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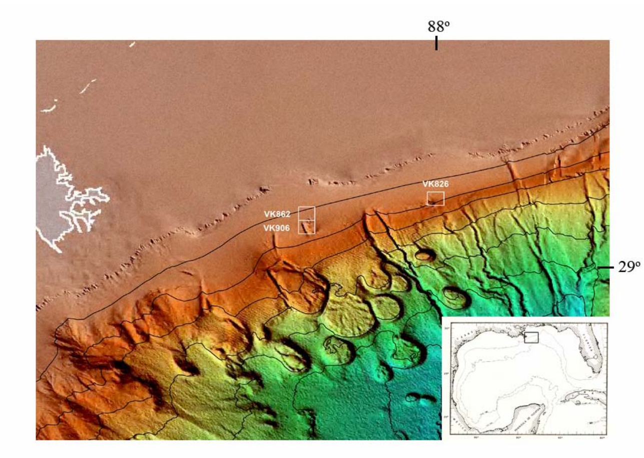

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

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Seafloor Characteristics and Distribution Patterns of *Lophelia pertusa* and Other Sessile Megafauna at Two Upper-Slope Sites in the Northeastern Gulf of Mexico

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William W. Schroeder

EXECUTIVE SUMMARY

Habitat-forming deep-water (a.k.a. cold-water) coral ecosystems are known to serve as important components of the world's oceans and seas. One of the principal species of branching scleractinian corals that form deep-water assemblages is the tuft coral *Lophelia pertusa.* Generally, these corals are very slow to develop and fragile. As a result they are vulnerable to sustaining damage that if extensive can require years for recovery, if at all. Unfortunately this situation is already occurring globally principally due to destructive fishing practices and secondarily as a consequence of activities associated with exploration and extraction of fossil fuels. In light of the continuing expansion of oil and gas activities into the deep Gulf of Mexico (GoM), there is a crucial need to understand the basic biology and functional ecology of these unique systems, and ultimately to determine appropriate management strategies for their protection.

Beginning in the early 1990s, results from research supported by the Minerals Management Service (MMS), the National Oceanic and Atmospheric Administration, the National Science Foundation and the US Navy have made important contributions to our understanding of deep-water corals in the GoM. However, it was not until 2003, when the MMS funded the study "Characterization of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral" that a comprehensive effort was undertaken to specifically examine the biology and ecology of deep-water corals. Also in 2003, the MMS funded this study to document the seafloor characteristics and the distribution patterns of *L. pertusa* and other sessile megafauna at two of the principal sites of interest specifically targeted for the comprehensive study. The two sites, Viosca Knoll 826 (VK826) and Viosca Knoll 862-906 (VK862-906) are located on the upper DeSoto Slope subprovince, which extends westward from the northern end of the West Florida Terrace and the DeSoto Canyon to the eastern side of the upper Mississippi Fan.

VK826 has the most extensive development of *L. pertusa* found in the GoM to date. The primary site is located on a 90 m/295 ft tall, isolated knoll on the seaward steepening upper DeSoto Slope. A second site, the crest and upper portions of a small 26 m/85 ft tall pinnacle shaped mound, lies approximately one kilometer northeast of the top of the main knoll. Seafloor characteristics documented at VK826 included locally hummocky terrain made up of carbonate capped knolls and ridges, some with steep vertical relief, terrace-like features composed of carbonate outcrops/buildups, boulders, slabs, rubble, sediment veneered hardgrounds, extensive shell lag deposits and open flats of unconsolidated sediment, and a sediment fan-debris field with large boulders and blocks and smaller material of various sizes and shapes. *Lophelia pertusa*, the gorgonian *Callogorgia americana delta*, antipatharians, and tubeworms were all widely distributed across large portions of VK826 while anemones were restricted to the deeper seafloor adjacent to Knobby Knoll. The dominant megafauna taxon at this site is *L. pertusa* which has successfully developed extensive assemblage complexes, comprised of large colony aggregations/thickets, at numerous locations on the main knoll and a thicket-coppice complex covering the top of Knobby Knoll. Conversely, the most extensive developments of both *C. americana delta* and the antipatharians are scattered, small stands or fields of usually fewer than 25 individuals. These occur in the debris field on the southwestern side and flank of the knoll for both taxa and also on the deeper seafloor west of the knoll for *C. americana delta* and across the central region of the south side of the knoll for the antipatharians. Tubeworms are present throughout a large portion of the study site but generally occur only in scattered clusters of small individuals or as isolated large bushes.

VK862-906 is located in a low-relief mound and ridge complex 2.3 km/1.2 nm northeast of the eastern rim of a small submarine canyon on the upper DeSoto Slope subprovince approximately 37 km/20 nm west-southwest of the VK826 site. The primary study site is a small, low-relief mound formed from large blocks and boulders in the southeast corner of lease block VK862. Water depths at the study site range between 304-333 m/997-1093 ft. A second site, located in the northeast corner of lease block VK906, is approximately 1100 m to the southwest of the primary site. The area surveyed includes portions of two generally north-south oriented parallel ridges, covered with carbonate pavement, and adjacent unconsolidated sediment flats. Water depths ranged from 328 to 352 m/1076 to 1155 ft. Three of the five megafauna taxa reported from VK826 also occur at VK862-906: *L. pertusa*, antipatharians and anemones. The only significant development of *L. pertusa*, an aggregation of at least five large colonies, was found on the crest of the mound site in VK862. Other smaller colonies were observed scattered throughout the site; with a slight preference for the northern flank of the mound. No *Lophelia* were observed at the ridges site in VK906. The dominant taxa at both the VK862 and VK906 sites, in terms of numbers and biomass, are anemones. The largest megafauna observed were the antipatharians with individual colonies estimated to be between 2.1-2.4 m/7-8 ft tall. There appear to be at least four species of antipatharians and collectively they are the second most abundant megafauna taxa at both sites.

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BACKGROUND

Habitat-forming deep-water[1] (a.k.a. cold-water) coral ecosystems are known to serve as important components of the world's oceans and seas (Rogers 1999: Freiwald et al. 2004; Freiwald and Roberts 2005; Morgan et al. 2006). Generally, these ecosystems are very slow to develop and fragile. As a result they are vulnerable to sustaining damage that if extensive can require years for recovery, if at all. Unfortunately this situation is already occurring globally principally due to destructive fishing practices and secondarily as a consequence of activities associated with exploration and extraction of fossil fuels (Rogers 1999; Gage 2001; Hall-Spencer et al. 2001; Fossa et al. 2002; Schroeder 2002; Glover and Smith 2003). One of the principal species of schleractinian corals that form deep-water ecosystems is the tuft coral *Lophelia pertusa.* Moore and Bullis (1960) were the first to publish on the presence of *L. pertusa* in the Gulf of Mexico (GoM). They reported collecting *L. pertusa (=prolifera)* in 1955 from a trawl in 420-512 m/1378-1680 ft of water on the continental slope approximately 74 km/400 nm east of the Mississippi River delta. Since then numerous reports have been published on the occurrence of living *L. pertusa*, as well as *Madrepora oculata*, in the GoM. These have been summarized by Schroeder et al. (2005). In addition, Newton et al. (1987) have described Late Pleistocene age *L. pertusa* structures on the west Florida carbonate ramp slope.

Beginning in the early 1990s, results from research supported by the Minerals Management Service (MMS), the National Oceanic and Atmospheric Administration (NOAA) and the US Navy have made important contributions to our understanding of deep-water corals in the GoM (e.g., Schroeder 2002; Reed et al. 2003, 2004, 2005, 2006; Schroeder et al. 2005). However, it was not until 2003, when MMS funded the study "Characterization of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral," that a comprehensive endeavor was undertaken to specifically examine the biology and ecology of deep-water corals. In contrast, the distribution and ecology of *Lophelia* reefs and banks from the coasts of Europe have been well documented (Mortensen and Rapp 1998, Mortensen et al. 1995, 2001; Freiwald et al. 1997; Rogers 1999; De Mol et al. 2002; Roberts et al. 2003; Taviani et al. 2005).

In the GoM, the indurated surfaces that large, tall, branching deep-water coral colonies require for secure attachment are either 1) hydrocarbon-derived and microbially mediated carbonate deposits[2] (carbonates with anomalously negative carbon isotope compositions relative to the carbon pool in seawater – See Roberts and Aharon 1994) formed at cold seep sites on the Texas-Louisiana, DeSoto, and Gulfo de Campeche slopes or 2) limestone deposits formed on the west Florida and Banco de Campeche slopes and in the Florida Straits.

In light of the continuing expansion of oil and gas activities into the deep GoM, there is a crucial need to understand the basic biology and functional ecology of these unique systems, and ultimately to determine appropriate management strategies for their protection. One of the first steps in achieving these goals is to survey and describe deep-water coral communities and their geologic settings. This research report directly addresses this need by documenting the seafloor characteristics and the distribution patterns of *L. pertusa* and other sessile megafauna at two sites

[1] In this report 'deep-water' is defined as water depths greater than 300 meters or approximately 1000 feet.

[2] Here after in this report the term 'authigenic' will be used to denote these carbonates.

in the northeastern Gulf of Mexico. Both sites[3], Viosca Knoll 826 (VK826) and Viosca Knoll 862-906 (VK862-906) are located on the upper DeSoto Slope subprovince **(Figure 1)**, which extends westward from the northern end of the West Florida Terrace and the DeSoto Canyon to the eastern side of the upper Mississippi Fan (Martin and Bouma 1978). The seafloor in this slope region has a relatively smooth surface only occasionally altered locally by low-relief hillocks and small submarine canyons.

DATA AND METHODOLOGY

U.S. Navy Submarine *NR1*

In July 2002, the U.S. Navy Nuclear Research Submarine *NR1*, and the surface support vessel, *SSV Carolyn Chouest*, conducted deep seafloor survey operations at VK826 (19-20 July) and VK862-906 (21-23 July) in support of a cooperative research project with The University of Alabama and Texas A&M University. High-resolution side-looking sonar, bathymetry and video data were collected with the submarine operating between 10-30 m/32-98 ft above the seafloor in water depths ranging between 300-600 m/984-1969 ft. Over 50 km/27 nm of track-lines were surveyed at VK826 **(Figure 2)** while over 60 km/32 nm were surveyed at VK862-906 **(Figure 3)**.

Navigation data on *NR1* was provided by an onboard Doppler velocity log (DVL), coupled with an ultra-short base line (USBL) acoustic tracking system aboard the *SSV Carolyn Chouest* producing a relative navigational accuracy of +/- 5 m/16 ft. However, the post-cruise offset error (navigational drift) was in the order of 350 m/1148 ft to the east northeast. Best-estimate adjustment factors were then calculated for each of the survey sites by comparing *NR1* positions with the positions of known 'bench mark' seafloor features determined from available precision bathymetric surveys. These factors were subsequently applied to the 'raw' navigation data sets to produce 'corrected' data sets. Because of the uncertainties associated with this process an absolute navigational error of up to +/- 50 m/164 ft must be acknowledged.

Twenty-five kilohertz single-beam acoustic altimeter data, coupled with pressure-depth data from the submarine, and integrated with navigation data from both the DVL and USBL systems, was simultaneously collected and has been extracted into a series of large ASCII files containing latitude, longitude, and depth information that can be gridded into three-dimensional renderings of the seafloor bathymetry. The data are generally accurate to within one meter. These data were then assembled into comma-delimited text files (*.csv) using Surfer© software that produced three-dimensional terrain models of the seafloor. Side-looking sonar (SLS) data were collected with SeaScan PC© system operating at a frequency of either 150 kHz or 600 kHz, with range settings varying from 50 to 200 m/164-656 ft per side, respectively. The preponderance of the sonar data, over 70 gigabytes, was collected at the lower of the two frequencies with a range setting of 75 m/246 ft per side (150 m/492 ft swath). The sub's track lines were programmed to be approximately 135 m/443 ft apart in order to achieve a 10% overlap of the seafloor areas surveyed. The second phase of processing utilized SonarWeb© software to compile comprehensive mosaics of the seafloor for each of the study areas. Video data was collected with

[3] Named for the Minerals Management Service lease block in which they occur.

two camera systems aboard the *NR1*. A forward looking black & white fixed focus system that provided for a wide field of view in front of the submarine as it proceeded along track, and the downward looking black and white pan/tilt/zoom camera, mounted coaxially with the forward altimeter. Nearly two terabytes of video data were collected.

Harbor Branch Oceanographic Institution Johnson-Sea-Link Manned Submersibles

Video and visual observation records (dive logs) were obtained for 26 *Johnson-Sea-Link (JSL)* dives over the period 1991-2005 (**Table 1**). These data along with video and visual observations obtained on *NR1* serve as the principal sources of documentation of the seafloor and macroepifauna at the two study site. The quantity and quality of the documentation obtained during each *JSL* dive varied significantly in that it was dependent on the planned dive work tasks, the actual times required to successfully achieve those tasks, the area covered during the dive, and visibility.

Accurate navigation data for determining the position of the *JSL* during some dives was problematic. For example, water depths reported at positions for the *JSL* do not agree with the known bathymetry of the dive site. This most often occurred during dives that investigated large areas or required long transits between work sites. In other cases the recorded positions for the *JSL* plot out in a scattered manner not consistent with the known sequence of stops and moves made during the dive. For some dives subjective / qualitative corrections could be applied to the questionable dive tracks to reduce the degree of position uncertainty. Unfortunately, the navigation during a few dives remains marginal to unreliable.

