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Short Communication

ROV DIVES UNDER GREAT LAKES ICE

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INTRODUCTION

Observations of the underside of ice have a wide variety of applications. Severe under-ice roughness can affect ice movements, rough under-ice surfaces can scour the bottom disturbing biota and man-made structures such as pipelines, and the flow rate of rivers is often affected by under-ice roughness. A few reported observations of the underside of an ice cover have been made, usually by cutting a large block of ice and overturning it, by extensive boring, or by remote sensing. Such operations are extremely labor-intensive and, in some cases, prone to inaccuracies. Remotely operated vehicles (ROV) can partially solve these problems. In this note, we describe the use, performance in a hostile environment, and results of a study in which a ROV was deployed under the ice in Lake Erie (North American Great Lakes).

INSTRUMENTATION AND OBSERVATION PLAN

Direct observations of the underside of an ice cover were conducted using a MiniROVER MK II (Benthos Corporation) ROV equipped with a low light (7 lux minimum illumination), color video camera with a wide angle (F4.8) lens and lights. A tent mounted on a movable platform (Fig. 1) was used to house a color video monitor, video and audio tape recorders, an electronics and vehicle navigation control monitor, and a propane heater. Power was supplied by an 1100 W gasoline-powered generator.

Sites were selected on the basis of surface appear-

Fig. 1. View of topside operations. Covered sled housed the video and ROV control electronics, and the ROV operator.

ance. An access hole was cut through the ice using a power auger and a reciprocating saw. The block of ice from the access hole was submerged under the surface of the ice next to the hole. Video data were collected by moving the vehicle horizontally under the ice with the camera positioned at 55° (maximum camera angle) from the horizontal. Due to the configuration of the thrusters and video camera, it was not possible to view the underside of the ice in a position normal to the water–ice interface. Thus the relationships between the solar altitude, the ice type, and the angle of view of the submarine camera influence the images. All underwater photos in this note were from 35 mm photography of a black and white TV monitor showing the video images.

RESULTS

Dives were made under clear ice, candled-clear ice, and refrozen slush, all 18 to 25 cm thick, and in

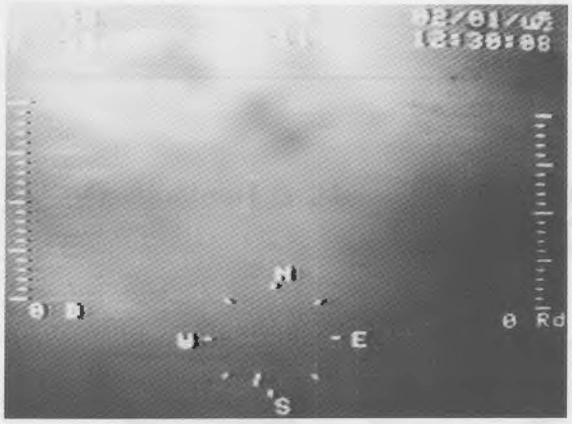

Fig. 2. The underside of a mixed clear-white ice layer showing the billowy appearance of the ice and small specks of flocculent material (upper right).

Fig. 3. A topside view of the smooth ice. Note mixed clear (black) and refrozen slush (white) ice patches, and cracks.

the vicinity of a ridge approximately 3 m thick. Natural incident radiation during both clear and partly cloudy skies was sufficient to collect most of the daytime video data without external lighting. Lights were used during a few day (in the ridge area) and all of the night dives, but at times scattered light from the ROV (due to particulate matter in the water column) detracted from views of the ice. The lights at night slightly enhanced the imagery of cracks.

Figure 2 shows a typical view of the underside of the ice cover. The lack of definition is the most striking feature. The appearance of the underside of most of the ice, except for the ridge described be-

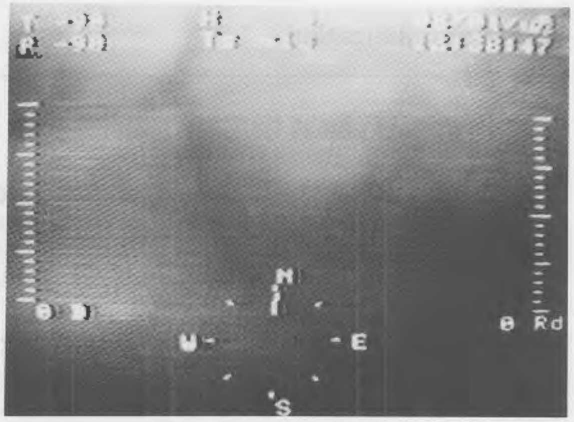

Fig. 4. A "Y"-shaped crack as shown by the video camera under mixed clear/refrozen slush ice.

