INSTALLATION OF A MULTITHERMISTOR CABLE
AND DATA ACQUISITION SYSTEM
AT
PANARCTIC ET AL. CAPE ALLISON C-47
OFFSHORE WELL, ARCTIC ISLANDS

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SUMMARY

Since late 1981, the Earth Physics Branch has been developing a fully integrated system to acquire precise ground temperatures for several years following abandonment of offshore petroleum exploration wells. This project complements an ongoing program through which similar data has been acquired over the years at 130 holes in the onshore regions of northern Canada. The conceptual design of the system and the day-to-day management of the project has been contracted out. By 1984, a system had been acquired, and a suite of acceptance tests and further bench and field tests had been performed. Negotiations were entered into with Panarctic Oils Ltd. and the Canada Oil and Gas Lands Administration for a demonstration deployment in an Arctic Island well. In early May, 1985, an installation was completed successfully at the Panarctic et al. Cape Allison C-47, an offshore well abandoned in 250m of water between Ellef Ringnes and King Christian Islands in the central Sverdrup Basin.

Data was recovered from the system for a week following installation, and then in mid-June and late July. The process to convert the digitally recorded data into temperature is discussed in some detail. The nature of these early temperature profiles confirms the proper operation of the system and illustrates the dynamic thermal behaviour during the first two and a half months as the well begins its slow recovery from the disturbances due to drilling and testing. Two distinct temperature gradients are emerging from this early data; each corresponds to major lithologic units encountered in this well.

This report gives a brief history of the development of the project. The involvement of Earth Physics personnel in the actual deployment operations is described, complementing a similar report being prepared by the contractor, Dobrocky SEATECH.

CONTENTS

Appendices

FIGURES

TABLES

1.0 INTRODUCTION

Since the issuance of a Request for Proposal in January, 1982, the Earth Physics Branch has been pursuing the development of a system to acquire precise temperatures in an offshore well. The concept was motivated by a) the interest in complementing an extensive data base acquired over more than a decade through the preservation of onshore exploratory wells and their logging at periodic intervals (Taylor et al., 1982), b) an apparent lack of similar data in Canada's offshore areas and c), a perceived need for deep reliable temperature data within the next few years in the geotechnical design and engineering of hydrocarbon production systems.

The design target was a system that would measure and record a dozen to twenty precise temperatures in the upper 1000m of an offshore well drilled in up to 400m of water, at intervals of hours to days for two or more years. Because of the highly technical nature of deploying such a system from an offshore drill-rig and the variety of data acquisition systems available, the entire concept development and project demonstration was contracted to Canadian consulting companies who had specialized experience in offshore geotechnical engineering. A more detailed chronology of the project is given in Taylor and Judge (1985); contractor reports over the past 3 years provide specific information on the development of concept and methodologies (EBA Engineering, 1982), on a market search of suitable instrumentation (EBA Engineering, 1983) and on the acquisiton and field testing of the integrated system prior to deployment (Dobrocky SEATECH, 1984). The contractor selected as project manager for the demonstration deployment, Dobrocky SEATECH, will be submitting a report on this most recent phase of the project by September 27, 1985.

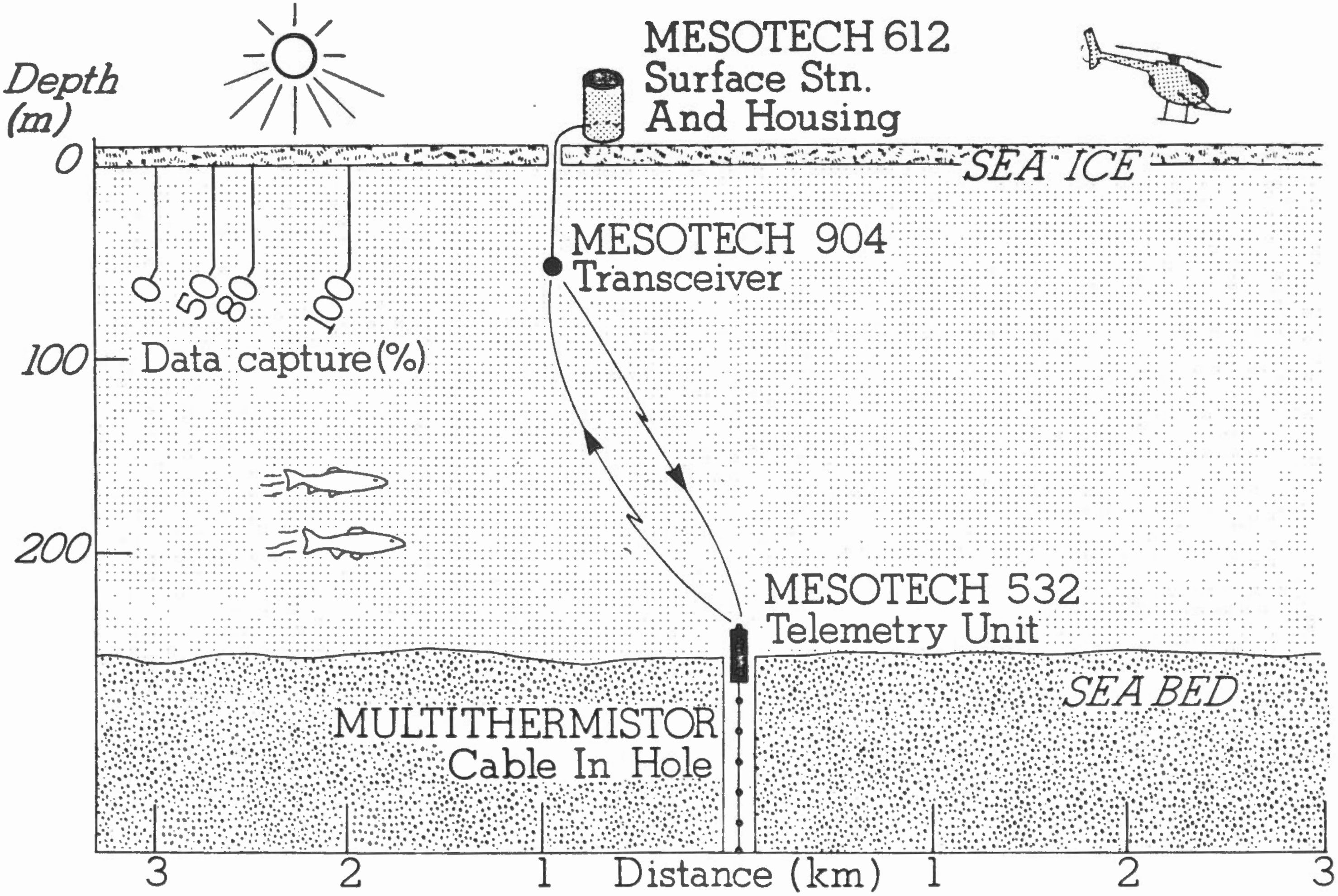
On May 8, 1985, a demonstration deployment was made in Panarctic et al. Cape Allison C-47, an offshore well drilled in 250m of water between Ellef Ringnes and southeastern King Christian Island in the Canadian Arctic Archipelago (Figure 1.1). Permission to use this well and to leave out the regulatory cement plug at the seabed, as required for this installation, was obtained from the Canada Oil and Gas Lands Administration. An 830m multiconductor cable with breakouts for 13 thermistors over its length has been installed in the section of the well above the next regulatory plug (Figure 1.2). A multichannel data acquisition system is connected to the top of the cable and rests in a casing adaptor just above the seafloor (Figure 1.3). This subsea unit is acoustically interrogated at preselected intervals by the telemetry unit left on the sea ice above, causing the thermistor resistances to be scanned and a digital data transmission to be made back to the surface recorder.