NOAA-OE 2003 Northern Gulf of Mexico Deep-Sea Habitats Expedition

During this expedition video surveys at both VK826 and VK862-906 were conducted by the NOAA Ship *Ronald H. Brown* (Cruise RB-03-07-leg-2) using an Innovator ROV as part of project OE_2003_011: The occurrence and ecology of deep-water corals and associated communities (W. Schroeder PI). Six hours of video were obtained at VK862-906 during two dives (numbers 30 and 31) and four hours of video were obtained at VK826 during three dives (numbers 32, 33 and 34) (Unpublished NOAA Cruise RB-03-07-leg-2 Report including ROV data logs, videos and photographs).

Oryx Energy Company, Inc. Pre-Exploratory Site Survey

In 1990 a video survey of the seafloor was conducted at VK 826 for Oryx Energy Company, Inc., Dallas, Texas, in conjunction with pre-exploratory drilling activity (personal communication Shane Bird, OEC). The survey was undertaken using a Hydra 1070 Remotely Operated Vehicle (ROV) system deployed from the *M/V C Hawk*. Vessel and ROV positioning were determined using "SPOT" long range radio positioning and a Trackpoint II© acoustic tracking system respectively. Eighty hours of black and white and color video were recorded in either VHS or 3/4" formats. Results of this survey are presented in reports prepared by Oceaneering International, Inc. (1990) and Gallaway et al. (1990).

Table 1

JSL Dive Information

JSL Dive Number	Date	Areas Investigated	JSL Dive Number	Date	Areas Investigated
		VK 826 [Main Knoll]			
3096	08/25/91-p	Crest – E	4730	07/21/04-a	S - NW
3097	08/26/91-a	Crest – W	4731	07/21/04-p	S - W
3098	08/26/91-p	SE – S – SW	4732	07/22/04-a	S
3261	08/06/92-a	Crest – Crest-rim	4733	07/22/04-p	S
3262	08/06/92-p	SW – Crest	4736	07/24/04-a	Crest – S
4410	06/06/02-a	N – Crest – S	4865	09/11/05-a	S
4411	06/06/02-p	W – Crest – E	4866	09/11/05-p	S – Crest – N
3355	10/18/02-a	S	4737	07/24/04-p	S
4652	11/17/03-p	S – Crest	4867	09/12/05-a	NW – S
4729	07/19/04-a	S	4872	09/14/05-p	NW - S
		VK 826 [Knobby Knoll]			
4868	09/12/05-p	Crest and upper portions			
4871	09/14/05-a	Crest and upper portions			
		VK 862 [Mound]			
4734	07/23/04-a	Low-relief mound and adjacent areas			
4735	07/23/04-p	Low-relief mound and adjacent areas			
4869	09/13/05-a	Low-relief mound and adjacent areas			
		VK 906 [Two Ridges]			
4870	09/13/05-p	Two N-S parallel ridges			

a = a.m.; p = p.m.
C = Crest <440 m/1445 ft
CR = Crest-rim 440-455 m/1445-1493 ft
N/S/W/E = North, South, West, East sectors >455 m/1493 ft

Video Frame-Grabs

Frame-grabs were obtained from each of the video tapes, utilizing Topaz Moment© V2.1, that best represented the seafloor characteristics and macrofauna for the area being surveyed.

Attribute Maps

Attribute maps, illustrating generalized distribution patterns of exposed or partially sediment veneered authigenic carbonate deposits and five groups of sessile megafauna (*L. pertusa*, *Callogorgia americana delta*, antipatharians, sea anemones and tube worms), were produced for the two sites with Adobe Photoshop© software. These maps utilize the side-looking sonar seafloor mosaic for each site as the base layer.

RESULTS

Viosca Knoll 826

VK826 has the most extensive development of *L. pertusa* found in the GoM to date (Schroeder et al. 2005). The primary site is located in the southwest corner of the lease block, on a 90 m/295 ft tall, isolated knoll on the seaward steepening upper De Soto Slope (**Figures 1 and 4**). It was discovered in 1990 during an ROV survey conducted for Oryx Energy Company, Inc. (Dallas, Texas) in conjunction with pre-exploratory drilling activity and later described by Schroeder (2002). **Figures 5 and 6** depict the three dimensional terrain and the SLS mosaic of the seafloor for the north-south and the east-west surveys respectively. The explored region is centered on 29°09.5′N, 88°01.0′W, in water depths of 430-552 m/1410-1810 ft, and includes: 1) most of the crest, crest-rim and north, south and west sides; and 2) portions of the east side and southern and western base/flank regions **(Figures 5 and 6)**.

The extensive deposits of harden substrates present at the site are hydrocarbon-derived and microbially mediated authigenic carbonates (CSA Final Report 2007) which take the form of hardgrounds, build-ups/outcrops, blocks, boulders, slabs and rubble; some with vertical relief up to 4 m. Surficial sediments ranged from slightly gravelly sandy mud to gravelly mud (CSA Final Report 2007). In addition, the presences of apparently very old living tubeworms, small bacterial mats and numerous accumulations of disarticulated lucinid and vesicomyid shells **(Figure 7)** suggest this site is at a senescent phase of chemosynthethic community activity.

Whether the presence of deep-water corals is biologically linked to local hydrocarbon seepage or present simply because hard substrate is produced and often available where seepage occurs is yet unresolved. A second site investigated, the crest and upper portions of a small 26 m/85 ft tall pinnacle shaped mound, lies approximately one kilometer northeast of the top of the main knoll at 29°10.2′N, 88°00.7′W **(Figure 5)**. Water depths at the crest and base of the mound are 454/1490 ft and 480 m/1575 ft respectively. It has been named Knobby Knoll (Schroeder in press).

In general the *Lophelia* colonies at this site, as well as VK862-907, are the tubular ecotype with an open branched growth habit (**Figure 8a** and see Freiwald et al. 1997). Overall, the colonies have a bushy morphology comprised of irregular, dendritic branching; often highly anastomosed **(Figure 8b** and see Cairns 1979). Colonies less than 50-75 cm (20-30 in) in diameter are usually completely white, indicating live polyps. Larger colonies and aggregated colonies are often light to dark brown in color at their base and center, where the polyps have died, with many having only white terminal branches or no white corallum at all **(Figures 8c-d)**. Other sessile megafauna observed at these sites are the gorgonian *C. americana delta*, at least two species of antipatharians, one of which has been identified as *Sibopathes macrospina* (Opresko 1993) and one or two unidentified species of anemones.

Seafloor Characteristics

The crest of the main knoll, at depths <440 m/~1445 ft, is flat **(Figures 5 and 6)** and covered with a combination of broken hardgrounds, low-relief outcrops/buildups, shell pavements and unconsolidated sediment **(Figures 9a-c)**. The adjacent crest-rim, at depths of 440 m/1445 ft to as deep as 455 m/1493 ft, has a moderate slope **(Figures 5 and 6)** and consists of locally hummocky terrain made up of carbonate capped knolls and ridges, some with steep vertical relief, and relatively flat terraces constructed of hardgrounds, shell pavement and unconsolidated sediment **(Figures 9d-f)**.

The seafloor of the upper regions of the north and south sides of the knoll, at depths generally between 455-470 m/1493-1575 ft, are a mixture of moderate to steep slopes and terrace-like features composed of carbonate outcrops/buildups, sediment veneered hardgrounds, extensive shell lag deposits and open flats of unconsolidated sediment **(Figures 10a-c)**. A gully and associated sediment fan-debris field on the southwestern side and flank of the knoll, at depths of 470-550m/1575-1805 ft, is evidence of the occurrence of one or more debris flows **(Figures 5 and 6)**. The debris field, at depths of 520-550 m/1706-1805 ft, consists of broken hardground, large boulders and blocks (up to 3-4 m/10-13 ft tall by 1-2 m/3-7 ft wide) and smaller material of various sizes and shapes **(Figures 10d-f)**.

The northwest side of the knoll has a moderate slope **(Figures 5 and 6)** and consists of a combination of hardgrounds and low relief buildups/outcrops **(Figure 11a)** and open areas of unconsolidated sediment. On the other hand the steep upper region of the west-southwestern side **(Figures 5 and 6)**, at depths of 452-470 m/1483-1575 ft, consists of a series of ridges and/or hummocks and swales of unconsolidated sediment. Some of these features have vertical relief of 1-3 m/3-7 ft from crest to trough and the crests are often covered with hard substrates **(Figures 11b-c)**. On the lower slope, between depths of 470-510 m/1575-1663, the seafloor is a mixture of exposed carbonate **(Figure 11d)**, shell lag deposits **(Figure 7d)** and unconsolidated sediment. Further to the west the seafloor levels off to depths around 518 m/1700 ft **(Figure 5)** and consists of a complex of buildups/outcrops, hardgrounds, boulders, slabs, rubble and unconsolidated sediment **(Figures 11e-f)**.

To the east, the seafloor initially levels off into a relatively flat area consisting mostly of fine, unconsolidated sediment and scattered patches of both exposed and sediment veneered carbonate material **(Figure 12a)**. Further to the east the slope increases rapidly and is composed entirely of fine, unconsolidated sediment **(Figure 12b)**. To date little has been learned about the seafloor characteristics at Knobby Knoll, the small 26 m/85 ft tall pinnacle shaped mound northeast of the primary study site, because the areas surveyed are densely covered by *L. pertusa* development. What is apparent is the hummocky or knob-like construction at the top of the mound **(Figure 12c)** and the large slab-like or hardground-like nature of the substrate exposed further down the feature **(Figure 12d)**.

Distribution Patterns of *Lophelia pertusa* and Other Sessile Megafauna

Only isolated colonies or small clusters of *L. pertusa* are present on the crest of the main knoll **(Figure 13a)** where most of the hard substrate has not been colonized by any sessile megafauna **(Figure 9a)**. On the adjacent crest-rim both the number and size of *L. pertusa* colonies increase. Individual colonies as large as 1.5 m/5 ft in diameter and colony aggregations up to 1.5 m wide x 1.5 m high x 4 m (5 ft x 5ft x 13 ft) long have developed on the knolls and ridges **(Figures 9d and 13b-c)**. However, most of the hard substrate remains un-colonized and no other sessile megafauna have been observed **(Figures 9e and 13d)**. Extensive assemblages of *L. pertusa* have developed on the upper regions of both the north and south sides of the knoll. Fields of individual colonies, up to 2 m in diameter, and clusters of aggregations/thickets, some as large as 2 m wide x 2 m high x 4 m (6.5 ft x 6.5 ft x 13 ft) long occur on both exposed hardgrounds and buildups/outcrops and on sediment veneered hardgrounds **(Figures 8c, 10b and 14a-d)**. In addition, small assemblages of large antipatharian colonies have developed across the central region of the south side of the knoll **(Figures 14e-f)**. Generally the carbonate substrate in the debris field and adjacent seafloor on the southwestern flank of the knoll is un-colonized **(Figures 10d-f)**. The most common representative of the sessile megafauna, the gorgonian *C. americana delta*, occurs in scattered, small clusters **(Figure 15)** and a few large antipatharian colonies have been documented (See the lower portion of **Figure 10f**). Only small colonies of *L. pertusa* colonies have been observed **(Figure 15a-b)**. Also present in this region are large tubeworm bushes **(Figure 7b).**

The moderately sloping upper region of the northwest side of the knoll has both extensive assemblages of *L. pertusa* **(Figure 16a)**, that in many areas are in the initial phase of thicket building **(Figure 16b)**, as well as large areas with un-colonized substrate **(Figure 11a)**. The deeper region further to the northwest becomes mostly open areas of unconsolidated sediment with scatter, smaller patches of exposed substrate partially covered with *L. pertusa*. On the steeper upper region of the west-southwest side the carbonate capped ridges and hummocks provides substrate for both isolated individuals and assemblages of *L. pertusa* **(Figure 16c)**. The density of *L. pertusa* colonies decreases and amount of un-colonized substrate increases on the lower slope **(Figure 11d)**. *Callogorgia americana delta* and antipatharians are the principal components of the sessile megafauna colonizing the hard substrates on the deeper adjacent seafloor **(Figures 11e-f and 16d-e)**. Also present are scattered large tubeworm bushes and small brown (dead) *L. pertusa* colonies. On the east side of the knoll, only scattered clusters of small *L. pertusa* colonies, attached to both exposed and sediment veneered carbonate material, have been observed **(Figure 16f)**.

Lophelia pertusa development on Knobby Knoll is extraordinary **(Figures 17a-b)**. It is so dense that, as stated in the section above, carbonate substrate is visible in only a few locations. In fact, aggregation/thicket production in some areas has likely reached a level of initial coppice development (see Mullins et al. 1981) and may be responsible for the hummocky or knob-like nature at the top of the mound **(Figures 12c and 17a)**. The only other sessile megafauna observed at this site were several medium to large antipatharian colonies attached to the exposed substrate on the sides of the mound **(Figure 12d)**.

