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Surface Geology and Biology at the Head of Kaoping Canyon off Southwestern Taiwan

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ABSTRACT

A preliminary geological and biological survey of Kaoping Canyon off southwestern Taiwan was conducted with a remotely operated vehicle (ROV). Twenty-one dives (25-160 m depth) were conducted at 12 stations on the canyon walls and adjacent continental shelf. Total bottom time from this series of dives was 17.0 hours. Surface sediments, microtopography, and faunal assemblages were generally similar along the series of stations across the canyon although local variability was apparent. However, features observed on canyon stations differed significantly from those of the adjacent shelf. Surface sediments on the canyon-shelf break were dominated by fine sands, silts and clays. Outcrop sediments along the canyon walls appeared to be composed of clay and were laminated and burrowed. Mass-wasting processes probably eroded the canyon walls and resulted in the deposition of gravel and shell fragments at the foot of the outcrops. Erosional feature, typically in the form of stepped terraces, were most pronounced at the lower parts of the canyon walls. Shelf areas adjacent to the canyon were relatively flat and covered by fine-grained sediments. A small number of taxa included soft corals, crabs, shrimps, crinoids and fishes were observed in the canyon. The diversity of macro-faunal organisms appeared to be greater at the shelf break than in the canyon. No systematic changes in sediment types with associated faunal assemblages could be grouped into distinct canyon habitats.

1. INTRODUCTION

Kaoping Canyon, located at about 22°27'N, 120°21'E, is a major physiographic feature on the continental margin off southwestern Taiwan (Figure 1). The canyon was thought to end about 40 km from coastline due to limited deep-water soundings and was described as a glacially eroded submerged marine valley (Ma, 1947, 1948, 1963). Studies related

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to submarine canyons around Taiwan, with few exceptions, have primarily used regional bathymetric survey data (Boggs *et al.*, 1979; Chen, 1989). The recent discovery of the 240 km course of the Kaoping Canyon extending from the mouth of the Kaoping river down to the lower continental slope at a depth of about 3,000 m (Liu *et al.*, 1991) has generated renewed interest. Yu *et al.* (1991) described the morphology and hydroacoustic characteristics of the head of Kaoping Canyon using bathymetric profiles and 3.5 kHz echograms. The stratigraphy, structure, sediment dispersal and accumulation, and biological activity related to the formation and development of Kaoping Canyon have received little attention.

The current study was initiated as a part of a cooperative program of undersea research between NOAA's National Undersea Research Center, The University of Connecticut at Avery Point, Groton, U.S.A. and the Institute of Oceanography, National Taiwan University, Taiwan, ROC. Herein we report on the surface geology and biology at the head of Kaoping Canyon, and adjacent shelf regions, from direct underwater observations using a remotely operated vehicle (ROV). The objectives of this study were to: (1) describe surface sedimentary features and the microtopography of the head of Kaoping Canyon, (2) determine the distribution of canyon fauna and associated habitat features, and (3) determine if mass-wasting movements, bioerosion and other processes contribute to the geological and biological variations in the canyon.

1.1 Canyon Setting

Three submarine canyons have developed within a distance of 50 km along the continental margin off southwestern Taiwan (Figure 1). These canyons (i.e., Kaohsiung Canyon, Kaoping Canyon, and Fangliao Canyon) can be categorized into two types: the river extension type and the fault-related type. Kaoping Canyon belongs to the first type which runs across the continental shelf and is well aligned with the Kaoping river on land. Kaohsiung and Fangliao Canyons are associated with the fault-related type (Yu and Wen, 1991, Yu *et al.*, 1992). Kaoping Canyon is the largest of these three canyons, extending over 240 Km from the mouth of the Kaoping river across the continental shelf and slope to the northern extension of the Manila Trench (Yu *et al.*, 1991, Liu *et al.*, 1992, Yu, 1992). The head of Kaoping Canyon, about 20 Km from the shoreline, is characterized by high and steep walls. Canyon relief exceeds 600 m and cross-sectional morphology varies from V-shaped to broadly U-shaped (Yu *et al.*, 1991).