The geophysical motivation for the project is outlined in the following section, but the principal purpose of the report is to descibe the events leading to the successful deployment and present some of the first season's data. The involvement of Earth Physics Branch personnel in the preparations for the demonstration deployment and in the installation are described in section 3. Temperatures were logged through a manual interrogation of the system during the first week following installation and automatically thereafter, with data being recovered in mid-June and again in late July, when the surface station was removed from the ice platform for the brief open water season. This first season of data is discussed with some geological implications in section 4. Future plans for the system installed at Cape Allison are described section 5. Finally, section 6 brings together a variety of recommendations for future versions of the equipment and for procedural modifications for subsequent deployments.

Five appendices augment the main body of the report. Appendix A describes in detail the various calibrations undertaken on the complete system to ensure a faithful thermistor resistance to temperature conversion. Appendix B complements section 3 by providing a chronology of events surrounding the deployment. A selected set of the temperature data is presented in Appendix C. Appendix D considers the total cost of the project from concept development to successful deployment. Throughout the report, references are made to photographs taken during the installation and data retrievals; these are presented as an annotated photo-journal in Appendix E.

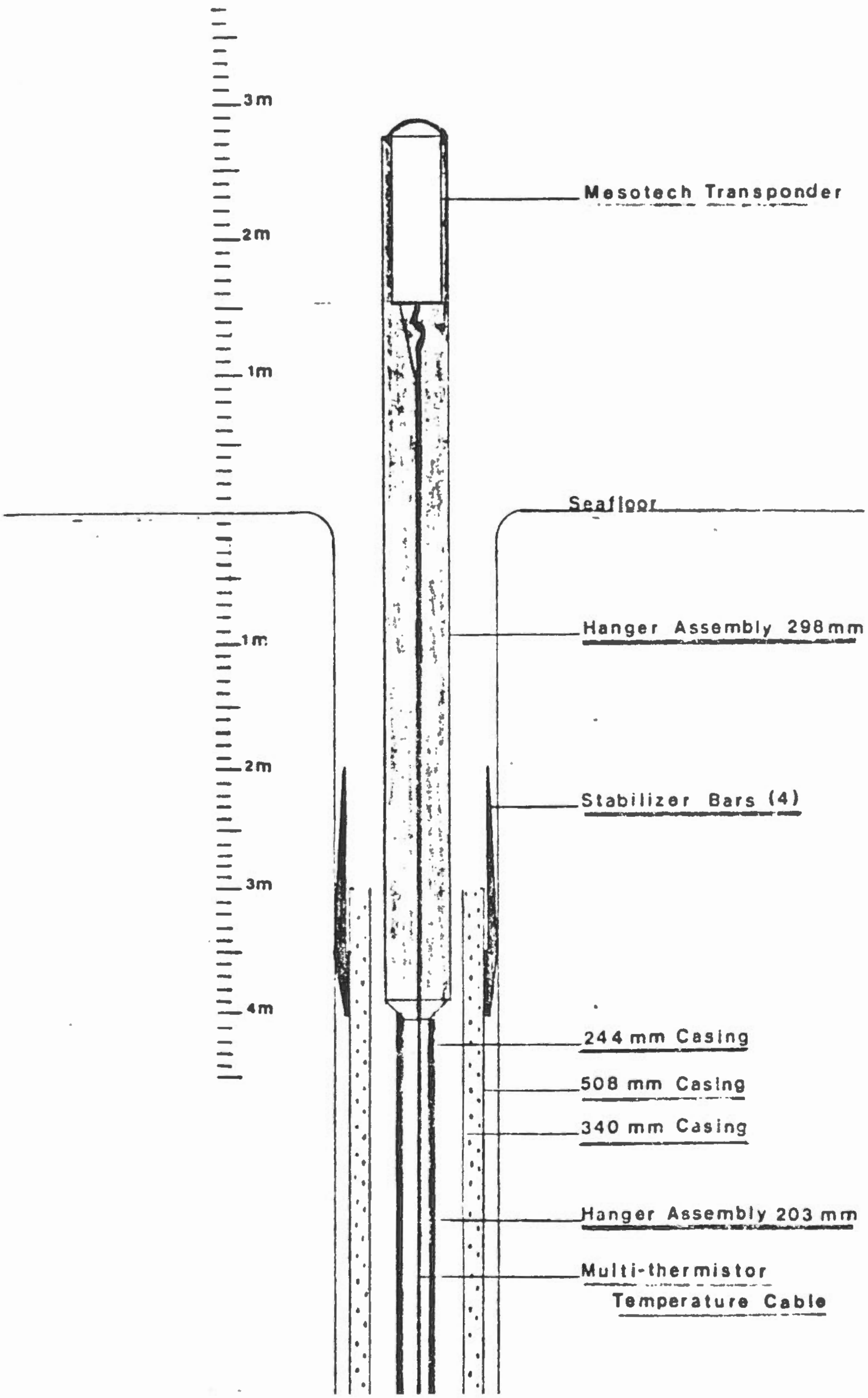
Location of Cape Allison well, Arctic Islands. The onshore exploratory wells from which EPB has been acquiring precise temperature data over the years are shown with the permafrost thickness determined at each; numbers in brackets are EPB file numbers (see Taylor et al., 1982 for identification of wells).

