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UNDER-ICE SCUBA TECHNIQUES FOR MARINE GEOLOGICAL STUDIES

PATRICK MCLAREN
DAVID FROBEL

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CONTENTS

Illustrations

UNDER-ICE SCUBA TECHNIQUES FOR MARINE GEOLOGICAL STUDIES

ABSTRACT

SCUBA techniques were used in an under-ice diving program to examine coastal processes in a high arctic environment. It proved to be a valuable method of study, and geological techniques of observation, sampling, photography and in situ shear vane measurements were undertaken successfully. Divers clad in variable-volume dry suits were able to withstand up to an hour in below freezing water. Major problems encountered were cramped and cold feet and the regulator freezing open which resulted in a free flow of air. With experience, many problems were overcome and a dive procedure developed ensuring maximum work efficiency and safety. The cost, including a compressor, to outfit one diver completely was approximately $3170. 00. It is hoped that more scientists will be able to use this relatively simple technology to arrive at both questions and answers necessary to understand the arctic marine environment.

RESUME

Des techniques de plongée sous la glace en scophandre autonome furent employées dans le codre d'un programme d'études sur les processus de l'environnement côtier du Grand-Nord. Cette méthode révélée efficace permettent l'application fructueuse de techniques d'observation géologiques, d'échantillonnage, de photographie et de mesure en place au scissomètre. Revêtus de combinaisons imperméables à volume variable dans des eaux à environ 29°F (-1. 7°C) purent supporter des périodes allant jusqu'à une heure.

Le froid qui s'engourdessaient des pieds et le blocage par le gel du régulateur en position ouverte, occasionnant des fuites d'air, furent les problèmes les plus sérieux. L'expérience permit, à la longue, de résoudre plusieurs problèmes mineurs et, de mettre au point une technique de plongée assurant un optimum d'efficacité et de sécurité lors des travaux. Le coût total pour un plongeur, y compris le compresseur, s'élève à environ $3170. 00. Un plus grand nombre d'hommes de science pourraient utiliser ces techniques relativement simples en vue d'une meilleur compréhension de l'environnement marin arctique.

INTRODUCTION

From June 1 to August 13, 1974, the authors undertook an extensive under-ice diving program in Byam Channel, Queen Elizabeth Islands as part of a two-year coastal process study on the east coast of Melville Island and west coast of Byam Martin Island. During this time a total of 93 dives, making up 50 underwater hours, were successfully completed. Twenty-five different locations were examined and the geological understanding of this high arctic coastal environment has been incomparably increased.

This paper is designed to examine technical aspects of cold water (under-ice) diving as well as geological techniques that were found possible to be carried out successfully. The authors began the dive program as beginners and much experience was gained by trial and error. Many of the comments on dive techniques, therefore, must be taken only as advice and they are not necessarily the only way that they can be undertaken. This paper is written with the beginner in mind who no doubt will develop his own procedures to suit his own requirements as he gains experience. The authors hope to encourage the use of diving in geological studies, and if this paper can help eliminate any myths of the dangers involved and inform the reader of real problems that were encountered, the purpose will have been achieved.

WHY DIVE?

Perhaps the answers to this question are obvious; however the fact is that marine and coastal geologists, particularly in Canada, have made only limited use of SCUBA (Self-Contained Underwater Breathing Apparatus) technology. It is belabouring a point to discuss the observational doctrines in geological sciences. SCUBA allows direct observation of shallow marine environments and if it were possible to do nothing else at all, this alone makes it worthwhile. Interpretations of piston cores, grab samples, sub-bottom profiles and side scan sonar records inevitably will be changed or enhanced after the bottom has been seen (Reimnitz *et al.*, 1973). (Having observed numerous shallow-water arctic environments, the question arises whether grab samples can give a true impression at all.)

But SCUBA can be used for more than simply observational purposes. Bottom descriptions can be made underwater, samples can be taken where they are most typical or important and, above all, in an undisturbed

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Figure 1.

The authors demonstrating the variable-volume dry suit (Unisuit). In this case the suits have been blown up with air. The two valves are clearly visible on either side of the chest. The diver's right-hand valve contains the nozzle for air intake; the left-hand valve is for air exhaust. GSC photo 202652

Figure 2.

Tender checking divers' equipment before entering the water. The Unisuit whip originates from the first stage of the regulator at the top of the tank, passes under the right arm and snaps into the air intake valve. The letters A and B indicate the antifreeze cup and tank pressure gauge respectively.
GSC photo 202652-A

state for structure and micropaleontological analyses. Photography, possibly the most important technique of all, becomes far more meaningful when the geologist himself is the photographer. Engineering properties of sediments can be measured in situ and it is possible to measure slopes and construct profiles of features such as ice scour or the underside of an ice surface. For these reasons, the authors are of the opinion that any person connected with marine and coastal environmental geology should consider the possibilities of diving.

QUALIFICATIONS

Any person with a reasonable degree of physical fitness is probably capable of diving. A standard diving course is essential to learn fundamentals and to become familiar with equipment. Such courses commonly can be taken in six weeks.

Very few people are physically incapable of diving, but rarely some are unable to equalize pressure in their ears (Council for National Co-operation in Aquatics, 1972). Under-ice diving causes psychological stresses which will be most prevalent for a beginner. If an individual has a fear of water and/or is prone to claustrophobia, it is probable that diving will be impossible. Such psychological stresses will diminish with experience. Three members of the party had never had diving experience before, yet after some training and practice, all three became useful underwater.

EQUIPMENT

Cold is the greatest limiting factor on a diver's performance in arctic waters, and thus only specialized equipment can be used. The following outlines this equipment, its use, and associated problems.