2. MATERIALS AND METHODS

A MiniRover MK-II ROV was used to conduct survey dives in Kaoping Canyon from 2 to 8 May, 1991. Twenty-one daytime dives were made at 12 stations on the east and west canyon walls, and adjacent shelf (Figure 2). Observations were made on the shelf at depths from 25-39 m, and on the eastern and western walls of the canyon from 45-161 m and 64-132 m, respectively. Station locations are given in Table 1. Total bottom time for the ROV was 17.0 hours. At each station, the support ship was anchored and the ROV surveyed an area within a 30-50 m radius from the downweight (Figure 3). Strong currents and topography limited the ability of the ROV to conduct continuous transects in the area, hence all observations were related to depth. Video imagery was recorded with an 8 mm videotape recorder. A 35 mm still camera was used to take high-resolution images of specific

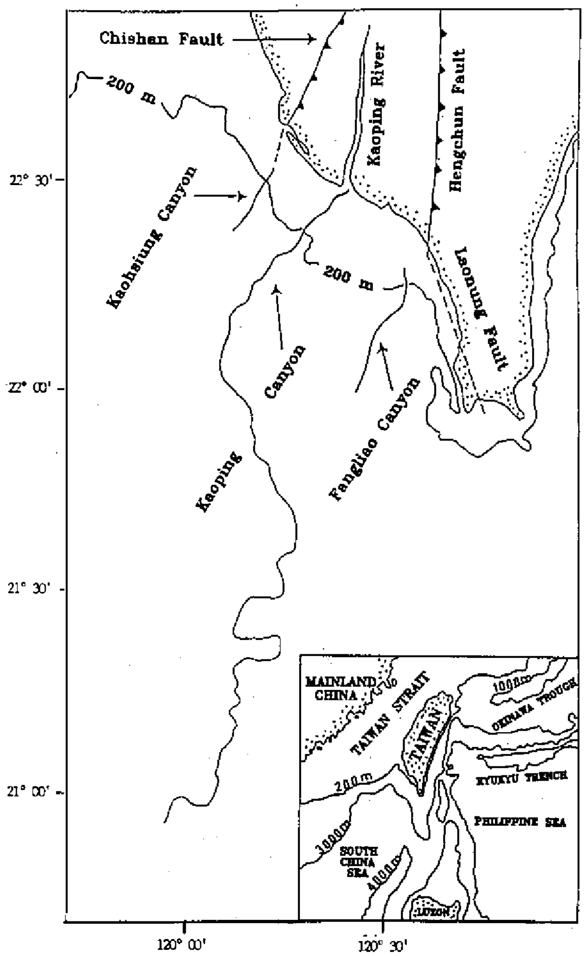

Fig. 1. Location of submarine canyons off southwestern Taiwan.

geologic features and organisms for species identification. Image data was used to determine surface sediment types, canyon topography, habitat types and related geological and biological information.

3. RESULTS

3.1 General Observations

The steep sides of the east wall consists of a series of laminated clay outcrops (1.5-6 m height) and sand/silt terraces. Heavier materials (e.g., shell, gravel) aggregated at the base of the outcrops. The gentle slope of the upper west wall had dense shallow furrows in cohesive sand, silt and clay sediments as did the continental shelf proper northeast of the canyon. These features were the result of trawling activities by extensive fishing in the area. The deeper portion of the western wall had outcrop and terrace features similar to those on the east wall.

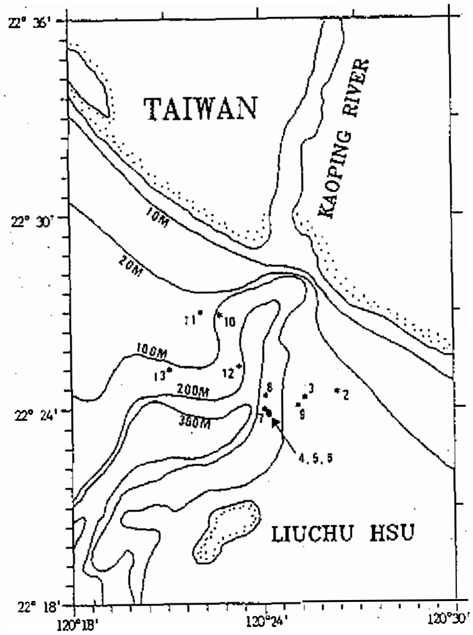

Fig. 2. Location of ROV dives in Kaoping Canyon.

Table 1. Summary of dive locations.