Evidence of Anthropogenic Disturbances

The only evidence of anthropogenic disturbances observed on the SLS mosaics, or in the video was long linear furrows cut into the seafloor on the main knoll. The furrows ranged from simple, narrow (approximately 10 cm/4 in) grooves **(Figure 18a)** to irregular, wider (up to 1.5 m/5 ft) ruts that have completely disrupted the seafloor (e.g., sediments overturned and either piled up into small ridges or mounds or scraped away forming trenches or depressions) **(Figure 18b)**. When megafauna were present, moderate to severe damage to individual colonies or colony aggregations often resulted **(Figures 18c-d)**. However, the SLS mosaics indicate that no extensive area-wide destruction has occurred although these features are present throughout the main knoll survey area. As proposed by Schroeder (2002) it is apparent that the furrows were produced when wire anchor cables, deployed in conjunction with oil and gas drilling operations conducted in this region, struck the bottom one or more times.

Viosca Knoll 862-906

VK862-906 is located in a low-relief mound and ridge complex 2.3 km/1.2 nm northeast of the eastern rim of a small submarine canyon on the upper DeSoto Slope subprovince **(Figure 1)**. The primary study site is a small, low-relief mound in the southeast corner of lease block VK862 **(Figure 19)**. It is centered on 29°06.4′N, 88°23.0′W, or approximately 37 km/20 nm west-southwest of the VK826 site. Water depths at the study site range between 304-333 m/997-1093 ft. A second site, located in the northeast corner of lease block VK906, is approximately 1100 m to the southwest of the primary site. The area surveyed at this site is centered on 29°05.9′N, 88°23.1′W and includes portions of two generally north-south oriented parallel ridges in water depths of 328-352 m/1076-1155 ft **(Figure 19)**. The hard substrates present at these sites are hydrocarbon-derived and microbially mediated authigenic carbonates (CSA Final Report 2007). No evidence of chemosynthethic community development has been observed. _Note_: Based on similarities between the cross-sectional profiles and water depths in the adjacent submarine canyon and the depth recorder tracing presented in figure 1 of Moore and Bullis (1960) this site is presently considered the most likely location where *L. pertusa* was first collected in the Gulf of Mexico by Moore and Bullis in 1955[4].

Seafloor Characteristics

The most arresting characteristic of the low-relief mound at the VK862 site is its ruggedness. It is primarily formed from large blocks and boulders; some with vertical and/or horizontal dimensions in the order of 5 m/16 ft **(Figures 20a-b)**. Gaps and deep-crevices between the blocks and boulders result in a very craggy, irregular and often steep-sided topography **(Figure 20c)**. Conversely the flanks of the mound are generally gently sloping and covered with combinations of smaller boulders and blocks **(Figure 20d)** and/or pavements made from clasts and nodules of varying sizes and shapes **(Figure 20e)**. The bottom immediately surrounding the

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[4] Until 2002 the location where Moore and Bullis (1960) first collected *L. pertusa* in the Gulf of Mexico had not been revisited since their *MV Oregon* cruise in 1955. In 2002, Greg Boland with MMS (personal communication) was identifying potential sites for a deep water coral study. After examining USDI-MMS in-house 3D-seismic surface amplitude and bathymetry data he found that bathymetry at the original trawl location (*MV Oregon* station 1283; 29° 5'N, 88° 19'W; 13 March 1955) did not match the description and depth recorder tracing (Figure 1) presented in Moore and Bullis (1960). Rather, he determined that the most likely location of the Moore and Bullis site was approximately 7 km/3.8 nm to the west of the published location where strong reflectivity and bottom features appeared to coincide with a potential coral habitat (in close proximity to the VK 862-907 site described in this report). To confirm this, in July 2002 the original trawl location was investigated by the U.S. Navy submarine NR-1 (Unpublished cruise logs) and no evidence of coral or hard substrate was observed or imaged on sonar at, or in the vicinity of, this location. For additional information see Schroeder et al. (2005).

mound is flat and composed of sediments ranging from gravelly muddy sand to gravelly mud (CSA Final Report 2007) or partially exposed hardgrounds **(Figure 20f)**. The crests and most of the sides of the two ridges at VK907 are covered with carbonate pavements in the form of small-boulder to cobble size nodules and flat plates or slabs **(Figures 21a-b)** while the deeper adjacent regions are all covered with fine unconsolidated sediment.

Distribution Patterns of *Lophelia pertusa* and Other Sessile Megafauna

Only one significant development of *L. pertusa* was found at VK862-909. An aggregation of at least five large colonies, up to 90 cm (35 in) in height, and numerous small colonies on top of a 5 m/16 ft tall boulder at a depth of 309 m/1101 ft near the crest of the south side of the mound at VK862 **(Figures 20a and 22a)**. This is the shallowest reported site for *L. pertusa* in the GoM (Schroeder et al. 2005). Other smaller colonies were observed scattered throughout the site; with a slight preference for the northern flank of the mound **(Figure 22b)**. The dominant taxa at both the VK862 and VK906 sites, in terms of numbers and biomass, are two unidentified anemones **(Figures 20, 21, and 22c-d and f)**. Densities as high as 45-50 individuals per square meter were recorded at a number of locations **(Figures 20a and 22c)**. The largest megafauna observed were gigantic antipatharians at VK862 where they have reach small 'tree' dimensions **(Figures 22e-f)**. A few individual colonies are estimated to be between 2.1-2.4 m/7-8 ft tall with base diameters of up to 7-8 cm/2.7-3.1 in. Large portions of the carbonate were observed to be bare or colonized by only small individuals.

Evidence of Anthropogenic Disturbances

No evidence of anthropogenic disturbances was observed on the SLS mosaic or in the video recordings from the VK862 or VK906 sites.

SUMMARY

Viosca Knoll 826

Seafloor Characteristics

Seafloor characteristics documented at VK826 are listed below and their locations at the study site are indicated on **Figures 23** and **24**:

1. <u>Crest of the main knoll</u>: Broken hardgrounds, low-relief outcrops/buildups, shell pavements and unconsolidated sediment.
2. <u>Crest-Rim of the main knoll</u>: Locally hummocky terrain made up of carbonate capped knolls and ridges, some with steep vertical relief, and relatively flat terraces constructed of hardgrounds, shell pavement and unconsolidated sediment.
3. <u>North and south sides of the main knoll</u>: Terrace-like features composed of carbonate outcrops/buildups, sediment veneered hardgrounds, extensive shell lag deposits and open flats of unconsolidated sediment.
4. <u>Southwest side of the main knoll</u>: A gully cut by one or more debris flows.

5. Southwest flank of the main knoll. A sediment fan and debris field composed of broken hardground, large boulders and blocks and smaller material of various sizes and shapes.
6. Northwest side of the main knoll: Hardgrounds and low relief buildups/outcrops and open areas of unconsolidated sediment.
7. Steep upper slope of the west-southwest side of the main knoll: Ridges and/or hummocks and swales of unconsolidated sediment; some with crest capped with hard substrates.
8. Adjacent western flank of the main knoll: A complex of buildups/outcrops, hardgrounds, boulders, slabs, rubble and unconsolidated sediment.
9. Knobby Knoll: Hummocky or knob-like construction at the top and exposed slab-like or hardground-like substrate on the sides.

Lophelia pertusa and Other Sessile Megafauna Distribution Patterns

Distribution patterns of *L. pertusa*, *C. americana delta*, antipatharians, anemones and tubeworms at VK 826 are depicted in **Figures 25-27**. These attribute maps utilize the SLS seafloor mosaic produced from the north-south trackline survey as the base layer. Refer to **Figure 5** for the location of the mosaic relative to the seafloor terrain. The area inside yellow ellipses denotes that part of the study site in which all representatives of the designated taxon have been observed, regardless of size, density or whether they were alive or dead. On the other hand, the area inside red ellipses denote regions of the study site where living large individuals or dense assemblages of the designated taxon have been observed. Although the maps are based on the substantial data set collected and analyzed during this research project they are only 'best estimate' products that are intended to portray, as accurately as possible, the general distribution pattern of each of the megafauna taxa.

Lophelia pertusa, *C. americana delta*, antipatharians, and tubeworms were all widely distributed across large portions of the study site **(Figures 25a, 25b, 26a, and 27)** while anemones were restricted to the deeper seafloor adjacent to Knobby Knoll **(Figure 26b)**. The dominant megafauna taxon at this site is *L. pertusa* which has successfully developed extensive assemblage complexes, comprised of large colony aggregations/thickets, at numerous locations on the main knoll and a thicket-coppice complex covering the top of Knobby Knoll **(Figure 25a)**. Conversely, the most extensive developments of both *C. americana delta* and the antipatharians are scattered, small stands or fields of usually fewer than 25 individuals. These occur in the debris field on the southwestern side and flank of the knoll for both taxa and also on the deeper seafloor west of the knoll for *C. americana delta* and across the central region of the south side of the knoll for the antipatharians **(Figures 25b and 26a)**. Tubeworms are present throughout a large portion of the study site **(Figure 27)** but generally occur only in scattered clusters of small individuals or as isolated large bushes (i.e. within the red ellipses).

Viosca Knoll 862-906

Seafloor Characteristics

Seafloor characteristics documented at VK862-906 are listed below and their locations at the study site are indicated on **Figure 19**:

1. VK862: A rugged low-relief mound formed from large blocks and boulders.
2. VK906: Portions of two parallel ridges, covered with carbonate pavement, and the adjacent unconsolidated sediment flats.

***Lophelia pertusa* and Other Sessile Megafauna Distribution Patterns**

Three of the five megafauna taxa reported from VK826 also occur at VK862-906: *L. pertusa*, antipatharians and anemones. The only significant development of *L. pertusa*, an aggregation of at least five large colonies, was found on the crest of the mound site in VK862 **(Figure 19)**. Other smaller colonies were observed scattered throughout the site; with a slight preference for the northern flank of the mound. No *Lophelia* were observed at the ridges site in VK906 **(Figure 19)**. The dominant taxa at both the VK862 and VK906 sites, in terms of numbers and biomass, are anemones. The largest megafauna observed were the antipatharians: numerous colonies having attained small 'tree' dimensions at the VK862 site. There appear to be at least four species of antipatharians and collectively they are the second most abundant megafauna taxa at both sites.

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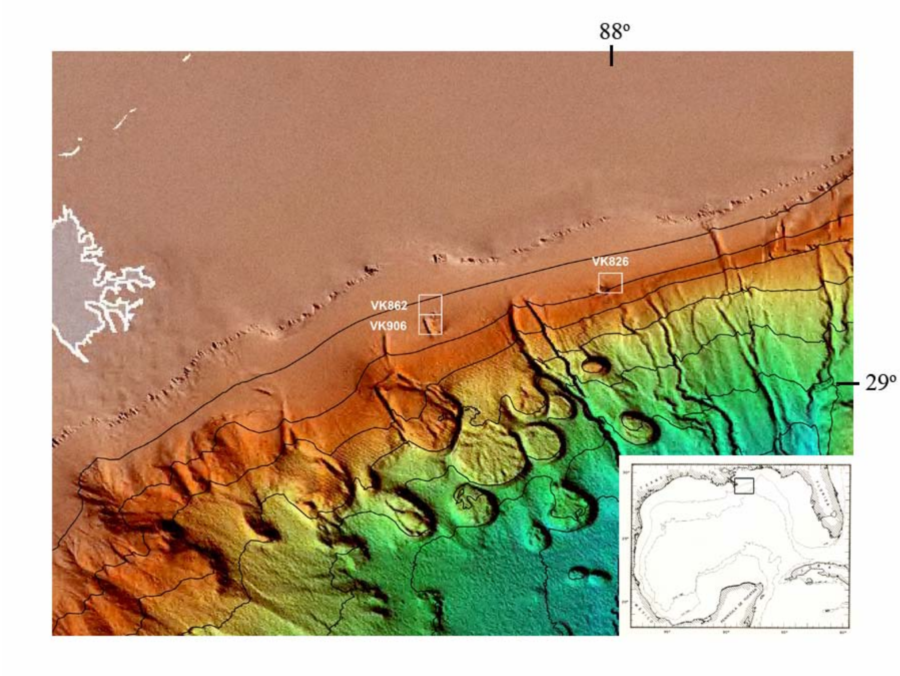


Figure 1. Detailed view of study sites VK826 and VK862-906 on the upper portion of DeSoto Slope in the northern Gulf of Mexico.