The Variable-Volume Dry Suit

The diving suit must provide necessary insulation against the cold. It is unlikely that a wet suit would be capable of providing enough warmth, particularly for repetitive diving. The authors used Unisuits made by Poseidon. This is a variable-volume or inflatable dry suit made of neoprene and lined with nylon (Fig. 1). It is a one-piece suit including hood and boots; a water tight, high-pressure zipper runs from below the chest around the crotch and to the top of the back. Single layers of rubber form water-tight seals at wrists, neck, and face. Two push-button valves are located on either side of the chest, for air intake and air exhaust respectively. Air to inflate the suit comes from the diver's air supply via a rubber hose known as the whip, which originates from a low pressure port on the regulator and snaps into the intake valve on the suit (Fig. 2). The valves allow the diver, with some practice, to control his own buoyancy. Necessary accessories for the suit should include Unisuit long underwear (a one piece, pile-lined garment worn under the diving suit), silicone spray to lubricate valves and zipper and to keep the seals soft and pliable, and spare neoprene and neoprene cement for repair work.

Donning and doffing the suit requires some agility, and for the beginner is an extraordinarily exhausting and difficult undertaking. It is helpful to have assistance. Poseidon supplies an excellent instruction booklet and therefore it is not necessary to describe the dressing or care of the suit in detail. The most difficult part of the procedure is putting the head through the neck seal. This must be pulled down to fit snugly about the neck. It does not appear to matter if it is wrinkled, but it should not be folded back over itself to give an apparently more comfortable fit.

The seals are the most fragile parts of the suit and should be handled with extreme care. When possible always avoid pulling directly on them. Before each dive the zipper, valves, and seals should be sprayed with silicone lubricant to prevent seizure and deterioration of the rubber material.

Long underwear, heavy socks, thin gloves, sweaters, etc. can be worn beneath the regular Unisuit underwear. How much and what type of extra clothing depends on the diver's personal susceptibility to cold. In most cases, however, one layer of extra clothing should be sufficient. Anything that restricts circulation or prevents the seals from being tight will increase the diver's rate of chilling.

The Unisuit was seldom completely water-tight and it most commonly leaked around the neck seal. Water sometimes entered the suit at the wrists and feet and on a few occasions at the zipper. On climbing out of the water it is possible for the zipper to catch on the ice and be pulled open. After only one occurrence, the diver remembers to check the zipper each time before re-entering the water. Cold hands and feet were the greatest discomforts suffered during a dive.

Buoyancy control is mechanically as simple as pushing a button. The beginner, however, may find himself either nose diving to the bottom or rising uncontrollably, sometimes feet first, towards the surface. Releasing air from the suit is best accomplished by rolling over on one's back and allowing the air to accumulate in the chest of the suit before pushing the valve. On ascent it is often necessary to vent expanding air to slow the rate of rising.

A minor problem that everyone experienced was air leaking through the neck seal and expanding the hood of the suit. Although this did upset the diver's buoyancy, more than anything else it produced a sense of uneasiness. It did not feel natural since the straps of the mask pulled around a cushion of air rather than the solidity of one's head. It was usually possible to squeeze the air out of the hood with one's hands, or if necessary to pull the face seal away from a cheek and allow the air to escape.

When putting air into the suit, best control is achieved with short bursts rather than prolonged inflation. This also reduces the possibility of the valve freezing open. The best thermal protection for the diver is achieved by having some air in the suit at all times.

