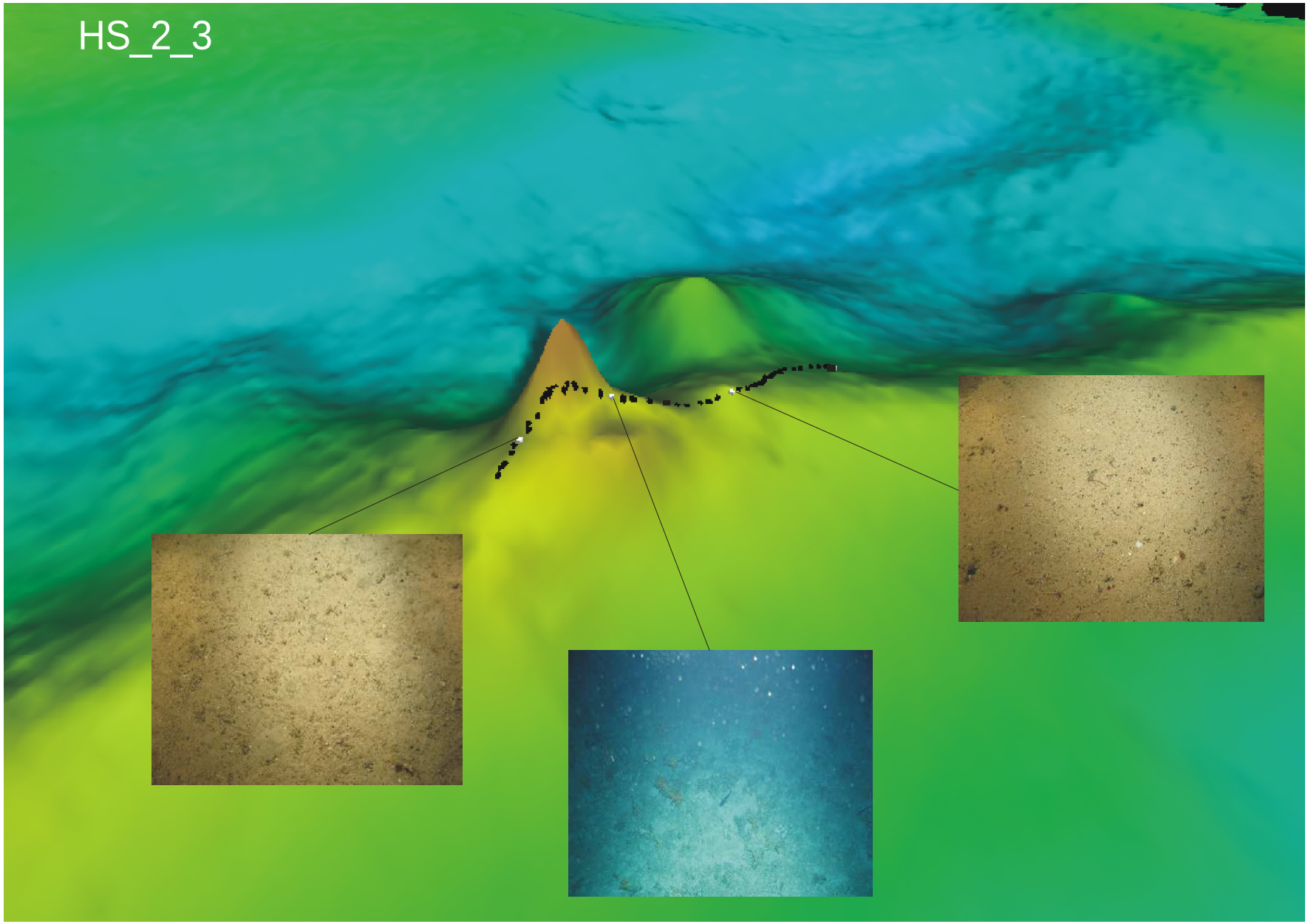

Figure 12. 3D image of a pinnacle with the camera tow (HS_2_3) draped on. Selected images show the change in habitat observed.

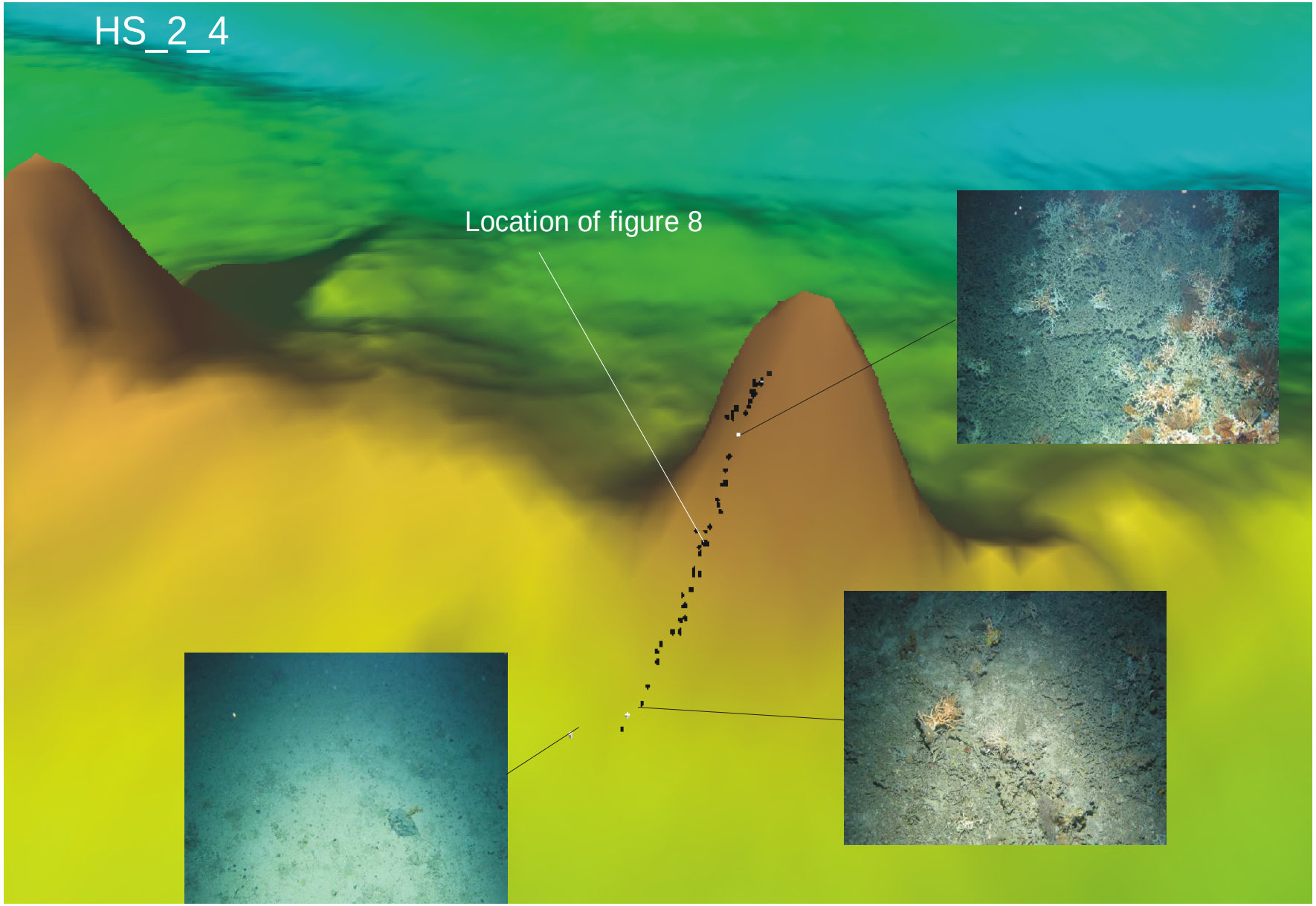

Figure 13. 3D image of a pinnacle with the camera tow (HS_2_4) draped on top. Selected images showing the change in habitats observed.

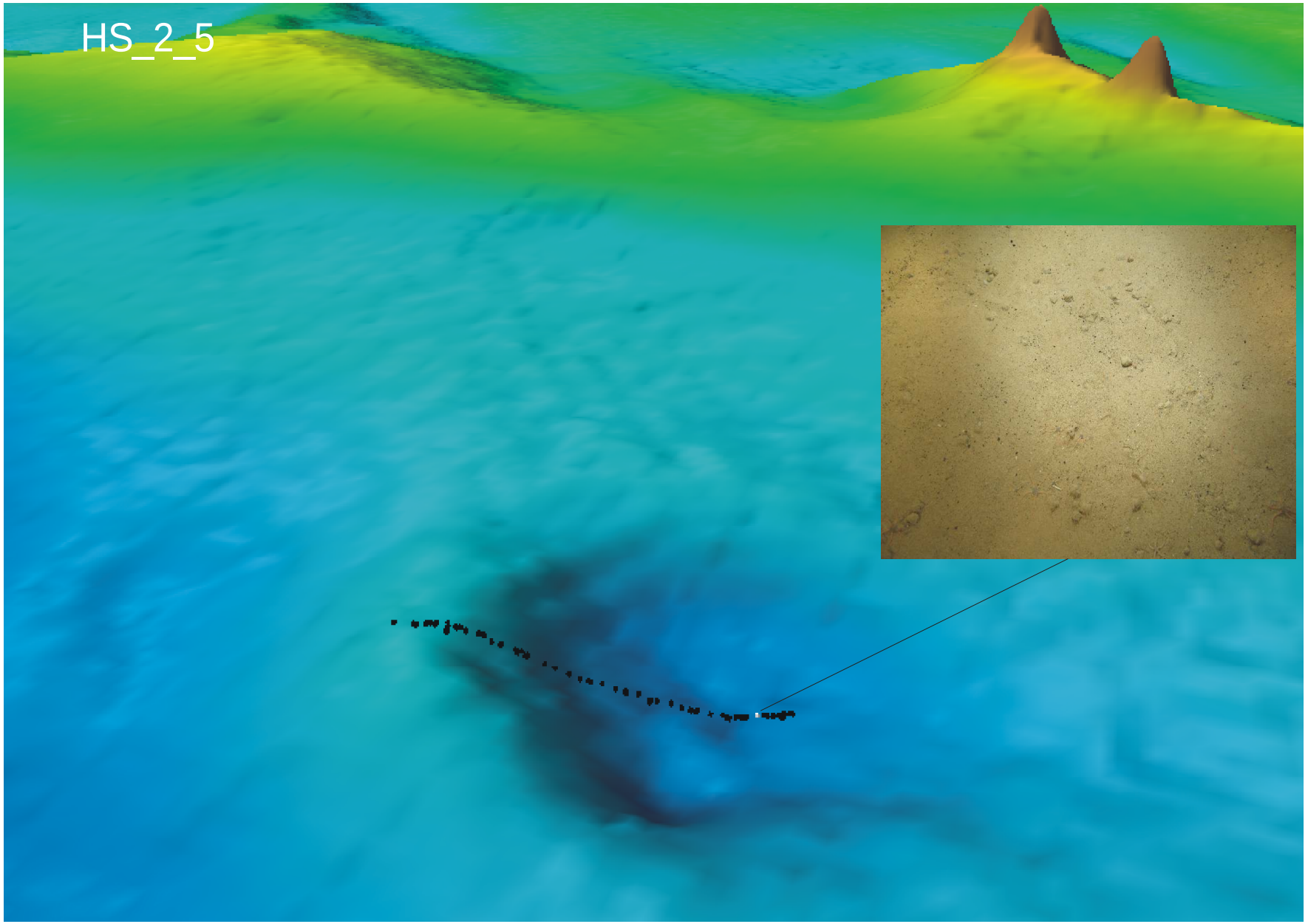

Figure 14. 3D image with the camera tow draped on top (HS_2_5) the selected images illustrated the one continuous habitat observed.

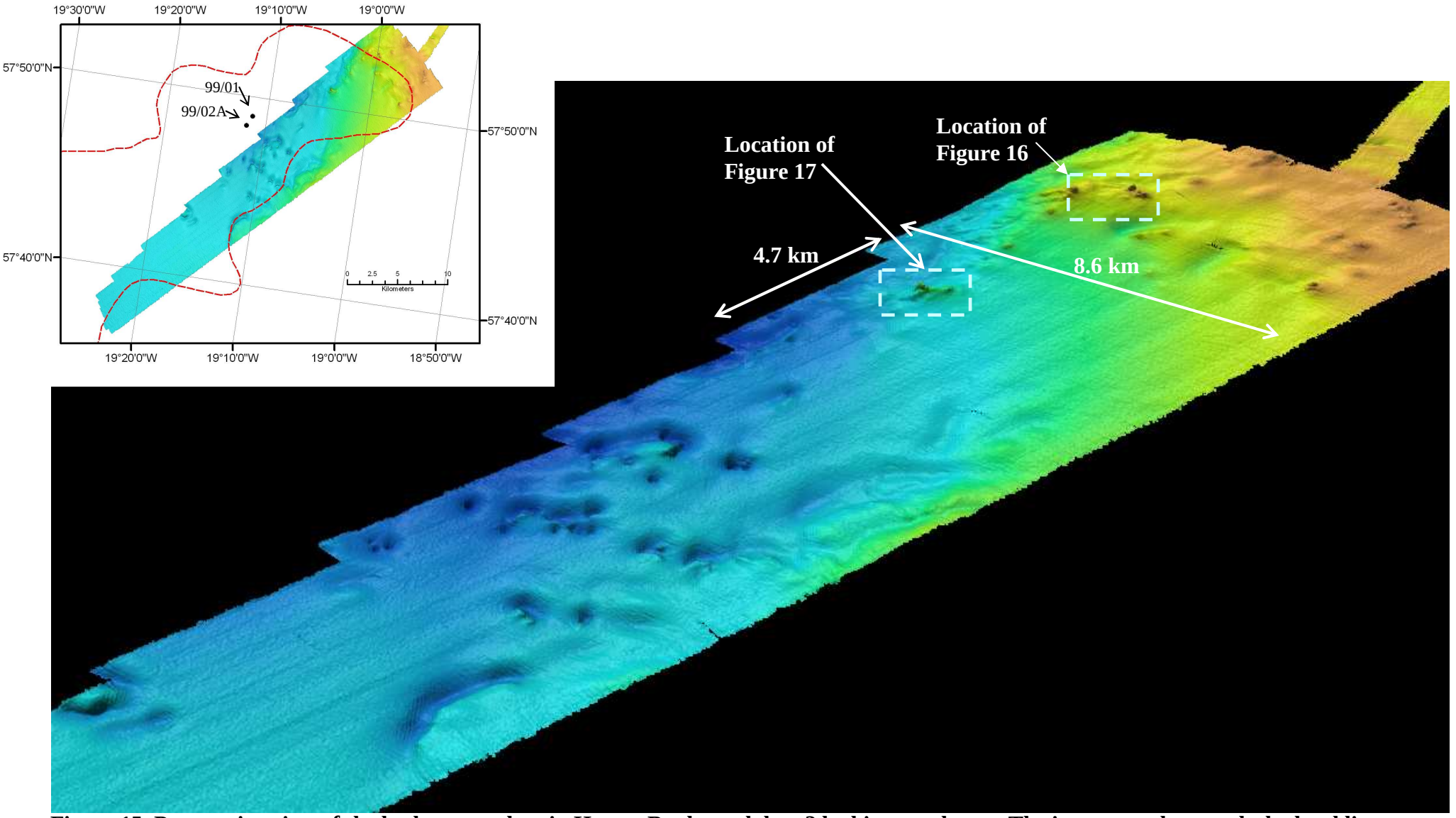

Figure 15. Perspective view of the bathymetry data in Hatton Bank south box 2 looking northeast. The inset map shows a dashed red line denoting the outline of a 'window' in the basalt and the location of BGS boreholes 99/01 and 99/02A located <2km to the west of the area of multibeam. The window in the basalt appears to roughly coincide with the area of bathymetric hollows, while the area of elevated sea bed and pinnacles in the northeast of the study area are located outside the basalt window.