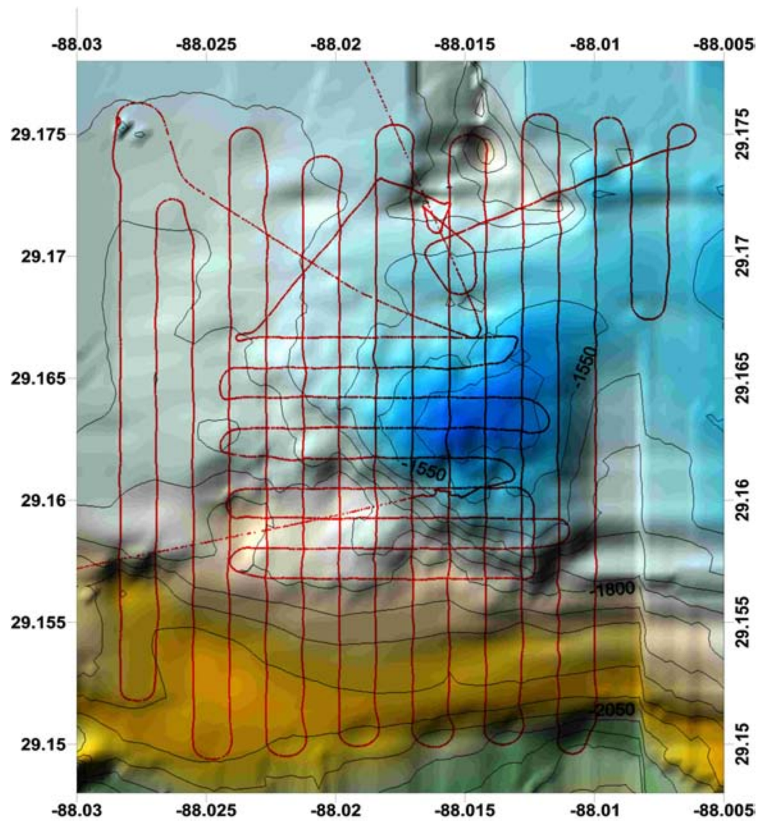


Figure 2. NR1 survey track-lines at VK 826.

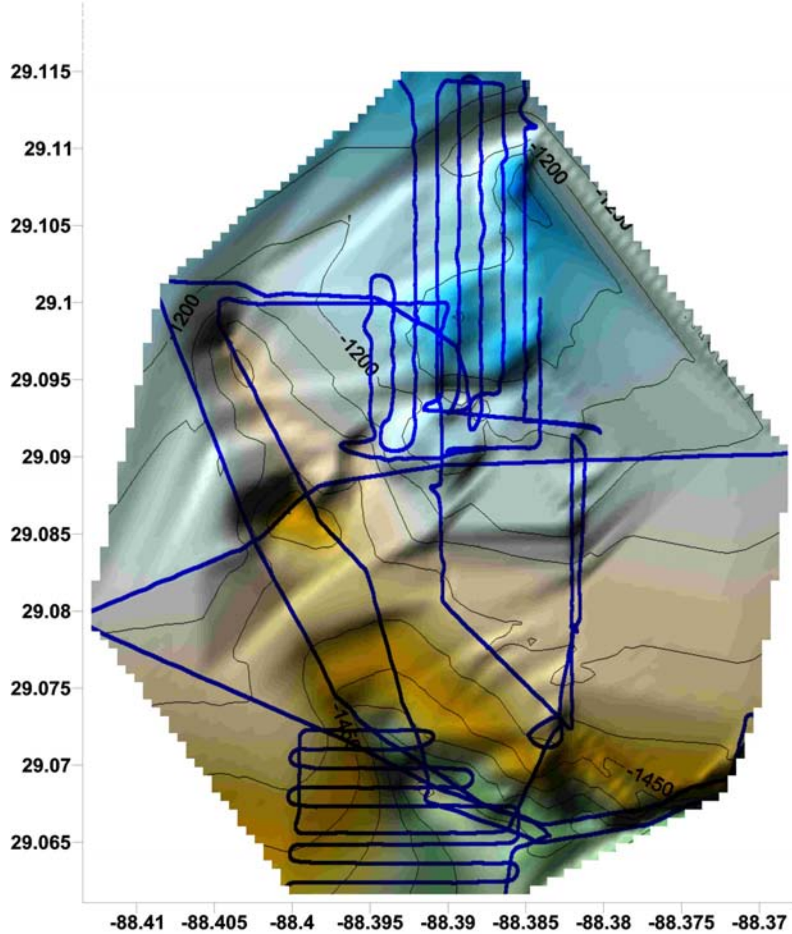


Figure 3. NR1 survey track-lines at VK 862-906.

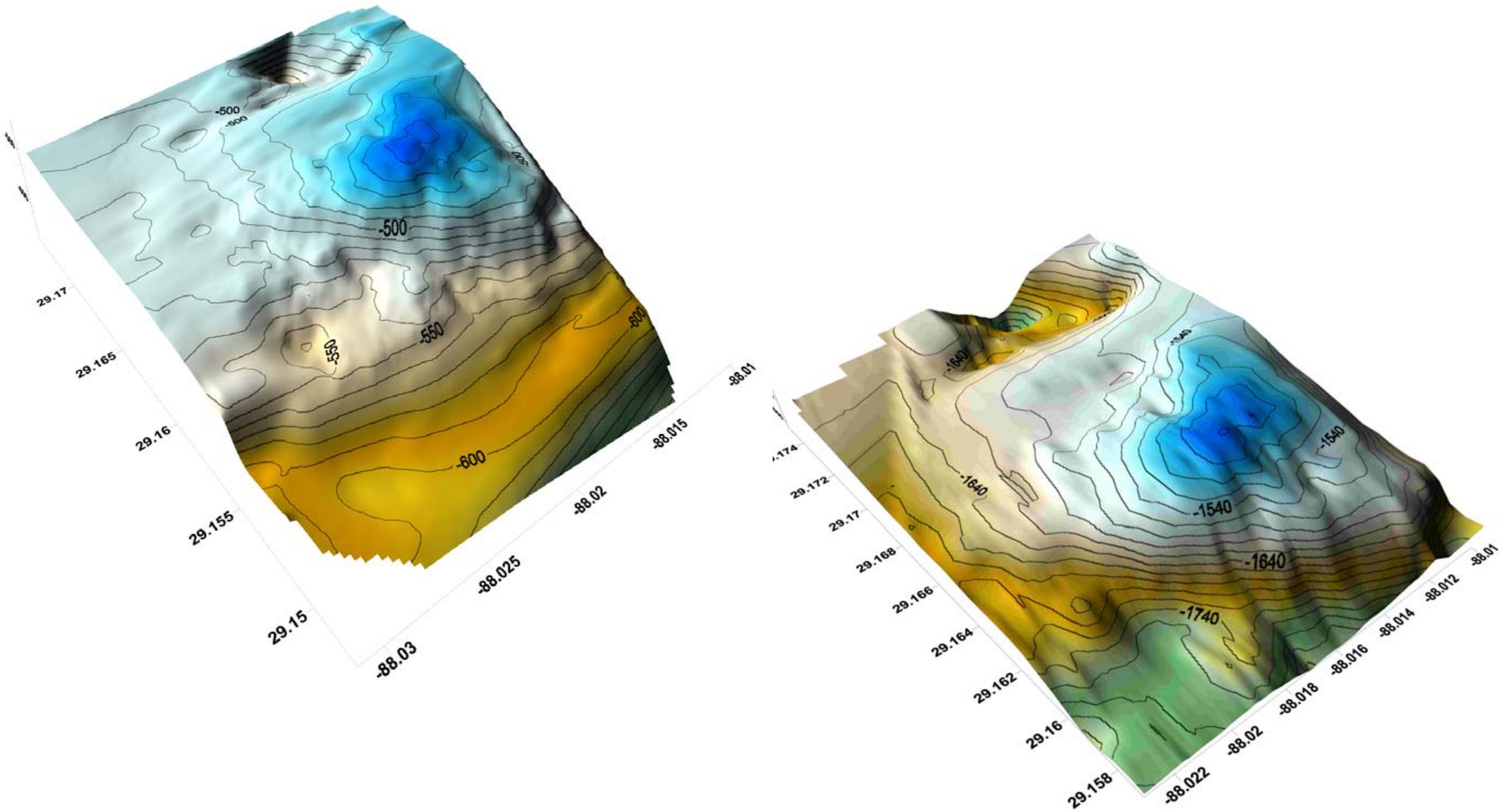


Figure 4. Three-dimensional terrain at VK826 viewed from the southwest; (left panel) water depth in meters; (right panel) water depth in feet.

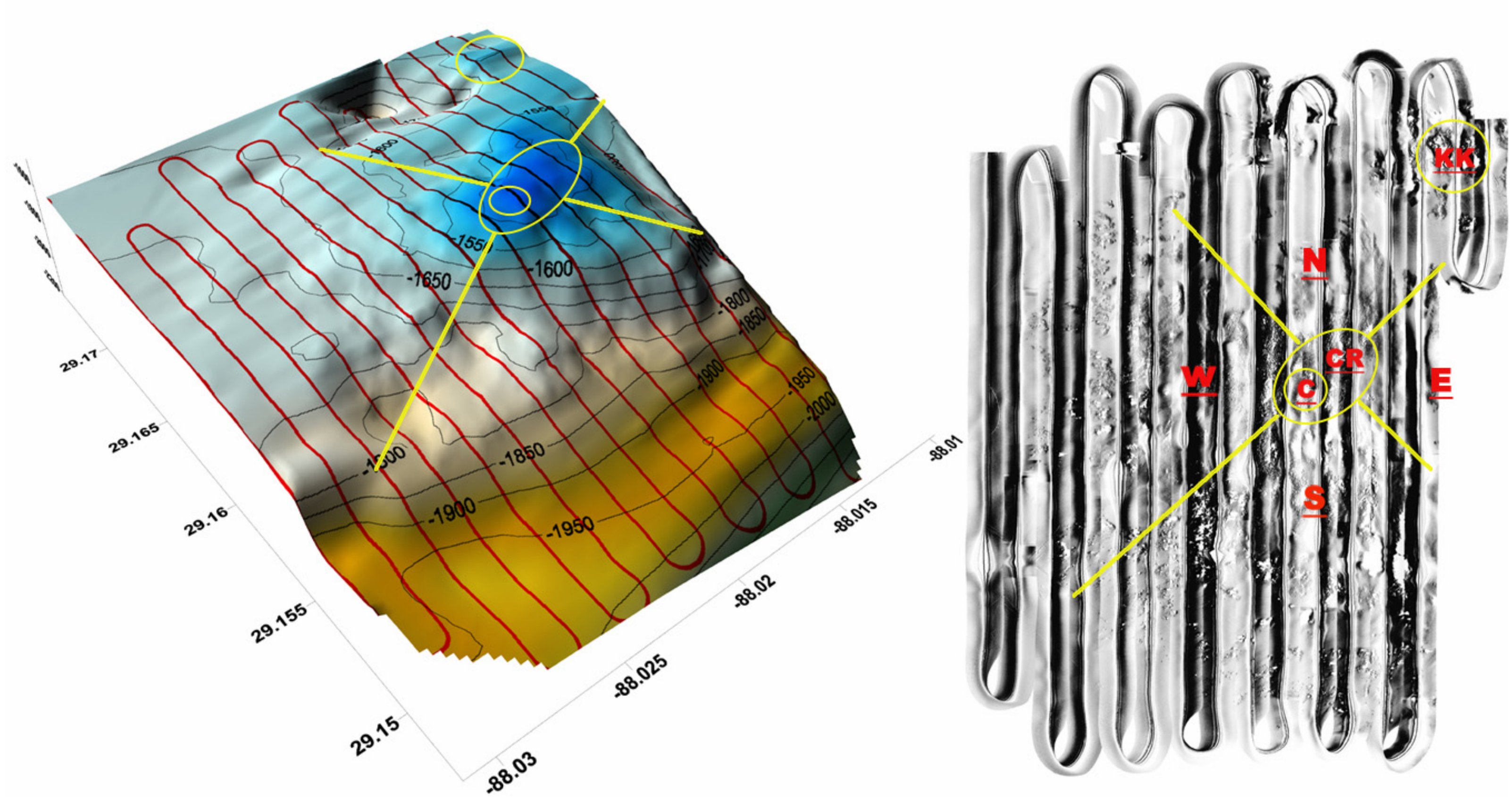


Figure 5. VK826 three-dimensional terrain and the side-looking sonar mosaic of the seafloor for the north-south trackline survey. Refer to Figure 2 for the location of the north-south tracklines relative to the east-west tracklines. C – Crest; CR – Crest-rim; N – North; S – South; W – West; E – East; KK – Knobby Knoll.