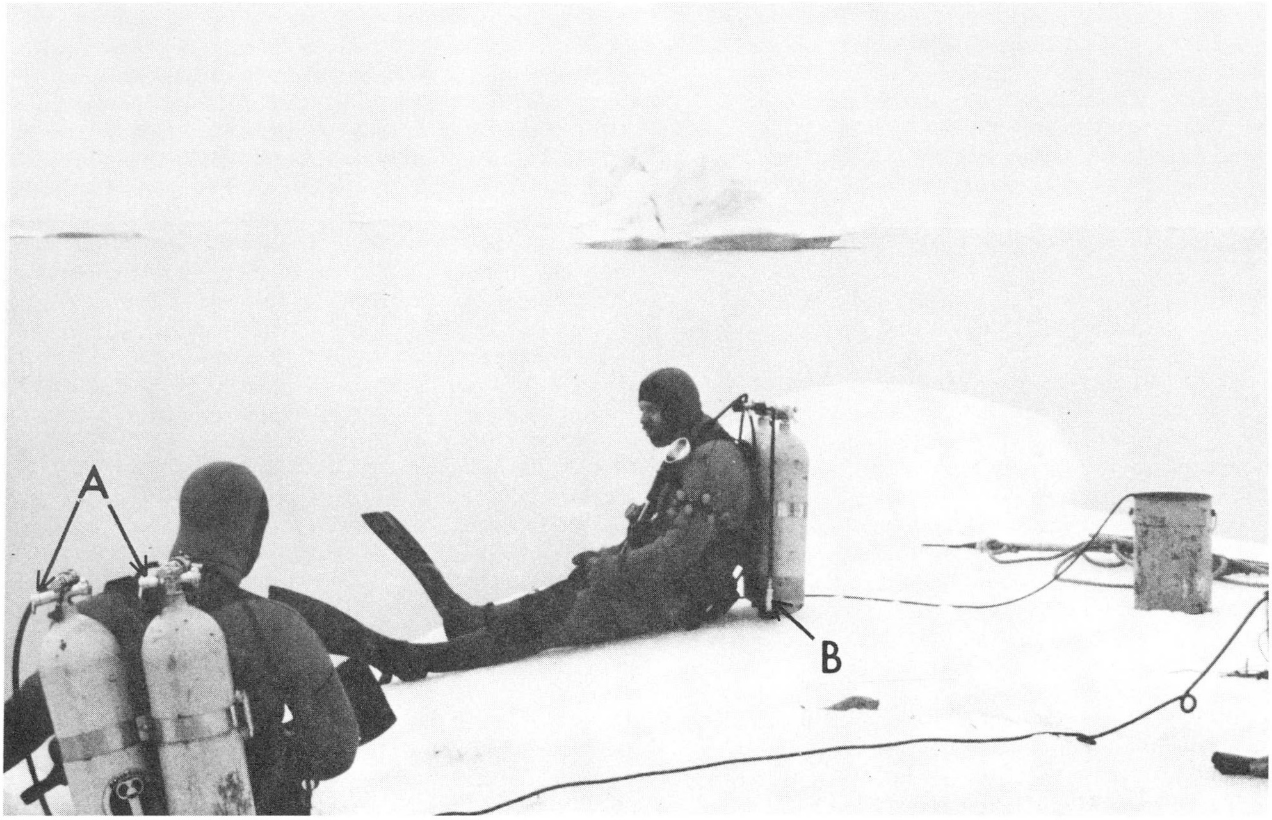

Figure 3.

Divers using an ice flow as a dive platform. The reserve valves on the tanks (A) are in the down position. The secondary regulator (B) hangs down by the divers side in case of an emergency. Note the tether lines in their bucket containers. GSC photo 202652-B

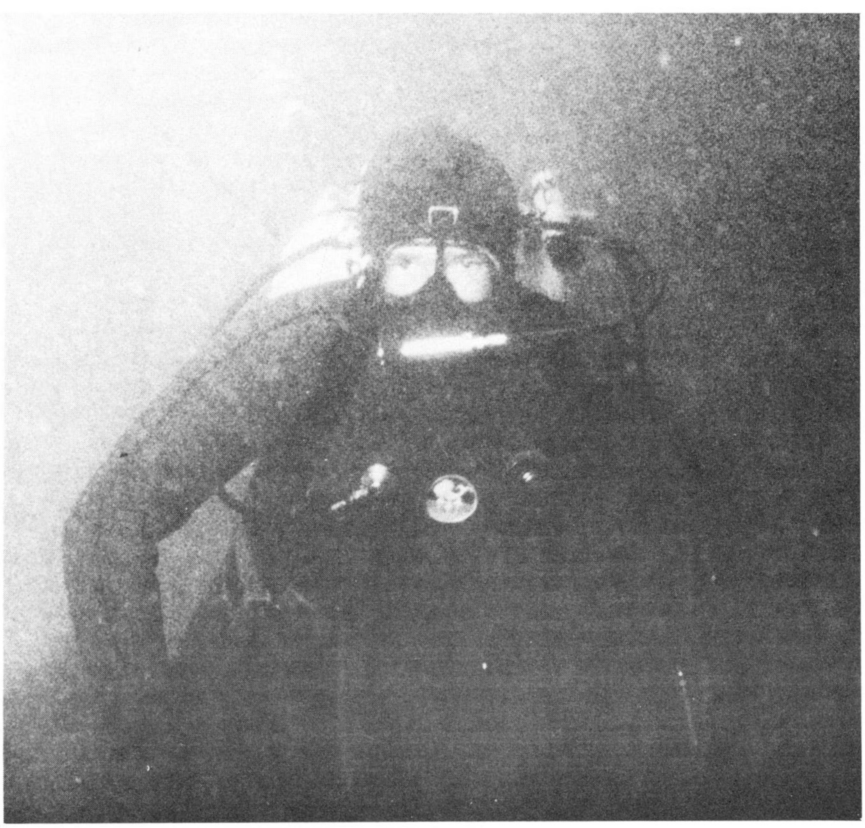

Figure 4.

Diver in water wearing the full face mask. The Unisuit whip, antifreeze cap and secondary regulator are all clearly visible. GSC photo 202652-C

Minor tears did develop in the suits but were easily mended with neoprene cement. One major weakness in the Unisuit is the tendency for the hard rubber soles to pull away from the feet. A large amount of neoprene cement temporarily mended them but a satisfactory glue was not found.

After each dive the suit and underwear should be hung in a warm place to dry.

Regulator

The purpose of the regulator is to supply air to the diver at ambient pressure. The Poseidon Cyklon 300 regulator, which has been designed for cold water use, was used. This is a single hose, two stage demand type regulator which can be equipped with a flexible rubber cup filled with an antifreeze liquid (alcohol). The latter is called an antifreeze cup and is attached to the first stage (Fig 2) it is essential for cold water diving. The first stage also has a low pressure port for attachment of the Unisuit whip and a high pressure port for a tank pressure gauge (Fig. 2).

For safety twin tanks were used on the dives, each having its own regulator. The tank and regulator not in use (secondary regulator) served as a backup (Fig. 3) should the other regulator fail (primary regulator). Since the latter had the Unisuit whip, tank pressure gauge, and usually a full face mask attached to it, it was necessary for the diver to surface when the first tank became low and have the two regulators switched. The secondary regulator would then be put on the first tank which would still contain sufficient air (approximately 500 PSI) for an emergency. When diving, both tanks of air were turned on, and the diver would breathe from one tank while his spare regulator hung down by his side, easily accessible in an emergency.