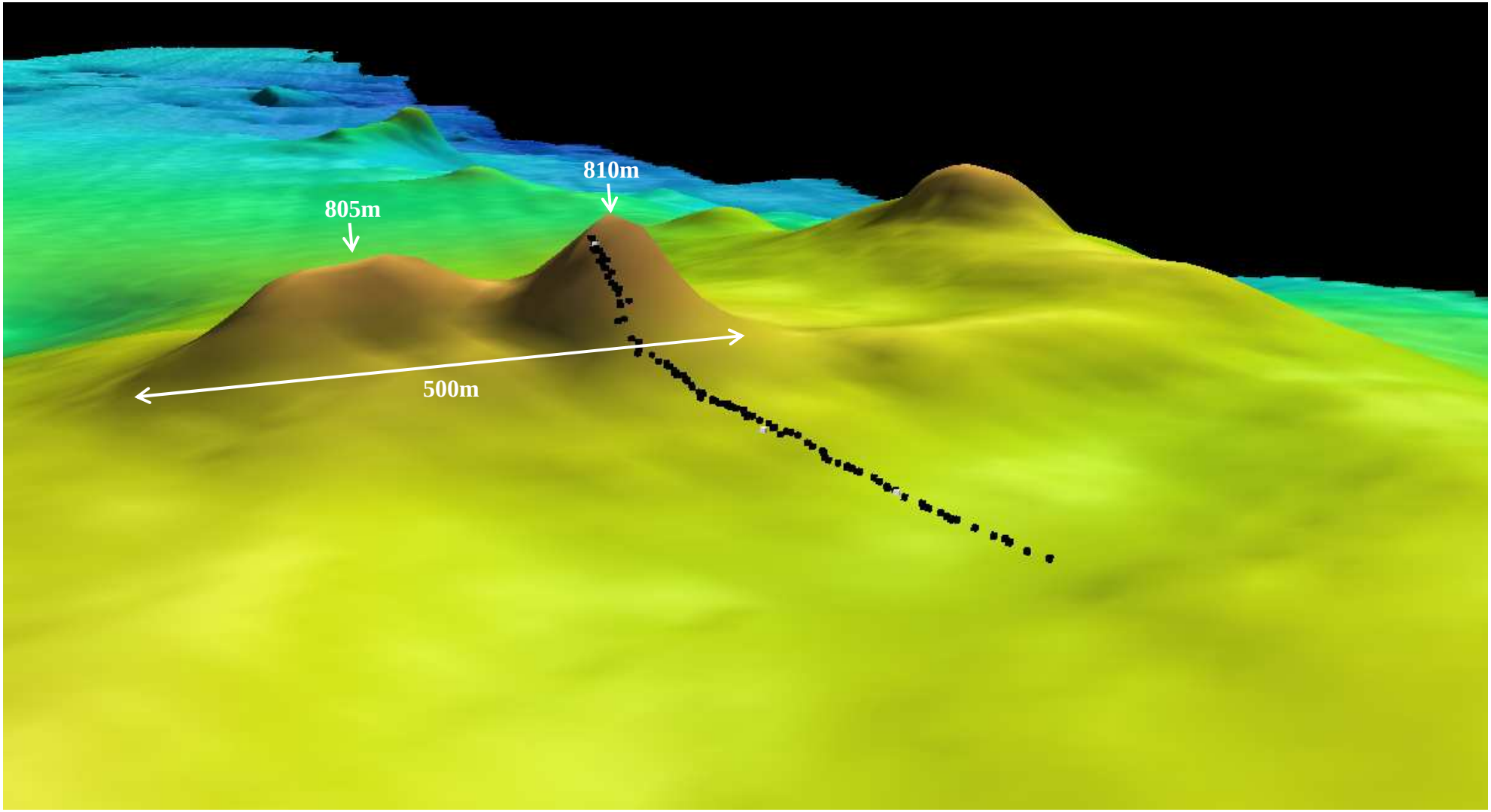

Figure 16. Camera transect HS3_1 over a pinnacle in the north of multibeam area Hatton Bank south box 2. For location see Figure 15.

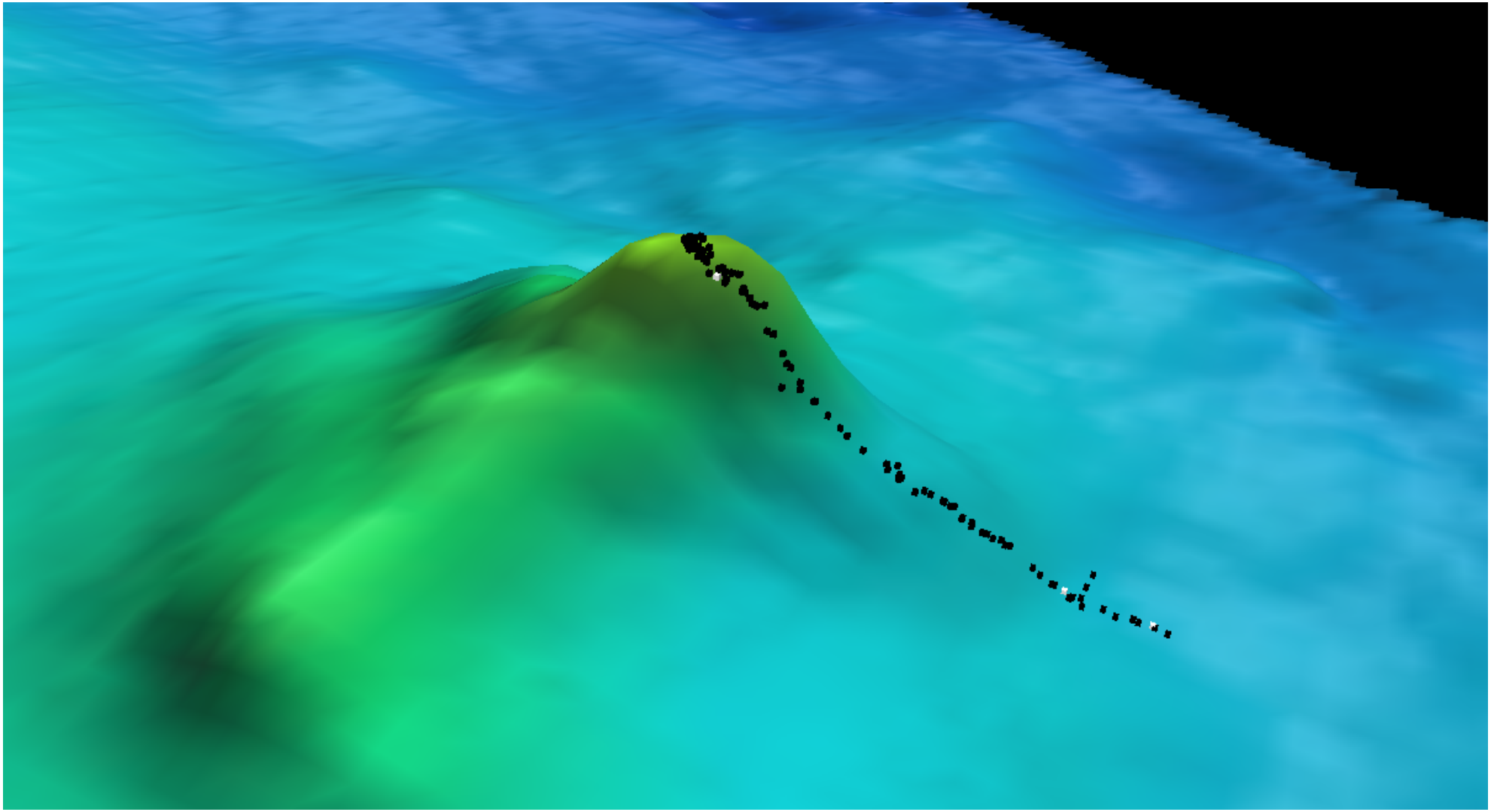

Figure 17. Camera transect HS3_2 over a pinnacle in the central section of multibeam area Hatton Bank south box 2. The top of the pinnacle lies in ~850m of water and is 40m in height above the surrounding sea bed. For location see Figure 15.

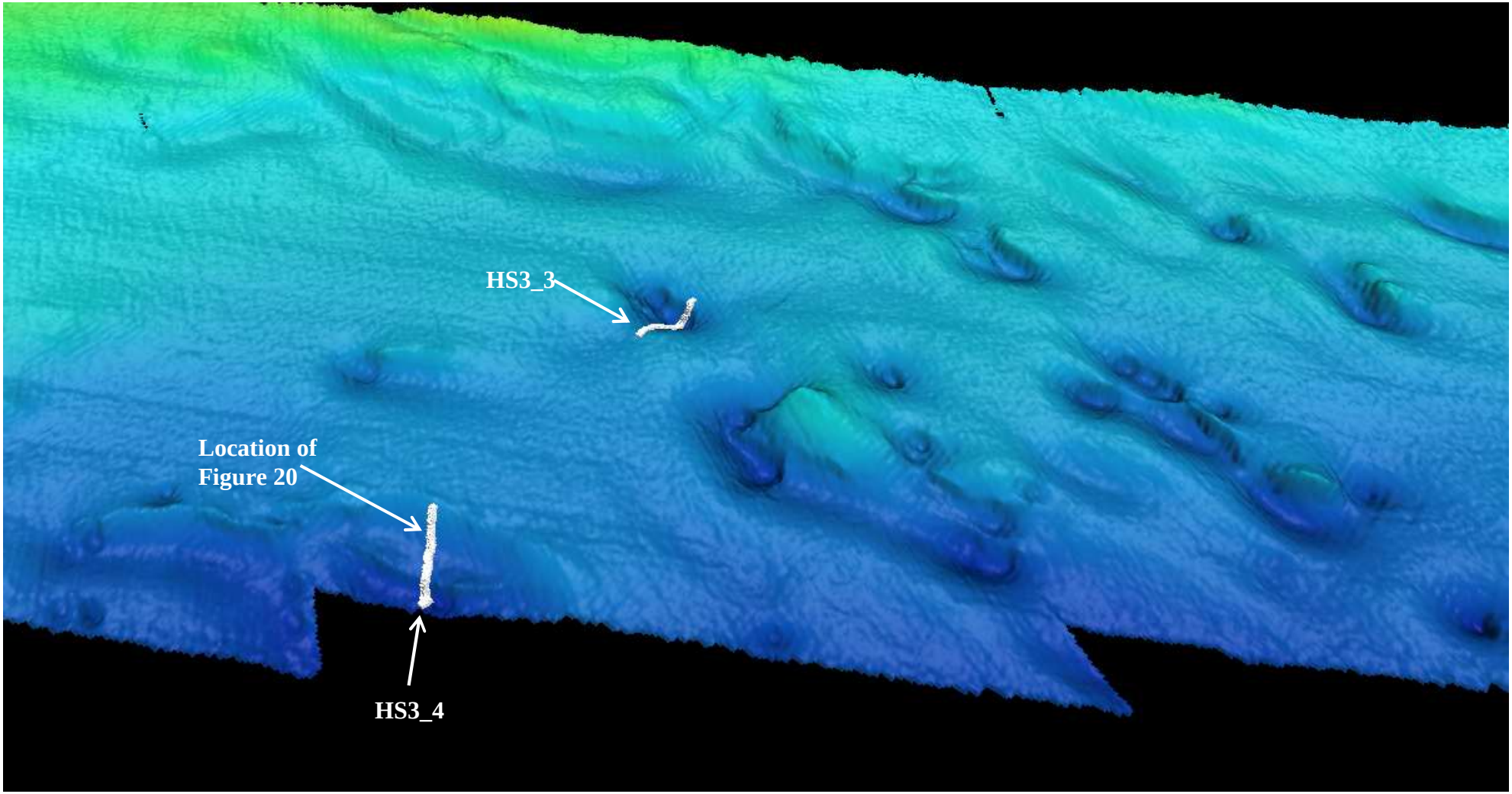

Figure 18. Perspective view looking southeast showing the range of bathymetric features located in the central area of Hatton Bank south box 2. Camera transect HS3_3 is located in a circular depression approximately 30m in depth, the transect is ~950m in length. Transect HS3_4 covers two scarps, heading west the upper scarp is 20m in height, the lower 10m.

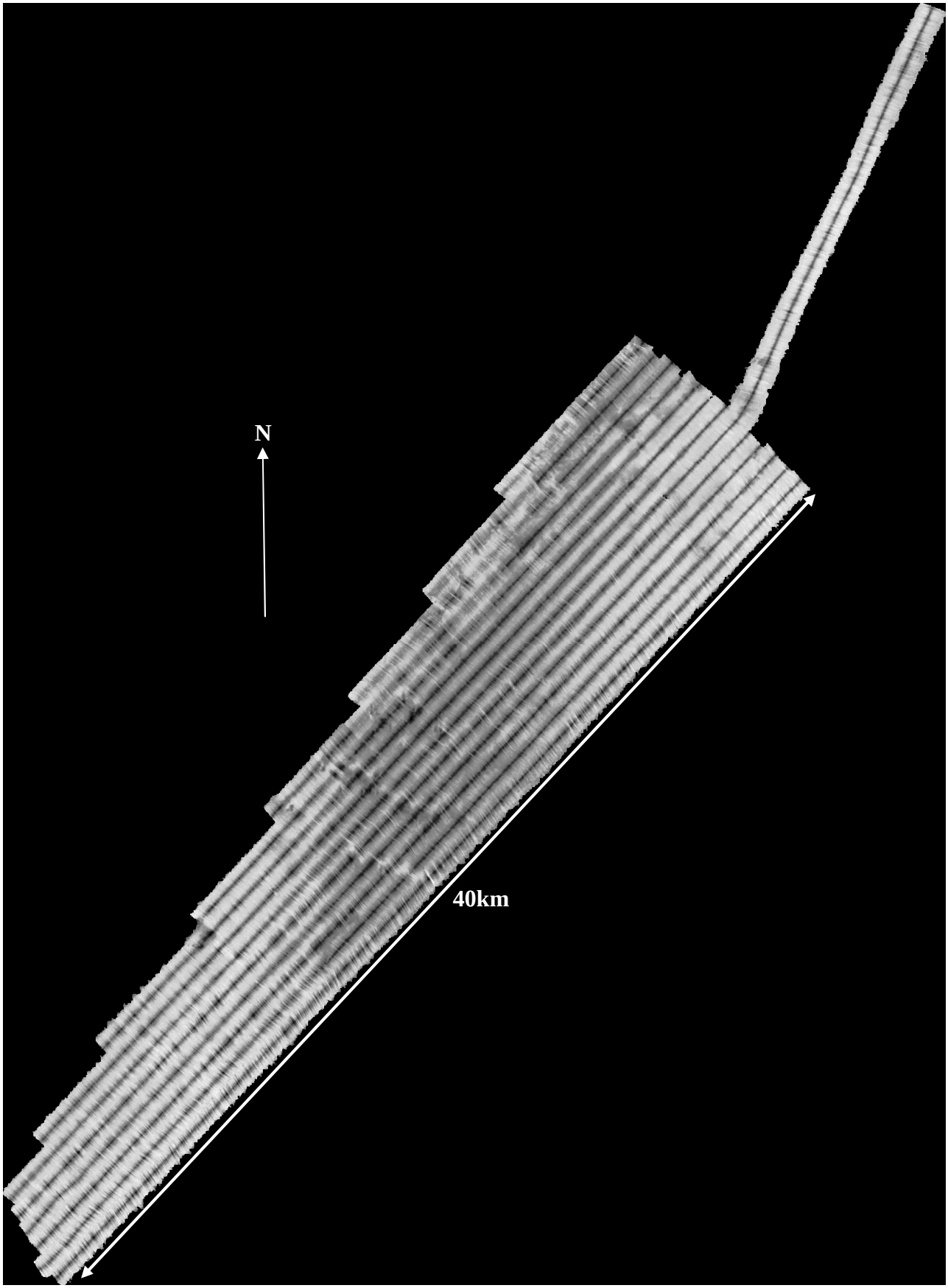

Figure 19. Backscatter image of Hatton Bank south box 2. The dark stripes orientated northeast-southwest are track-line artefacts, spaced at ~650m intervals.

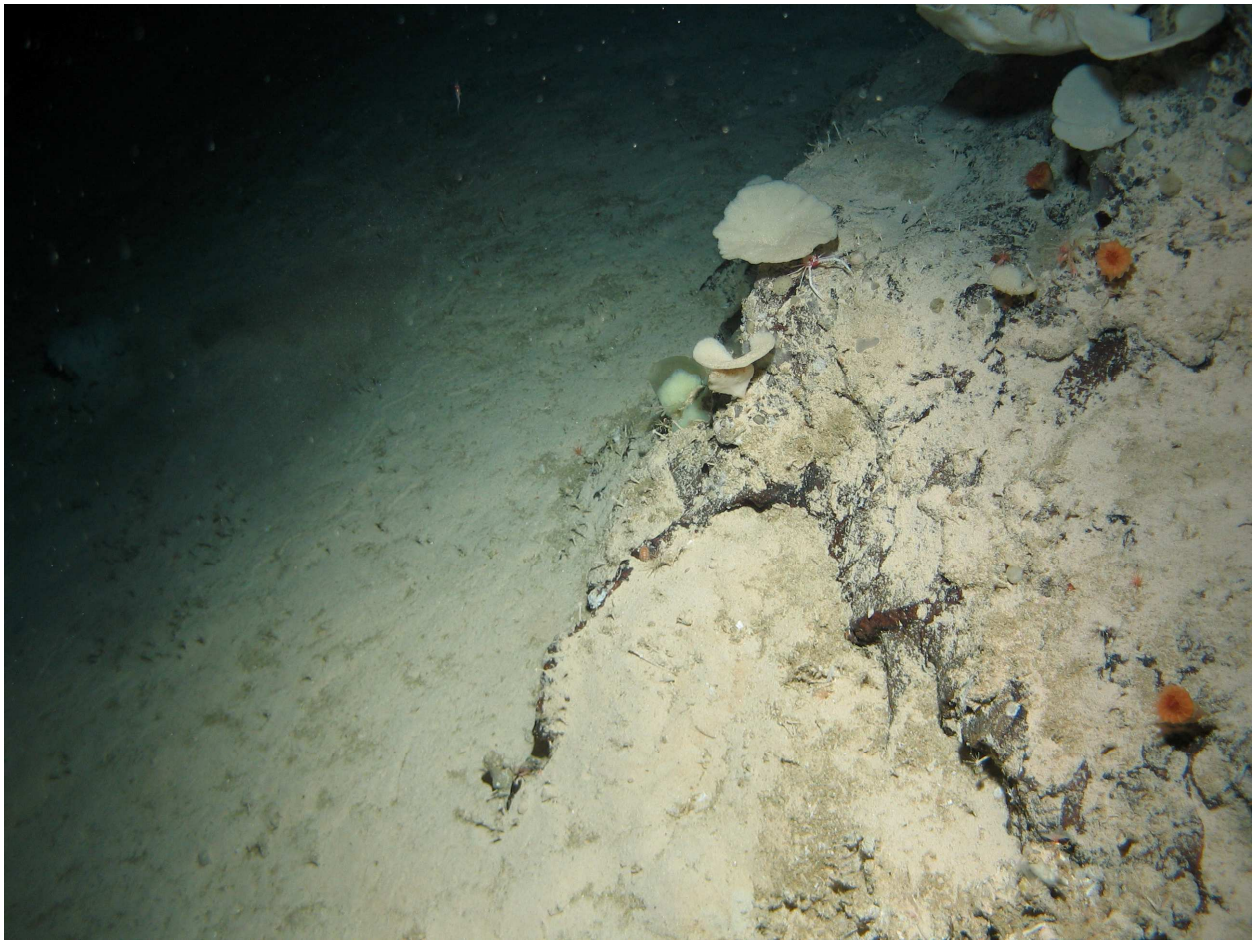

Figure 20. Image HS3_4_037 showing bedrock outcrop on the upper scarp. The bedrock is colonised by cup corals (*Caryophyllia sp.*) and cup sponges (*Axinella sp.*). It is suggested that the bedrock comprises sedimentary rock of Upper Palaeozoic–Mesozoic age. For location please see Figure 18.

