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Clustering of Suspension-Feeding Macrobenthos Near Abyssal Hydrothermal Vents at Oceanic Spreading Centers

by

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Preliminary Communication

CLUSTERING OF SUSPENSION-FEEDING MACROBENTHOS NEAR ABYSSAL HYDROTHERMAL VENTS AT OCEANIC SPREADING CENTERS*

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Abstract--A community of abundant suspension-feeding organisms was photographed around an active hydrothermal vent at the Galapagos Rift. A site on the crest of the East Pacific Rise where hydrothermal discharge is suspected also has a dense colony of sessile organisms. The high standing crop of macrobenthos in these patches probably results from local increases of deep-sea food supply near hydrothermal plumes in the bottom water.

There is a widespread belief, based primarily on measurements of conductive heat flux, that oceanic spreading centers are sites of hydrothermal circulation of seawater through hot, new basalt (e.g., TALWANI, WINDISCH and LANGSETH, 1971; LISTER, 1972). It has been proposed that hydrothermal fluids discharging at the ocean floor have temperatures as high as 150 to 300°C (WOLERY and SLEEP, 1976), but rapid dilution hampers identification by the temperature anomaly alone: local anomalies of up to about 0.1°C have been measured in the bottom water at spreading centers (e.g., WILLIAMS, VON HERZEN, SCLATER and ANDERSON, 1974; RONA, MC GREGOR, BETZER, BOLGER and KRAUSE, 1975), but some temperature changes of this magnitude may result from normal hydrographic processes (FEHN, SIEGEL, ROBINSON, HOLLAND, WILLIAMS, ERICKSON and GREEN, 1977). In May 1976, warm, buoyant plumes that unequivocally resulted from hydrothermal discharge were sensed and sampled 8 to 40 m above the central volcanic ridge at the spreading axis of the Galapagos Rift (WEISS, LONSDALE, LUPTON, BAINBRIDGE and CRAIG, 1977). The device used was a conductivity-depth-temperature probe (CDT) and a rack of specially designed sampling bottles attached to the belly of the Marine Physical Laboratory's deep-tow vehicle (SPIESS and MUDIE, 1970). During our search for hydrothermal plumes the acoustic sensors of the vehicle were determining plan position and height off bottom, and mapping the geology (LONSDALE, 1977a). One of the plumes was sensed and sampled while the vehicle was photographing the sea floor with its battery of black and white stereo and color cameras. Our photographs, collected in an overlapping swath 10 m wide, show that close to the discharge vent (a gaping axial fissure) that underlies this plume the joints and fractures in the basalt are frosted with white and bright yellow chemical precipitates, and that within 15 m of the fissure there is a remarkable community of large and abundant benthic organisms (Fig. 1).

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* Contribution of the Scripps Institution of Oceanography, new series.