The most common problem was the second stage of the regulator freezing open. This resulted in a free flow of air through the mouthpiece. This usually started with only a minor air leak but would become steadily worse if the regulator continued to be used. A diver can continue breathing from a free-flowing regulator but it is tiring against the continuous rush of air. For a beginner a free flow is a relatively alarming happening but with experience it becomes only a nuisance.

When aware of air escaping from the regulator, the diver must return to the surface to have it cleared of ice and dried by the tender (assistant). The heater of the helicopter was used on some occasions to thaw it out. Sometimes a little silicone grease on the moving parts of the second stage seemed to help. A dive commonly could be continued after a regulator was treated on the surface, but if free flow persisted the diver was not allowed back in the water.

Regulator freeze-up was not predictable. It may be more frequent when air temperatures are above freezing, but this is only conjecture. It is important to breathe as little as possible through the regulator when out of the water since the resulting condensation aggravates the problem, especially when temperatures are low (below $0^{o}F$). Freeze-up may occur more often after the primary regulator has been switched to the second tank. For this reason it is good practice always to clear the valve on the tank of moisture by passing a short blast of air through it before putting on either regulator. Further modification or redesign of the second stage is really necessary to eliminate this problem. It is felt that for a heavy dive program one extra regulator for each four in use would be sufficient back-up for parts or replacement.

Tanks

Standard steel (2250 PSI) SCUBA tanks were used. Two mounted in a double back pack were carried by each diver (Fig. 3) and gave a sufficient air supply for almost all dives. On occasion an additional single tank was used to extend the length of the dive.

Each tank is equipped with a reserve valve (Fig. 3) which, when in an upright position, causes the diver to experience difficulty in breathing when the pressure of his tank reaches 500 PSI. This warns the diver that his air supply is becoming low, and by pulling the valve into its down position, breathing becomes normal and the diver can return to the surface. A pull rod at the side of the tank allows this valve to be manipulated.

It was found that using the tank reserve warning system was unsatisfactory for tethered diving. Too often the rope became caught up in the pull rod and not only pulled it out of place but forced the reserve valve to the down position without the diver's knowledge. This problem was overcome by diving with the reserve valves in the down position only and using a tank pressure gauge to warn the diver. It was then the diver's responsibility to check the gauge periodically and to surface when his air supply became low.

A diver leaving the water wearing two tanks required the assistance of two people to get up onto the ice. This may not be possible if the second tender (assistant) is busy looking after another diver. An alternative to this is to have the diver remove his tanks while in the water and hand them out. The diver is then almost light enough to get out by himself and can do so easily with the help of one person.

Mask

Two types of masks were used during the diving program, the standard face mask covering the eyes and nose only and the full face mask which covers the face completely and has the regulator mouthpiece incorporated. There are advantages and disadvantages to each and the final decision as to which to use is a matter of diver preference.

The standard face mask leaves part of the forehead, cheeks, and lips exposed to the water. There is no doubt that this results in the diver becoming cold more quickly. However, the standard mask is cleared more easily should it become flooded and buddy breathing is done more easily since the regulator is independent of the mask. To use a secondary regulator should the primary one fail is a straightforward matter of remov-

Figure 5.

Diver with Nikonos camera system and photographic scale. Note the flash bulbs on his right arm and depth gauge on his left wrist.
GSC photo 202652-F

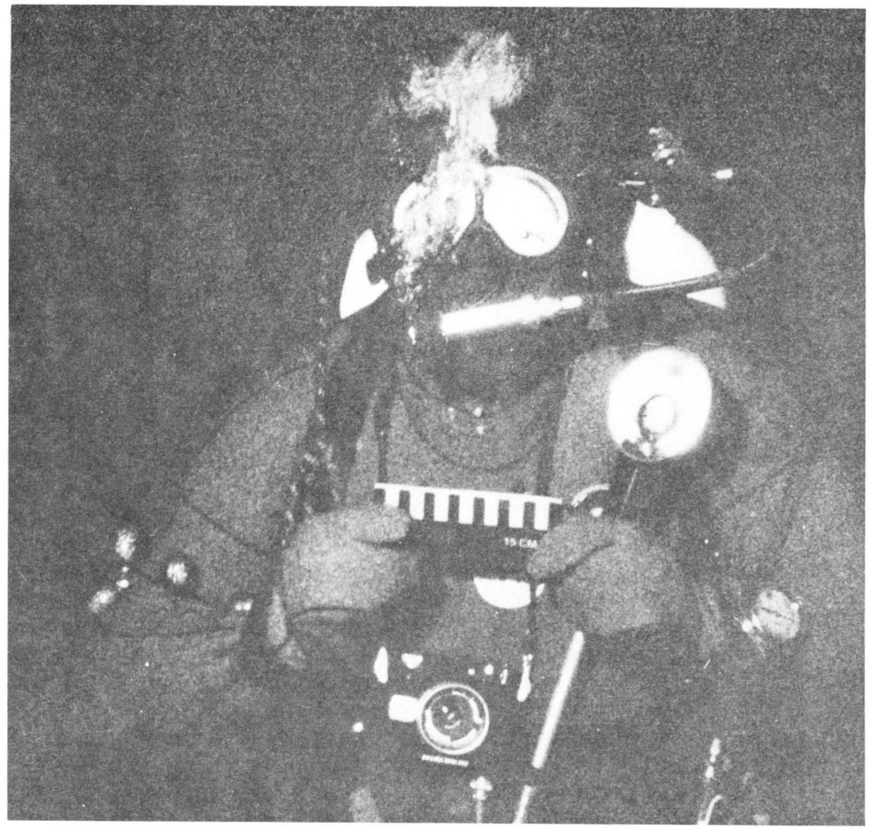

Figure 6.