Station	Dive Number	Depth (m)	Location Lat.(W)	Long.(E)
2	2,3,4,5	25	22°24' 30"	120°26' 20"(S)
3	6	42	22°24' 20"	120°25' 19"(S)
4	7,8	60-148	22°23' 54"	120°24' 10"(E)
5	9	63	22°24' 00"	120°24' 03"(E)
6	10	72	22°23' 51"	120°24' 12"(E)
7	11,12	84-117	22°23' 50"	120°24' 12"(E)
8	13,14	145-158	22°24' 24"	120°24' 05"(E)
9	19,20	39	22°24' 06"	120°25' 06"(S)
10	15	98-128	22°26' 54"	120°22' 42"(W)
11	16	58-69	22°27' 00"	120°22' 06"(W)
12	18	101-135	22°25' 18"	120°23' 18"(W)
13	21,22	127-131	22°25' 12"	120°21' 06"(W)

S - Shelf northeast of Kaoping Canyon
E - Eastern wall
W - Western wall

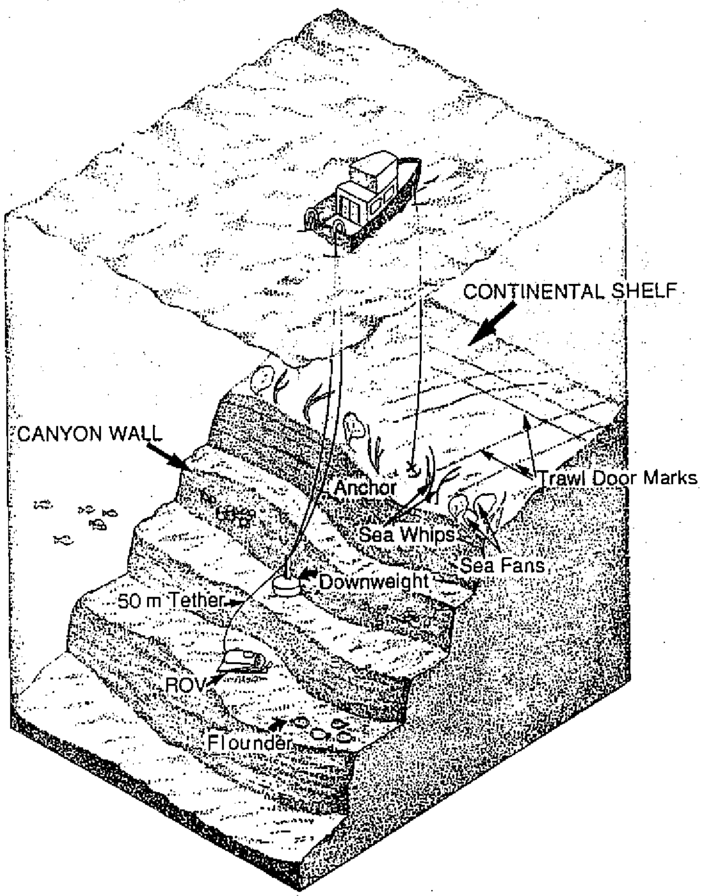

Fig. 3. Conceptual representation of a typical ROV deployment. The support ship is anchored at the edge of the continental shelf and drifted back over the steep canyon wall. A downweight is used to reduce the effects of current on the tether. A 50 m segment of tether connects the ROV to the downweight.

The diversity and density of mobile macro-fauna was very low. Habitat complexity was also low and consisted of low relief sedimentary structures (e.g., burrows, depressions) and-coral debris. Some species of mobile fauna were associated with specific features (Appendix 1). For example: rockfish (Scorpaena sp.) occurred in burrows or shallow depressions, a moray eel (Ophichthus sp.) was observed in a small circular burrow, gobies (primarily Amblyeleotris fasciata) were in and around burrows and shallow depressions, and portunid crabs excavated burrows and depressions around coral debris. Other taxa such as pleuronectid flounders (primarily Plagiopsetta glossa) and penaeid prawns were not associated with any specific structure.

The diversity of epifauna was also low. Coral debris was the only substrate for attachment in this area, especially around the shelf break along the east wall. Crinoids, sea whips and soft corals were common taxa.

The steep outcrops along the canyon walls were heavily burrowed in some places. Burrows were round to ovoid and generally 1-3 cm diameter. Most burrows had distinct edges and no signs of collapse. However, no observations were made of any taxa which occupied these features.

A summary of surface sediment distribution, topography, and sedimentary features in the canyon and on adjacent shelf areas is shown in Figure 4. Vertical structure and sedimentary features observed on six typical dives are summarized in Appendix 2.