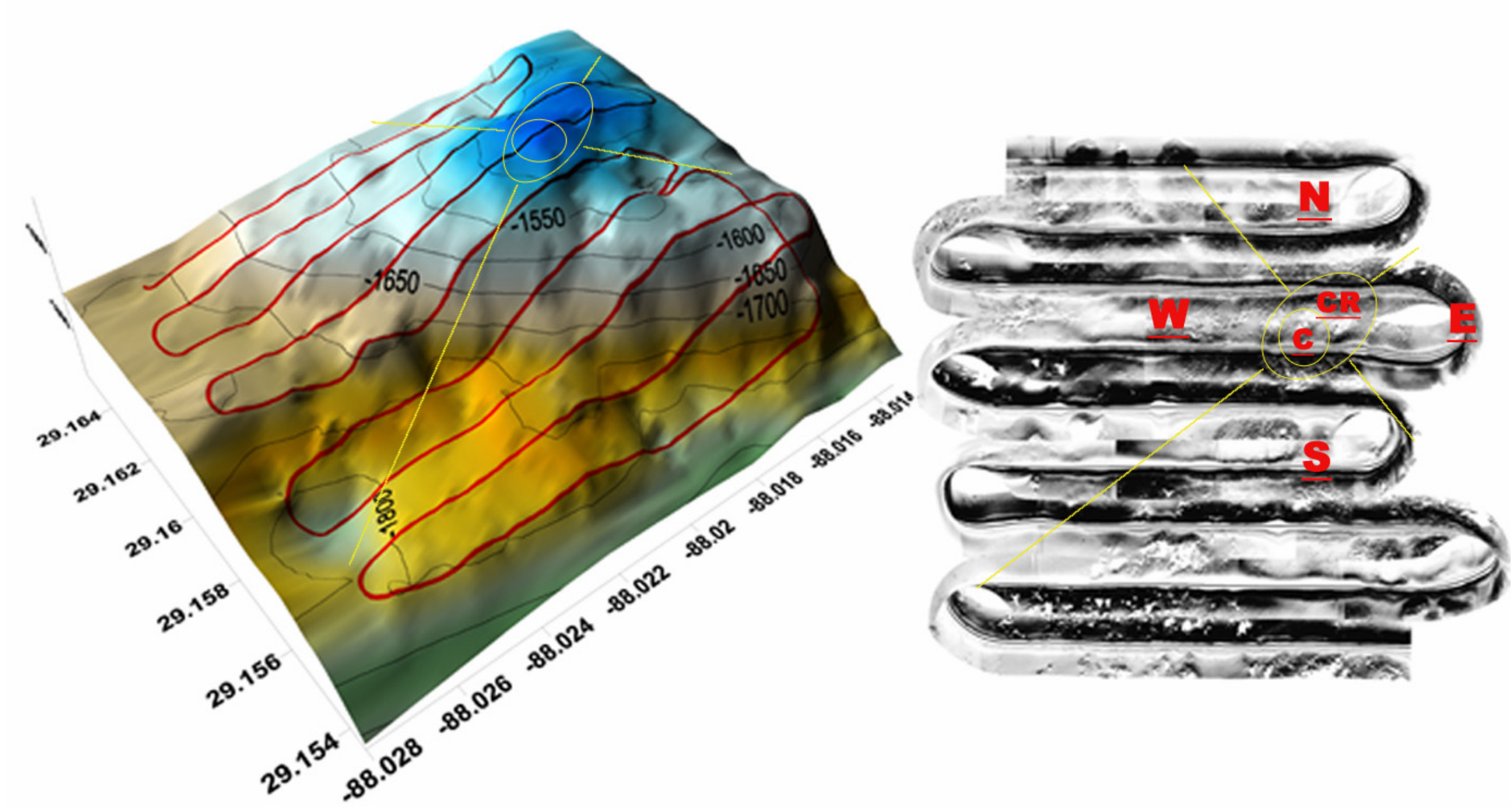
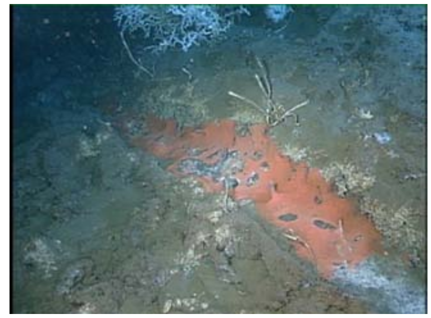


Figure 6. VK826 three-dimensional terrain and the side-looking sonar mosaic of the seafloor for the east-west trackline survey. Refer to Figure 2 for the location of the north-south tracklines relative to the east-west tracklines. C – Crest; CR – Crest-rim; N – North; S – South; W – West; E – East; KK – Knobby Knoll.

a.

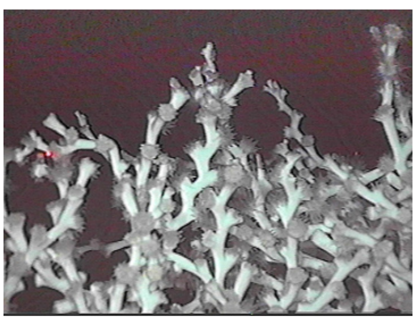
b.



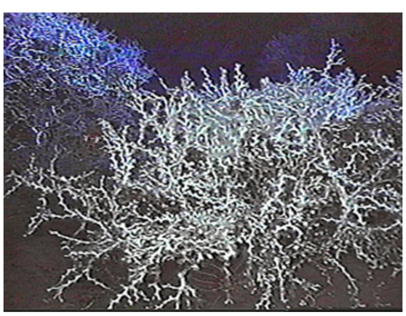
c.

d.

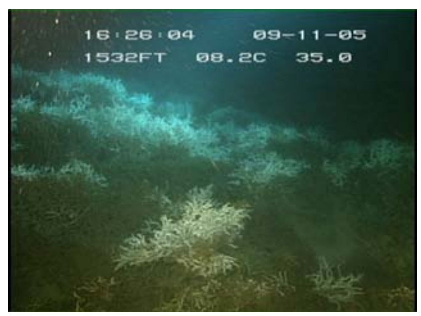
Figure 7. VK826-a. Small cluster of tubeworms on the crest-rim of the knoll; b. Large tubeworm bush on southwest side of the knoll; c. Small bacterial mat on the crest of the knoll; d. Shell lag deposit on the south side of the knoll.



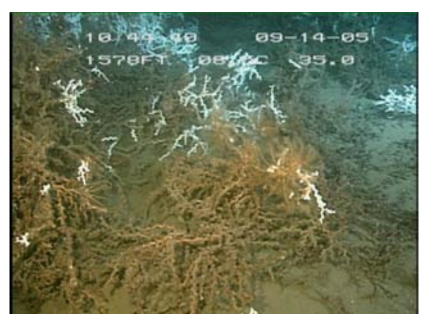
a.



b.



c.



d.

Figure 8. *Lophelia pertusa* at VK826: a. Close-up of a tubular ecotype colony with an open branched growth habit (Freiwald et al. 1997); b. Large thicket on south side of the knoll; c. Aggregations on hardground/buildups on the north side of the knoll; d. Colonies with white, living polyps only on the terminal branches.

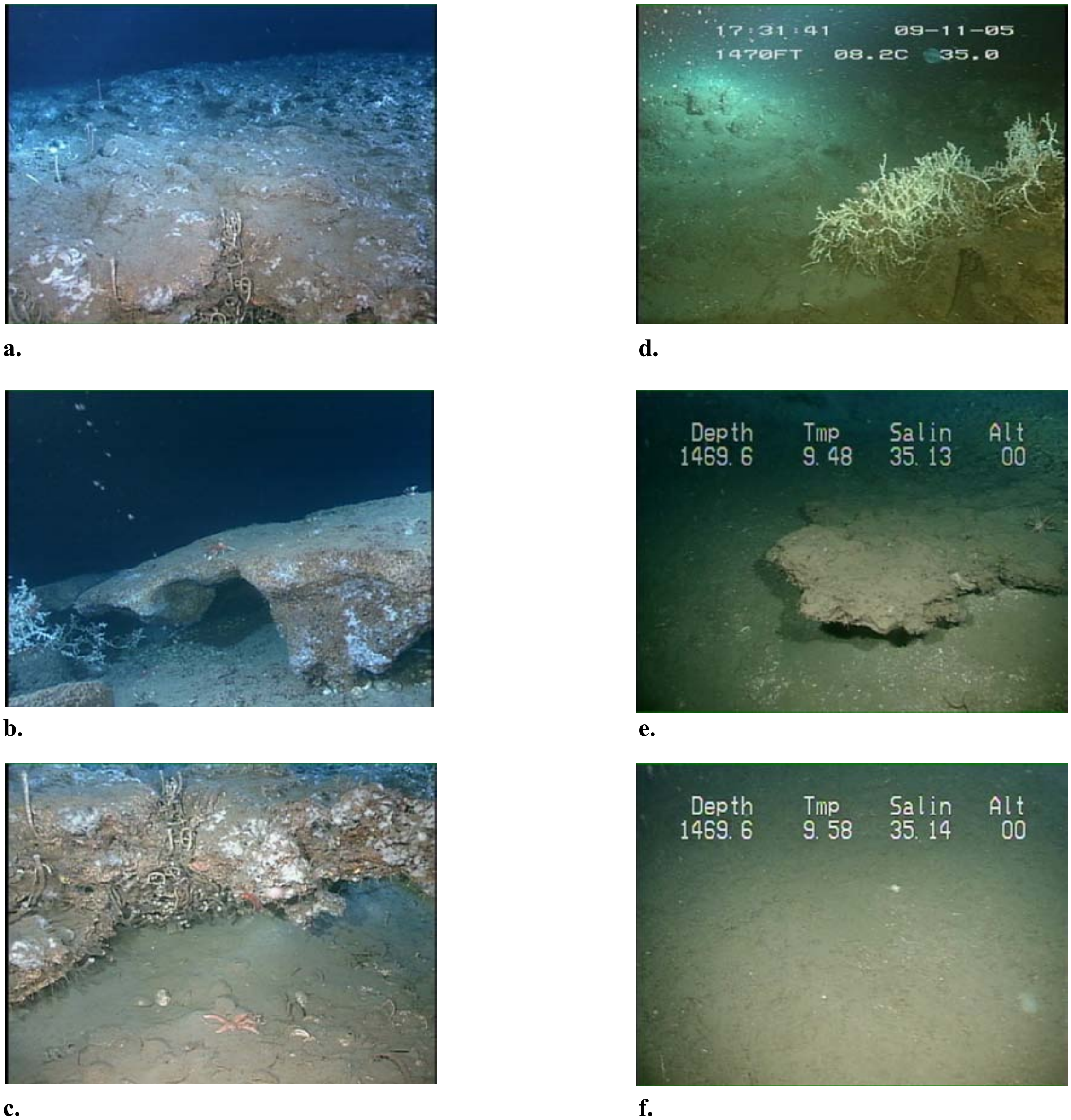
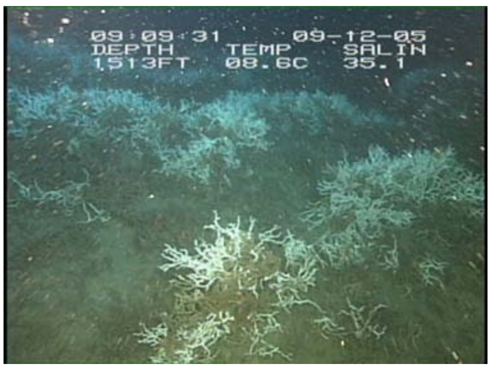


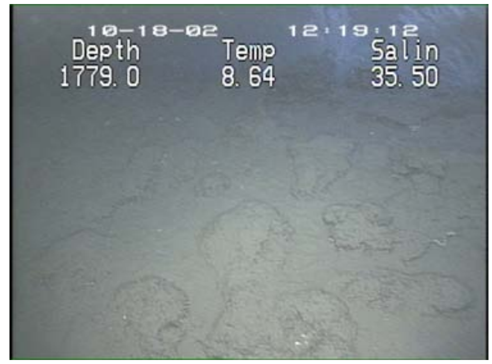
Figure 9. VK826-a-c. Hardgrounds, low-relief outcrops/buildups and fine sediment on the crest; d-f. Hummocky terrain, carbonate capped ridge and shell pavement and fine sediment on the crest-rim.

a.



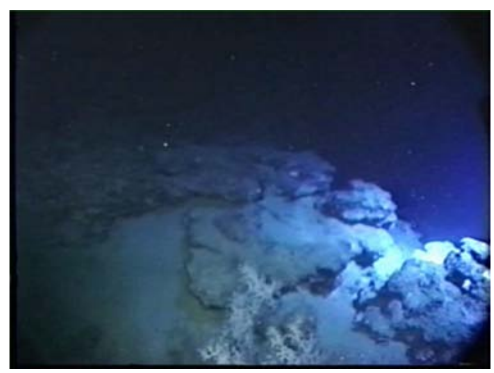
b.

c.



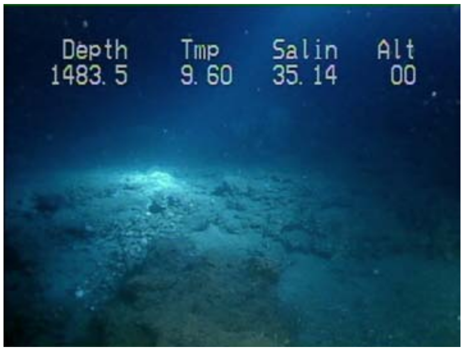
d.

e.



f.

Figure 10. VK826-a-c. Outcrops/buildups and hardgrounds on the upper regions of the north and south sides of the knoll; d-f Broken hardground and large boulders and blocks in the debris field on the south-southwestern flank of the knoll.



a.

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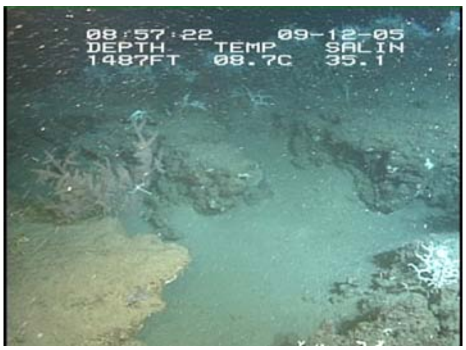
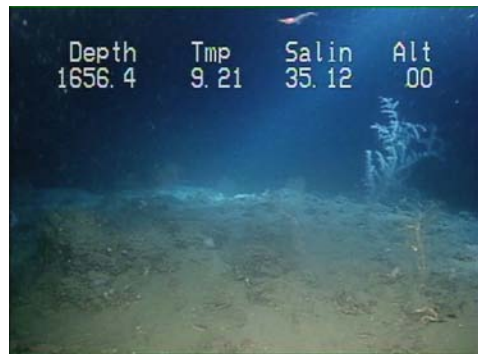


b.