FIGURE 1.1



Schematic of the well instrumentation at the offshore Cape Allison C-47 well. The Mesotech model 612 surface telemetry unit is housed on the sea ice; at intervals of 4 hours, it interrogates the subsea telemetry unit model 532 installed in the top of the well. This unit scans the 13 thermistors on the downhole cable, and transmits the coded data back to the surface station, where it is stored in bubble memory. The acoustic transmission is tolerant of up to 2 km of ice drift before some data is lost.

FIGURE 1.2



Cross-section of the installation in the well. Stabilizer bars reduced motion of the BOP stack and casing stub after the 340/508 mm casings were cut. The thermistor hanger assembly is a casing adaptor designed to hold the Mesotech model 532 unit above the seafloor and to protect it as the casing stub BOP stack were lifted off.

FIGURE 1.3

2.0 IMPORTANCE OF PRECISE THERMAL DATA TO OFFSHORE GEOLOGY

The unique properties of arctic environments, whether onshore or off, are largely attributable to their temperature regime. Many phenomena in the arctic are the direct result of the critical dependence of various physical properties with temperature. While geothermal data in the form of temperatures and thermal properties represent but one of a suite of geophysical parameters that provide geological insight, temperatures can provide one of the better "ground truths" in arctic regions. Geophysicists use geothermal temperatures to calculate the terrestrial heat flux in the study of the geology and tectonics of a region. Petroleum engineers use this information and concepts of palaeothermal regimes to assess petroleum maturation possibilities in the quest for hydrocarbon resources.

Precise temperature profiles, to several hundredths of a degree accuracy and to depths of a thousand metres or so, have been acquired during the past twenty years at over 130 onshore wells in the Canadian arctic, entirely through the opportune use of exploratory wells (Judge, 1974; Taylor et al., 1982, 1985). About 40 wells in this data set are located in the Arctic Islands.

Few measurements to this detail and accuracy have been made in our offshore arctic areas, and our thermal understanding of these areas is similarly lacking. The major effort in frontier exploration in Canada at present is directed to the offshore, giving rise not only to a 'need to know' but also an opportunity to obtain deep temperature information on a very cost effective basis.