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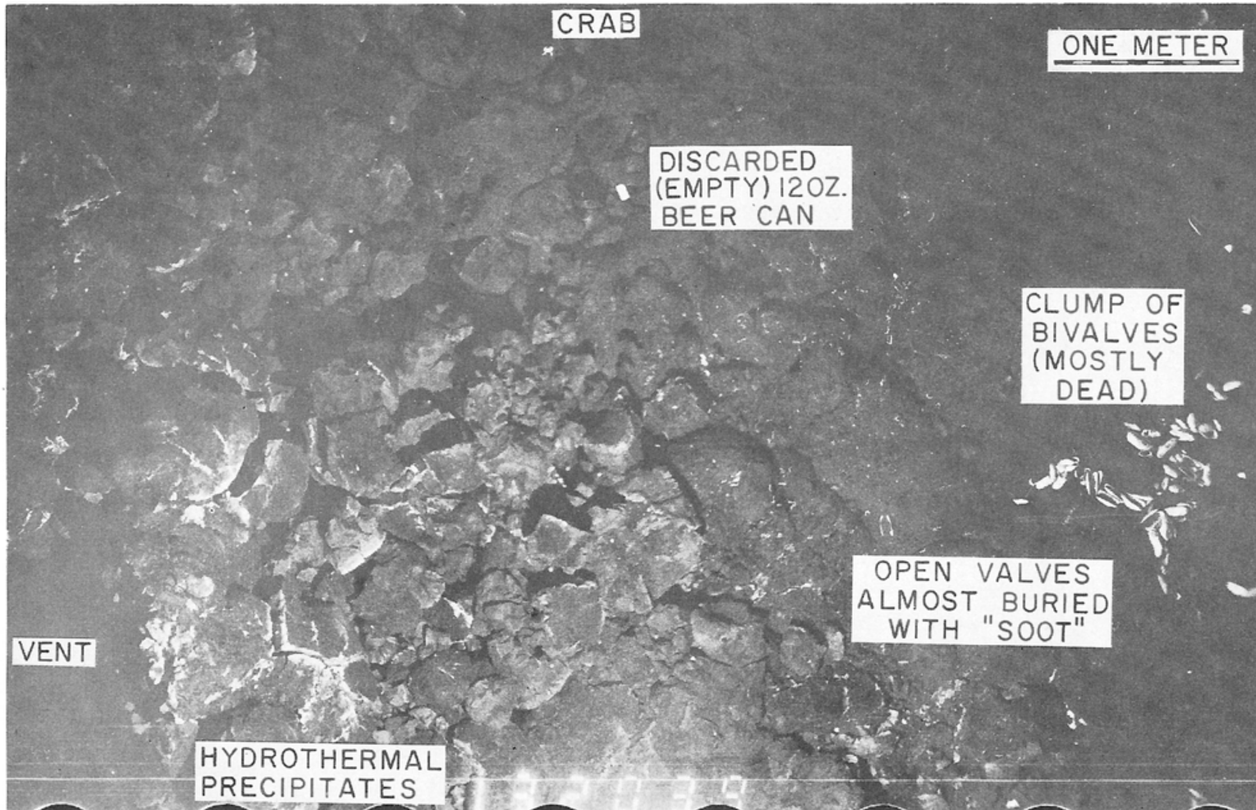

Figure 1. Photo taken 13.20.39 GMT 29.5.1976 at central high of Galapagos Rift. Depth 2488 m. Beer can gives scale. The encrusted rocks at the left of this frame are at the edge of the axial fissure which was acting as a hydrothermal vent when it was obliquely crossed 40 seconds (30 m) before.

The community photographed around the plume at 0°47.84'N, 86°09.18'W is dominated by light-colored bivalve mollusks with elongate shells whose average size (15 to 18 cm long) is unusually large for deep-sea forms. For example, CLARKE (1962) described a collection of 650 abyssal mollusks of different species that has a maximum length of 2.8 cm and an average length of only 0.3 cm. The density is also high, with the mollusks tending to occur in clumps of 20 or more individuals that almost cover patches of rock. Several scavenging crabs were also seen near the clam shells (Fig. 1). Mollusks and crabs are absent on the 1500 other deep-tow photographs from elsewhere in the inner rift, despite their abundance near the vent. Several other patches of fracture-filling precipitates were located, but none had associated animals or active plumes. The region underlies productive surface water, but large suspension feeders are generally rather uncommon, with only a few sponges seen attached to rocks. Pockets of pelagic sediments are heavily burrowed and tracked by deposit feeders. These are thought to predominate in most abyssal communities (e.g., HESSLER and JUMARS, 1974), although SOKOLOVA (1972) has suggested that suspension feeders are in the majority in the oligotrophic zone (which does not include the Panama Basin).

Many of the clumps of mollusk shells consist of dead individuals, with the valves (open, but still attached at the umbos) being partly buried by a dark colored dust, or "soot" (Fig. 1). This material is interpreted as a fine-grained metalliferous sediment (probably of manganese oxide) that precipitated out of the rising hydrothermal fluid; a nephelometer attached to the deep-tow vehicle measured a spike of high turbidity as it passed through the plume. Perhaps its deposition has killed the mollusks, though they may have died because favorable growth conditions created by hydrothermal discharge temporarily ceased. MACDONALD and MUDIE (1974) reported another biological calamity at this same site that may be attributable to a hydrothermal event: after recording a swarm of microearthquakes that were probably caused by hydrothermal activity (K. C. MACDONALD, 1977, pers. comm.) they found over 80 dead and dying benthic fish floating on the surface.