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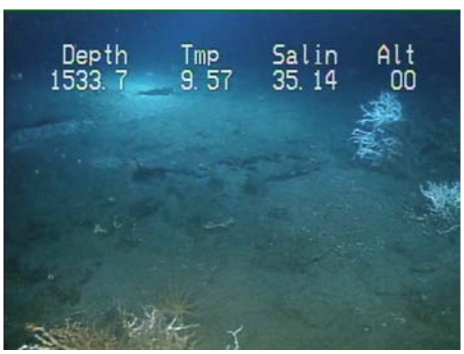


c.

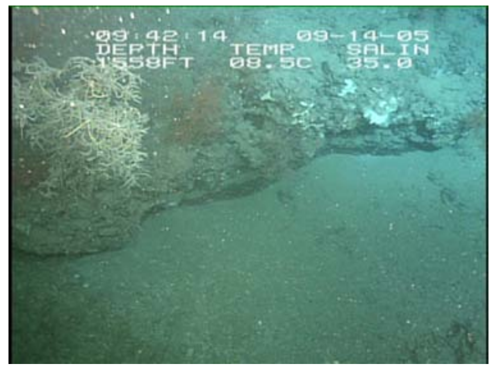
f.

Figure 11. VK826-a. Hardgrounds and low-relief buildups/outcrops on the northwest side of the knoll; b-c. Hard substrate covering the ridges and hummocks on the upper slope of the west-southwestern side of the knoll; d. Exposed carbonate on the lower slope of the west-southwestern side of the knoll; e-f. Buildups/outcrops, hardgrounds, boulders, slabs, and small rubble on the base and flank of the west side of the knoll.

a.

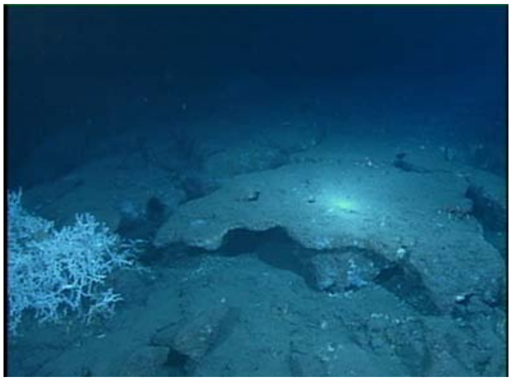
b.

c.

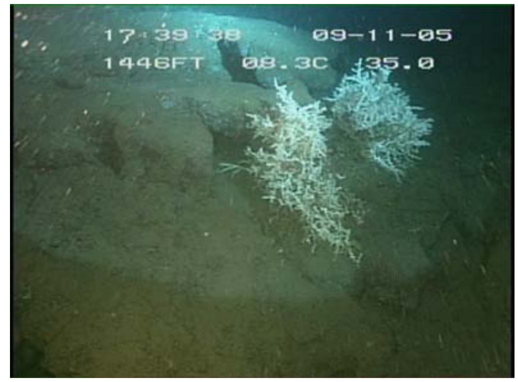


d.

Figure 12. VK826-a. Fine sediment and carbonate rubble east of the crest of the knoll; b. Mounds of fine unconsolidated sediment on the east side of the knoll; c. *Lophelia pertusa* covered hummock at the top of Knobby Knoll; d. Exposed carbonate slab or hardground covering fine unconsolidated sediment on the side of Knobby Knoll.



a.



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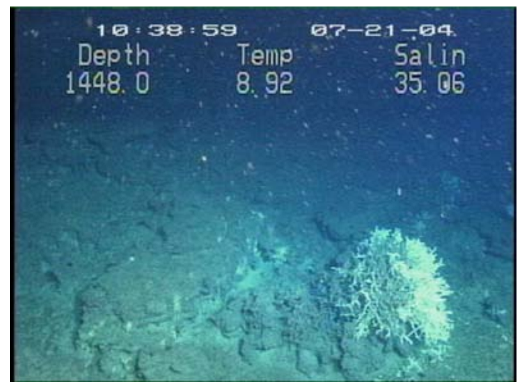
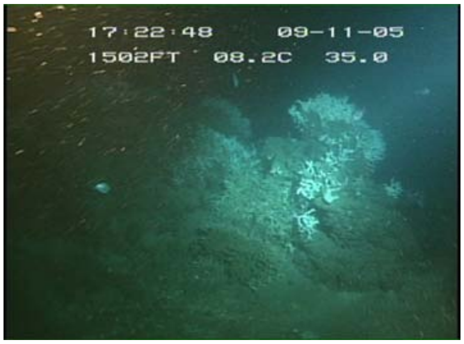
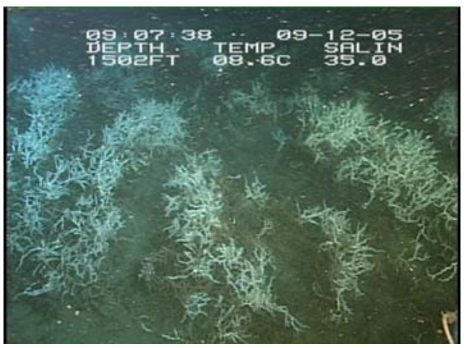


d.

Figure 13. VK826-a. Large individual colony of *Lophelia pertusa* on otherwise bare hard substrate on the crest of the knoll; b. Aggregation of *Lophelia pertusa* colonies on the crest-rim; c. Large colonies of *Lophelia pertusa* attached to hard substrate on top of a ridge with steep vertical relief; d. Mostly un-colonized hard substrate on the crest-rim.

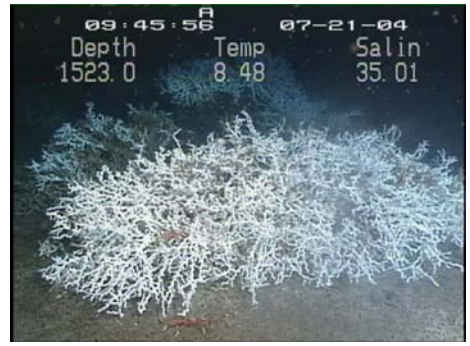


a.



b.

c.



d.

e.

f.

Figure 14. VK826-a. A cluster of *Lophelia pertusa* colonies on a buildup/outcrop on the north side of the knoll; b-c. Fields of *Lophelia pertusa* aggregations/thickets on the north and south of the knoll; d. Large *Lophelia pertusa* aggregation/thicket on sediment covered hardground on the south side of the knoll; e-f. Large black coral colonies in the central region of the south side of the knoll.

a.

c.

b.

d.

Figure 15. VK826-a-d. Examples of *Callogorgia americana delta* in the debris field and adjacent seafloor on the southwestern flank of the knoll; note the small white colonies of *Lophelia pertusa* in Figures a, b.

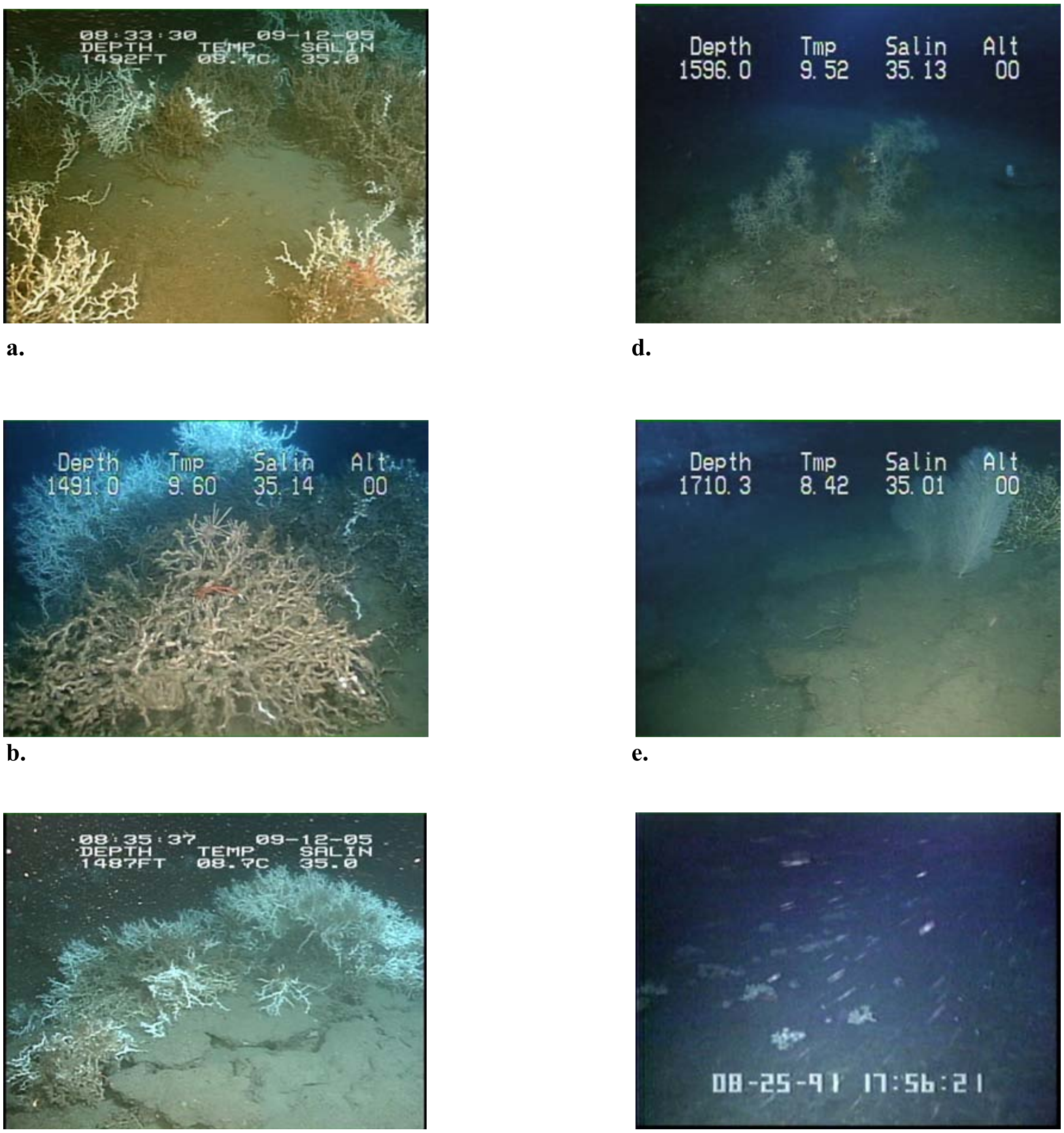
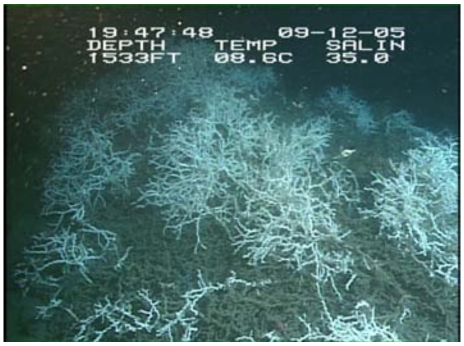
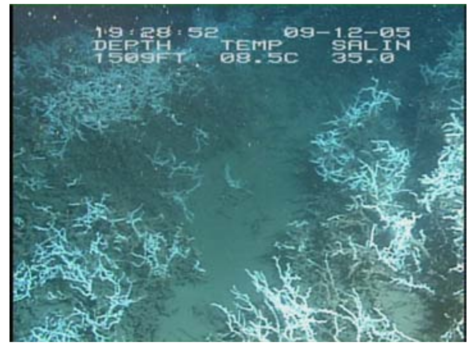


Figure 16. VK826-a-b. *Lophelia pertusa* assemblages on the northwest side of the knoll; c. *Lophelia pertusa* colonies on a carbonate capped hummock on the upper region of the west-southwestern side of the knoll; d-e. Antipatharians and *Callogorgia americana delta* on the deeper adjacent seafloor to the west; f. Cluster of small *Lophelia pertusa* colonies on the east side of the knoll.



a.



b.

Figure 17. VK826-a. *Lophelia pertusa* thicket(s) at the base of 4.5 m high knob/coppice(?); b. *Lophelia pertusa* aggregations/thickets and sediment chute on the steep upper slope of Knobby Knoll.

a.

c.

b.

d.

Figure 18. VK826-a. Narrow, simple furrow in the seafloor on the upper slope of west side of knoll; b. Wide, irregular rut in the seafloor on the upper slope of west side of knoll; c-d. Damage to *Lophelia pertusa* colonies/aggregations on the upper slope of west side of knoll.