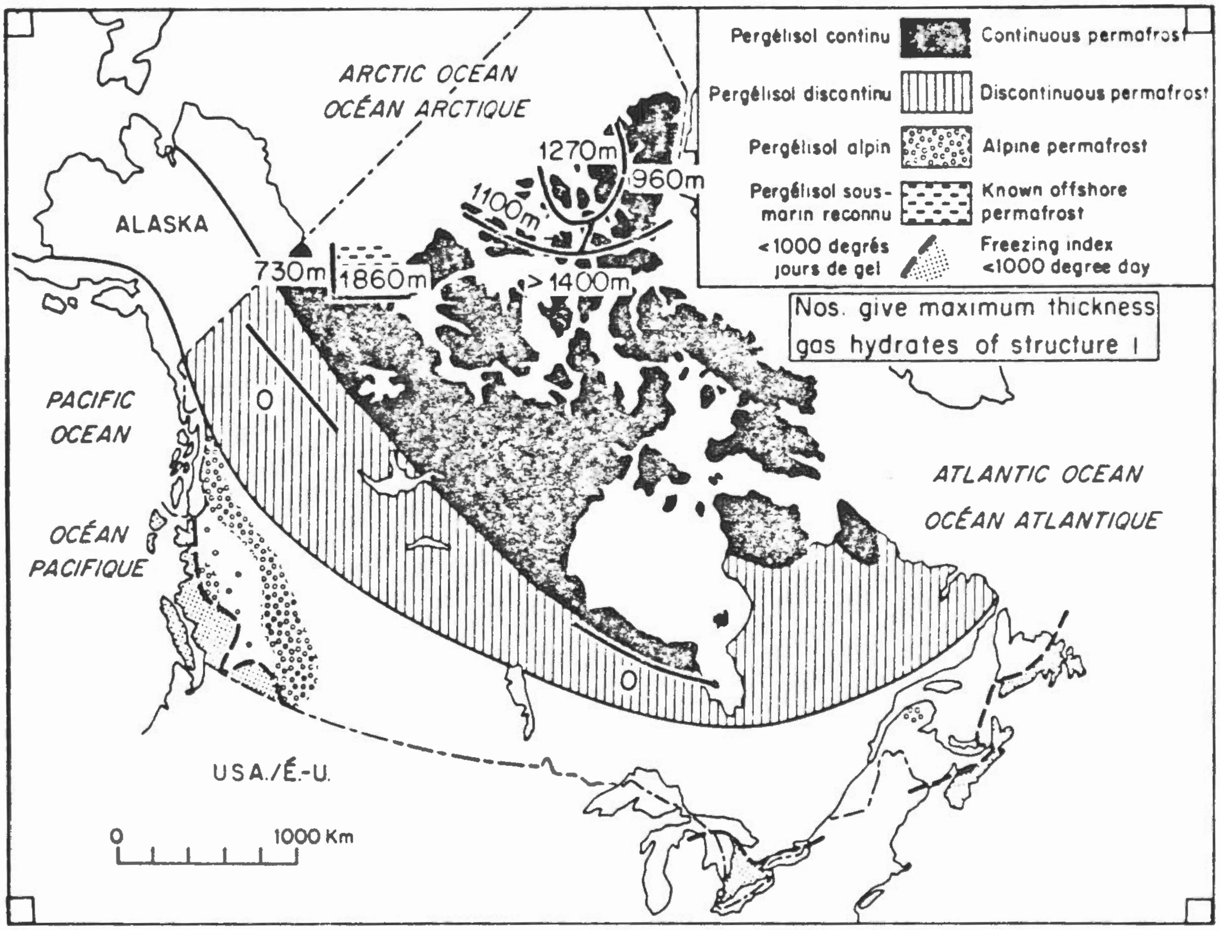
2.1 Current geothermal knowledge, Inter-island channels, Arctic Archipelago

A number of wells have been drilled in the offshore Arctic Islands, and several hydrocarbon resource pools have been identified. The temperature monitoring system recently installed at Cape Allison is currently monitoring temperatures in one of these pools. Industrial data at the previous offshore exploratory wells have provided estimates of deep temperature data (Geotech, 1983).

Occurrences of natural gas hydrate have been suspected at a number of arctic wells, some of them offshore (Figure 2.1; Judge, 1982; Hardy and Assoc., 1984). With deep water temperatures slightly below $0^{o}C$, hydrates may be stable to considerable depths (Figure 2.2), depending mainly on the temperature gradient; low gradients favour thicknesses of more than 1000m below the seabed (Figure 2.3). If hydrates are intersected in an instrumented well, a series of temperatures measured over months to a year or more may detect the considerably different thermal regime due to the latent heat of their dissociation.

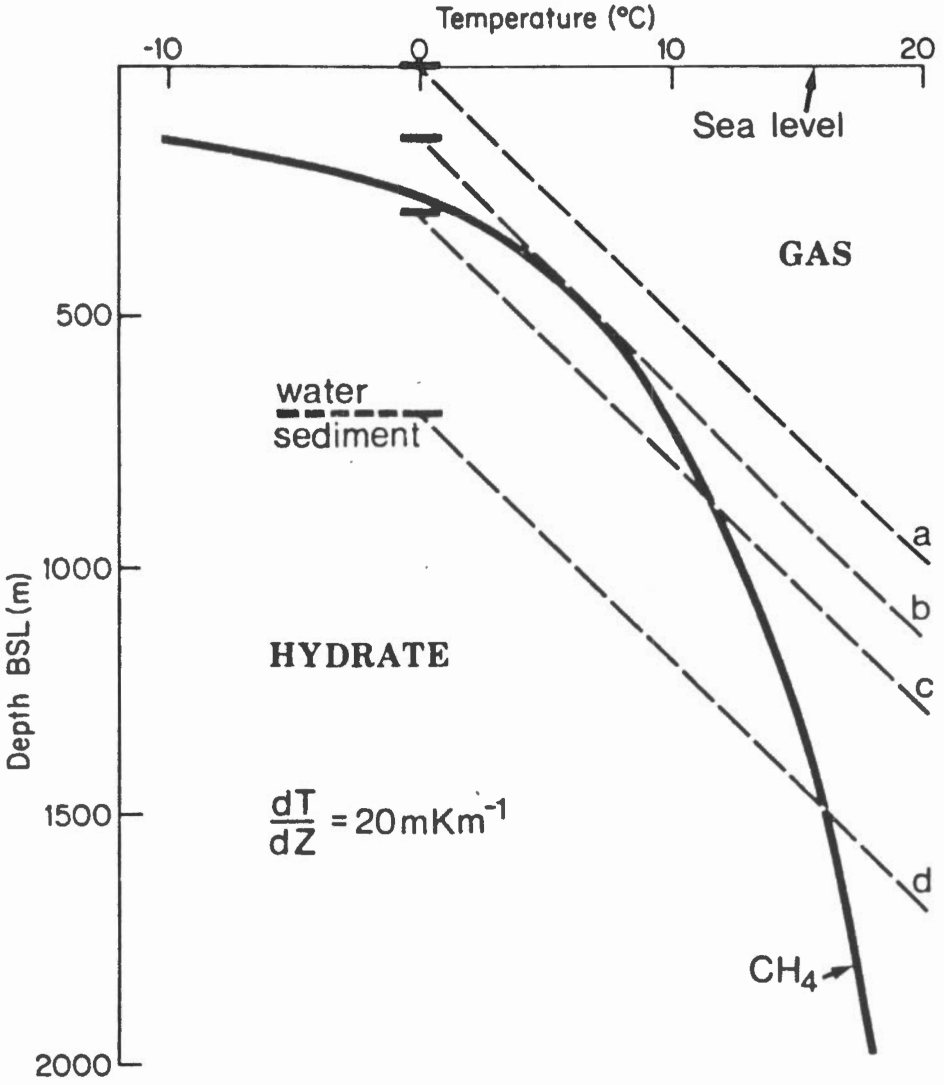
Precise temperatures to depths of a 1000m, and thermal conductivities determined from drill cuttings, provide data with which to calculate the terrestrial heat flow typical of the region. These studies are nearing completion for onshore wells (Taylor et al., 1983; 1986) and would benefit considerably from detailed temperature data from several offshore wells to fill in the regional distribution in this archipelago. Heat flow values permit an estimate of temperatures at greater depths based on the lithology (e.g. Judge, 1973) and provide a key control in geothermal history analysis and petroleum maturation studies (Skibo and Price, 1985).