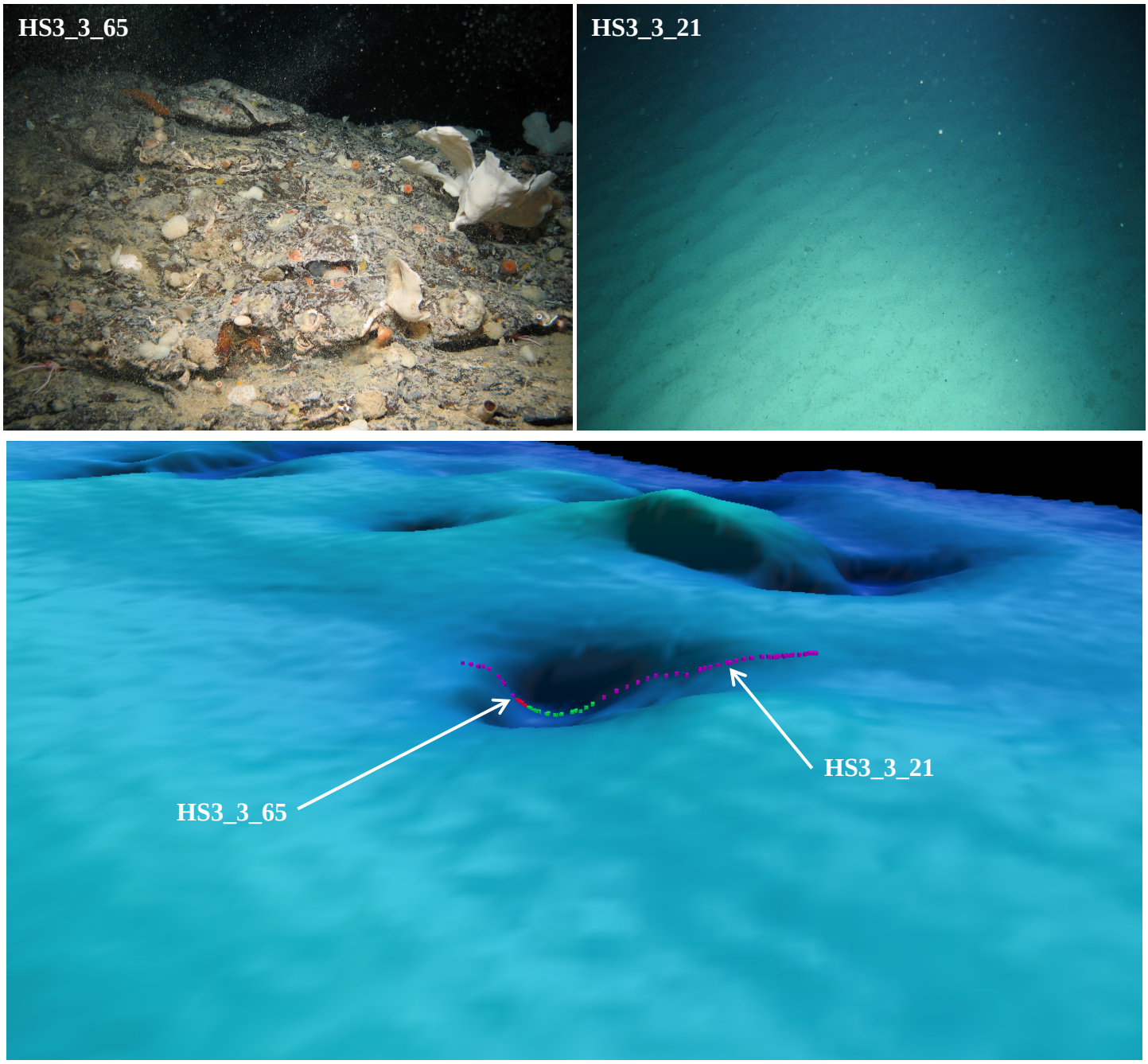

Figure 21. Image HS3_3_21 showing rippled sea bed in the central area of Hatton Bank south box 2. Image HS3_3_65 shows bedrock outcrop within a circular depression. It is suggested that the bedrock may comprise Upper Palaeozoic–Mesozoic sedimentary rock. The perspective view of transect HS3_3 looking southwest shows the location of the images.

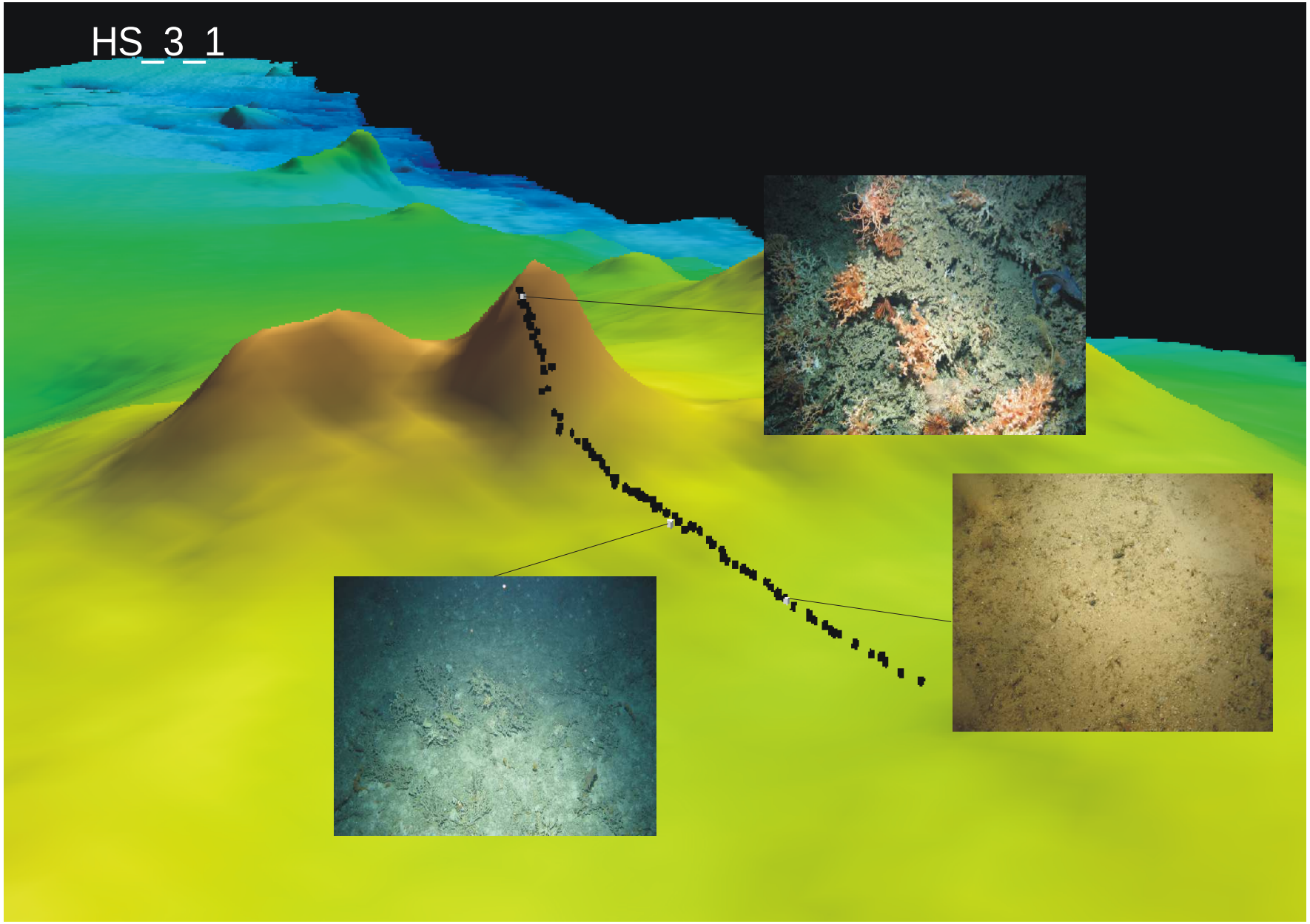

Figure 22. 3D image of a pinnacle with the camera tow draped on top (HS_3_1). Selected images show the change in habitat observed.

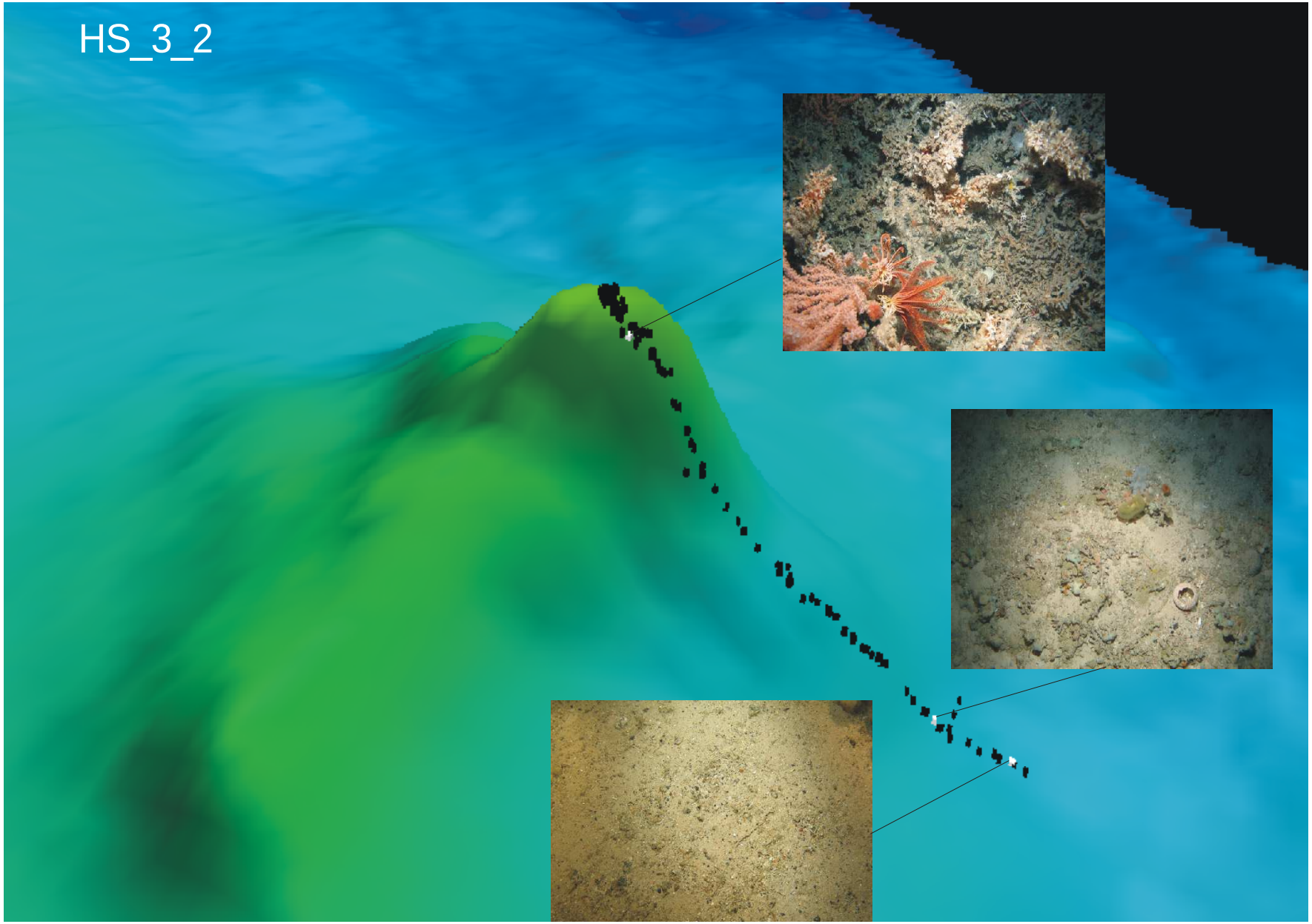

Figure 23. 3D image of a pinnacle with the camera tow draped on top (HS_3_2). Selected images show the change in habitats observed.

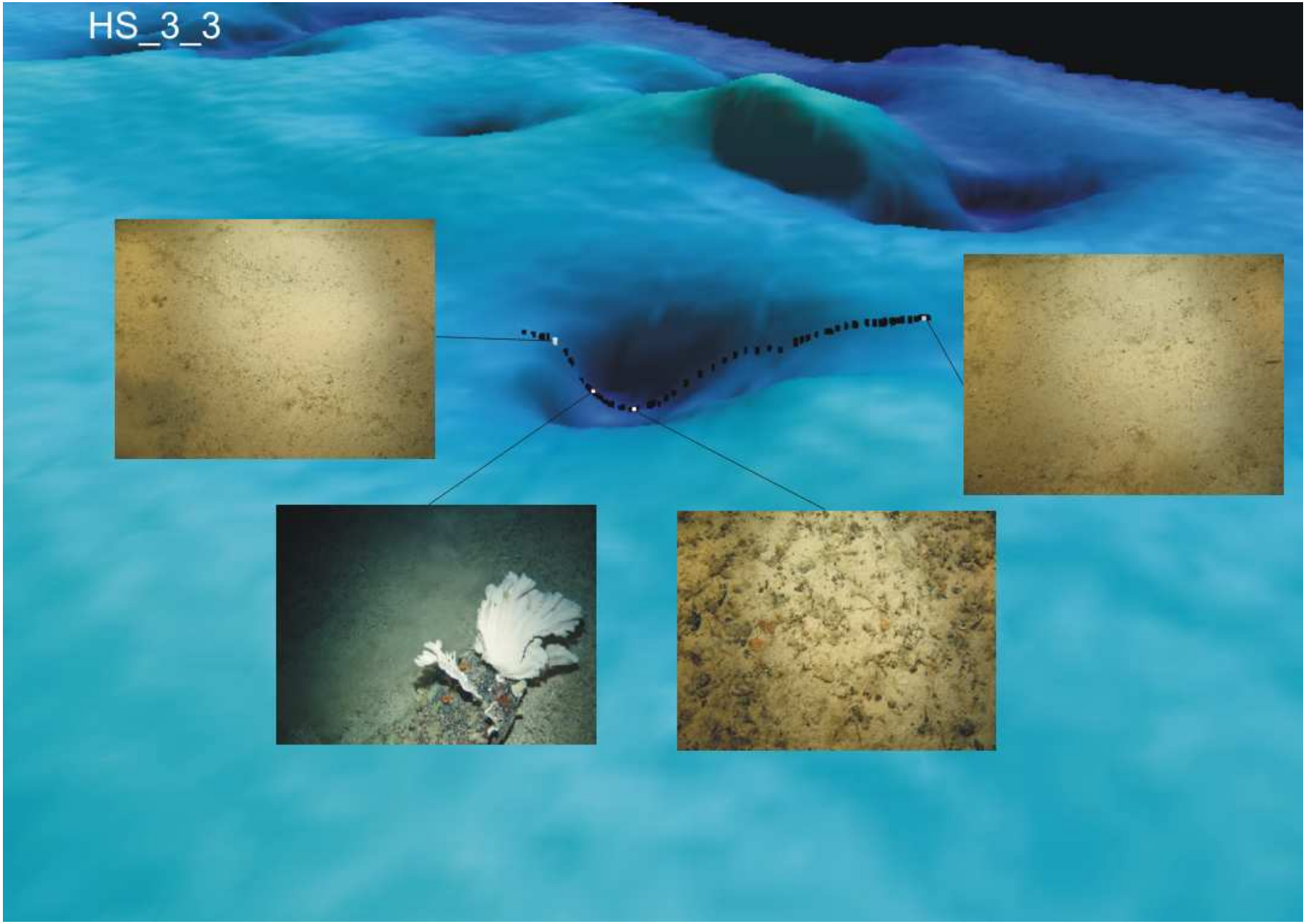

Figure 24. 3D image with the camera tow draped on top (HS_3_3). Selected images highlighting the change in habitats.