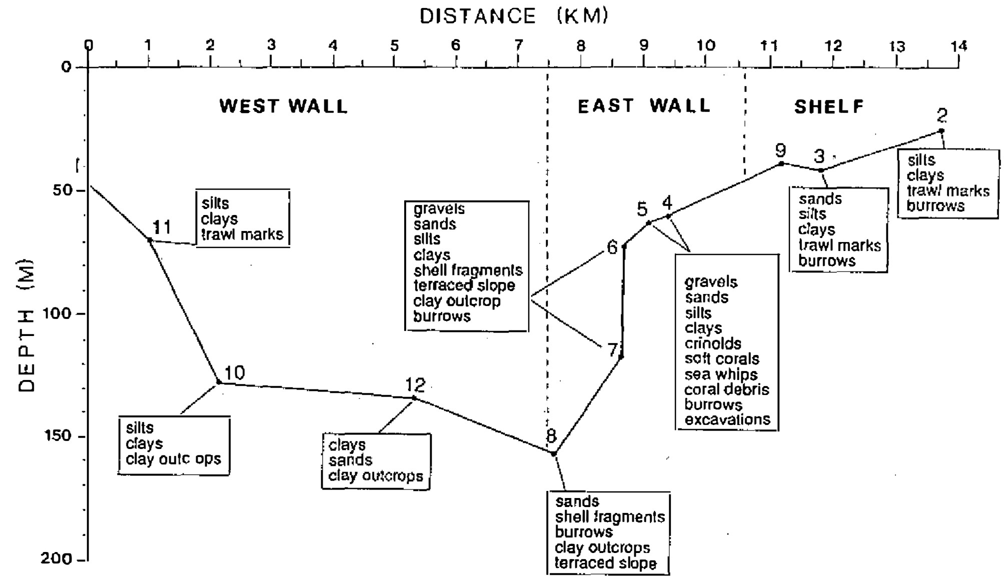

Fig. 4. A summary of surface sediment distribution, topography, and sedimentary features across the canyon and on the adjacent continental shelf.

3.2 Specific Site Observations

Continental Shelf Northeast Of Canyon (25-42 m) - The sea floor surface at station 2 was mostly covered with cohesive silts and clays. Furrows from the doors of trawl gear were common features. Scattered burrows were present but were less abundant relative to deeper areas in the canyon. Virtually no habitat structure (e.g., live coral, dead coral skeletons) was present in this area.

The area at station 3 was covered by sands, silts and clays with a cohesive appearance. Trawl door furrows were more extensive than at station 2, indicating extensive fishing activities. A galatheid(?) crab was observed in a concave cone shaped burrow. A portunid crab excavated a depression and horizontal burrow under debris. A burrowing shrimp (unidentified) was observed feeding at the entrance of a burrow 4-5 cm in diameter.

Eastern Canyon Wall (60-158 m) - Sediments along the shelf break and upper wall (stations 4-6; 60-80 m) generally consisted of sands, silts and clay. Sea whips, sea fans, soft corals, crinoids and hydroids were attached to biogenic debris and gravels. Shallow excavations, probably formed by crabs, were common around the attached fauna and piles of debris. Several extensive excavations (ca. 1 m in diameter) were also observed. Crabs (portunids and galatheids) and numerous small fishes (generally Amplyeleotris sp.) were associated with these features. There were also small-scale sedimentary differences between stations. The sediments at station 5 were more cohesive and vertical burrows 2-4 cm in diameter were common. Sand and gravel were more extensive at station 6. No burrows were observed at this station.

Between 80 and 158 m (stations 4, 7 and 8), the canyon wall consisted of a terraced slope with occasional slump structures. Clay outcrops were exposed along the vertical walls between terraces and coarse-grained materials such as sands, shell fragments and cobble were deposited at the base of these vertical segments. A sedimentary overhang was observed on dive 12 at 106 m above a 1.5 m vertical layered clay outcrop. The walls were heavily excavated in some sections with horizontal burrows. No organisms were observed at the entrance of any of these structures.

Western Canyon Wall (58-135 m) - The slope was covered by silts and clays (stations 10-13). A prominent vertical clay outcrop of nearly 4 m high at 101 m was observed on dive 15 at station 10. Spur and groove (i.e., deeply incised vertical outcrops) were observed on the wall near 107 m depth on dive 15. A sedimentary overhang, like the one observed on the eastern wall, was observed above a 6 m vertical layered clay outcrop at 128 m on dive 18 at station 12.

Species of penaeid shrimps and pleuronectid flounders (generally Plagiopsetta glossa) were observed along the slope but were not associated with any particular bottom structure. Large and dense aggregations of myctophid fishes were also observed in the water column and along the canyon wall. These fishes reacted strongly to the lights on the ROV so no useful observations regarding depth distribution and aggregation structure could be made.

On the upper slope (58-69 m), dense trawl door furrows were partially filled by clays and silts. Sparse clusters of burrows were observed in this area but no mobile fauna was present.

4. DISCUSSION

The shelf areas we observed adjacent to Kaoping Canyon were covered by fine sands, silts and clays similar to those as described by Boggs *et al.* (1979). Shelf sediments also predominated along the eastern canyon wall. Localized coarse sands, gravel and shell fragments occurred on the upper east wall and at the bottom of laminated clay outcrops (84-158 m). Deposits of coarse-grained material at the base of outcrops are probably due to mass-wasting movements along the steep faces.