The Cape Allison instrumentation is expected to quantify the offshore thermal regime in the King Christian-Ellef Ringnes frontier area; a future deployment in the western part of the Sverdrup Basin would determine any thermal signature associated with the Lougheed Arch in this area of promising resource potential.



Permafrost distribution and potential thickness of natural gas hydrate occurrences in Canada. Permafrost map after Brown, R.J.E., Hydrological Atlas of Canada, 1978.

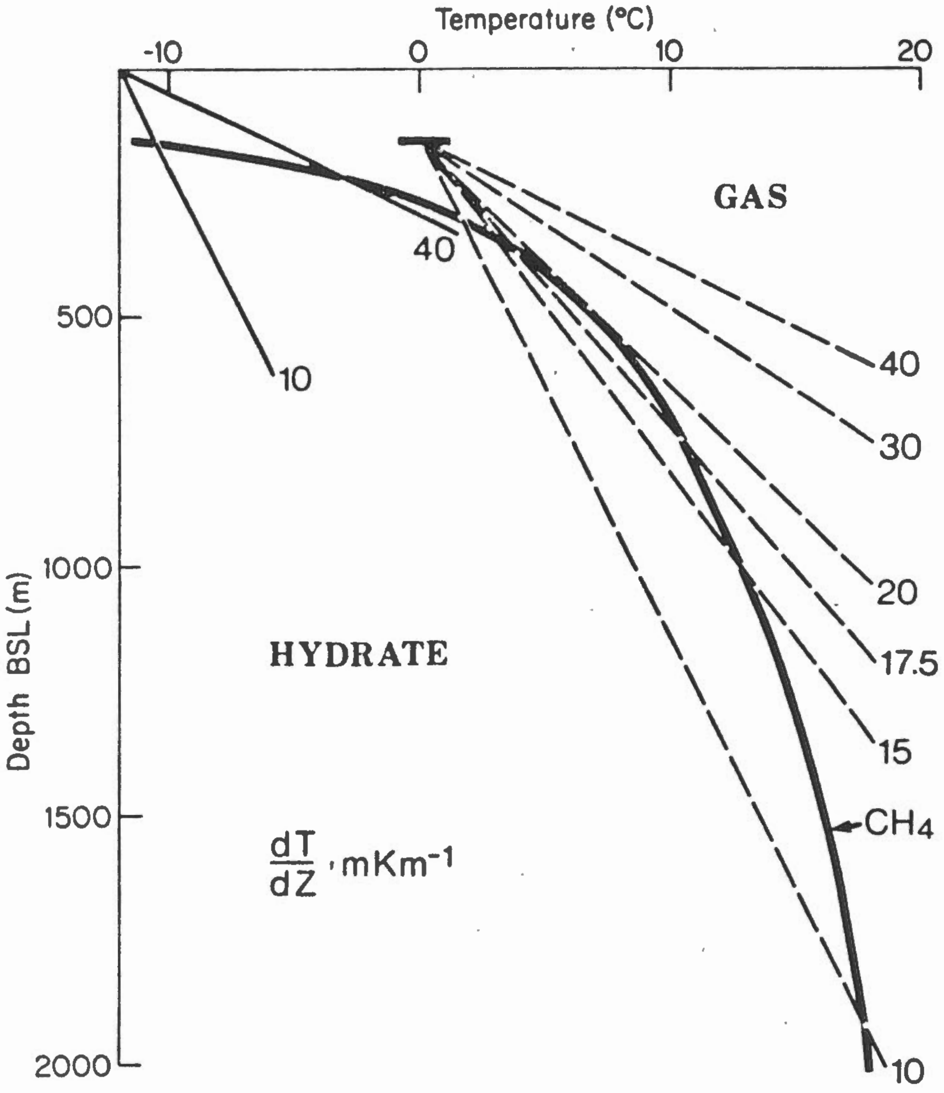
FIGURE 2.1



Hypothetical sediment temperature profiles for water depths of 0, 150, 300 and 700m. The water/sediment interface is assumed to be at 0°C. The portion of a temperature profile lying below the methane hydrate stability curve indicates the depth interval over which hydrate could potentially occur.

(from Taylor et al., 1979)

FIGURE 2.2



The thickness of the potential hydrate zone is quite sensitive to the geothermal gradient, as shown here for water of 150m depth. In such shallow water, hydrate is not stable for the larger gradients; in water deeper than about 250m, some hydrate might occur regardless of gradient. The same span of gradients is shown for an onshore arctic location where the surface temperature is -12°C.