This report of phenomena at hydrothermal vents in the Galapagos Rift is preliminary in that teams of scientists are presently diving there aboard DSRV ALVIN and are sampling the hydrothermal precipitates and benthic organisms that we photographed (K. CRANE, 1977, pers. comm.). Because specimens of the mollusks will soon be available for laboratory examination, it does not seem sensible to speculate about their taxonomy or ecology. However, their observable life habit of attachment to lava that is almost bare of sediment indicates that they are suspension feeders, and, as the standing crop of benthic organisms is thought to depend primarily on the rate of food supply (SANDERS and HESSLER, 1969), we suppose that the clustering near a hydrothermal vent is caused by a higher flux of suspended food particles across the site. Suspension feeders grow best where active water movement brings food without their having to expend energy. It is known from analysis of worldwide deep-sea photographs that the regional distribution of sessile suspension feeders is partly correlated with the speed of bottom currents, with some taxa apparently restricted to sea floor that is swept by fast thermohaline flow (HEEZEN and HOLLISTER, 1971). The relative paucity of sessile megafauna photographed throughout most of the Galapagos inner rift could be accounted for by the slow currents measured there (a 504-hour average speed of 3.9 cm s^{-1} 20 m above the central high 630 m east of the plume of Fig. 2; LONSDALE, unpublished data).