Surface sediments on the western wall were similar to those on the eastern wall. However, coarse-grained gravel and shell fragments were not found at the bottom of outcrops. The lack of coarse-grained materials on the western wall could be related to the more gentle slopes hence reducing downslope transport. Alternatively, cross-shelf transport processes (e.g., currents along the canyon axis) deposited coarse-grained material only on the eastern side of the canyon.

Based on the plane view of the bathymetry of the Kaoping Canyon head (Figure 2), the part of canyon crossed by the the ROV transect can be represented by a meander bend (The Kaoping Canyon belongs to the river-extension type as mentioned previouly). The classical sedimentation model (Leopold and Wolman, 1960) of meander bends suggests that the inner bank (western canyon wall) is the site of deposition while the outer bank (eastern canyon wall) is the place of erosion. Lateral deposition of the western wall may result in a gentle slope while the erosion on the eastern canyon wall may result in a steep one. The sediments eroded from the eastern canyon wall fell into the base of the wall or canyon floor where finer sediments were winnowed to give a lag of coarse-grained materials.

Distribution of sediments from the shelves across the canyon did not show any systematic changes in composition or associated fauna. However, the predominance of coarse materials (i.e., gravel, shell, debris) at the shelf break along the eastern wall was probably responsible for the relatively high density of soft corals and other sessile fauna found there.

Topographic differences between the stations were most pronounced on the lower canyon walls where terraced slopes or steep surfaces, interrupted with vertical outcrops, occurred. These are primarily erosional features resulting from slope failure of the canyon walls due to oversteepness and partly from the bioerosion of burrowing organisms (e.g., Twichell *et al.* 1985). The microtopography of the canyon walls clearly demonstrates that canyon wall morphology is primarily shaped by downslope processes and bioerosional activity; factors which were not recognized by the previous studies using large-scale survey techniques such as bathymetric profiles and 3.5 kHz echograms (Yu *et al.*,1991, Yu, 1992). It is noted that the Liuchu Hsu island, a carbonate buildup, is in the vicinity of eastern canyon wall. We postulated that the strata of eastern canyon wall are probably composed of carbonates which tend to resist erosion and maintain the cohesive strength to form the overhangs on the eastern canyon wall.

Faunal diversity and abundance were extremely low at all stations. Estimates of faunal densities were not possible due to the steep topography of the canyon walls and the difficulty of conducting transects. Species-time census techniques (Michalopoulos *et al.* 1992) could potentially be used if a survey design could take into account the long elapsed time (e.g., 20 minutes) between encounters with individual organisms.

Taxa observed on the canyon floor, with the exception of penaeid shrimp and pleuronectiform flounders, were generally found utilizing some forms of shelter. The shelters were either distinct burrows in the silt-clay bottom, excavations around and under debris, or burial into the surface sediments. Change in faunal diversity and abundance with types of substrate in submarine canyons and continental shelves has been documented previously (Cooper *et al.* 1987,1988; Langton and Uzmann 1989; Auster *et al.* 1991; Stein *et al.* 1992). However, due to the extremely low densities of organisms and small sample sizes for each taxa, it was not possible to establish statistically significant faunal-habitat relationships in the study area.

High densities of burrows were present in outcrops and along steep slopes on the canyon walls. The openings of most burrows had distinct edges as if recently been used, rather than rounded and partially collapsed as if abandoned. However, no burrow occupants were obsereved possibly because all dives were conducted during the day and the occupants of these structures may be active nocturnally.

The extensive trawling activities, which are apparent from trawl door furrows in the sediments, could have reduced spatial complexity on the shelf. The relatively dense assemblage of emergent fauna (e.g., sea whips, sea fans, soft coral) at the shelf break on east wall may represent a refuge area for these species which had previously occupied a larger region of the shelf.

The information obtained from these exploratory dives suggests several avenues for future study:

1. Determine rates of erosion (e.g., from outcrops) and deposition (e.g., comparisons between the eastern and western slopes) in relation to specific canyon features.
2. Determine how and by what oragnisms were the burrows formed.
3. Compare shelf and slope faunas using species-time video survey techniques (e.g., Michalopoulos *et al.* 1992).
4. Determine the effects of trawling on benthic habitats and living marine resources.