(from Taylor et al., 1979)

FIGURE 2.3

3.0 THE DEMONSTRATION DEPLOYMENT

Panarctic's drilling plans were announced in the fall of 1984; in consultation with the company and the Canada Oil and Gas Lands Administration (COGLA), the Cape Allison well was identified as a suitable well for the demonstration deployment of EMR's temperature monitoring system. The well was located in about 250m of water (as deep water as possible was desired in order to maximize the gas hydrate stability zone, see Figures 2.2 and 2.3), and the first deep regulatory plug was scheduled for about 1100m sub-seafloor, leaving sufficient open hole available for our 1000m cable. Panarctic and EMR had worked out a deployment procedure through a previous meeting, and Panarctic submitted this plan for an 'instrumented abandonment' to COGLA as part of their request for drilling authority. A critical part of the procedure required a secondary cement job early during the drilling of the well to ensure that the regulatory surface plug just below the the seabed could be safely omitted. This was done in February, early in the drilling of the well.

3.1 Pre-deployment activities

A couple of months prior to the deployment, V. Allen visited SEATECH's facilities at Sidney, B.C. to assess the preparations underway and to calibrate the A/D section of the acquisition system. The thermistor pods themselves were calibrated against a platinum resistance thermometer at the end of March in our laboratory in Ottawa. The two calibrations guarantee a faithful thermistor resistance to temperature conversion for the integrated system. Both calibrations are described and documented in Appendix A.

At the beginning of March, the length of open hole available to us was decreased from the original 1100m to about 900m below seafloor on account of the penetration of a formation that required a cement plug near the latter depth. In early April, the cable was shortened to 830m and professionally re-terminated in SEATECH's laboratory by Hal Hillburn, of 3H Products, Houston, Tx. Details are left to SEATECH's report.

The timing of the installation was delayed from the original well completion date of early April on account of a lengthy suite of tests that were run on the well. On May 1st, the testing was nearing completion and Taylor and Allen left Ottawa to join SEATECH personnel and Panarctic engineers in Edmonton for the flight north. The log of events during the week in the arctic is given in Appendix B; a narrative of the major elements of the deployment is given here to reflect the essence of the installation and to bring out suggestions for future deployments in their proper context.

3.2 Wellsite activities

Upon arrival of the EPB personnel at the rig site (photo 1 in Appendix E), the Dobrocky SEATECH personnel were preparing the equipment (photos 2-5) and Panarctic was preparing to cut the casing at the seafloor, a routine in conventional completions following the placement of the surface plug and preceding the lift off of the blow-out preventer stack (BOP) and the removal of the marine riser. The procedures from this point on differ from the conventional abandonment and relate to the installation of the multithermistor cable and subsea data acquistion system.

Following the cutting of the 244mm casing and retrieval of the stub and the combined cutting of the 348 and 508mm casings, the Thermistor Hanger Assembly (THA, photo 6) was run uneventfully into the well through the marine riser and the BOP stack, and its mid-section swedge landed on the 244mm casing cut (Figure 1.3).

The winch with cable pre-spooled on it was brought up to the rig floor (photo 7). A 4m, 5cm diameter steel sinker bar was attached to the clevis on the bottom of the cable and put over a sheave/dynamometer installed on the draw-works. Thermistors were installed, wrapped with several layers of electrical tape and tested just prior to running into the hole (photos 8-10).

About 250m of cable was run in, when a hang-up occurred. Panarctic engineers believed that the bullet-nosed sinker bar became wedged between the THA and the casing. The cable was brought in, with the thermistor breakouts being carefully taken through the sheave. Centralizer fins were welded onto the bottom of the sinker bar (photo 11) and run-in was restarted, testing each thermistor again as it went down. Of the three thermistors that went through the sheave in this operation, one had failed and was replaced. In additon, breakout 13 (at depth 150m on the cable) was open circuited. This was the breakout that had been repaired earlier by the manufacturer; while it tested properly in the lab, it failed apparently on application of tension in deployment. A thermistor was installed in case the defect closed again in the well.

When the plug at the top of the cable was reached (photo 12), the cable was hung off while the Mesotech unit was installed in the Electronic Protection Sleeve (EPS, photo 13). The nylon braid on the drum was brought through the protection bars on the top of the EPS, and the thimble at the top of the cable attached to the eye on the bottom of the EPS. The electrical connection was made (photo 14). The entire system (cable, data acquisition system and transducer) was tested with an "in air" acoustic path before the electronics was lowered down the well (similar to photo 5).

Lift was transferred to the winch and nylon braid, and the EPS lowered down the well, until refusal, about 4m short of the depth below KB according to markers on the rope; this was attributed to stretch. Floats were tied to the top ends of the braid loop and let fall down the riser to rest at the water level (photo 15). At this point, it was believed that the total subsea system had been deployed, and the rig crew continued with some of their activities in preparation for lift off of the BOP stack.

Several hours later, the lifting of the stack was monitored on the underwater camera. Considerable quantity of mud poured from the stack as it was lifted off the casing cuts, and this made visibility difficult for a while. The THA was gradually revealed as the stack was lifted, but it was noted that the EPS had not landed in the THA; some minutes later the thermistor cable was seen extending taut from the bottom of the BOP stack into the THA in the well, now offset about 2m from the free-hanging stack due to the accumulated ice motion since spudding the well. The EPS had apparently hung up on some small edge within the stack, perhaps at a ram. There is a small (less than one cm) flat edge to the top and bottom edges of the EPS and this may have caused the container to catch or jack-knife within the stack. True to the drama of the moment, the subsea camera failed. Remedial action was left until some of the marine riser had been removed, at which time the cable angle to the well would be very small.