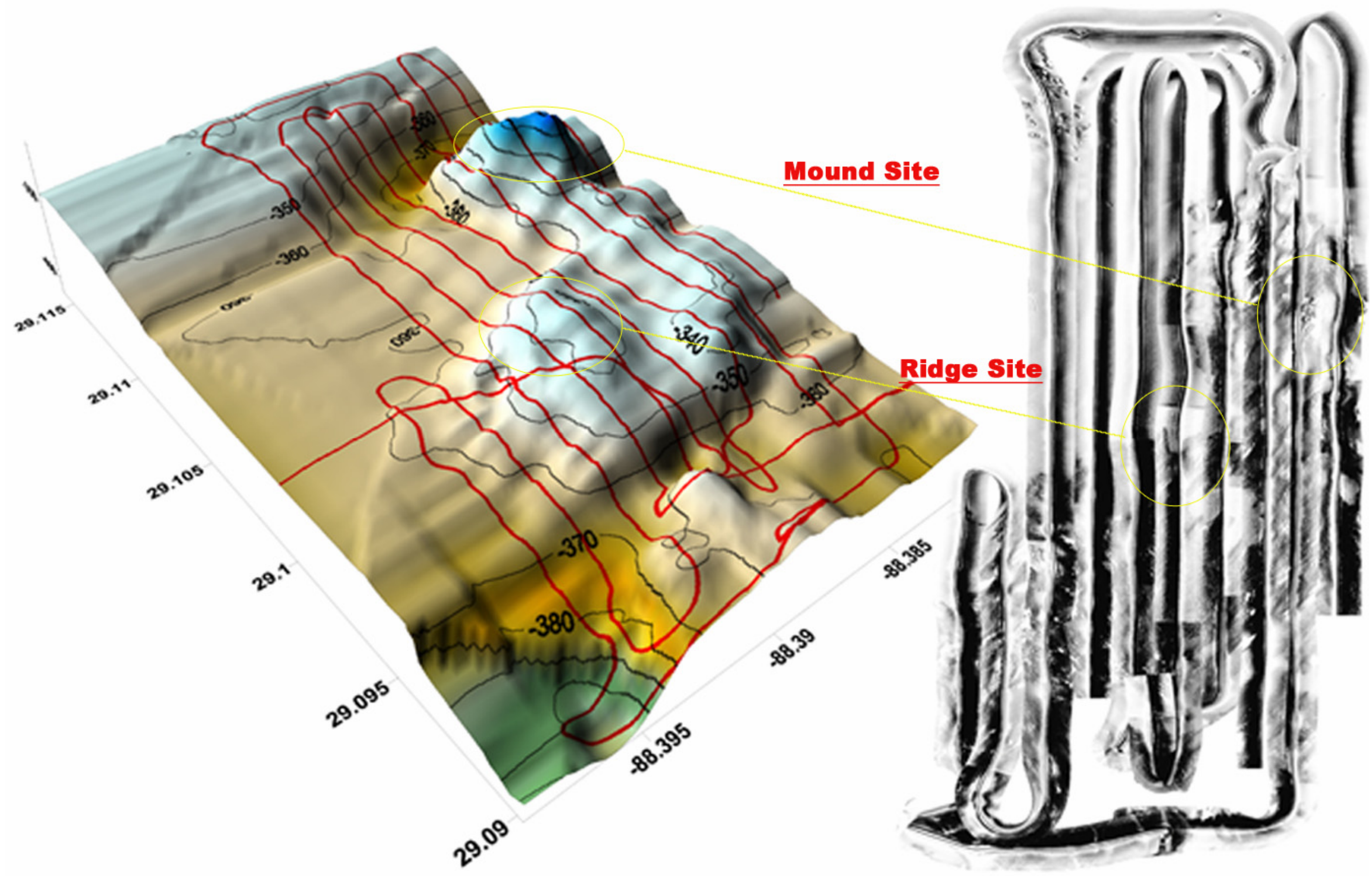
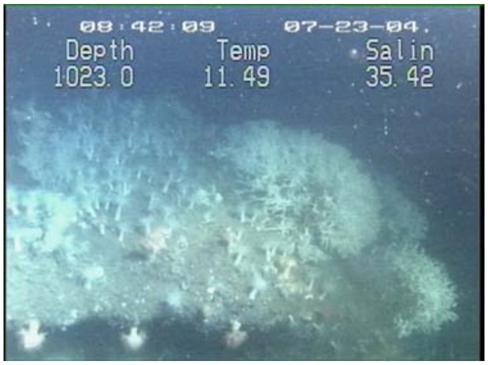


Figure 19. Three-dimensional terrain and the side-looking sonar mosaic of the VK862-909 seafloor. Refer to Figure 3 for the location of this survey area relative to the total area surveyed.



a.

b.

c.

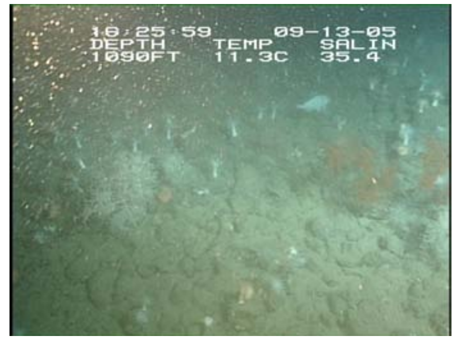
d.

e.

f.

Figure 20. VK826-a. Large block near the top of the mound densely colonized by anemones and large colonies of *Lophelia pertusa*; b. Large boulder near the top of the mound colonized mostly by anemones; c. Deep-crevice between two blocks; d. Small boulders on the southeastern flank of the mound; e. Western flank of the mound covered with a pavement of clasts and nodules of varying sizes and shapes; f. Flat partially exposed hardground south of the mound.

a.

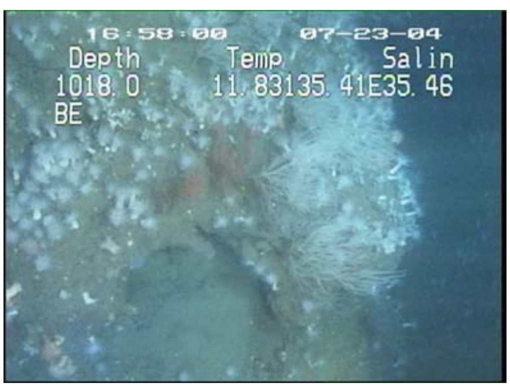


b.

Figure 21. Carbonate pavements composed of small-boulder to cobble size nodules and flat plates or slabs covering the crest (a) and east side (b) of the eastern ridge at VK906.

a.

b.



c.

d.

e.

f.

Figure 22. a. *Lophelia pertusa* aggregation on large boulder near the top of the south side of the VK862 mound; b. Isolated *Lophelia pertusa* colony attached to a small clast on the northern flank of the of the mound; c. Anemones and bamboo coral and antipatharians on a large boulder near the top of the mound; d. Anemones and antipatharians on rock rubble on the north flank of the mound; e. Large antipatharian on near the top of the of south side of the mound; f. Large antipatharian near the top of the mound.

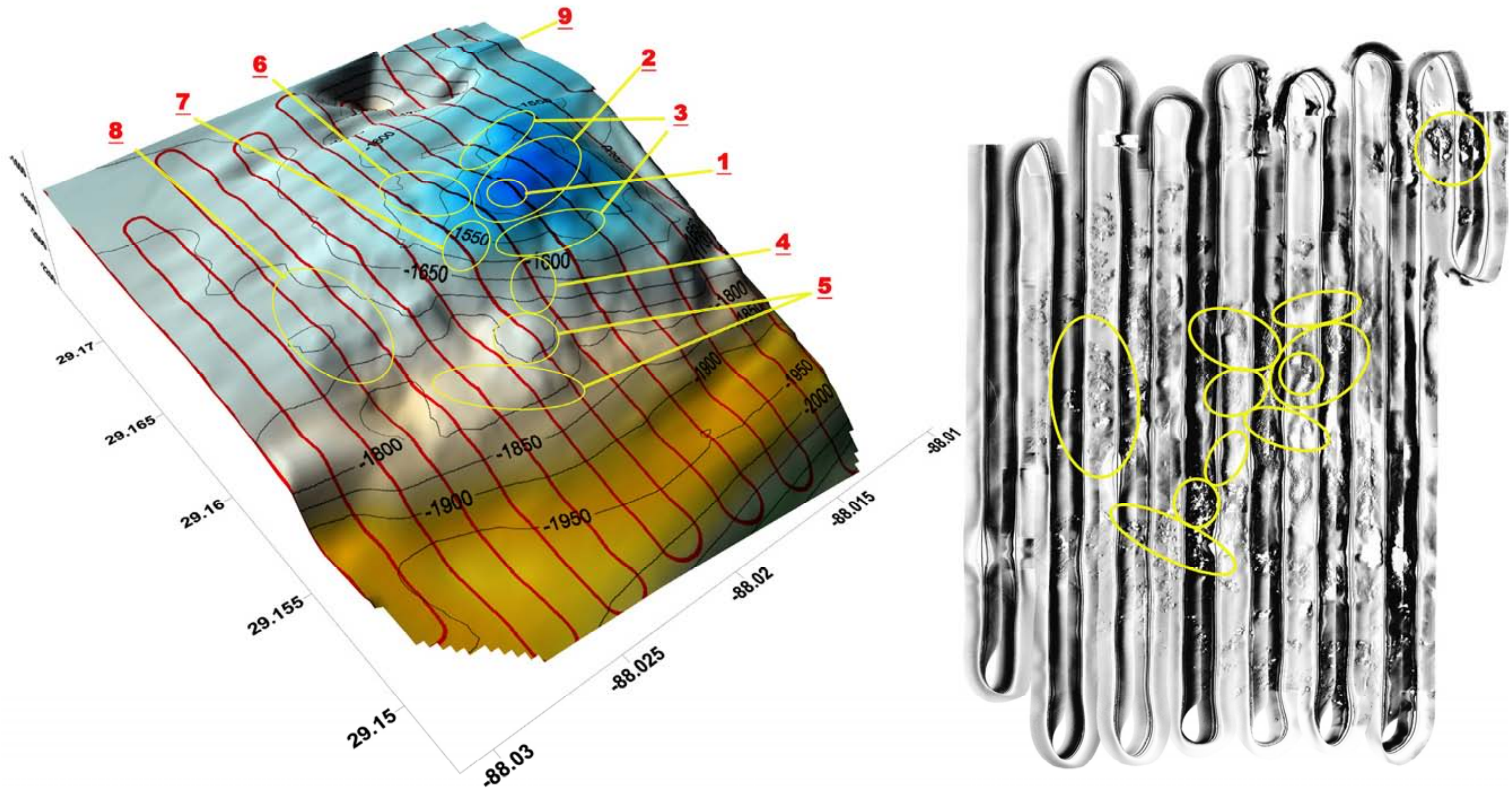


Figure 23. VK826 three-dimensional terrain and the side-looking sonar mosaic of the seafloor for the north-south trackline survey. Refer to the text on pages 9 and 10 for descriptions of designated areas. See Figure 2 for the location of the north-south tracklines relative to the east-west tracklines depicted in Figure 24.