Each of the four areas outlined above would benefit from or require the use of direct underwater observation capabilities. Subjects 1 and 2 could be accomplished using a time-lapse camera system to determine rates. A mobile underwater vehicle (i.e., large ROV or manned submersible) would be required for placement of the time-lapse system and measuring rods or sediment traps. Subjects 3 and 4 require a ROV or submersible to obtain the census data.

This study demonstrates the advantage of direct underwater observations for complementing other larger scale surface based sampling technologies (e.g., bathymetric profiling, grab samples). Additionally, fine-scale observations provide a perspective which can generate unique areas for future investigation.

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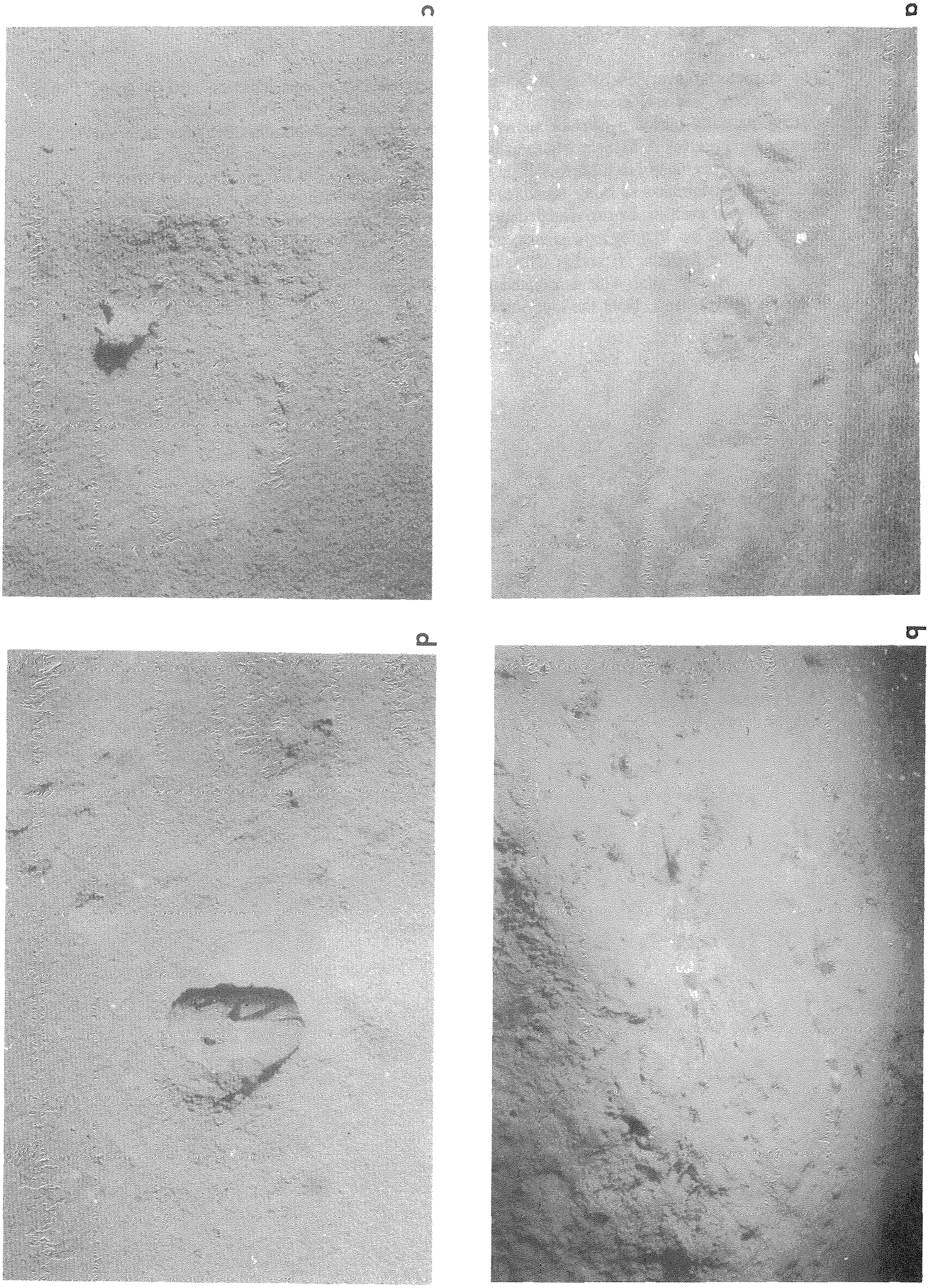
APPENDIX 1