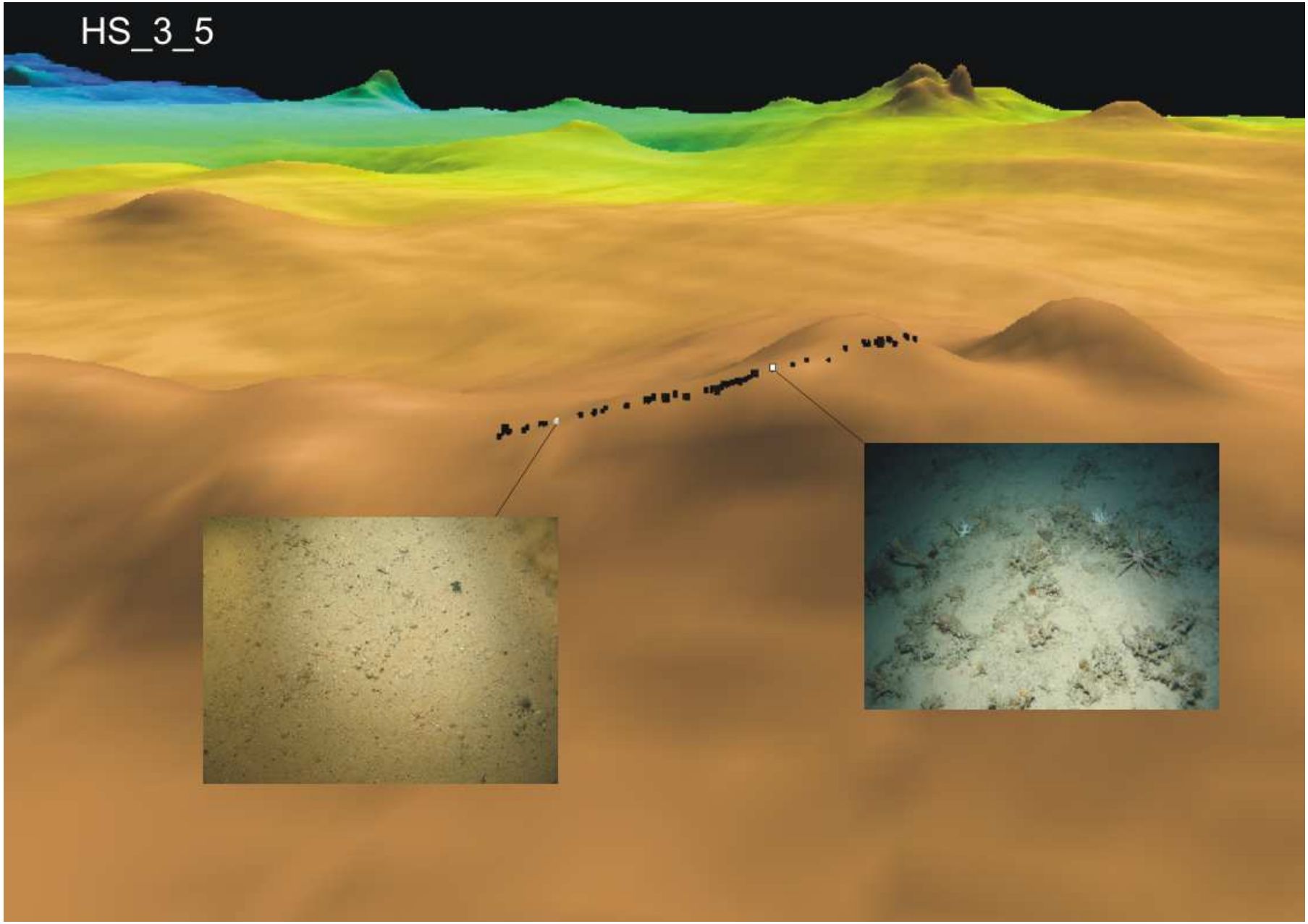

Figure 25. Camera tow of HS_3_5 with selected images to show the change in habitat.

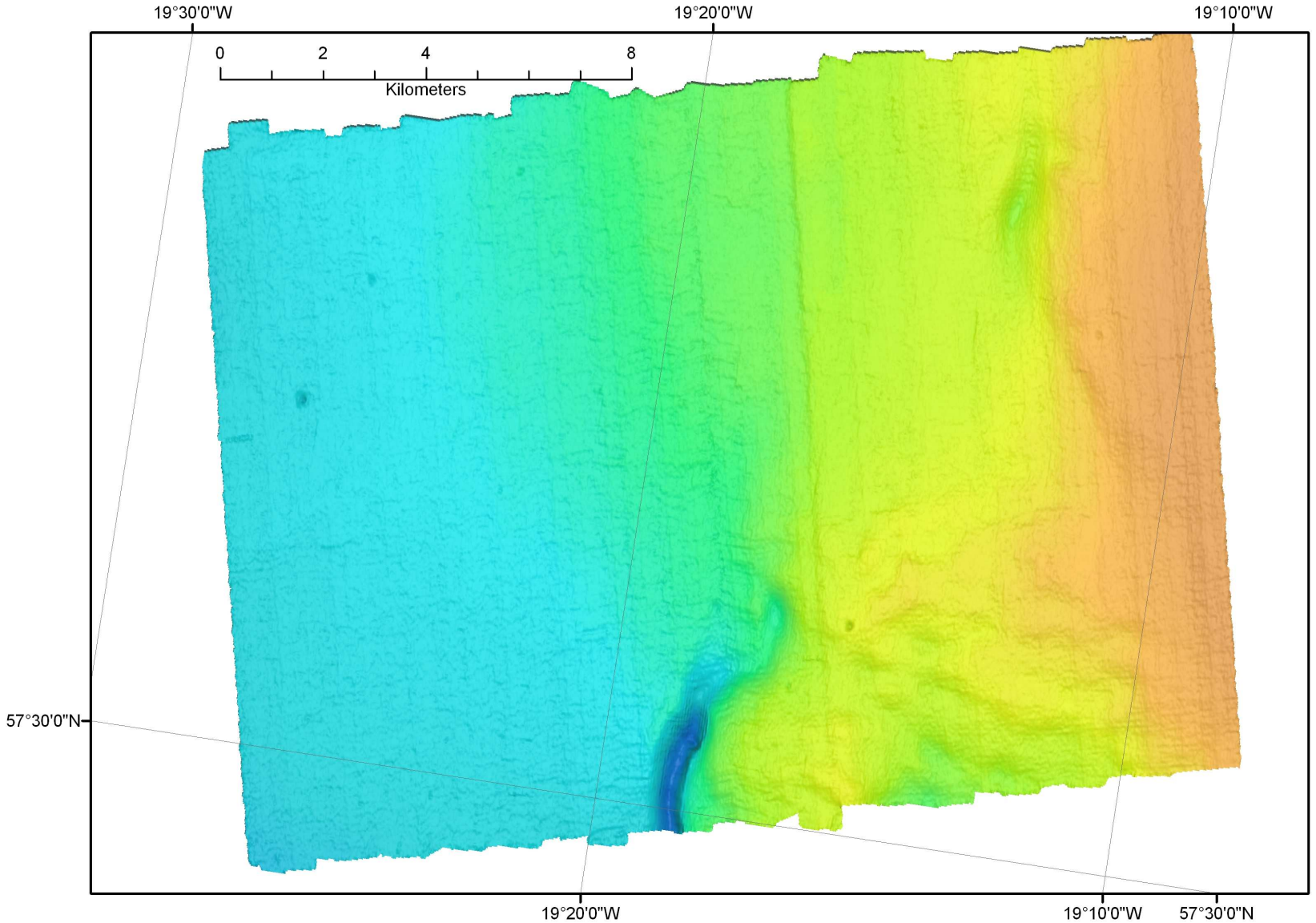

Figure 26. Multibeam image over Hatton Bank south box 3. The elevated area in the northeast of the image (orange) has a water depth of 870m, the canyon in the south of the image (dark blue) has a water depth of 945m.

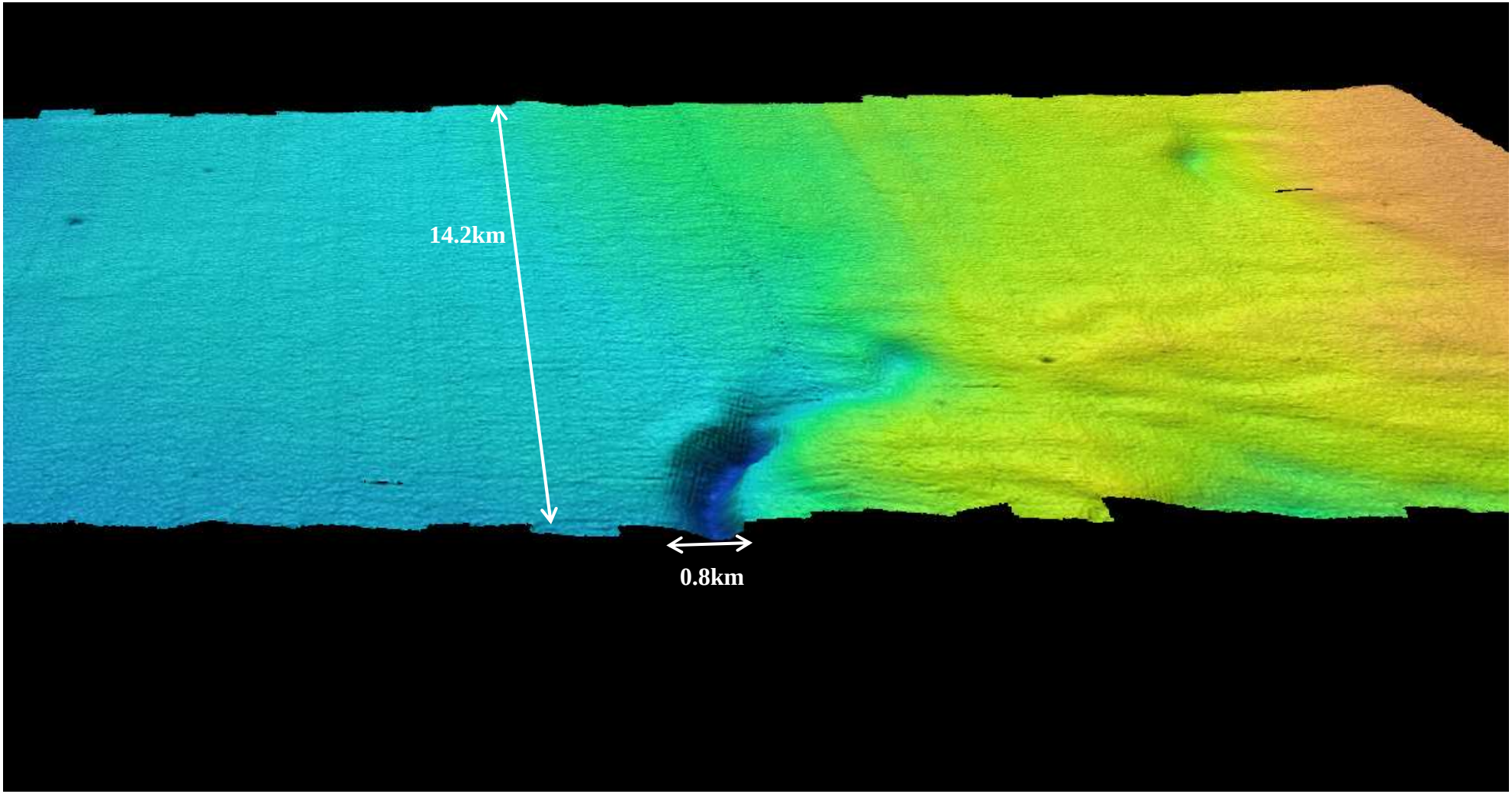

Figure 27. Multibeam image looking north along the possible canyon within Hatton Bank south box 3. The elevated area in the top right of the image has a water depth of 870m, the canyon has a water depth of 945m and the walls of the canyon are 35m in height.

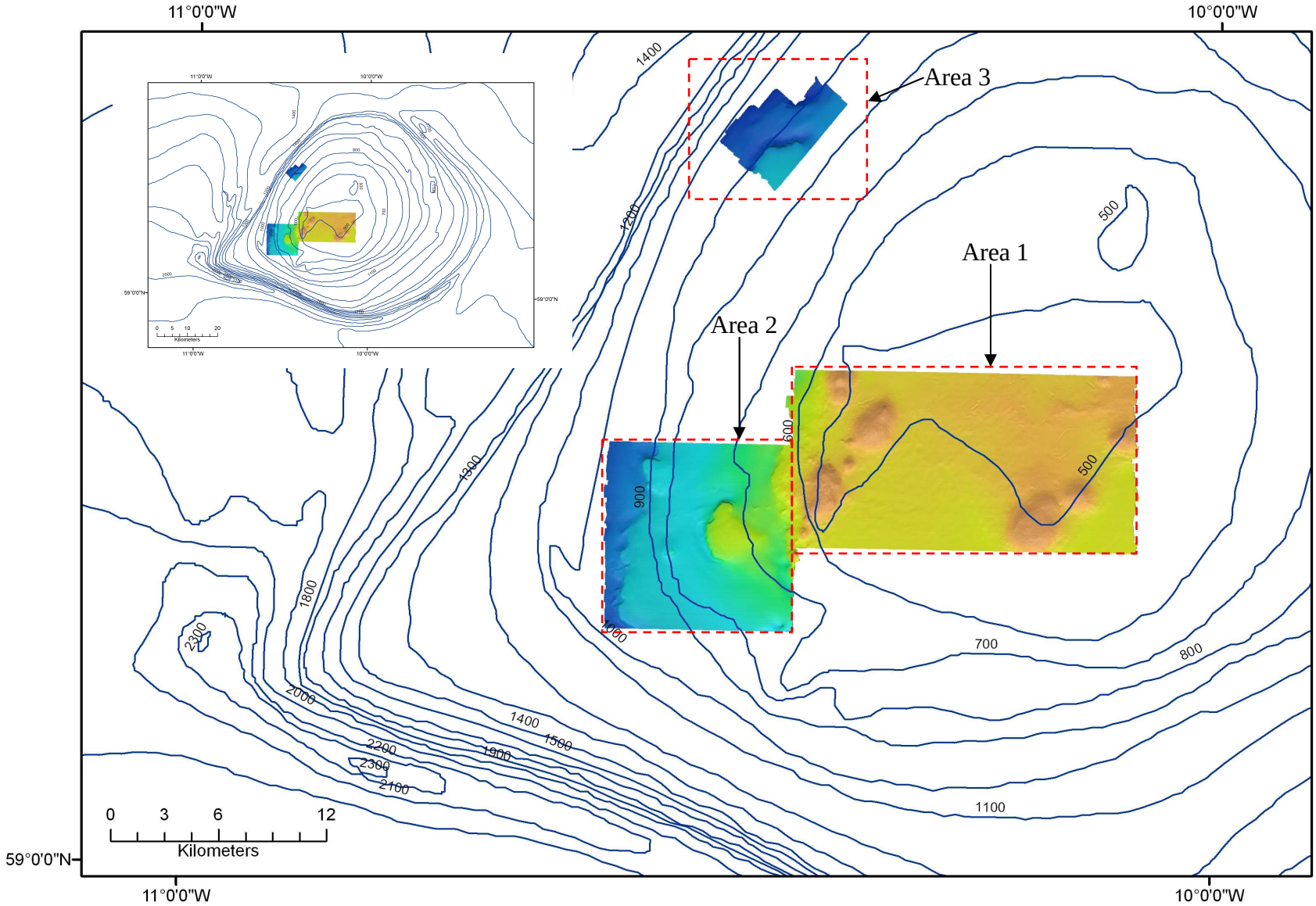

Figure 28. Image showing the location of all 3 areas of multibeam collected during the 0306 survey. The bathymetric contour lines are from GEBCO.

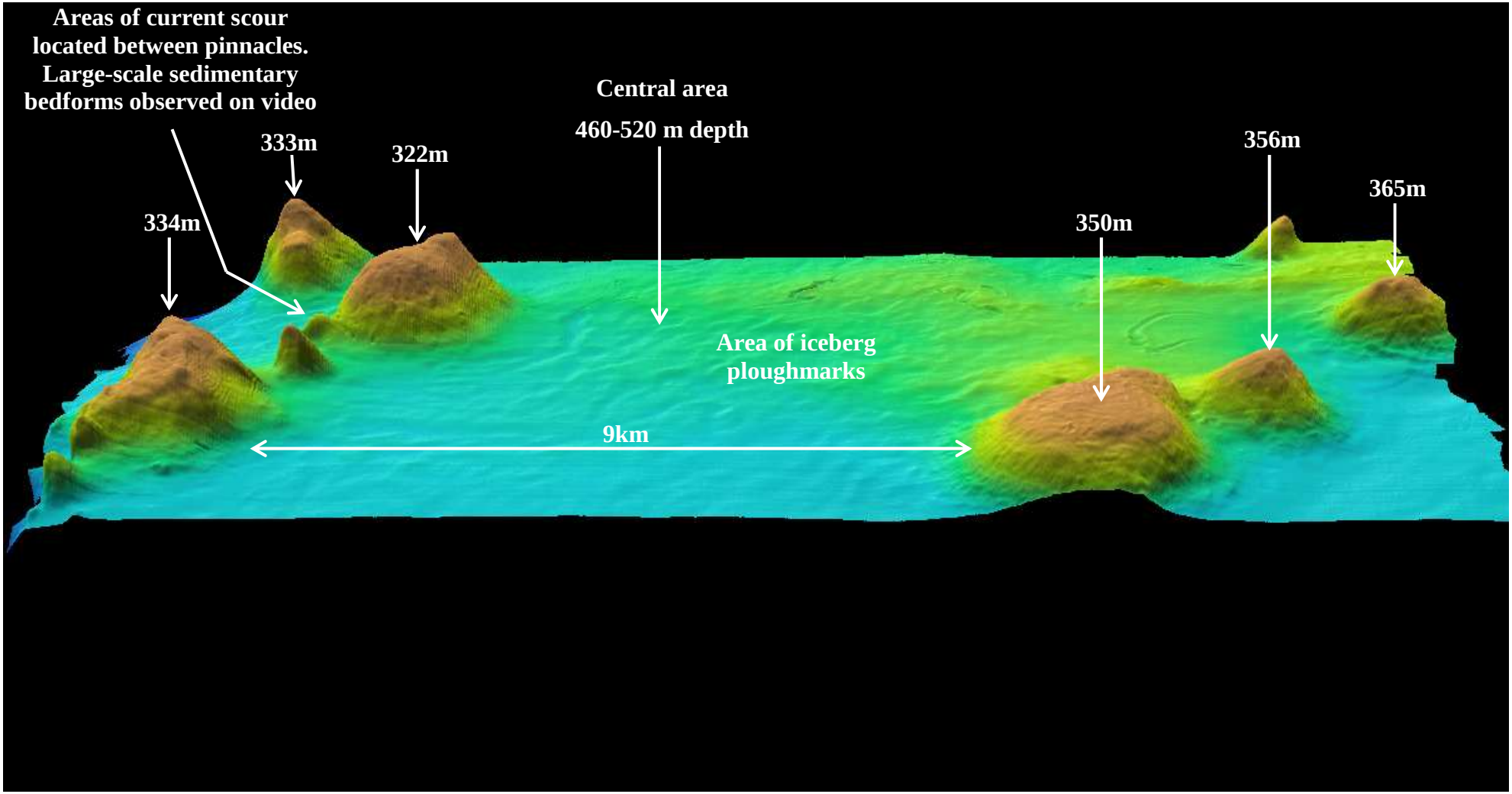

Figure 29. Multibeam data collected over Rosemary Bank 1, the perspective image is looking north. Iceberg ploughmarks are observed on the central area and on top of the larger pinnacles.