When about 100m of marine riser had been taken in, the nylon braid and floats were fished out of the riser; applying tension to the braid released the EPS container and the rig crew slowly lowered it out of the riser (photo 16) and, several minutes later, landed it in the THA in the well. The white semi-circular protector bars on the top of the EPS were just visible on the underwater camera protruding from the top of the THA, as planned so that the acoustic transducer would not be impeded by casing (photo 17).

The Mesotech surface station had been set up previously in the tide shack, several hundred metres from the rig and adjacent to the location chosen for the environmental protection container (EPC). At this point, the surface station was used to interrogate the subsea installation; except for the faulty breakout at 150m, a complete data set was attained. The digital output values were reasonable for the thermistors involved and the deployment was considered a success. Memory was erased, the system set to record records at 4-hour intervals and installed in the EPC in its final configuration (photos 18-20). This concluded Earth Physics' involvement with the rig, and Panarctic resumed their teardown operations.

Later in the day, the system was interrogated manually once again; the converted temperatures were reasonable, indicated that the well was cooling near the surface and warming between 500 and 800m and generally established that the temperatures were consistent with what might be expected for a well shortly after drilling. However, it appeared that fewer records were being written to memory while in the automatic mode. It was decided that further investigation of the functioning of the surface recorder had to be carried out. Harrington was left to stay for an additional week for this purpose and to obtained data through manual interrogations each day.

Taylor and Allen left Cape Allison May 9 with Hill and returned to Ottawa.

3.3 June visit to recover data

Allen and Hill returned to the ice pad on June 17th (photo 21) to make the first dump of automatically recorded data to the HP110 portable computer. It had not been possible to test the software on the system previously and it was found expedient to remove the Mesotech model 612 surface unit to Resolute for the initial dump (photo 23). It was then returned to the site for a further period of data accumulation. The data is discussed in section 4 and Appendix C.

Itwas apparent that the propane heating system in the Environmental Protection Container had experienced an explosion (sheared rivets) and a prolonged fire subsequent to its initial installation; this section of the EPC was decommissioned for the remainder of the data gathering period. (Described more fully in Dobrocky SEATECH, 1985).

3.4 July visit to remove the surface station

Allen and Judge visited the installation on July 22 during the Panarctic clean-up operations on the ice pad. Because of the condition of the EPC due to the fire, only the Mesotech unit and the salvagable parts of the heating system were retrieved; the shell of the EPC was left for Panarctic to dispose of.

The data in the bubble memory of the Mesotech unit was transferred to the HP110 disc in Resolute.

4.0 WELL TEMPERATURE DATA AT CAPE ALLISON

The first data was obtained at 0400 May 8th, 1985, immediately following successful deployment of the Mesotech subsea unit in the well. A further profile was obtained by manual interrogation of the system before Taylor and Allen left the site; Harrington similarly recovered six profiles daily for the additonal week he remained at the site investigating the uncertainty with timing of the automatic acquisition mode. Allen and Hill returned to the location on June 17, and Allen and Judge on July 22, to recover the automatically recorded data.

This section is restricted to the nature of this first season of data and its implications to the geothermics of the region. A technical discussion of the data and of the timing problem is left for Appendix C.

4.1 The first season's temperature data

Figure 4.1 is a graph of a selection of the temperatures from Table C.1 (Appendix C) measured between May 8 (the first profile) and July 22; the dashed line is the equilibrium profile (from Table 4.1) calculated from selected logs. The screened line indicates the approximate methane hydrate stability curve. Two distinct temperature gradients are emerging from even the earliest data. The upper 500m of the well exhibits a gradient of 12 mK/m, the lower section a gradient of 23 mK/m after one week; gradients of 13.2 and 27.6 mK/m over the same intervals are calculated for the equilibrium profile. Such contrasts in the geothermal gradient are often attributable to similar contrasts in thermal conductivity of the rock; the data suggests two distinct formations of differing lithologies. This interpretation must await release of the geology and calculation of thermal conductivities from rock chips recovered as drilling proceeded.

Figure 4.2 shows the same data plotted versus the logarithimic time function suggested by Lachenbruch and Brewer (1959) to obtain an estimate of equilibrium temperatures in wells disturbed by the drilling process. It is apparent that temperature logs taken for several weeks after abandonment of the well do not fit this simple logarithmic return to equilibrium model. A better estimate of equilibrium temperatures may be obtained next year when more logs have been taken. The results of the equilibrium temperature estimate are shown in Table 4.1, with a list of the logs used in the calculation.

4.2 Inferred cooling of the well

Looking at the individual measurements more closely, we note that the first two logs (Appendix C.4) indicate that the upper section of the well was cooling during the day following deployment, while the deeper section was warming slightly. Subsequent logs indicate that the upper 500m of the well is cooling from the various thermal disturbances due to 2 months of active drilling and 1 month of testing and logging; the deeper interval from 500 to 800m appears to cool less rapidly.