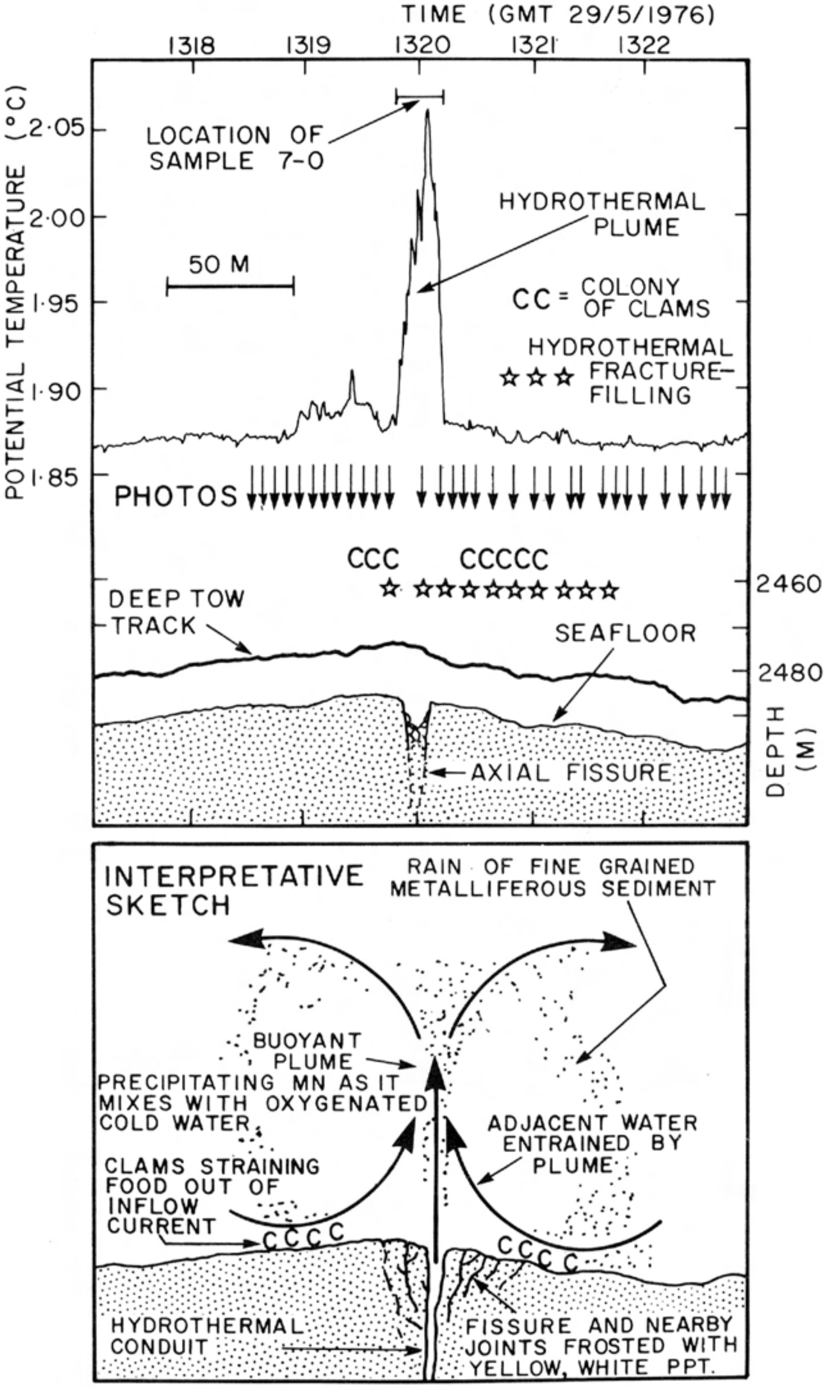

Figure 2. Deep-tow data during a camera run obliquely crossing an axial fissure on the Galapagos Rift central high. Sample 7-0 is the sample of hydrothermal fluid described by WEISS et al. (1977); for position in inner rift, see that paper. Below is an interpretative sketch of phenomena around a hydrothermal vent.

Elsewhere in the Panama Basin, suspension feeders are abundant at sites of fast bottom currents photographed in the Ecuador Trench, where outcrops of chalk swept by a 30 to 40 cm s^{-1} current at 3000 m are heavily bored, probably by lithodomous bivalves (LONSDALE, 1976, Fig. 12). The simplest explanation for clustering around a vent is that entrainment of bottom water by the rising buoyant plume creates local inflowing bottom currents that deliver food for the animals (Fig. 2). The distribution of mollusks around the plume but not immediately at the vent is consistent with this hypothesis; if it is true, then the extent of each benthic community may provide useful information on the horizontal scale of convective cells in the bottom water. However, biological processes directly dependent on injection of hydrothermal fluids may be an alternative or a supplement to this purely physical mechanism of increasing the local food supply. It has been suggested that bacteria are the main food source of abyssal filter-feeding mollusks (CLARKE, 1962). Rapid growth of chemoautotrophic bacteria occurs at many subaerial hydrothermal vents, and if such bacteria are abundant at the abyssal vents they could provide a local source of food for the mollusks and possibly a significant input of organic matter to the deep sea.

We also examined deep-tow photographs from another oceanic spreading center, where the direct physical evidence for hydrothermal circulation is more ambiguous. On the same expedition as the Galapagos Rift work, and using the same equipment, we surveyed and photographed the crest of the East Pacific Rise at $3^{\circ}25'$S, where the axis lies in a narrow (400 m) crestal rift zone with a shallow (10 to 35 m) summit graben atop a 2-km wide 100 to 150-m high axial volcano (Fig. 3; LONSDALE, 1977b). Identification of hydrothermal plumes is more difficult here, because the volcanic ridge is a sill separating bottom water that differs in temperature by almost 0.1°C, and exchange of water across the ridge results in packets of water bounded by steep thermal gradients, which may be mistaken for hydrothermal plumes. (They are the "false plumes" of WEISS et al., 1977). The best candidate for a hydrothermal plume within the summit graben (which the deep-tow instrument crossed 13 times at altitudes of 0 to 50 m) was sensed while bottom photographs were being taken on Camera Run 3-1, at about 0009 GMT 14 May (Fig. 3). Potential temperature initially increased by 0.12°C without the decrease in salinity characteristic of the "false plumes", but soon afterwards the deep tow vehicle briefly struck the bottom, and conductivity data became highly erratic. As a result, although the CDT temperature data suggest hydrothermal discharge near the point of impact, the lack of reliable salinity data through the peak of the anomaly prevents it from being distinguished unambiguously from a "false plume" caused by hydrographic processes. Subsequent camera runs across the summit graben 3 km north of this site (Fig. 3) were made without incident and with fully operational instruments, but no similar temperature anomalies were located.