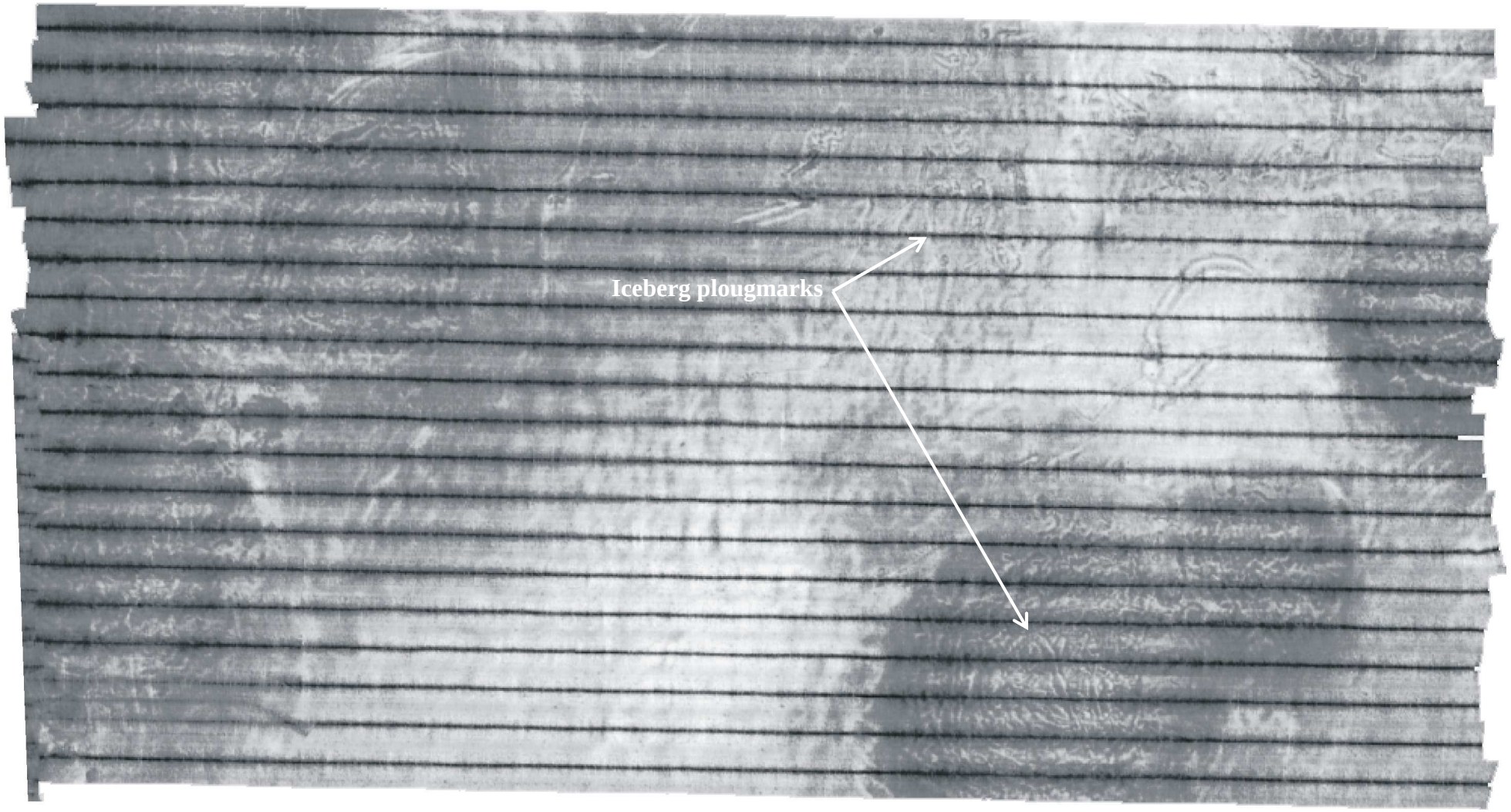

Figure 30. Backscatter image of Rosemary 1. The iceberg ploughmarks present on the pinnacle tops and the flat central area show up clearly. The high backscatter response on the pinnacles indicates that bedrock can be found at or close-to sea bed. Lower areas of backscatter indicated by the paler shades of grey indicate a softer sea bed comprising predominantly sand. The dark stripes orientated east-west are track-line artefacts, spaced at 500m intervals.

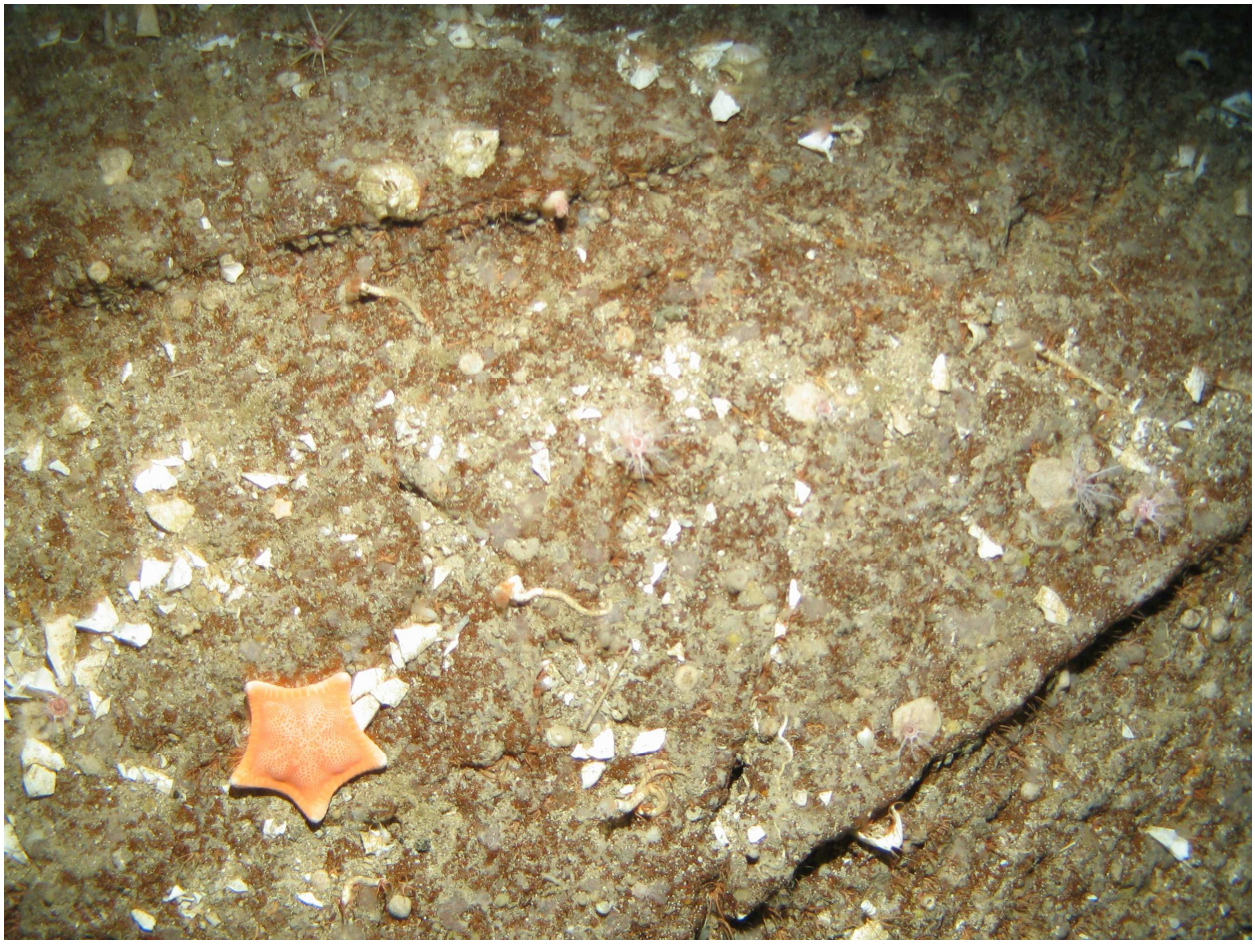

Figure 31. Image RB1_10_21 showing bedrock cropping out at sea bed. For location of camera transect RB1_10 see Figure 34.

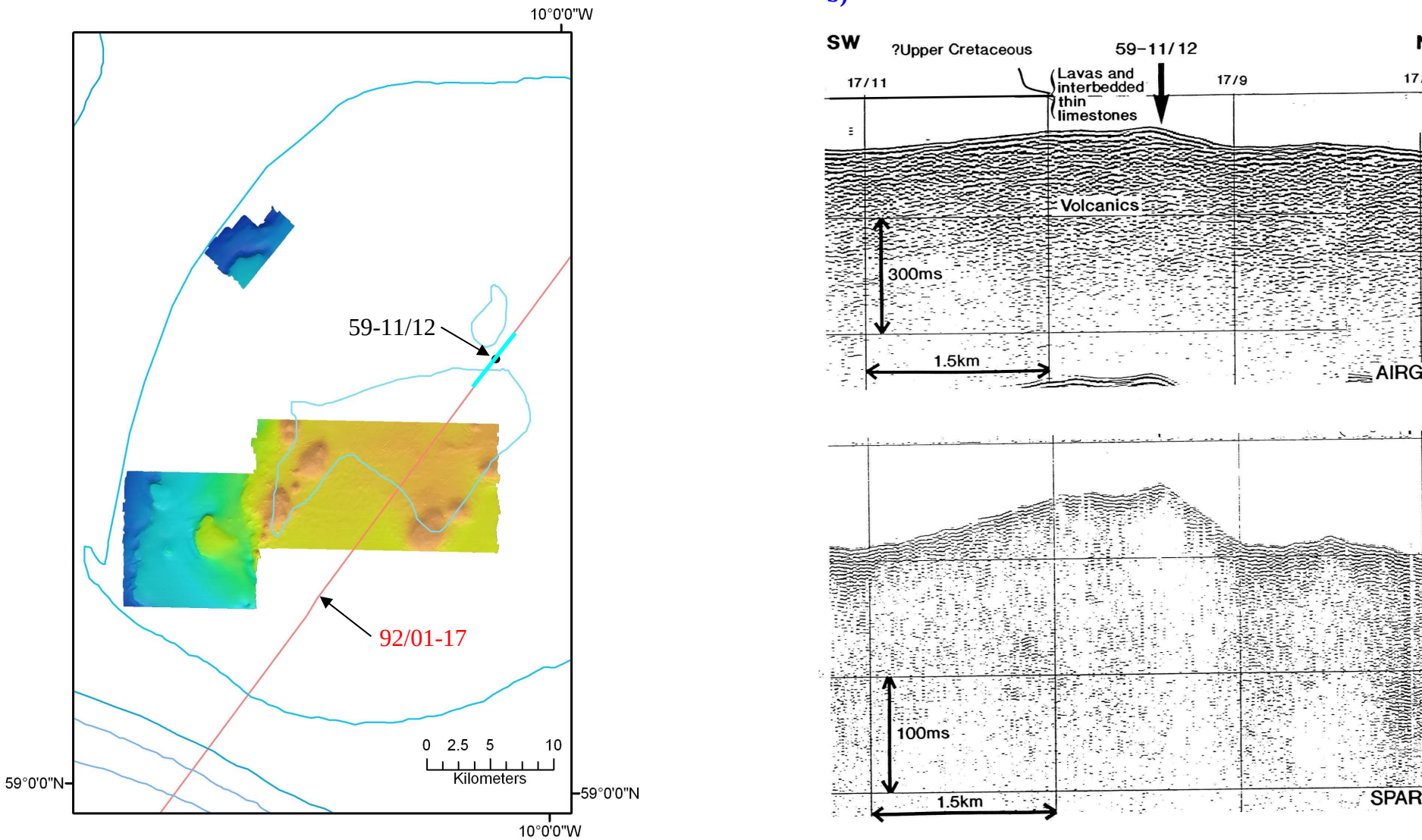

Figure 32. a) Combined multibeam image from the top of Rosemary Bank. The location of BGS sample 59-11/12 is shown along with the location of the seismic (highlighted in blue) shown in b). b) Section of BGS seismic line 92/01-17 over the location of sample 59-11/12 (from Stoker, 2005).

Figure 33. Image of a section of BGS sample 59/11-12 which comprises a 4m core through vesicular lava flows. Analysis of this core has revealed the core to be photo-tephrite in composition (Hitchen *et al.*, 1997). For location please see Figure 32.

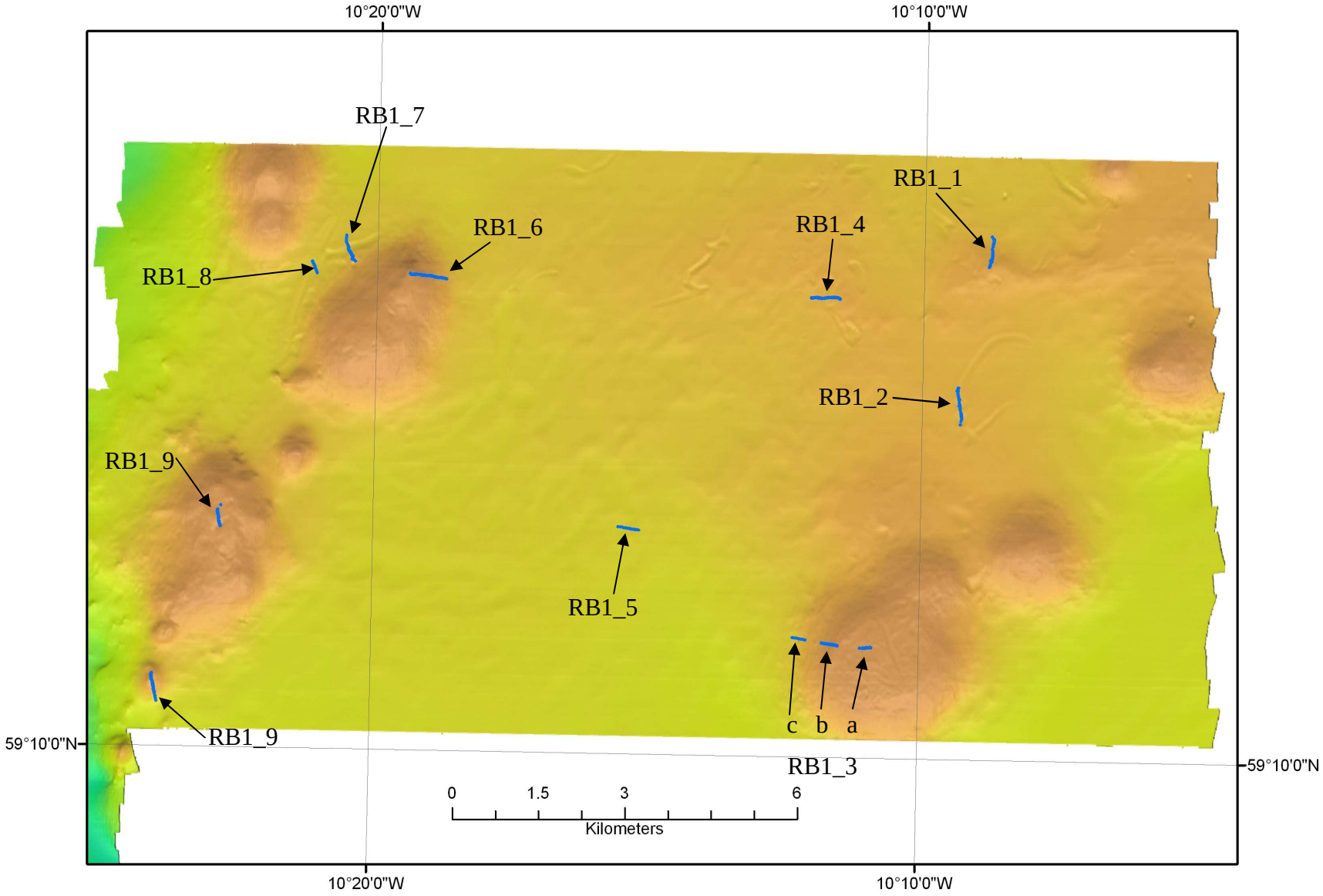

Figure 34. Image showing the location of all the camera transects in the Rosemary 1 area.