Diver resting in water after using his first tank. Note the down line attached to the ice pick. The shear vane and torque screw driver are lying immediately in front of the down line.
GSC photo 202652-D

ing the regulator from the mouth and replacing it with the other. (It is possible that the lips might be so numb that it is difficult to put a regulator into the mouth.)

The divers on this program preferred the full face mask (Fig. 4) mainly because of the increased warmth. It forms a complete seal with the hood of the suit. However, the capability of buddy breathing is lost and it is more difficult to clear. If the secondary regulator were required the entire face mask would have to be removed resulting in loss of vision.

It is possible to have prescription lenses glued into either type of mask and this is highly recommended if one ordinarily wears glasses. There were no mechanical problems experienced with the masks.

Fins

For use with the Unisuit, only "jet"-type fins are large enough both to fit over the boot of the suit and to give the required power and manoeuverability. These fins are constructed so that water flows through openings in the fluke giving greater thrust than with a standard fin. The fin slides over the Unisuit foot and is held in place by an adjustable strap that passes around the ankle. Poseidon supplies rubber "fin holders" designed to keep the fin more securely on the foot. These were unsatisfactory as they cramped the foot even more than the fin itself.

The fins were a major problem. To be secure they had to be tight but this inevitably caused painful cramps across the entire foot. Some dives terminated for this reason. On surfacing a diver's first request most often was to have his fins removed. This could be done without emerging from the water and after a few minutes of relaxation, they could be put on again.

If the legs and feet of the Unisuit inadvertently become overfilled with air, there is a tendency for the expansion to push the fins off. If they do come off one feels extraordinarily helpless. They are a vital piece of equipment: present design is tolerable but unsatisfactory.

Knife

Each diver wore a diving knife strapped to his calf or thigh. It is important both as a tool and a safety precaution. They were used for a variety of jobs such as scales in photos, as simple probes to test the hardness of bottom sediments, to dig or pry loose biological specimens and to chip ice samples from underwater ice formations.

In tethered diving there is the remote possibility of becoming tangled in rope and having to cut oneself loose. Kelp can also be a hazard.

After each dive the knife should be removed from its case, rinsed in fresh water if possible and wiped dry. A coating of silicone lubricant on the blade will help prevent rusting.

Depth gauge

A standard depth gauge was always worn (Fig. 5). The gauge not only was used to record the water depth but it also served as a way of estimating the relative depth of ice scour or under-ice configurations. In this way it was used somewhat as a survey instrument.

Weight belt

With the Unisuit the divers each required 42 pounds of lead weight. This will vary with the individual and depends on the person's buoyancy. It is more desirable to be slightly heavy and compensate with air in the suit rather than be too light and lose the insulation that the air provides.

Tether line

For under-ice diving, each diver should be linked to the surface tender by a rope. The tether serves several purposes; it allows some communication between diver and tender through a series of pre-arranged signals, it keeps the diver from becoming lost, and above all the diver can be hauled out in an emergency.

Best quality rope is advisable for the tether line. The divers used 150-foot lengths of mountain climbing rope which consisted of straight nylon fiber contained in a woven sheath. It remained very easy to handle even at below zero (^{o}F) temperatures and its red colour was clearly visible. To avoid tedious coiling and tangles we fed the rope in and out of buckets (Fig. 6).

Several methods of attaching the tether to the diver were tried. The first was to tie the rope about the diver's waist. This proved unsatisfactory since it allowed the knot to move about on the body making it difficult at times to locate the rope. If the knot worked itself around to the diver's back, there was a tendency for the line to become tangled around the tanks.

The second method proved better but also had disadvantages. The line was tied first to a mountaineering karabiner which was in turn slipped onto the belt of the backharness. This allowed one to locate the rope easily by feeling for the karabiner on the belt and the back pack itself eliminated the possibility of the rope sliding around to the back. However, some dive manuals maintain a tether line should never be attached to equipment (Jenkins, 1974) in case the equipment itself needs to be jettisoned. It was also realized that there was a remote possibility of the karabiner undoing the belt buckle by slipping under the catch and pulling it open, but loosening of the belt probably would be noticed by the diver.

While swimming a diver often can conveniently have the tether passing through his hand for quick response to signals and for the reassuring feel of its presence. It is a good idea to check the line occasionally to be sure it is free from obstruction such as irregularities in the ice or that there is not too much slack.

A weight was attached to the tether line to test water depth at proposed dive sites. No decompression limits were observed (i.e. the divers always were able to surface directly with no decompression stops) and dives were restricted to depths of less than 100 feet.