The topography in the crestal rift zone consists of a group of parallel linear ridges, up to 15 m high, 20 m wide and with very steep sides, that are probably formed by piling up of pillow lava along eruptive fissures (LONSDALE, 1977b), and are similar to the "pillow walls" on Puna Ridge, Hawaii (FORNARI, MALAHOFF and HEEZEN, 1977). Photographs taken in the troughs on either side of the wall struck by the deep-tow vehicle show extensive dusting of the lava with dark colored sediment, identified as the metalliferous precipitates that are common on the East Pacific Rise (e.g., BOSTROM and PETERSON, 1966) and that we sampled

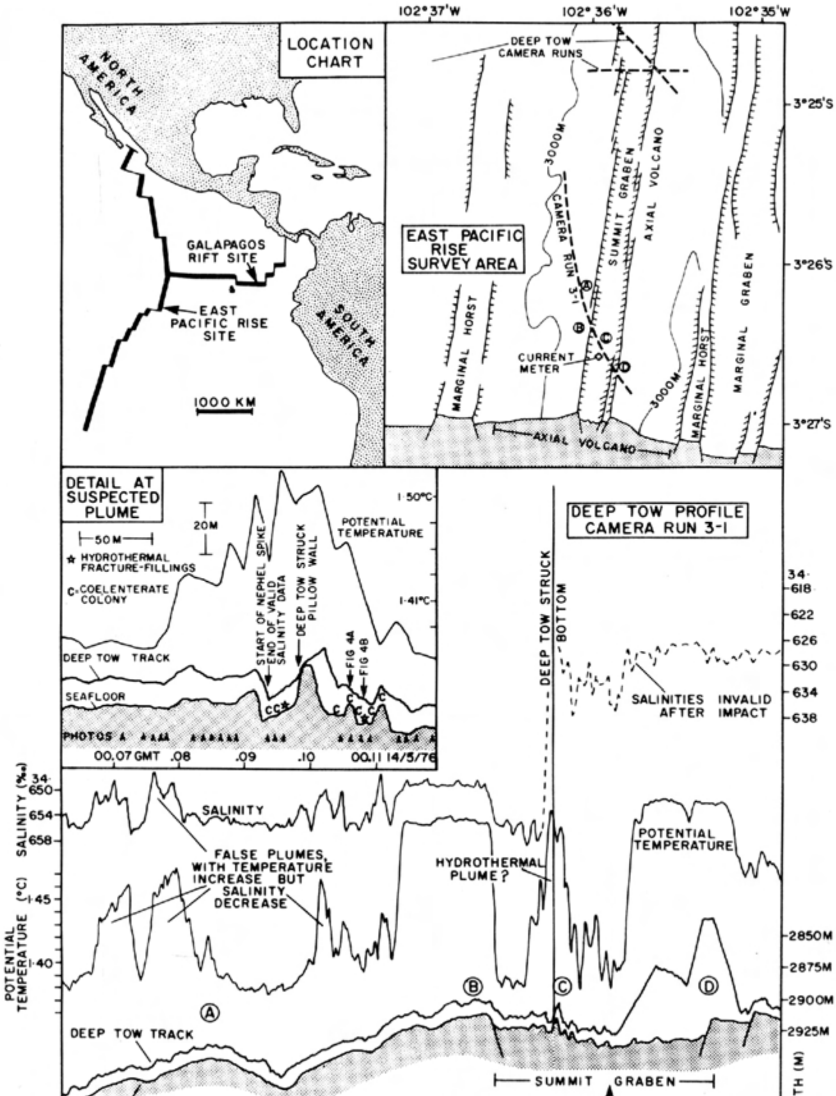

Figure 3. Top: Location map of the probable hydrothermal site on the crest of the East Pacific Rise, after LONSDALE (1977b). Bottom: Deep-tow data during Camera Run 3-1 across the summit graben of the East Pacific Rise. CDT data digitized at 12-s intervals. Inset shows location of coelenterate clusters at an expanded scale and events during the deep tow crossing. At 0009.2 GMT the nephelometer recorded a sharp increase in turbidity, measured conductivities became highly erratic, and calculated salinities decreased sharply by more than 0.02 $^{o}/oo$ (which is certainly not real). At 0009.8 GMT the deep tow vehicle briefly struck the rocky bottom; this event is marked on records of the acoustic sensors, and by the abrupt end of the data stream from the nephelometer, whose electrical connector was severed. A plausible interpretation is that the conductivity probe was dirtied just before the vehicle struck bottom, perhaps with sediment stirred up by the dangling deep tow stroboscope.