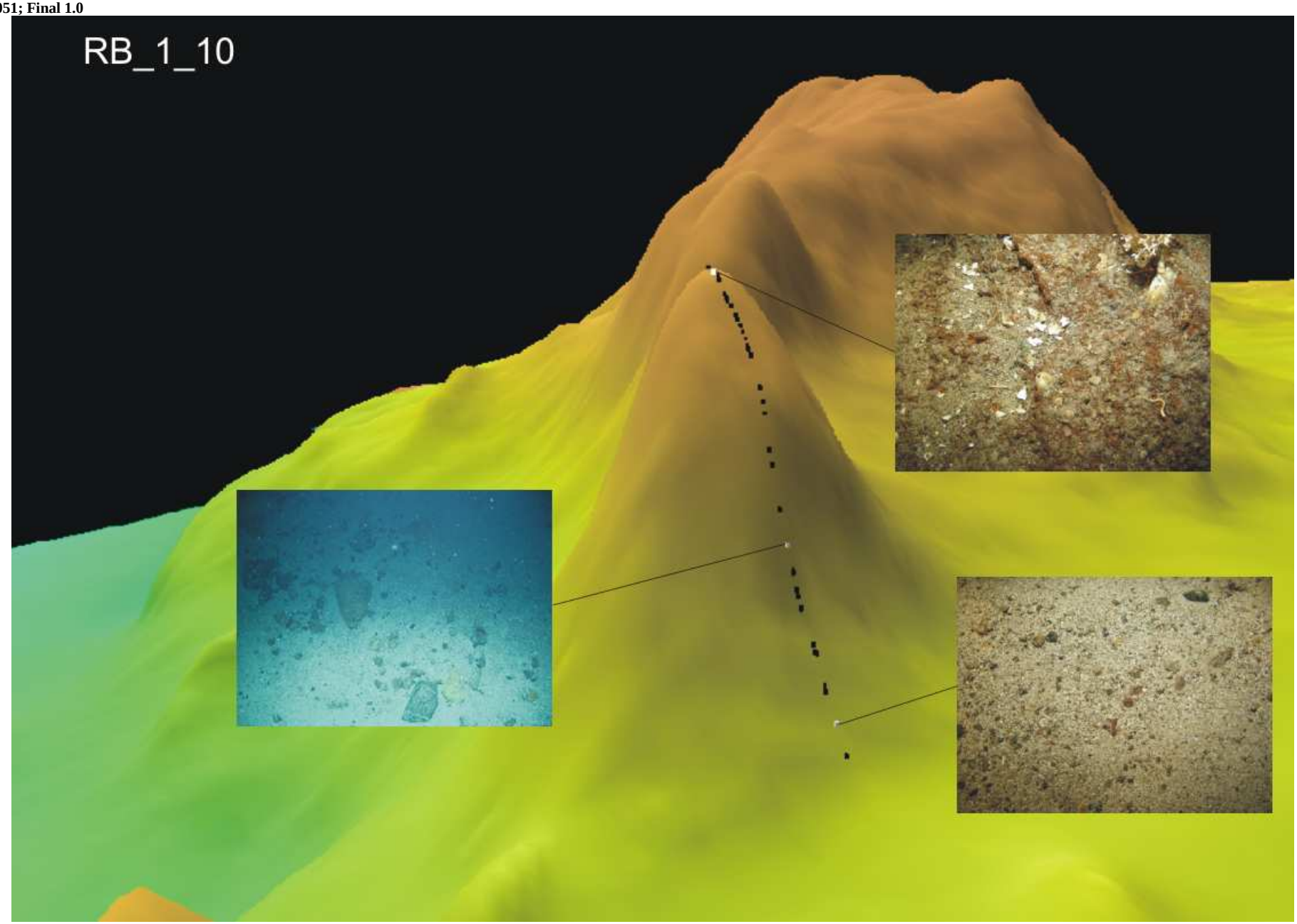

Figure 35. Camera tow of RB_1_10, with selected images showing changes in habitat.

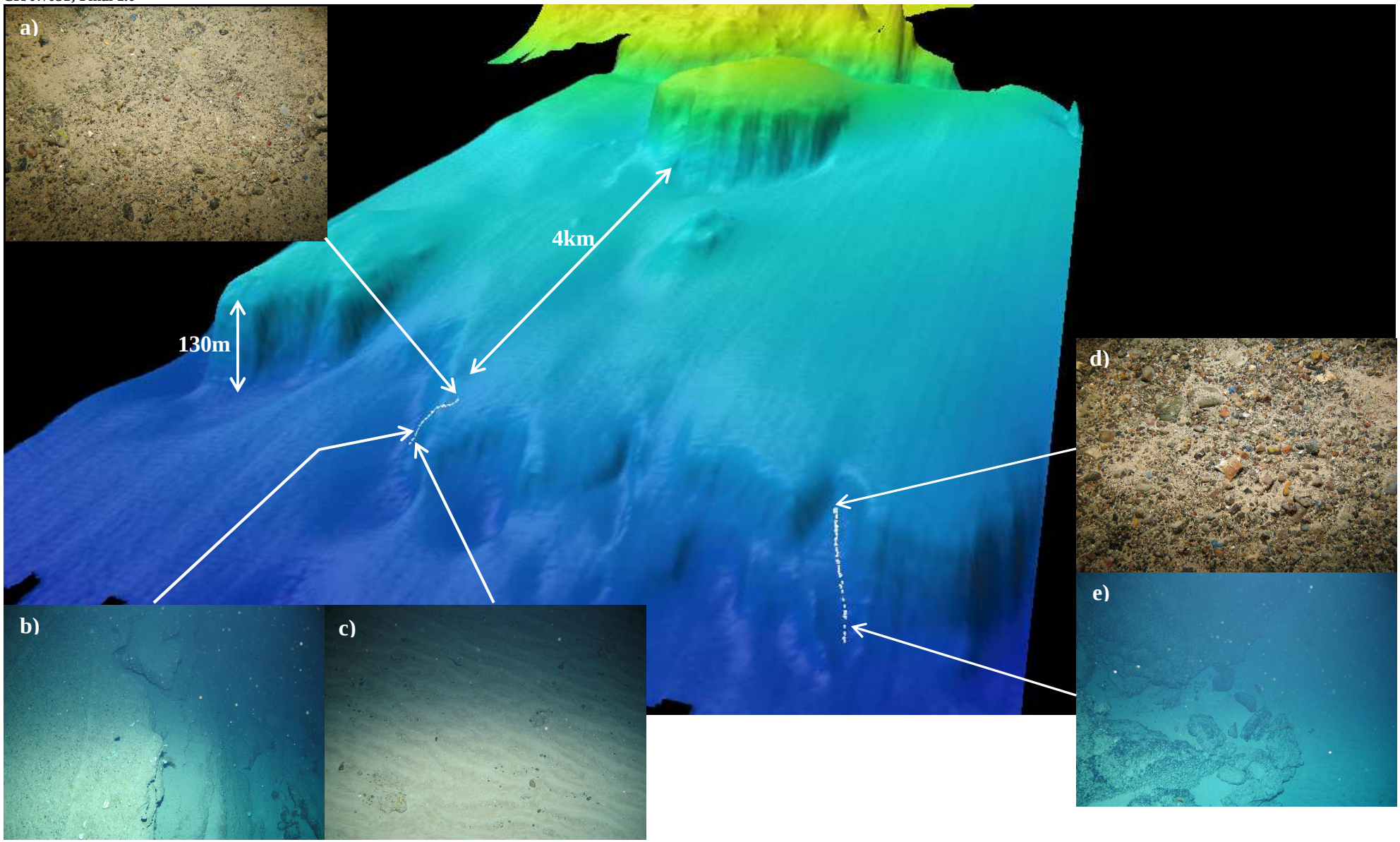

Figure 36. Rosemary area 2 view looking northeast (see Figure 28 for location). The greatest water depths can be found in the bottom left of the image, the shallowest (570m) can be found on top of the pinnacle. a) and d) Images RB2_1_01 and RB2_2_01 showing sand and gravel dominated sea bed. b) and e) images RB2_1_45 and RB2_2_65 showing bedrock cropping out at sea bed, e) also shows the beginning of the ripple field. c) Image RB2_1_48 showing the extensive ripple field present on the terrace.

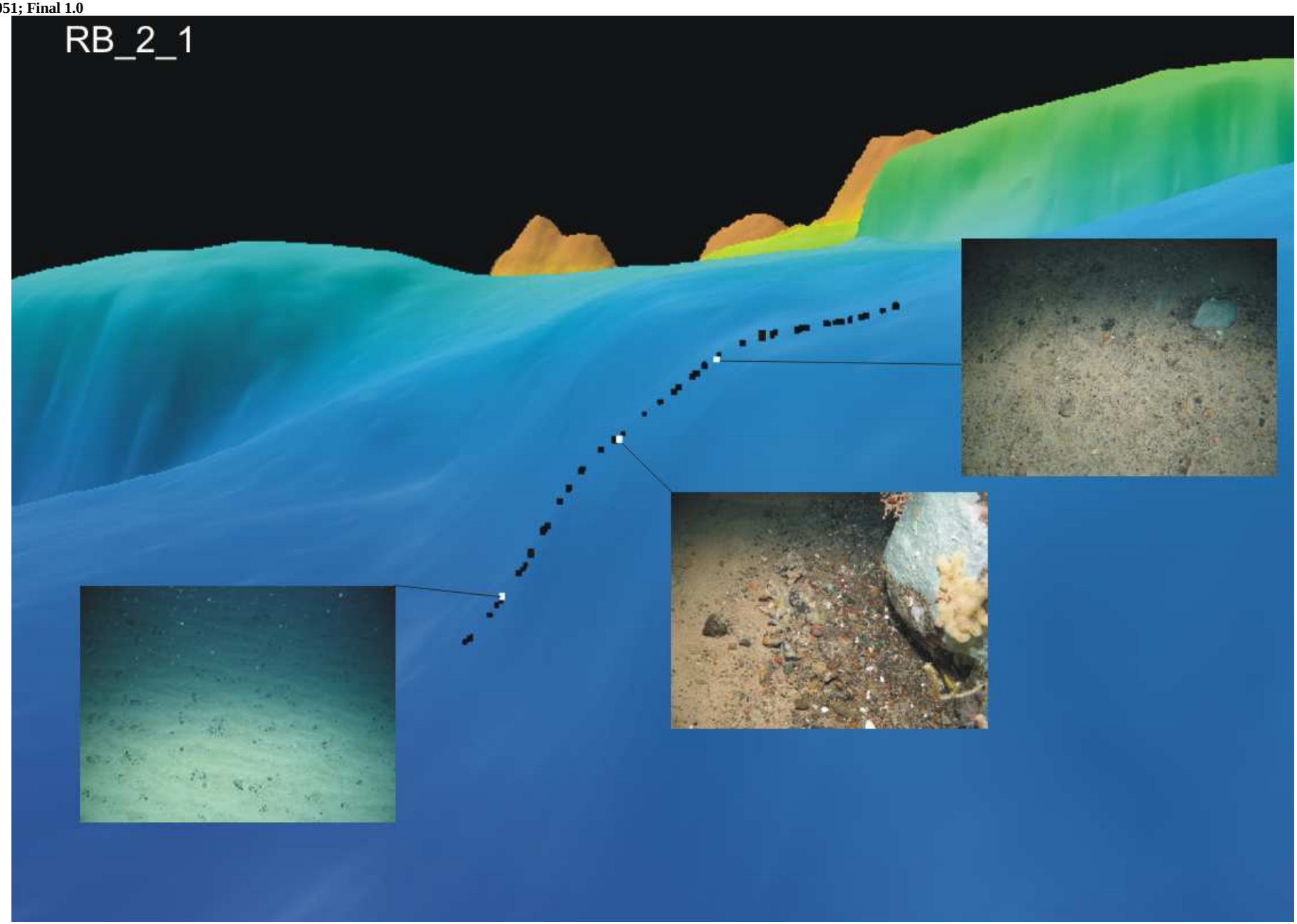

Figure 37. Camera tow of RB_2_1, with selected images to show changes in habitat.

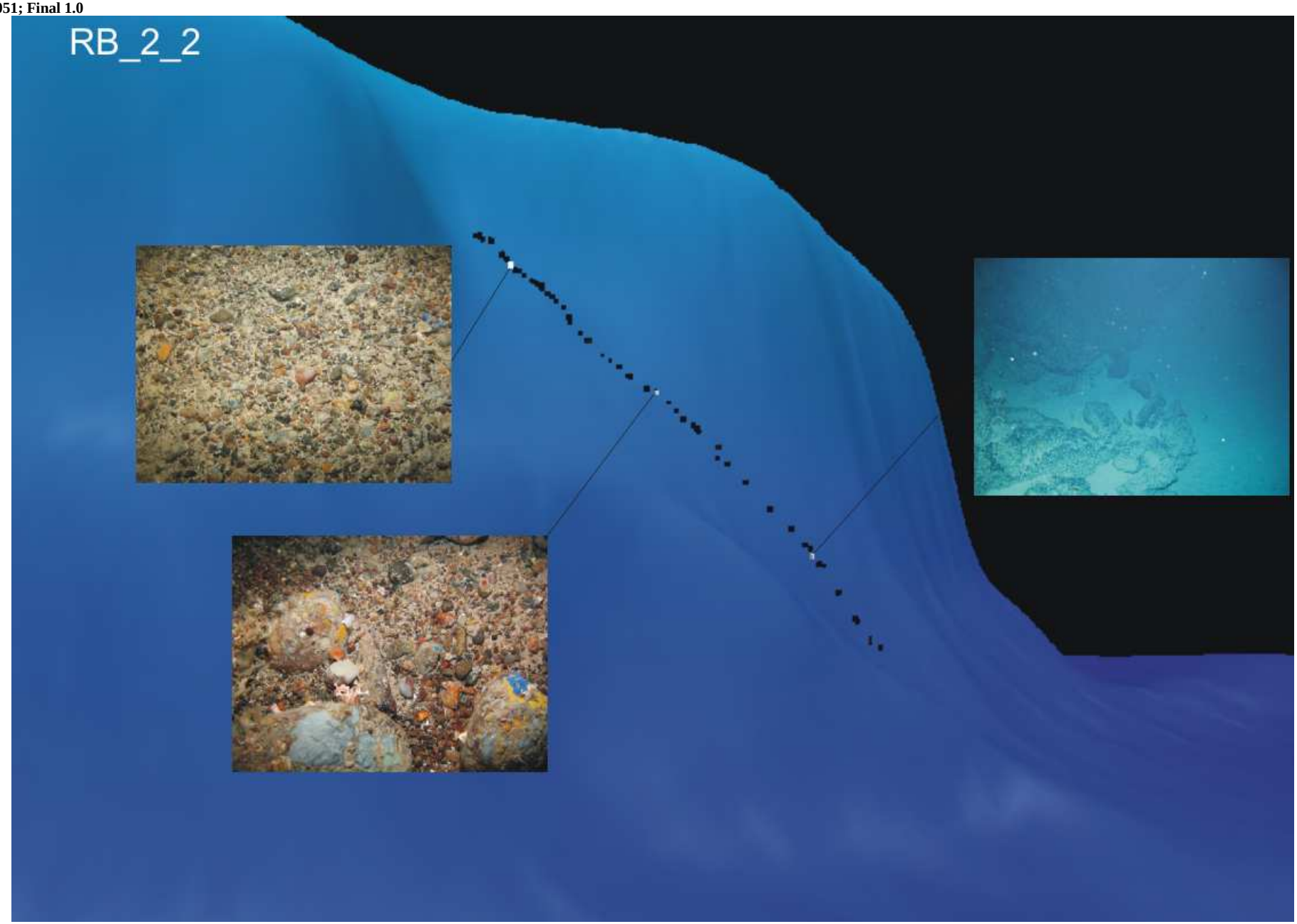

Figure 38. Camera tow of RB_2_2, with selected images showing changing in habitat.