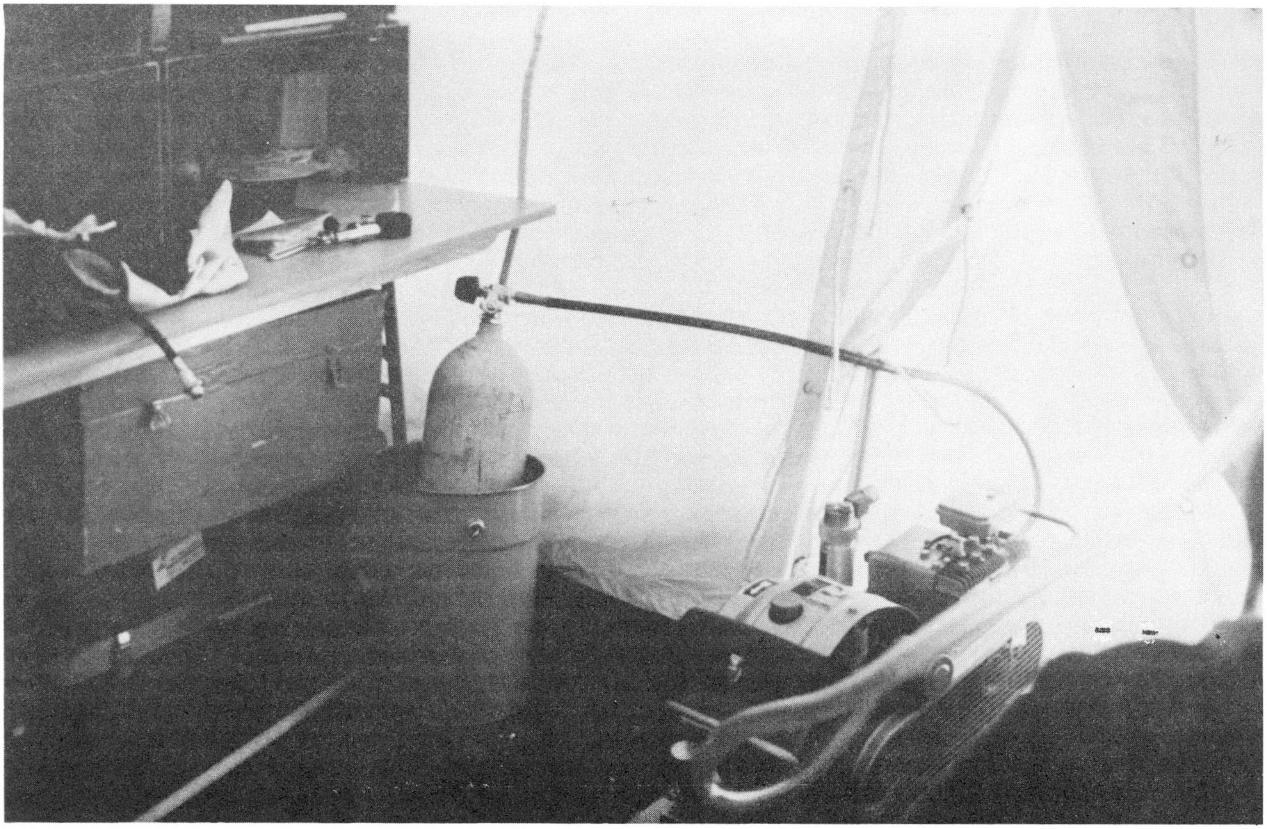

Figure 7. Air compressor situated in tent so that the exhaust is expelled out the door. The air intake tube in the foreground is placed through the roof of the tent. GSC photo 202652-E

Down line

A heavy, yellow polypropylene rope with a small boat anchor at the end was used as a down line for the divers (Fig. 6). At each dive site the anchor was lowered to the bottom and then raised several feet so it was hanging and the line was then made fast to a stake driven into the ice. (In some cases it was fastened directly to the skid of the helicopter.)

The line was used by the divers to control their rate of ascent and descent. The bright yellow line was highly visible and served as a marker for the dive hole and as a reference point to leave gear on the bottom and to keep the divers oriented. The anchor was useful to hang gear on, such as cameras or writing slates when not in use.

Air compressor

A small, portable gasoline-powered compressor was used to fill the tanks. For the standard 72-cubic foot tank, the compressor ran at the rate of 2.7 cubic feet per minute and filled an empty tank in approximately 25 minutes.

The compressor should be regarded as the most vulnerable part of the diving operation. It is subject to mechanical failures which can halt the entire program. Therefore regular maintenance, sufficient tools, and spare parts such as spark plugs, pull cords, and rewind starters are essential.

It should be stored in a warm, dry place and run in a well ventilated area. It must be in a position where there is no chance for engine exhaust to foul the air intake (Fig. 7). The compressor is a large expense for a diving operation but can be rented from some of the large diving equipment suppliers.

DIVE PROCEDURE

The following is an account of the dive routine that developed during the summer's field season. A routine ensures not only good safety techniques and maximum comfort for the diver but also limits the possibilities of essential items being left behind.

For each diver, a tender is required. Since two persons dived at a time, a party of four had to be transported to the dive site. A Jet Ranger 206 helicopter can carry the full load, provided it is on skids; when equipped with floats, two loads to the dive site are necessary. Dives were always through natural cracks, strudels (holes through which meltwater drains), or seal holes, and if these are rare at the beginning of a season, reconnaissance flights should be made to locate them and check their depth before flying out the divers. (The first hole was dynamited open and required a full day of hard work by five people to clear it of slush and ice blocks. Thus, it would be impractical to rely on making a dive hole at each site.)

The tenders should be responsible for assembling all equipment and loading it into the helicopter. If two loads are necessary, the tenders should go with the first load and have all the diving gear ready by the time the divers arrive. In camp the divers can spray their suits with silicone and do minor repair jobs; they also can help each other dress if necessary. It is important to be thoroughly warm and dry before putting on the Unisuit, particularly the feet. One or two Coleman stoves serve as efficient heaters.

Although with experience, the Unisuit can be put on and taken off with increasing ease and becomes more comfortable with familiarity, it is good practice to try and minimize the amount of time actually in the suit. For this reason, once the divers have dressed they should reach the dive hole and be in the water as quickly as possible.

Once at the dive site each diver and his tender worked separately. It was not necessary for the two divers to swim together provided the work was such that it did not require two divers. In fact, it is probably safer to swim alone since there is less risk of lines becoming tangled.

Each tender would help to put on the weight belt, tanks, and fins in that order, and assist the diver to sit beside the hole. Once sitting, the tender could put on his mitts, attach the safety line, fasten bands of flash bulbs about his arm or leg, etc. Before going into the water the tender should see that both tank reserve valves are in the down position.