nearby, and small patches of light colored material. These frost cracks in the lava just as at the Galapagos Rift (Fig. 1), and are similarly interpreted as hydrothermal precipitates localized at discharge vents. Within 40 m of these spots, fractured lava on the sides and at the feet of the pillow walls are densely carpeted with suspension-feeding coelenterates (Fig. 4). The most prominent members of this community appear to be large sea anemones (Actiniaria), each with a slim column, 10 to 12 cm long, and an expanded oral disk, 8 to 10 cm in diameter, that bears a single marginal circle of 24 5-cm long tentacles. On parts of the sides and crests of pillow walls sea anemones attain densities of 10 to 20 m^{-2}. Sea pens (Pennatulacea) up to 30 to 40 cm long are equally abundant, but their slender bodies are less obvious on the photos. Sessile suspension feeders are rare elsewhere in this survey area. In the 600 photographs taken of bare lava on the axial volcano away from this site of anomalously warm bottom water there is not a single sea anemone and only infrequent solitary sea pens and gorgonians. This region is more than 2000 km from the continent and near the southern margin of the equatorial high productivity zone, so that the flux of organic detritus to the sea floor is less than at the Galapagos Rift; for example, the rate of pelagic carbonate accumulation is less than half that of the Panama Basin (LONSDALE, 1977b). Another site with light-colored precipitates in rock fractures was photographed further north in the summit graben, but it had no cluster of animals nor temperature anomaly associated with it.

The intimate local association of dense colonies of suspension feeders and fracture-fillings of chemical precipitates, together with the hydrographic data, is persuasive evidence for an active hydrothermal vent on the axis of the East Pacific Rise at $3^{\circ}26.4'$S, similar to the better documented examples at the Galapagos Rift (WEISS et al., 1977). Searching for local clusters of filter feeding animals may be one of the simplest methods for locating the precise sites of presently active hydrothermal discharges at rise crests. The distribution of metalliferous precipitates may be a clue to their regional location, but these may be widely dispersed by currents: a current meter 50 m above the rise crest 350 m from the suspected East Pacific Rise plume (Fig. 3) recorded a maximum current speed of 18 cm s^{-1}, and LONSDALE (1976) proposed that transport in suspension from this part of the rise crest was responsible for metalliferous deposits hundreds of kilometers away in Bauer Deep. Light-colored fracture-fillings seem to be restricted to the immediate vicinity of vents, but they may persist long after hydrothermal discharge has ceased, before being obscured by new lava flows or sediment. The same is true for the empty valves of dead mollusks, but anomalously dense clusters of living filter feeders, most of which leave no remains after death, would not survive for long if hydrothermal discharge ceased or became highly episodic. Perhaps future searches for active hydrothermal vents at oceanic spreading centers should begin with a thorough photographic survey of the sessile macrobenthos.

I am indebted to the deep-tow engineers, and particularly J. Donovan and J. Rogers for their skill in safely obtaining fine bottom photos in rugged terrain. I thank R. Weiss and R. Hessler for discussion and for advising caution in both the interpretation of flawed CDT data and the identification of deep-sea animals from photographs alone. The manuscript was reviewed by R. Weiss, H. Craig, R. Hessler and F.N. Spiess and expertly typed by R. Hagen. Support was from National Science Foundation grants NSF DES 74-03690 and OCE 76-21592.