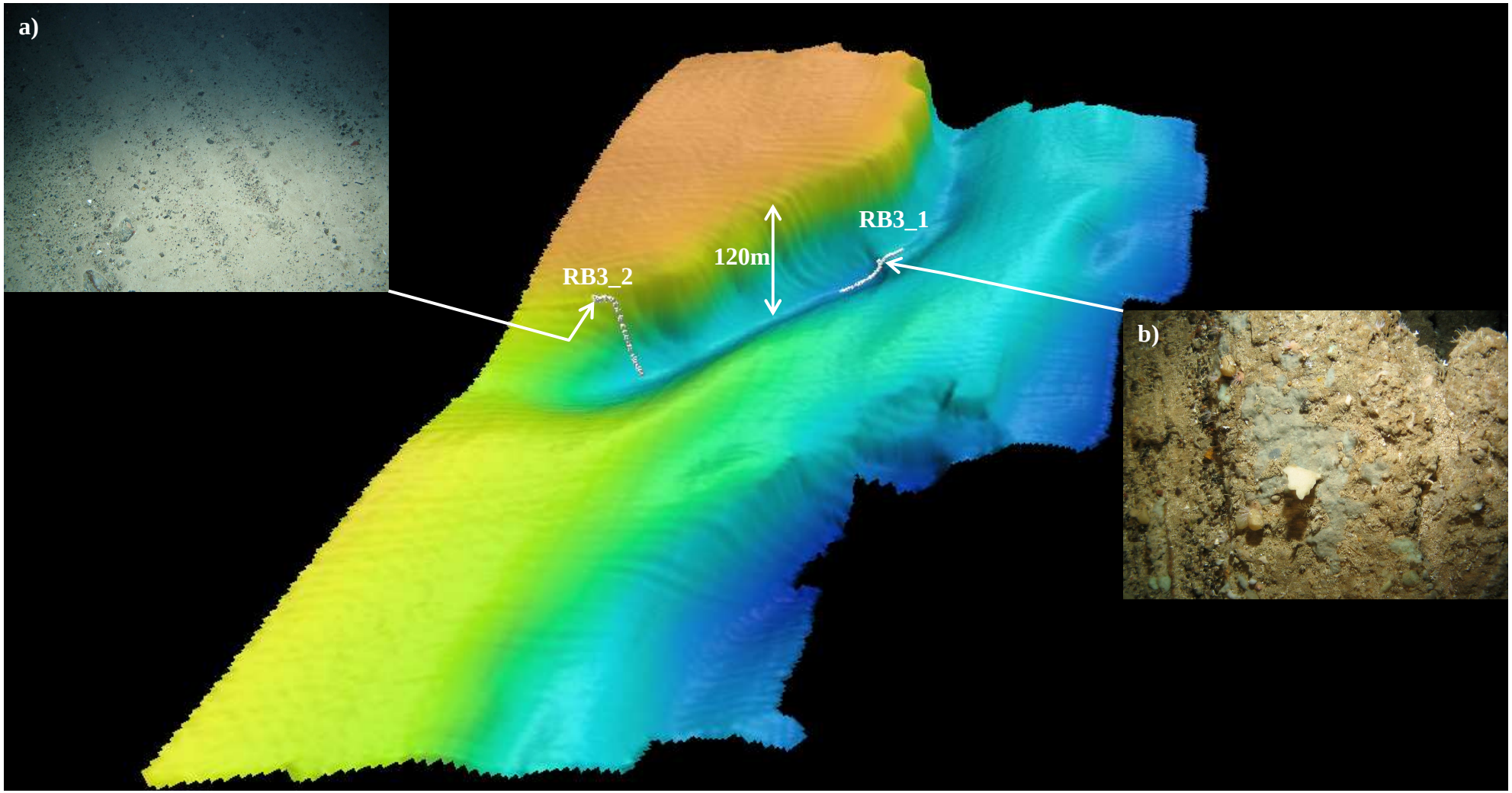

Figure 39. Rosemary area 3 view looking south (see Figure 28 for location). The greatest water depths (980m) can be found in the trench where transect RB3_1 was collected. The shallowest water depths (820m) can be found on top of the bank. a) image RB3_2_4 showing sand and gravel streaks on the sea bed. b) image RB3_1_29 showing bedrock at sea bed over the 'lip' within the trench.

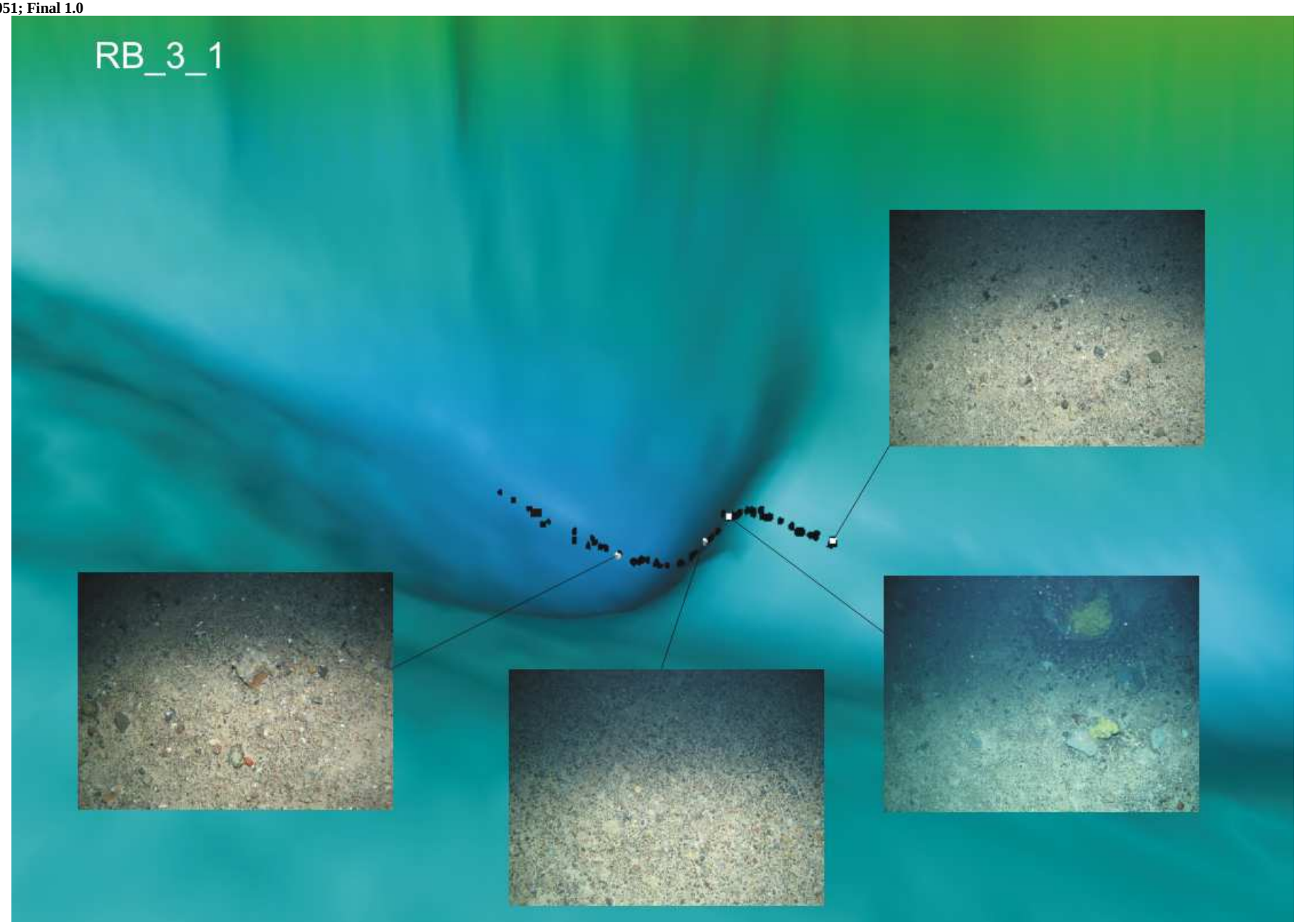

Figure 40. Camera tow of RB_3_1, with selected images to show changes in habitat.

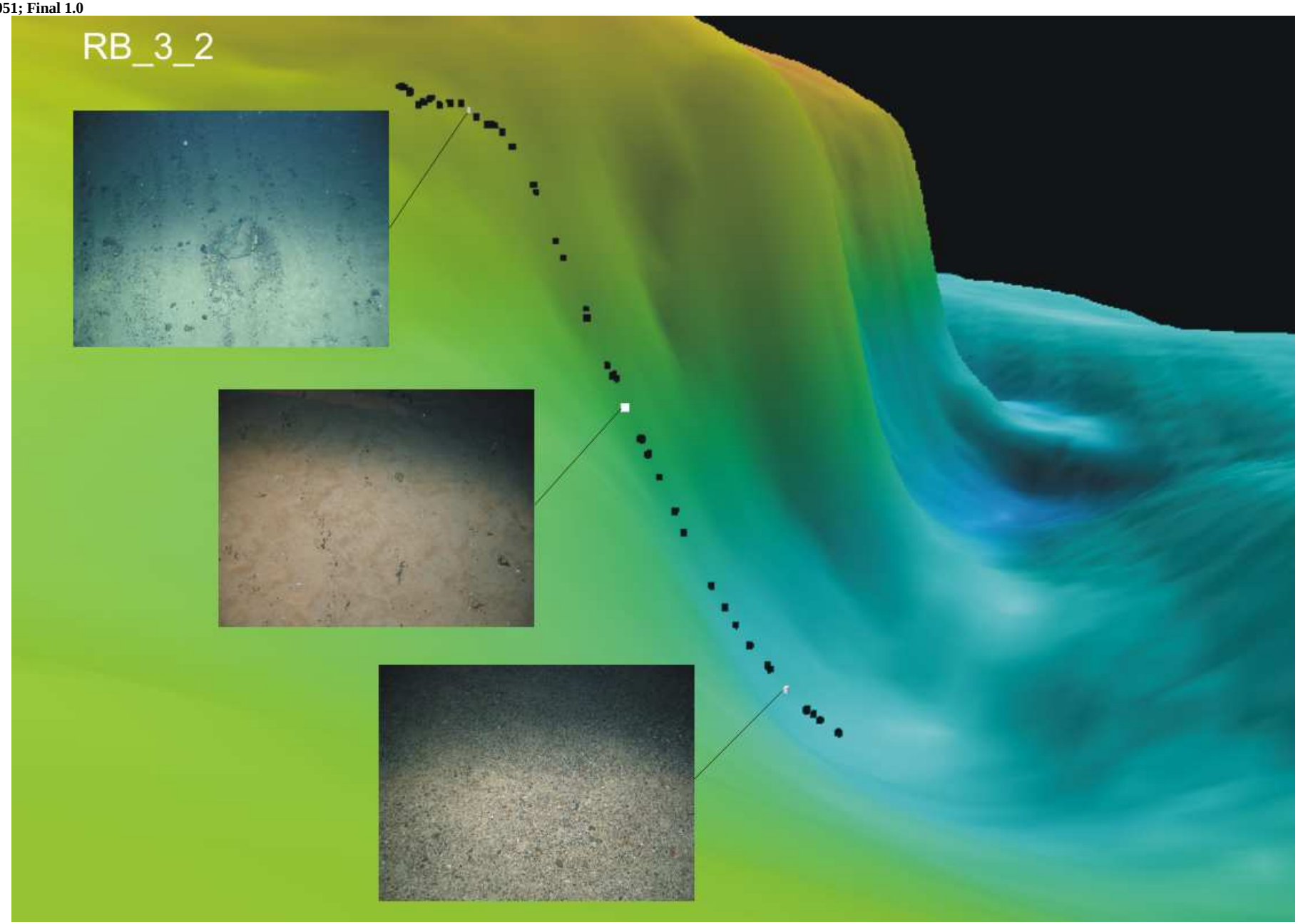

Figure 41. Camera tow of RB_3_2, with selected images to show changes in habitat.

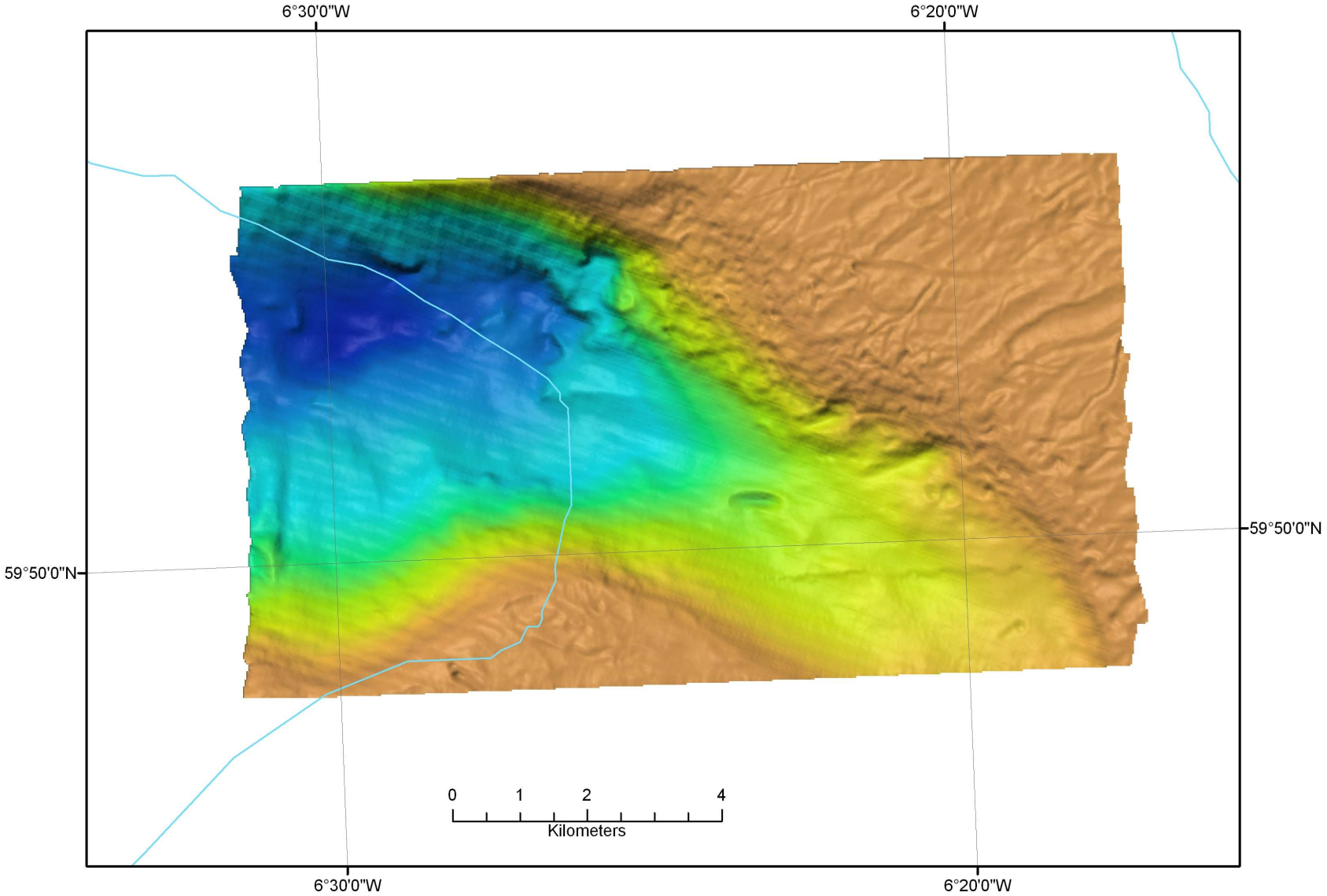

Figure 42. Image showing the extent of the multibeam coverage on the Wyville Thomson Ridge collected during survey 0306. The shallowest water depths are found on the top of the ridge (435m) and the deepest water depths indicated by dark blue colours (760m). During the survey 0406 the multibeam coverage was expanded significantly.

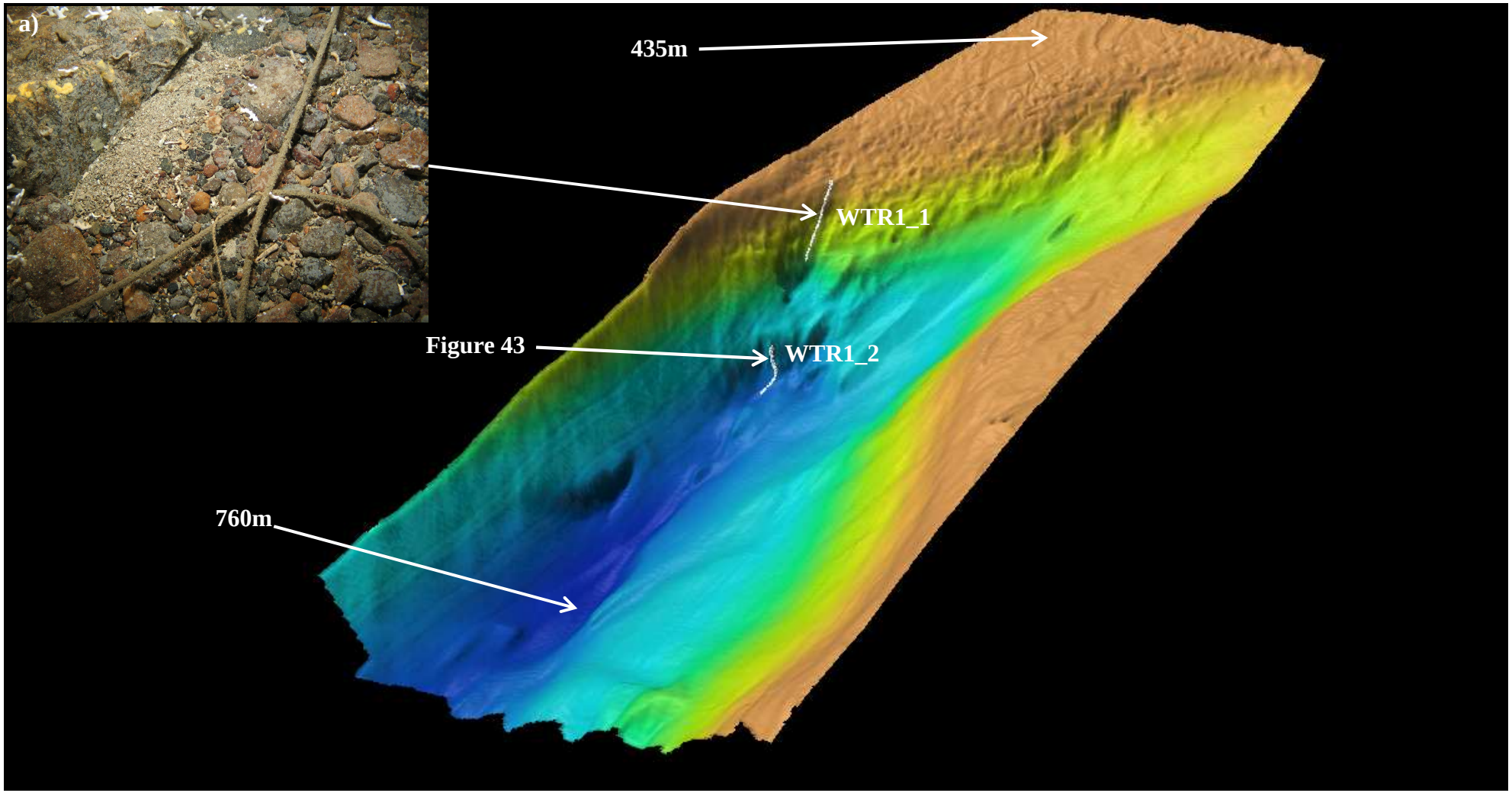

Figure 43. Image looking northeast towards the crest of the Wyville Thomson Ridge (for location see Figure 42). The two camera transects collected during the course of this survey are marked. Image WTR1_1_68 (a) shows anthropogenic debris on a sea bed comprising a gravel lag deposit.