During the dive, it is important for the tender to keep just enough tension on the line to be aware of the diver at all times. Too much tension causes the diver to be fighting his line, whereas not enough makes it impossible to relay signals through the line.

The following proved to be a satisfactory set of signals through the line.

(a) One tug: This can mean "I'm okay" or "Are you okay?" depending on whether the diver or the tender gives the signal. Regardless of who initiates the tug, it does demand an answering tug. The tender should make sure all is well with the diver periodically, and the diver must answer back. It is also a means of ensuring that the tension in the line is satisfactory.

(b) Two tugs: This is used by the diver when he requires more slack. For example, he may need to untangle the rope either from himself or from various obstacles.

(c) Three tugs: This is used by the diver to ask the tender to take up slack. However, eventually it came to mean "pull me back to the hole slowly". Sometimes if a diver is a long way from the hole, his hands are full, or his feet are tired, it is much easier to let himself be pulled back rather than to swim himself.

(d) Four tugs: "A dire emergency, pull me in as fast as possible". This did happen once to each author. In both cases, the tender was aware of the urgency of the tugs before all four were completed. It should be added also, that each case happened because of inexperience. In one case, the diver simply ran out of air which happened because he was wearing no tank pressure gauge; in the other, a bad free flow began and the diver, in fright, believed he could not breathe at all. Many subsequent occurrences showed this to be untrue and future difficulties became annoying inconveniences rather than frightening experiences.

With experience, the tender will learn to "feel" through the rope and understand exactly what the diver is doing, whether it be photography, taking a core, or writing notes, etc. It should be added that the tender also should keep a lookout for polar bears and a rifle be nearby. Some trouble was encountered with polar bears pushing equipment down the dive hole when it was left overnight. Several times a dive had to be made to recover the dive rope and down line before work could begin.

The most successful and least tiring dives occur when it is unnecessary for the diver to return to the surface for anything other than his own fatigue or to change tanks. For this reason, if it is possible, all scientific equipment should be taken to the bottom of the dive rope on the first descent. Then, using the down line for reference, the diver can leave behind gear he does not need to use immediately. This eliminates unnecessary travelling up and down which is not only a waste of air but tiring and tedious as well.

After one tank is empty (at or below 500 PSI), the diver must return to the surface where he can either have his regulators changed over and dive immediately, or come out for a complete rest. Generally the divers did not need to come out of the water, but usually had their fins taken off for a short time. This was easily accomplished by the diver lying on his back and giving each foot in turn to the tender. The regulators were easily changed while still in the water. When the dive was completed, divers returned to camp first while the tenders packed up gear.

The length of a dive is determined by a combination of various factors. Depth is most important since there is a direct relationship between volume of air used with increase in pressure. Therefore, dives of 80 to 100 feet were inevitably shorter than dives of 10 to 30 feet. A beginner will use his air faster than an experienced diver due to a combination of nervousness, excitement, and lack of energy conservation.

The dives made by the authors were most often in 30 to 50 feet of water, and the first tank generally lasted approximately one-half hour. Cold, foot cramps, or the completion of work usually terminated the dive before the second tank became empty. Each dive, therefore, lasted approximately three-quarters of an hour underwater.

At camp, the Unisuits and regulators were hung to dry and the tanks filled up again immediately. Two dives, one in the morning and one in the afternoon made a comfortable day's work. To try more probably would be unwise.

Figure 8.

Core tubes and goodie bag containing mallet and caps ready to be taken down by the diver. GSC photo 202652-G

Figure 9.

Apparatus to measure profiles underwater (HUPUP rods). GSC photo 202652-H

UNDERWATER GEOLOGICAL TECHNIQUES

Bottom description

Originally it was hoped to make all bottom descriptions by verbal communication to the surface with an underwater radio system. The field party was equipped with the Hellephone Underwater Communication System made by Helle Engineering of San Diego and included a surface unit (model 3112) and a diver unit (model 3110). Mechanically, the system worked well, although it is necessary to learn to regulate breathing since the noise of escaping air bubbles blocked the reception. It necessitated wearing a special mouth mask which contained no inside grip for the teeth. Thus, speaking was possible without a regulator in the mouth. However, comfortable breathing was dependent on the seal of the mouth mask being water tight and the lack of a mouth grip caused a feeling of insecurity. Several times the mouth mask flooded and this was so alarming that the divers ceased trying to use it. The alternative was to write notes on an underwater slate, which was most effective.

The slate consists of an 8 x 10-inch sheet of thick (1/8- to ¼-inch) clear plastic which has been painted white on the back and sanded to roughen the surface on the writing side. An ordinary lead pencil attached by some cord to the slate writes very well, and it is even possible to erase a mistake underwater. We found underwater note-taking simple and satisfactory. Bottom and ice "scenery" is sometimes very spectacular. A beginner will find that he may have forgotten the simplest observations such as water depth, type of sediment, etc. by the time he has returned to the surface. For this reason even the simplest notes will force the diver to observe objectively.

Photography

For the diving geologist photography is most important. Although underwater photographic techniques are not in the scope of this paper, it should be emphasized that considerable effort is required to produce good pictures. Church (1971), Frey and Tzimoulis (1968) and Greenberg (1963) are all excellent guides for underwater photography.

We used a simple Nikonos camera system with flash equipment. A metal scale was used (Fig. 5) and the divers became proficient at setting it on structures such as ice formations and scour marks to be photographed, changing flash bulbs, and positioning for the photo without disturbing the bottom. For a beginner this requires considerable concentration.