A pictorial overview of organism-sediment relationships and habitats. (a) A goby, Amblyeleotris fasciata, associated with a shallow depression. (b) Two flatheads Ongocia spinosa, partially buried in surface sediments. As ambush predators, this behavior may aid in prey capture. (c) A batfish, Malthopsis jordani, in a shallow circular depression. (d) A rockfish, Scorpaena sp., in a burrow. It is not clear if this group of fishes creates burrows or utilizes vacant burrows of other taxa. (e) A snake eel Ophichthus sp., in a shallow burrow. (f) A portunid crab in an excavated depression around a piece of coral debris. (g and h) Flounders such as, Plagiopsetta glossa, and penaeid shrimps were not associated with any specific habitat features. (i and j) Crinoids and sea fans were attached to gravel and coral debris. (k) A soft coral with associated galatheid crabs. (l) A heavily burrowed outcrop along the canyon wall. Note the layering of sediments.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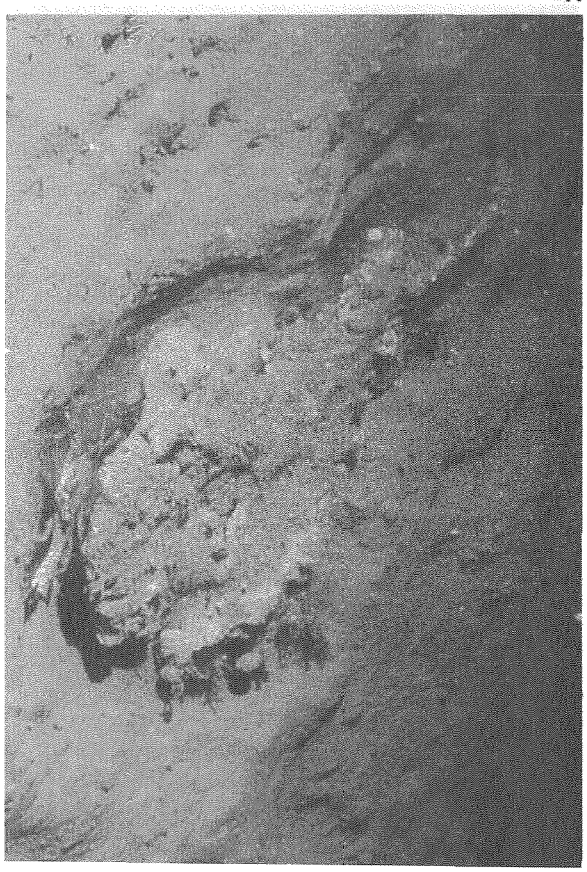

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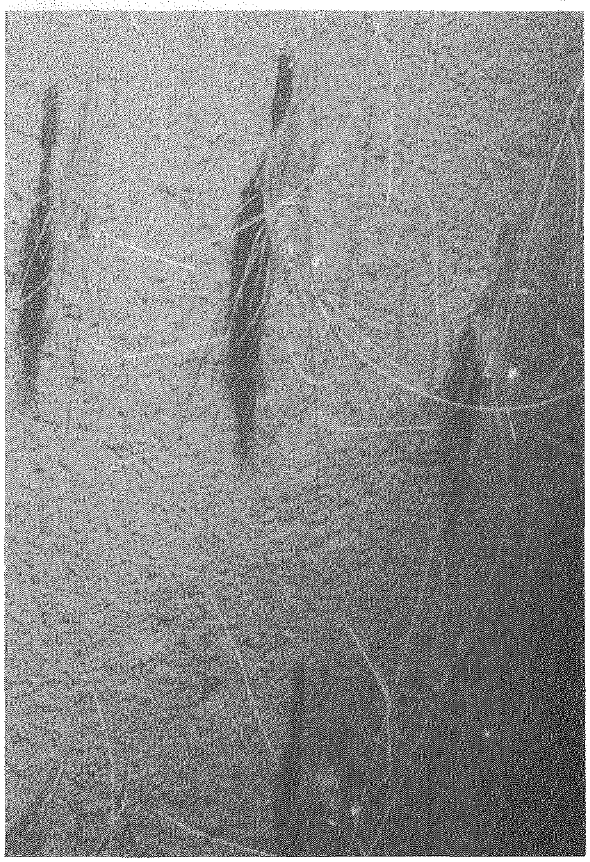