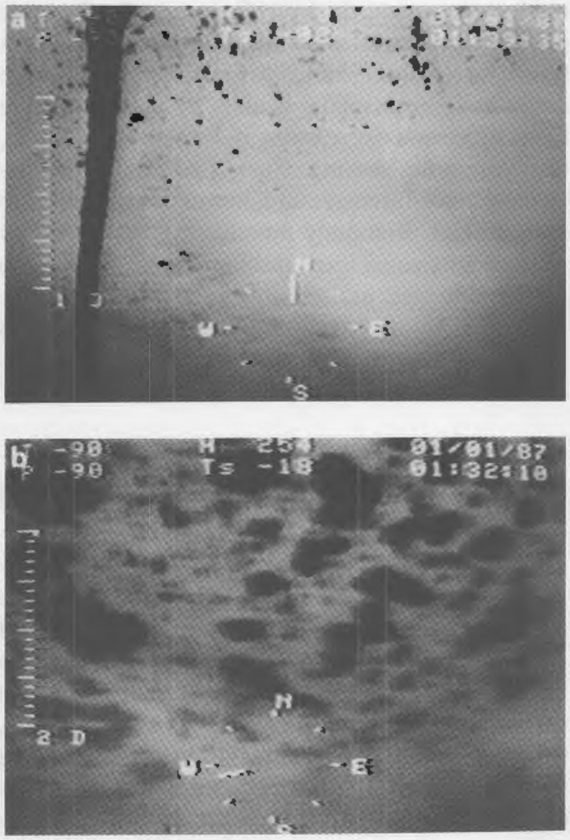

Fig. 5. Small (a) and larger (b) accumulations of flocculent material under the ice surface. The ROV umbilical cord is shown in (a) and two distinct layers of floc/ice are shown in photo (b).

Fig. 6. Bright spots of light represent incident solar radiation transmitted along the crystal boundary voids of deteriorating clear ice.

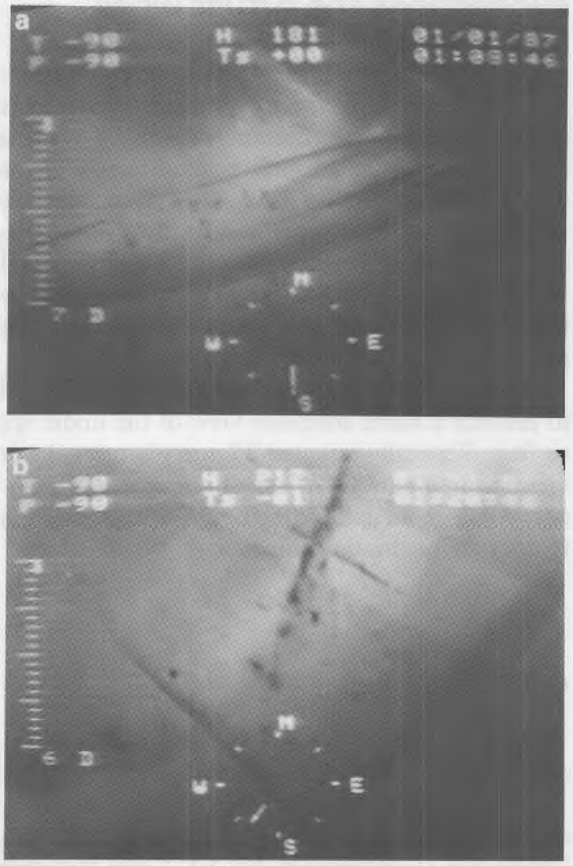

Fig. 7. Side views of ice blocks which formed the underside of a 3 m thick ridge.