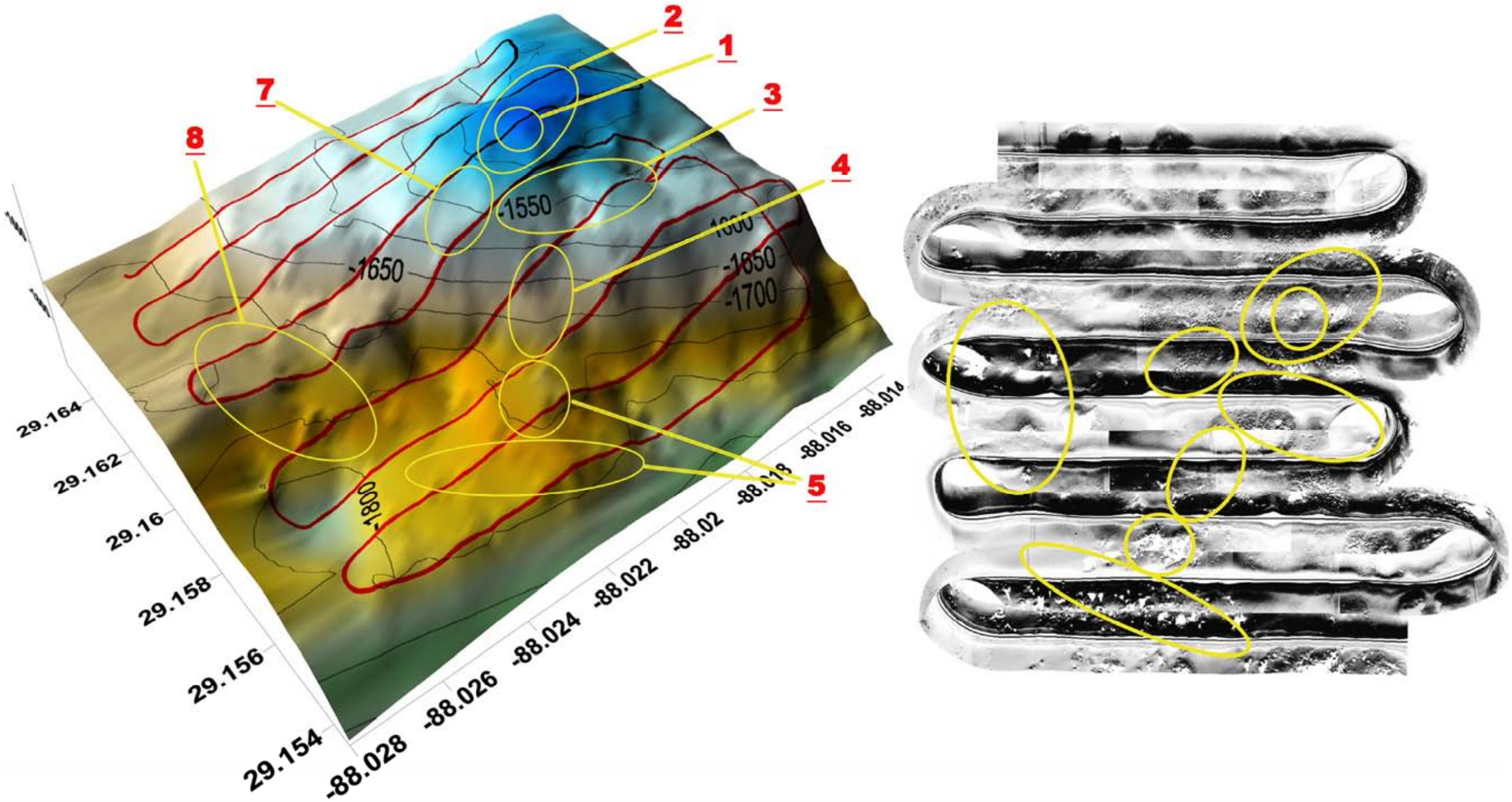
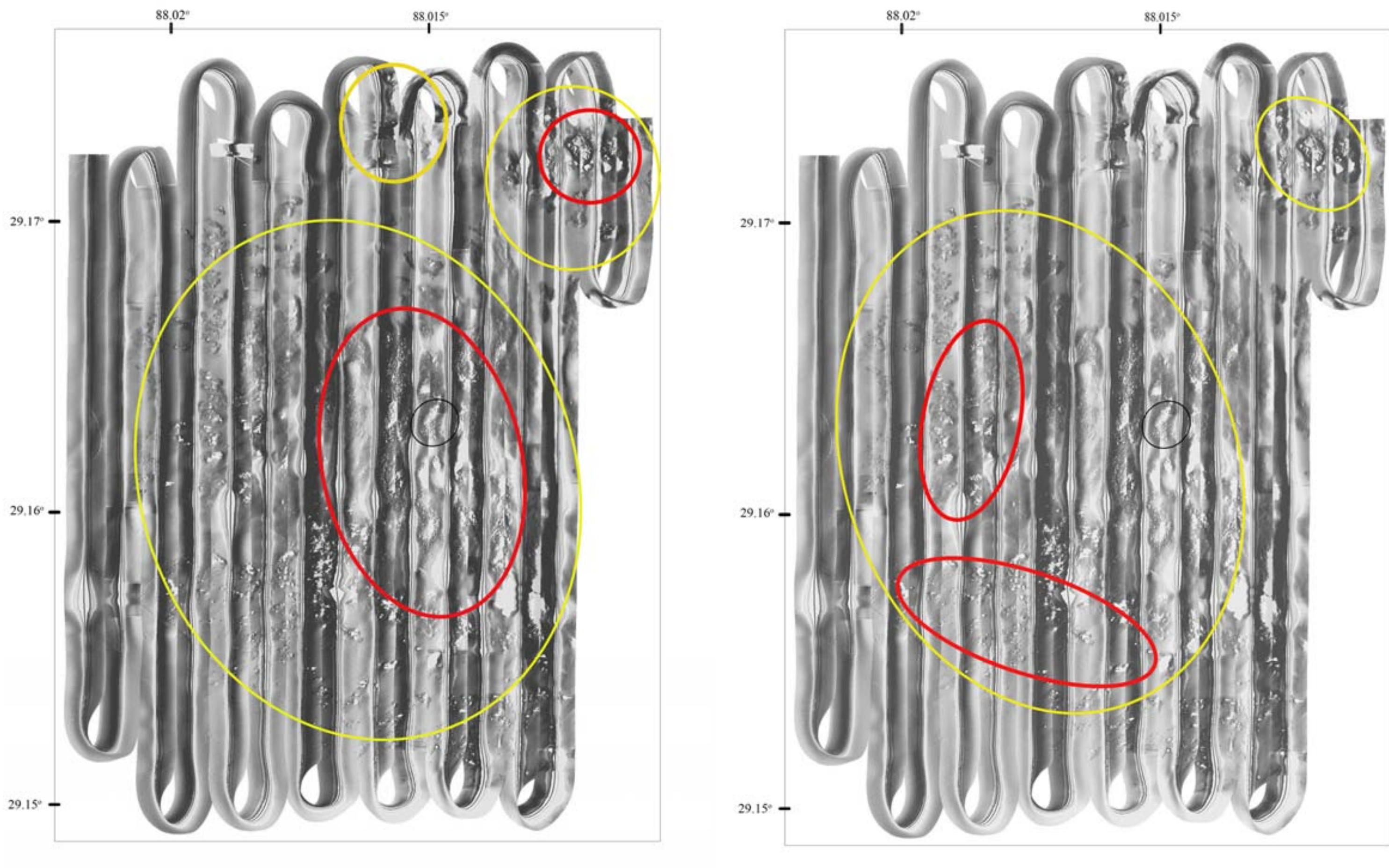
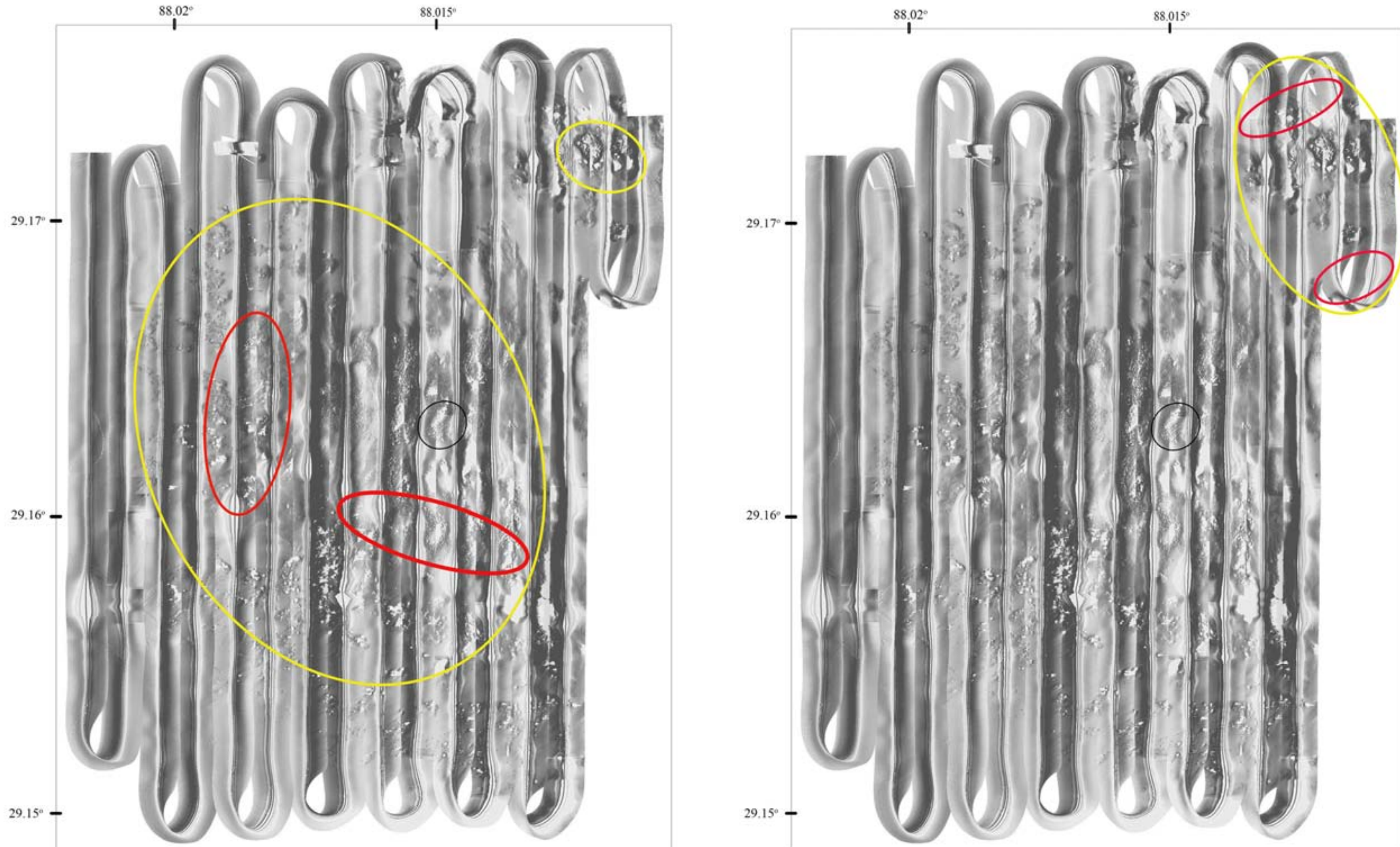


Figure 24. VK826 three-dimensional terrain and the side-looking sonar mosaic of the seafloor for the east-west trackline survey. Refer to the text on pages 9 and 10 for descriptions of designated areas. See Figure 2 for the location of the east-west tracklines relative to the north-south tracklines depicted in Figure 23.



Lophelia pertusa *Callogorgia americana delta*

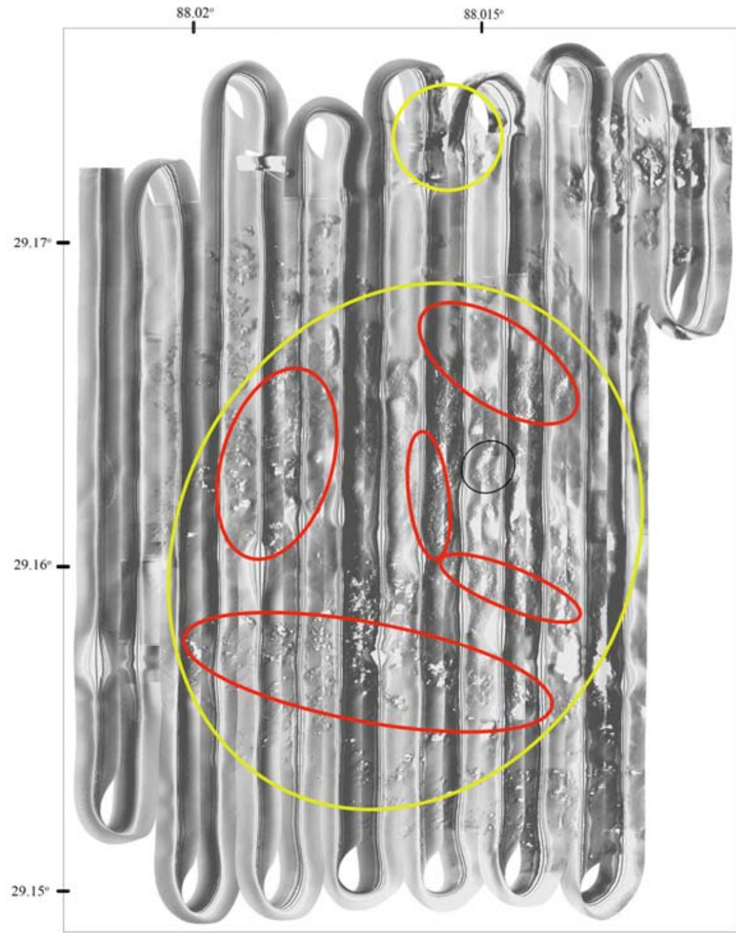
Figure 25. General distribution patterns of *Lophelia pertusa* and *Callogorgia americana delta* on VK826. Refer to Figure 5 for the location of the SLS mosaic relative to the seafloor terrain. The areas inside yellow ellipses denote that part of the study site in which all representatives of the designated megafauna have been observed, regardless of size, density or whether they were alive or dead while the areas inside red ellipses represent regions in the study site where living large individuals or dense assemblages of the designated megafauna have been observed. The small black ellipse denotes the crest of the knoll.



Antipatharians

Anemones

Figure 26. General distribution pattern of antipatharians and anemones on VK826. Refer to Figure 5 for the location of the SLS mosaic relative to the seafloor terrain. The areas inside yellow ellipses denote that part of the study site in which all representatives of the designated megafauna have been observed, regardless of size, density or whether they were alive or dead while the areas inside red ellipses represent regions in the study site where living large individuals or dense assemblages of the designated megafauna have been observed. The small black ellipse denotes the crest of the knoll.



Tubeworms

Figure 27. General distribution pattern of tubeworms on VK826. Refer to Figure 5 for the location of the SLS mosaic relative to the seafloor terrain. The areas inside yellow ellipses denote that part of the study site in which all representatives of the designated megafauna have been observed, regardless of size, density or whether they were alive or dead while the areas inside red ellipses represent regions in the study site where living large individuals or dense assemblages of the designated megafauna have been observed. The small black ellipse denotes the crest of the knoll.

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.