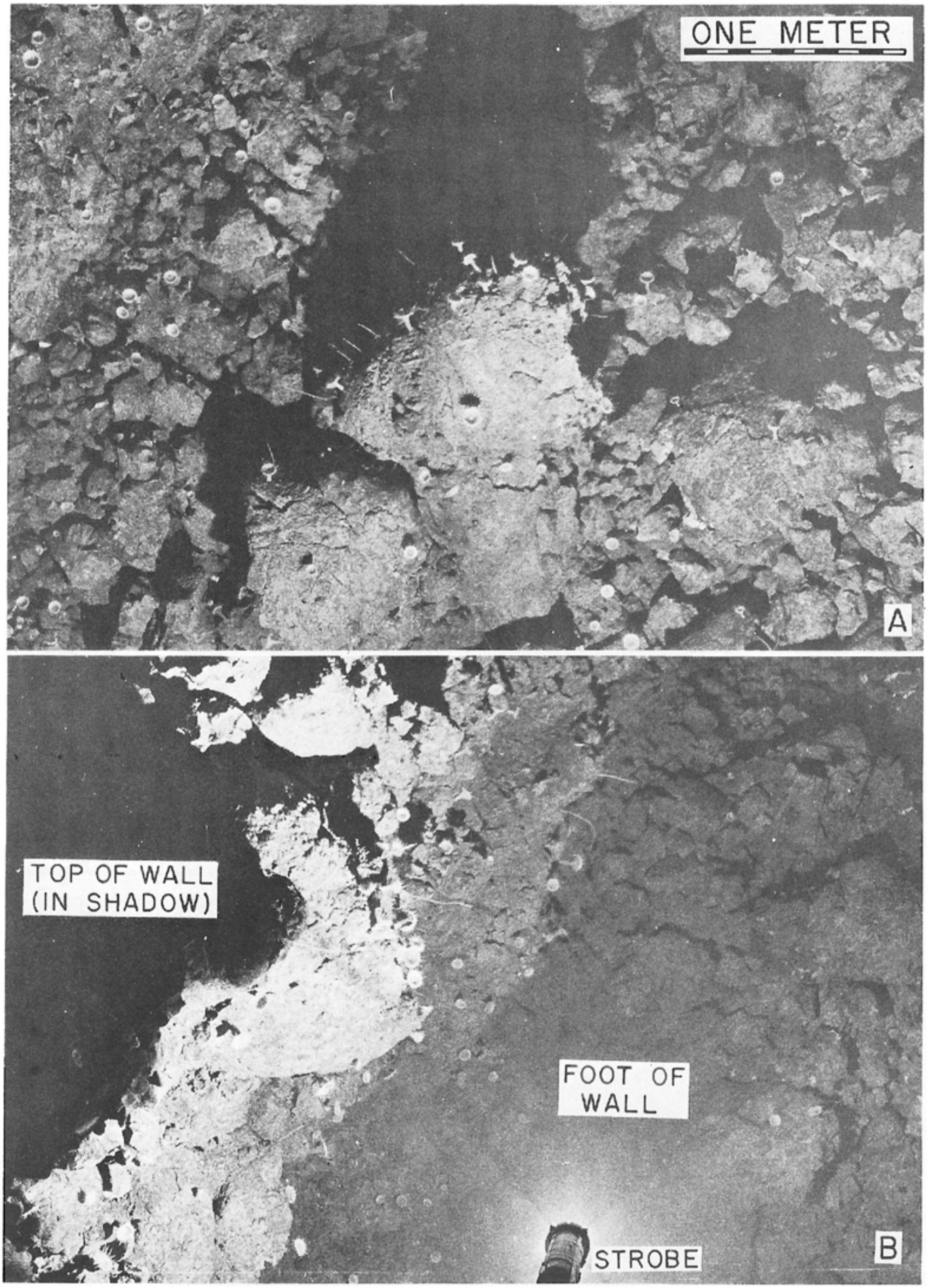

Figure 4. Bottom photographs within the summit graben of the East Pacific Rise. See Fig. 3 for location. Water depth 2925 m. Fig. 4a: Time 00.10.38 GMT. Top of a pillow wall with a dense coclenterate fauna. Sea amenones are also abundant on pillow basalt joint blocks at foot of wall (top left). Fig. 4b: Time 00.10.46 GMT. Obliquely approaching a pillow wall whose sides are covered with sea anemones and sea pens. Deep-tow instrument is moving from top to bottom of frame; the top of the wall, which the dangling strobe is about to hit, is above the level of the light.

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