Fig. 8. View showing the chaotic structure of ice blocks which composed the ridge and the subangular shape of the blocks in this area.

low, could best be compared with the appearance of the sky on a cloudy day with cumulus clouds interspersed in smooth overcast. This appearance is due to the fact that the ice cover was comprised of a mixed, irregular pattern of clear (black) ice interspersed with refrozen slush (white) ice, as is more clearly evident at the air–ice surface (Fig. 3), the diffuse nature of the radiation transmitted through the ice, and the oblique view of the ROV camera. Cracks were prevalent in the ice mixture. They were clearly visible on the top surface, but were difficult for an untrained eye to detect on the video images of the underside of the ice (Fig. 4).

The lack of definition in features on the underside of the ice was not because of inadequacies of the video system since several dives were also made to the bottom where the definition of rocks, sediments, shells, and the sediment–water interface was excellent. In addition, specks of brown, flocculent material ranging from 1–3 cm to several metres in diameter were observed with good resolution on the ice undersurface. The specks (Fig. 5) often served as a reference point to the undersurface of the ice in an otherwise relatively bland environment.

A block of ice was removed to observe the undersurface and the flocculent material more closely. The top surface (Fig. 3) was very smooth with undulations not exceeding 4–5 cm and the ice undersurface appeared just as smooth or smoother than the surface. Irregularities on the ice undersurface were primarily due to the flocculent specks which were set in depressions about 1 cm deep of the same size and configuration as the specks. An insect larvae (midge fly of the family Chironomidae), typically found in lake bottom sediments, was observed in one of the depressions. A portion of the ice block was melted and the brown flocculent material was subsequently collected and observed under a microscope to discern its composition and origin. It consisted of fine sediment, phytoplankton (principally diatoms) and zooplankton (copepods and cladocerans). The species observed typically inhabit the water column and many of the individuals were translucent and appeared to be partially decomposed. We surmise that bubbles of gas, generated by decomposition, emerged from the lake bottom covered with a film of surficial sediment, bottom fauna, and recently settled and decomposing plankton and became lodged on the underside of the ice. Since snow-free clear ice can transmit nearly 90% of the incoming radiation over a large portion of the 400–700 nm range (Bolsenga, 1981; Bolsenga and Vanderploeg, 1988; Bolsenga et al., 1988), solar radiation was absorbed by the flocculent speck thereby melting the ice and causing the depression. A particularly large emergence of adult midge flies was observed by local residents in the spring of 1988.

Figure 6 shows the underside of a deteriorating clear (black) ice surface with the sun shining brightly. The same effect was observed on numerous occasions and the moving video served to increase the amount of information, thus making this pattern more readily apparent. When a block of this ice was cut from the surface and removed to the air, water quickly passed through the block via the crystal boundaries. Consequently, the bright spots of light in the photo are due to incident light transmitted along the crystal boundary voids similar to a light pipe. The process could likely be important to biological processes requiring increased photosynthetically active radiation over the normal ambient level under the ice.

Side views of a 3 m-high ridge indicate the chaotic structure of the individual ice blocks from which the ridge was formed (Fig. 7). The jagged structure made observations difficult due to the danger of snagging the ROV or its umbilical cord. Lights were used during most of the dives because incident radiation transmission through the ridge was substantially reduced. The subangular shape of some of the ice blocks which formed the ridge are possibly due to smoothing of block surfaces by strong currents or by surface abrasion prior to formation of the ridge (Fig. 8). The ice ridge area was also characterized by large (up to several metres in diameter), irregular patches of brown flocculent material under the ice surface adjacent to the ridge (Fig. 5b). These large patches were in marked contrast to the small specks discussed previously. In this instance, turbulence or ice scour of the bottom at the time of ridge formation were the likely causes of such a large amount of bottom sediment on the undersurface of the ice.

SUGGESTIONS FOR FUTURE WORK

Several situations of importance were not examined. Formations due to ice pressure on bridge piers and dock pilings are important from an engineering standpoint and the subsurface relief in such areas would lend itself well to ROV study. The underside of river ice has been previously studied by cutting and overturning large blocks of ice (Ashton and Kennedy, 1972). ROV reconnaissance would be faster, but possibly the fine structure of the ice, such as ripple marks, might be difficult to distinguish.

Configuration of the ROV could also be altered to provide a more adequate view of the under ice surface. Vertically oriented 35 mm photographs or views from a number of angles might reveal methods which could exploit the optics of the situation to provide maximum contrast.

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