It i recommended that if flash equipment is required, it should be an electronic strobe. We found that carrying flash bulbs in neoprene holders fastened about an arm or leg is inconvenient and many flash bulbs were lost before being used.

Coring

Cores were taken in 2½- to 3½-foot plastic tubes approximately 2 inches in diameter: each tube was bevelled at one end to make a cutting edge (Fig. 8). Other equipment included a two-pound rubber mallet (negative buoyancy) and plastic caps carried in a net bag with a metal fastener. The latter is a standard diver's item known as a "goodie bag".

If a core was taken close to the down line it was possible for one person to do all the work. The bag and caps can be hung on the anchor and the diver, after hammering in the core tube, can swim back for the caps. However, coring can disturb the bottom to such a degree that often it was difficult to find the core tube after having left it. Because of this, two divers carrying all the necessary equipment to a chosen locality is preferable.

At the core site the work is easier to undertake if buoyancy is reduced as much as possible. One diver holds the core tube while the other hammers. It is good practice to switch jobs every 10 to 20 hammer blows to allow each other to rest.

When the tube is in as far as it can go a cap is put on the open end before extraction. One diver digs around the base of the tube with his hands while the other pulls and rocks it back and forth. Once loosened, the tube must be eased out very gently and a hand slipped under the bottom until a cap can be put on it. By this time, visibility commonly has deteriorated and everything must be done by touch. It is thus important that the two divers work as a team and are responsive to each other's needs.

Shear vane measurements

To measure the shear strength of the sea floor sediments, the techniques described by Dill and Moore (1965) were used. Hydro Products now manufactures the Dill-Moore Vane Shear Meter. It is an inexpensive instrument consisting of a small vane attached to the shaft of a calibrated torque screw driver (Fig. 6). The latter is manufactured by the Apco Mossberg Co. in Attleboro, Mass. It is an instrument easily used and little or no practice is required.

The vane is inserted into the sediment and a direct reading in ounce-inches can be made as the handle of the torque screw driver is rotated. The value was written on the slate and converted into shear strength. The torque screw driver head in the 0 to 24 ounce-inch range is satisfactory for most sediments. In an ice environment, however, the sediment is commonly so compacted within a scour that heads with higher ranges (0 to 48 or 0 to 96 ounce-inches) are required. The instrument must be rinsed in fresh water and lubricated after each dive.

Profiling

An instrument to measure topographic profiles was designed by P. McLaren and made by the Geological Survey of Canada; it will be referred to as MUPUP

(Mutually Perpendicular Underwater Profiling) rods (Fig. 9). These can be used to measure profiles of the topography of the bottom and of submarine ice configurations.

MUPUP rods consist of two graduated rods (2 metres long) that slide through a common block which holds the two perpendicular to each other. Each rod may be moved independently of the other and is held in place by a nylon friction grip within the block. The friction is sufficient to maintain the rods immobile. The vertical rod has small fish eye bubble levels attached at each end and when held in the vertical position it ensures the other rod is horizontal. A profile was accomplished by successively moving the rods up or down the slopes and reading the horizontal and vertical measurements.

They worked well in small scour only where it was possible to keep in a relatively straight line. For larger scour a base line, such as a rope stretched across the scour, was needed in order to maintain the right direction, but this was not attempted. The MUPUP rods were also used satisfactorily to measure the slope of a delta forefront.

Collecting fauna and flora

The Museum of Natural History had requested that faunal and floral collections be made. Usually one tank of air allowed sufficient time to collect all the easily recognized varieties. Both plants and animals were gathered at random and put into a goodie bag. All the fauna were invertebrates and swimming species such as shrimp and some varieties of worms were easily scooped into the bag. Sometimes a knife was used to dig out the roots of plants or burrowing organisms.

COST OF A COLD WATER DIVING OPERATION

Compared to the total cost of an arctic field season, diving is not a major expense. The following are approximate 1974 retail figures for all diving equipment required to outfit one diver.

(1)	Compressor (if rented - $200 per month)	$1, 605. 00
(2)	Unisuit	545. 00
(3)	2 tanks at $135	270. 00
(4)	2 regulators at $167. 50	335. 00
(5)	1 full face mask	56. 00
(6)	Unisuit long underwear	177. 50
(7)	fins	18. 00
(8)	knife	13. 00
(9)	45-pounds lead weight ($0. 65 per pound)	29. 25
(10)	weight belt	5. 00
(11)	tank pressure gauge (submersible)	43. 00
(12)	tank pressure gauge	23. 00
(13)	depth gauge	47. 95
		$3, 167. 70

FUTURE OF DIVING

Scientific diving using SCUBA has been practised since the early 1950's shortly after the invention of the aqualung by Cousteau and Gagnan. Dill (1954; Dill and Shumway, 1958) encouraged the use of diving for geological studies. With attention focused on arctic resources and consequently arctic environmental problems, an under-ice diving technology quickly developed. Bright (1972), MacInnis (1973, 1974), and Jenkins (1974) have done much to promote the techniques of SCUBA in this environment which undoubtedly poses unique problems. Kovacs and Mellor (1971), Welch (1972), Smith (1974), and McLaren (1974) are but a few scientists who have already begun to examine under-ice phenomena in North America.

Arctic terrestrial environments are known to be both unique and sensitive to changes that man is inducing. Arctic marine environments are now facing major development and there is an accelerating need for information about their nature. There is little doubt that diving will be one of the cheapest and most effective methods to enable scientists to arrive at both the questions and answers necessary to understand these environments. The technology exists and is relatively simple. It is hoped that more scientists will be able to take advantage of it.

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