Figure 44. Image WTR_2_023 illustrating the range in clast size and composition on the Wyville Thomson Ridge. Note the presence of biogenic sand and gravel comprising coral fragments. For location of camera transect please see Figure 43.

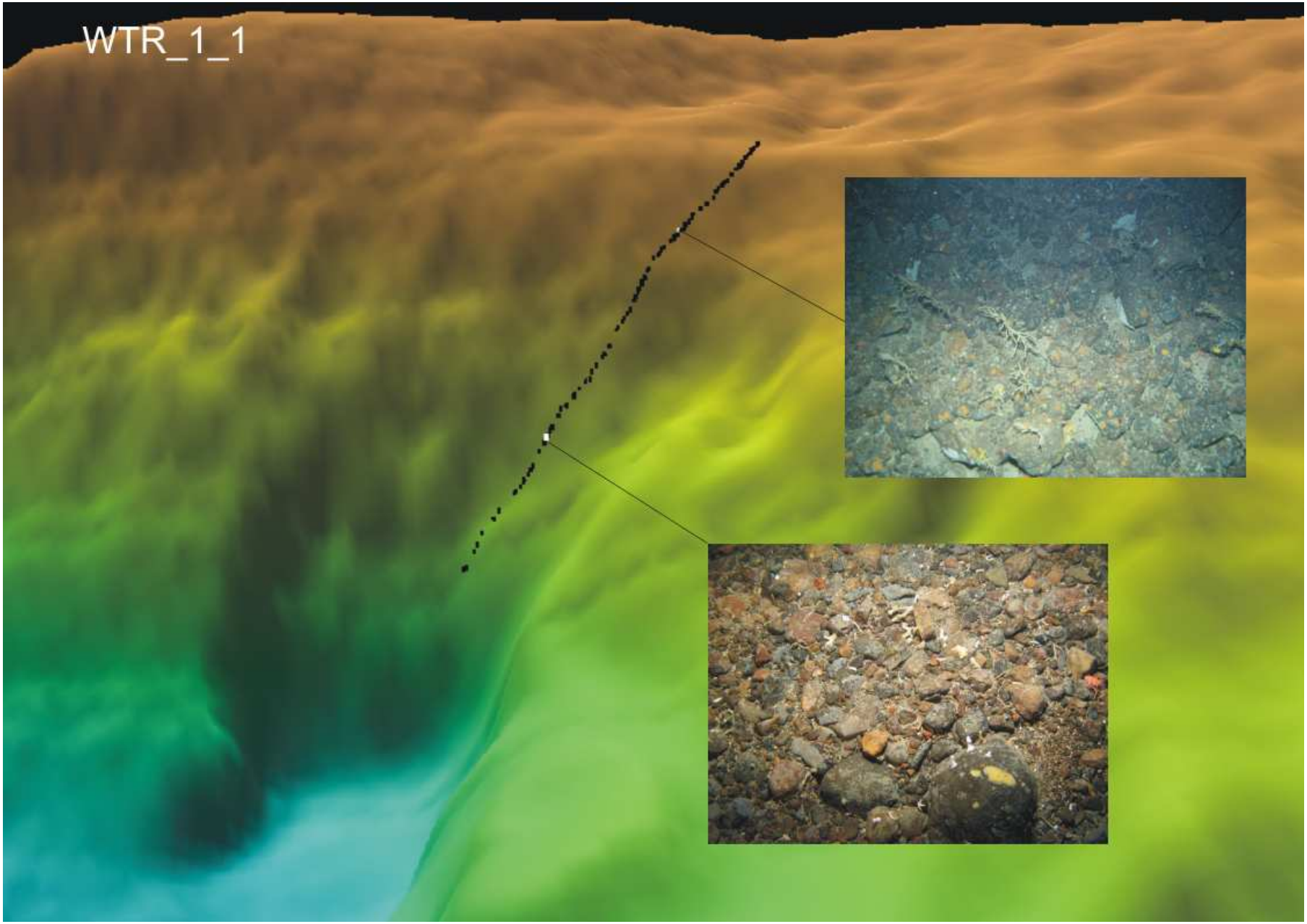

Figure 45. Camera tow of WTR_1_1, with selected images to show changes in habitat.

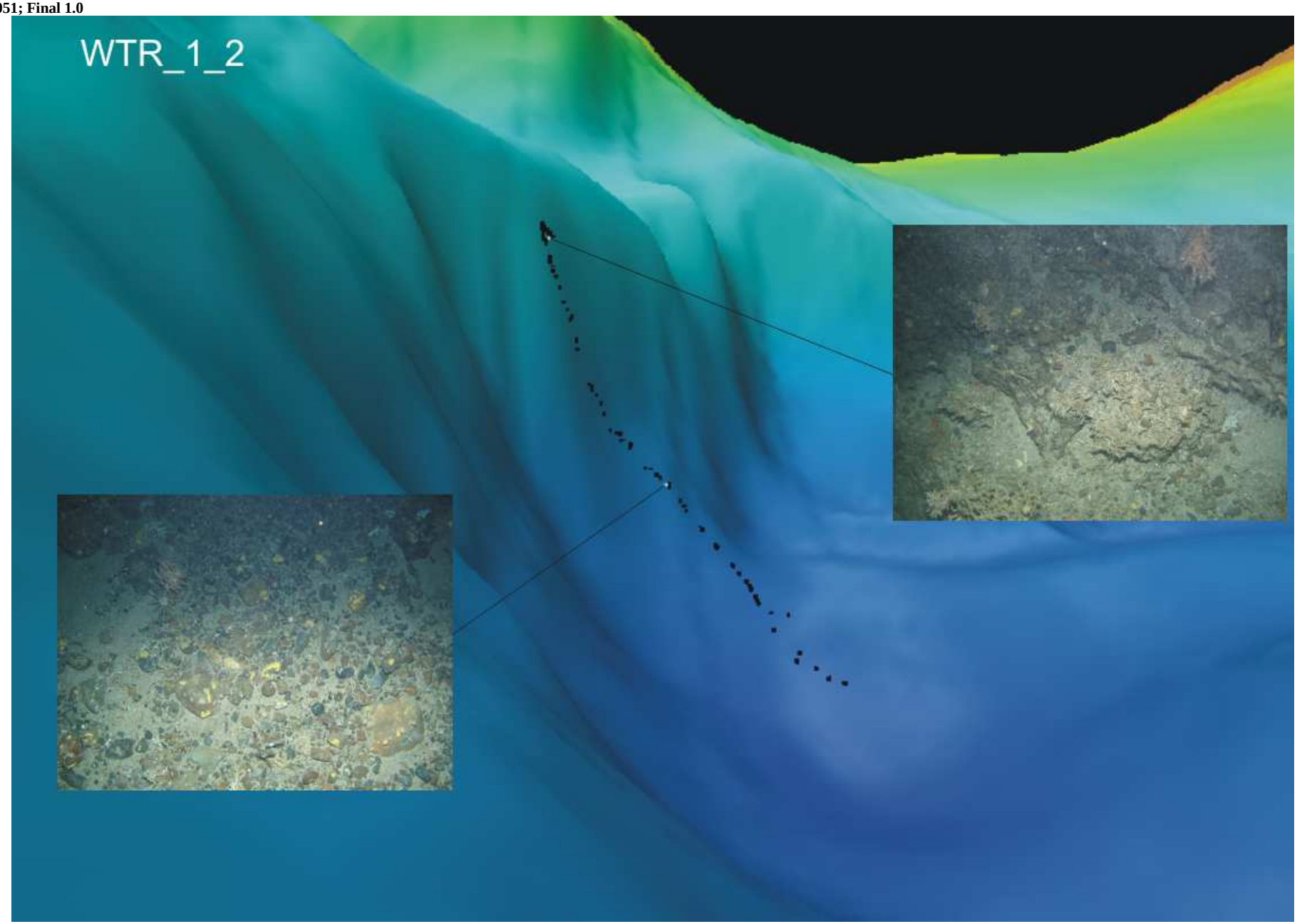

Figure 46. Camera tow of WTR_1_2, with selected images to show changes in habitat.

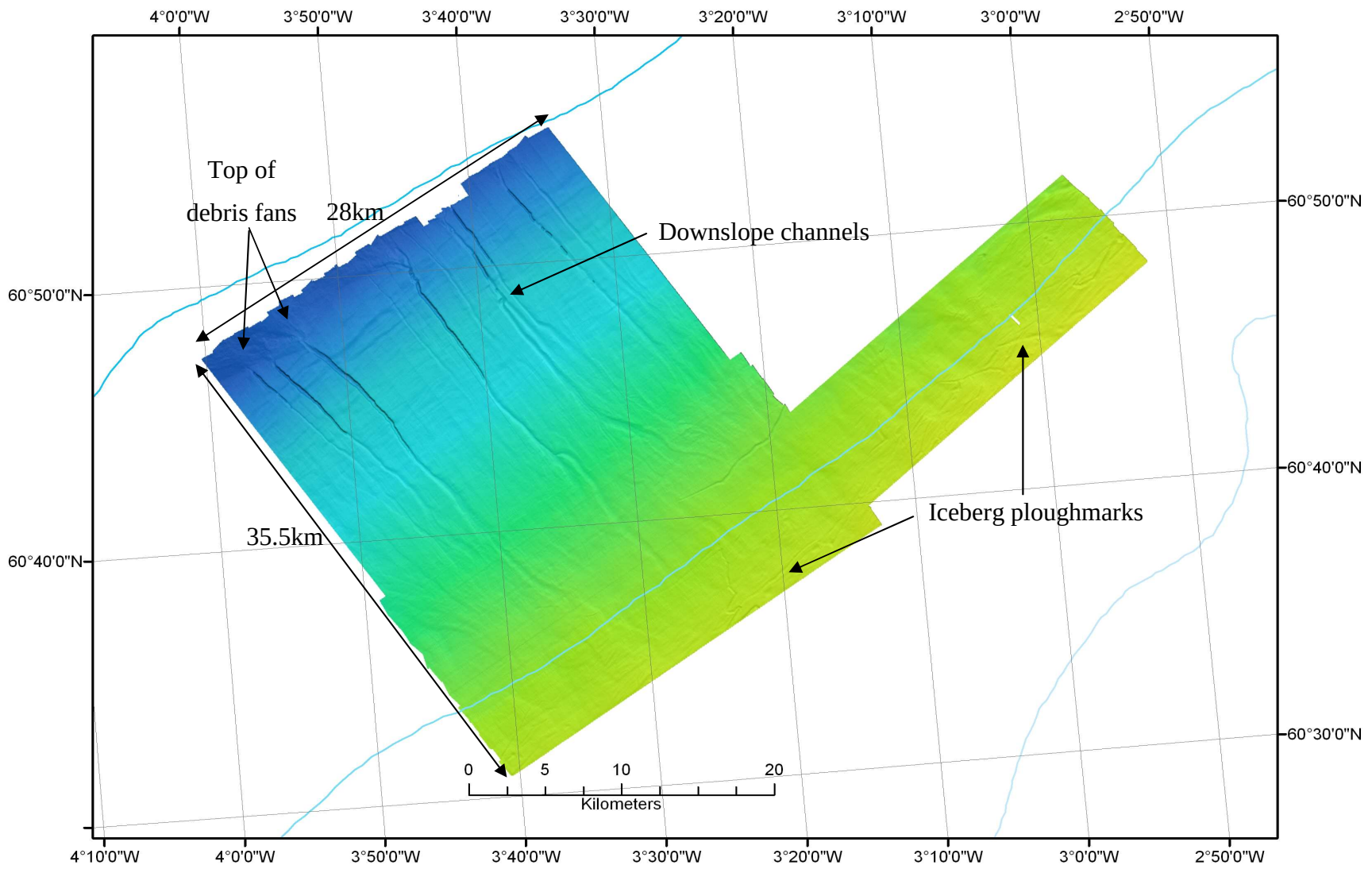

Figure 47. Multibeam bathymetry data collected during the course of 0306 and 0406 operations. The downslope channels can be seen extending from 500m water depth to just under 1000m water depth, due to restrictions in the operating capability of the equipment used, the debris fans known to exist at the bottom of the channels could not be imaged. Iceberg ploughmarks can be identified on the upper slopes of the Faroe–Shetland Channel.

Appendix 1 List of Personnel

Scientific Personnel

Heather A Stewart	British Geological Survey
Jaime S Davies	University of Plymouth
Natalie C J Coltman	Joint Nature Conservation Committee

Survey Personnel

Torbjörn Ekfeldt	Marin Mätteknik AB
Gustav Flink	Marin Mätteknik AB
Sofia Yassin	Marin Mätteknik AB
Hampus Arvidsson	Marin Mätteknik AB
Johan Barne	Marin Mätteknik AB
Olle Peterson	Marin Mätteknik AB
Fredrik Johansson	Marin Mätteknik AB
Craig Cameron	SEATRONICS Ltd

Ships Personnel

Lars Olofsson	Master
Svante Johansson	Chief Officer
Peter Falk	Second Officer
Lars-Erik Hedlund	Chief Engineer
Arne Löfgren	First Engineer
Joakim Arvidsson	Motorman
Per Karlström	Able Seaman
Lennart Gistedt	Able Seaman
Törner Hansson	Able Seaman
Max Sundgren	Deck Boy
Lennart Jönsson	Cook

Appendix 2 Table of Photographic Transect Locations

Site Label	Date	Start Time	Start Latitude (North)	Start Longitude (West)	End Time	End Latitude (North)	End Longitude (West)
HS2_1	29/08/06	12:14	58.055355	-18.721692	12:57	58.060349	-18.721888
HS2_2	29/08/06	14:32	58.064638	-18.757739	15:26	58.068665	-18.758751
HS2_3	29/08/06	17:13	58.045130	-18.779966	18:13	58.051064	-18.776893
HS2_4	29/08/06	19:07	58.063632	-18.767201	19:31	58.065092	-18.767819
HS2_5	29/08/06	21:00	58.068425	-18.812263	22:00	58.074012	-18.814657
HS3_1	31/08/06	19:25	57.888870	-18.997120	20:12	57.893530	-18.994946
HS3_2	31/08/06	21:51	57.851213	-19.067565	22:46	57.855575	-19.068271
HS3_3	02/08/06	08:14	57.795692	-19.124067	09:18	57.788152	-19.124179
HS3_4	02/08/06	10:39	57.827885	-19.130953	11:58	57.822011	-19.125745
HS3_5	02/08/06	14:06	57.875062	-18.916139	14:39	57.877748	-18.917160
RB1_1	06/09/06	22:29	59.248594	-10.146322	23:05	59.243755	-10.147011
RB1_2	07/09/06	00:01	59.224875	-10.155766	00:35	59.219118	-10.154960
RB1_3	07/09/06	01:35	59.184078	-10.181129	02:31	59.185443	-10.205110
RB1_4	07/09/06	03:46	59.238473	-10.192349	04:20	59.238587	-10.201058
RB1_5	07/09/06	05:31	59.201810	-10.252327	05:52	59.202308	-10.258659
RB1_6	07/09/06	07:29	59.241291	-10.323269	07:59	59.240496	-10.312210
RB1_7	07/09/06	09:11	59.243015	-10.340177	09:52	59.247042	-10.342941
RB1_8	07/09/06	11:09	59.241047	-10.351698	11:25	59.242843	-10.353235
RB1_9	07/09/06	12:23	59.201261	-10.379739	12:53	59.204541	-10.379658
RB1_10	07/09/06	13:25	59.177988	-10.399799	13:53	59.173686	-10.398110
RB2_1	07/09/06	15:32	59.177469	-10.566899	16:00	59.181265	-10.569290
RB2_2	07/09/06	17:21	59.141414	-10.574425	18:00	59.138861	-10.581929
RB_Moat*	07/09/06	20:08	59.008999	-10.544070	20:56	59.005926	-10.545475
RB3_1	08/09/06	13:50	59.379012	-10.440039	14:18	59.379083	-10.432331
RB3_2	08/09/06	15:13	59.376717	-10.407380	15:41	59.380252	-10.408898
WTR1_1	11/09/2006	13:51	59.876582	-6.410440	14:28	59.874323	-6.422269
WTR1_2	11/09/2006	15:29	59.870390	-6.439228	16:03	59.868595	-6.445421

*Ships position rather than camera position like all other transects.

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

BOLDREEL, L O, ANDERSEN, M S, and KUIJPERS, A. 1998. Neogene seismic facies and deep-water gateways in the Faeroe Bank area, NE Atlantic. *Marine Geology*, Vol. 152, 129-140.

BULAT, J, and LONG, D. 2001. Images of the seabed in the Faroe–Shetland Channel from commercial 3D seismic data. *Marine Geophysical Researches*, Vol. 22, 345-367.

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