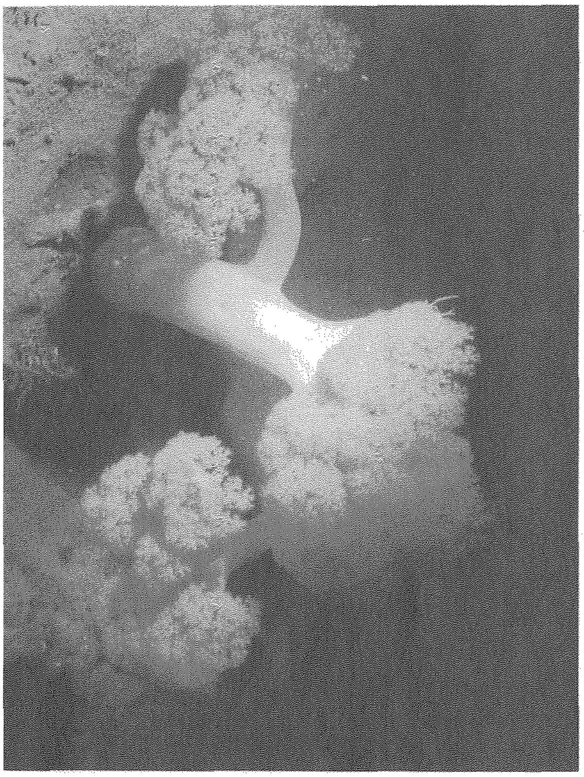

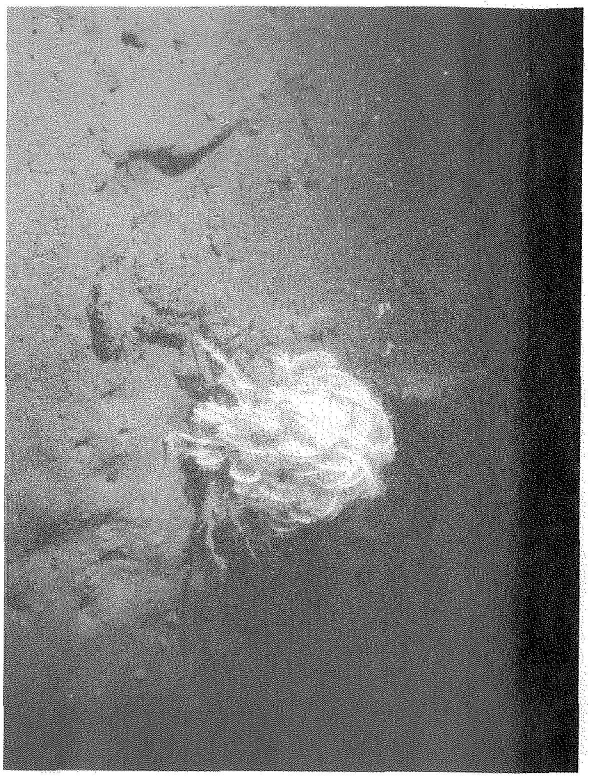

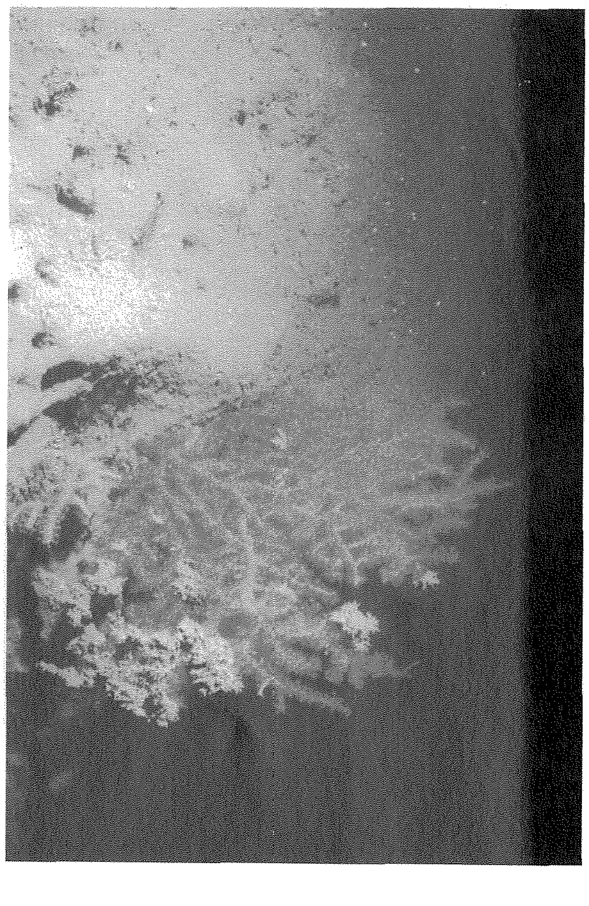

APPENDIX 2

Pictorial representations of the vertical structure and sedimentary features observed on six ROV dives. Refer to Table 1 for dive location. Depths are in meters.