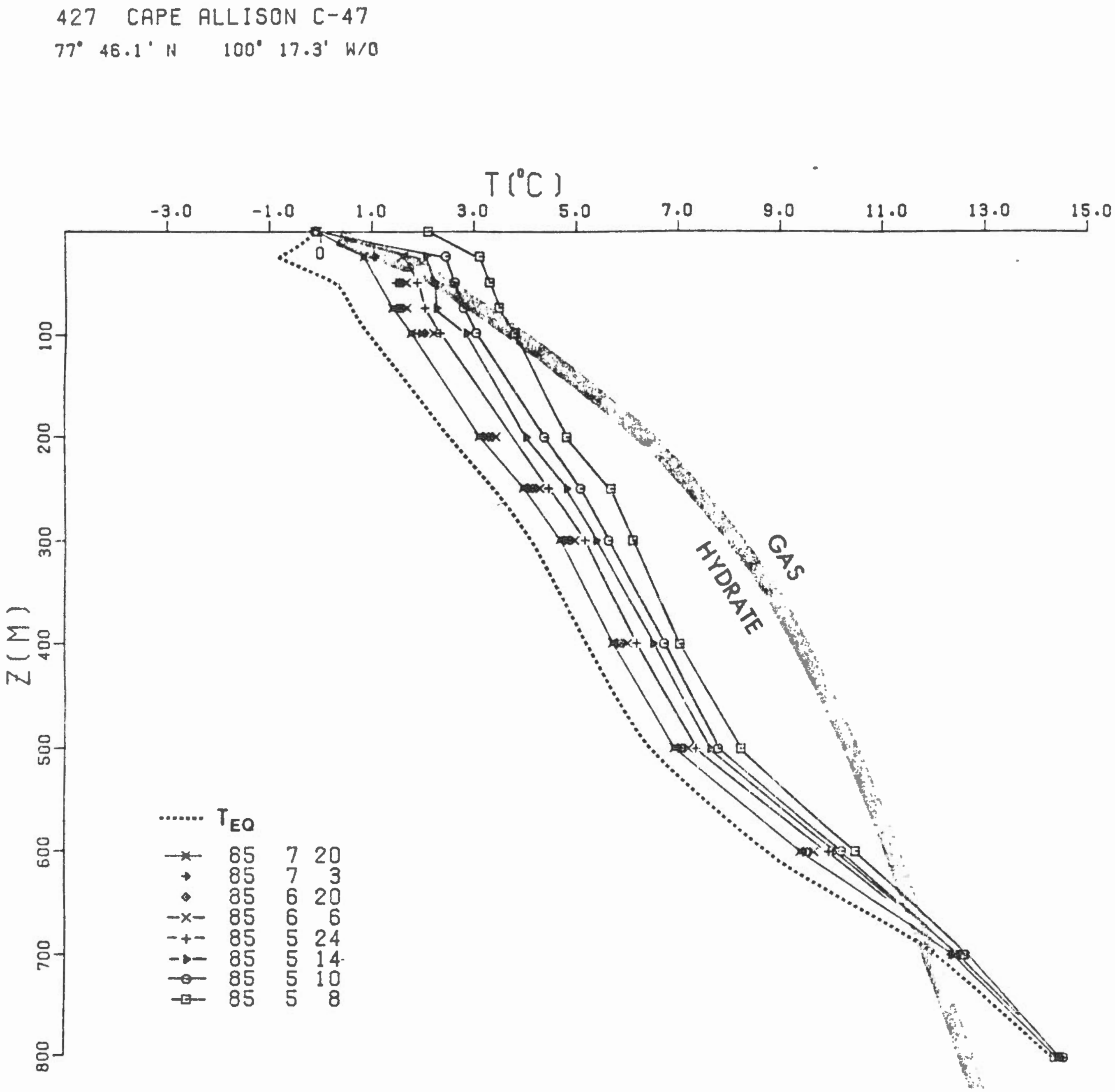
While the rate of cooling in this deeper instrumented section might be expected to be lower due to the presumed lower thermal conductivity of the lithology (considering the higher temperature gradient), an isothermal condition is approached at 800m. The well was drilled to a total depth of 2100m and penetrated the upper 800m in about two weeks (Al Duguid, pers. comm.). The magnitude of the disturbance in this interval depends on the difference between the undisturbed formation temperatures and the gross average circulation temperature. The seemingly isothermal condition at 800m might suggest that these two values were fortuitously similar at this depth. The thermal effect of the cementing history of the well is an unknown parameter. The first regulatory cement plug was placed just below this interval around 900m.

4.3 Hydrate stability zone

Figure 4.1 shows the methane hydrate phase curve considering a pressure to depth conversion based on hydrostatic pressures (e.g. Bily et al., 1974). If sufficient gas were present in the pore water within this interval of the well, hydrate and gas could exist as an ice-like compound to the left, or lower temperature side of the curve; methane in its gaseous form would exist for conditions represented at the right of the curve, or to higher temperatures. If in situ pressures are greater than hydrostatic, the curve would move up; salinity in the pore saturant would result in a curve lying somewhat to the left, or to lower temperatures. If the gas present were a low gravity natural gas, the phase curve may lie to higher temperatures which could intersect or exceed the temperature curve at 800m. Hence, the actual position of the phase curve for hydrate might vary but it would seem that the entire instrumented section of the well lies within a zone of potential hydrate occurrence.

Hydrate offers an alternate explanation for the isothermal section at 800m. A hydrated section would begin to dissociate to gas and water if downhole circulation temperatures exceeded the phase curve. Upon cessation of circulation, the well would cool to the phase curve in the hydrate interval, and, if gas had not escaped, further temperature reduction would be arrested, while the considerable amount of latent heat was dissipated in the 'refreezing' process. This would create an isothermal section lasting a period of time,

Additional information must be gathered before further analysis of the temperature profiles or of the isothermal point may be undertaken. Confidential geological logs may substantiate the change in lithology around 500m sub seafloor predicted from the change in temperature gradient. Drilling records kept by Panarctic may provide some information on circulation temperatures, and downhole geophysical logs (especially the sonic and resistivity tools) may reveal characeristics appropriate to a hydrated interval.



Selected temperature profiles following installation of the system at Cape Allison. The dashed curve is the estimate of equilibrium, or undisturbed, temperatures calculated from the first two and a half months of data. The stipled curve separates the region of potential occurrence of methane hydrate from methane gas, considering the hydrostatic pressure of the overlying 250m of water and of the lithology.

FIGURE 4.1

427 CAPE ALLISON C-47

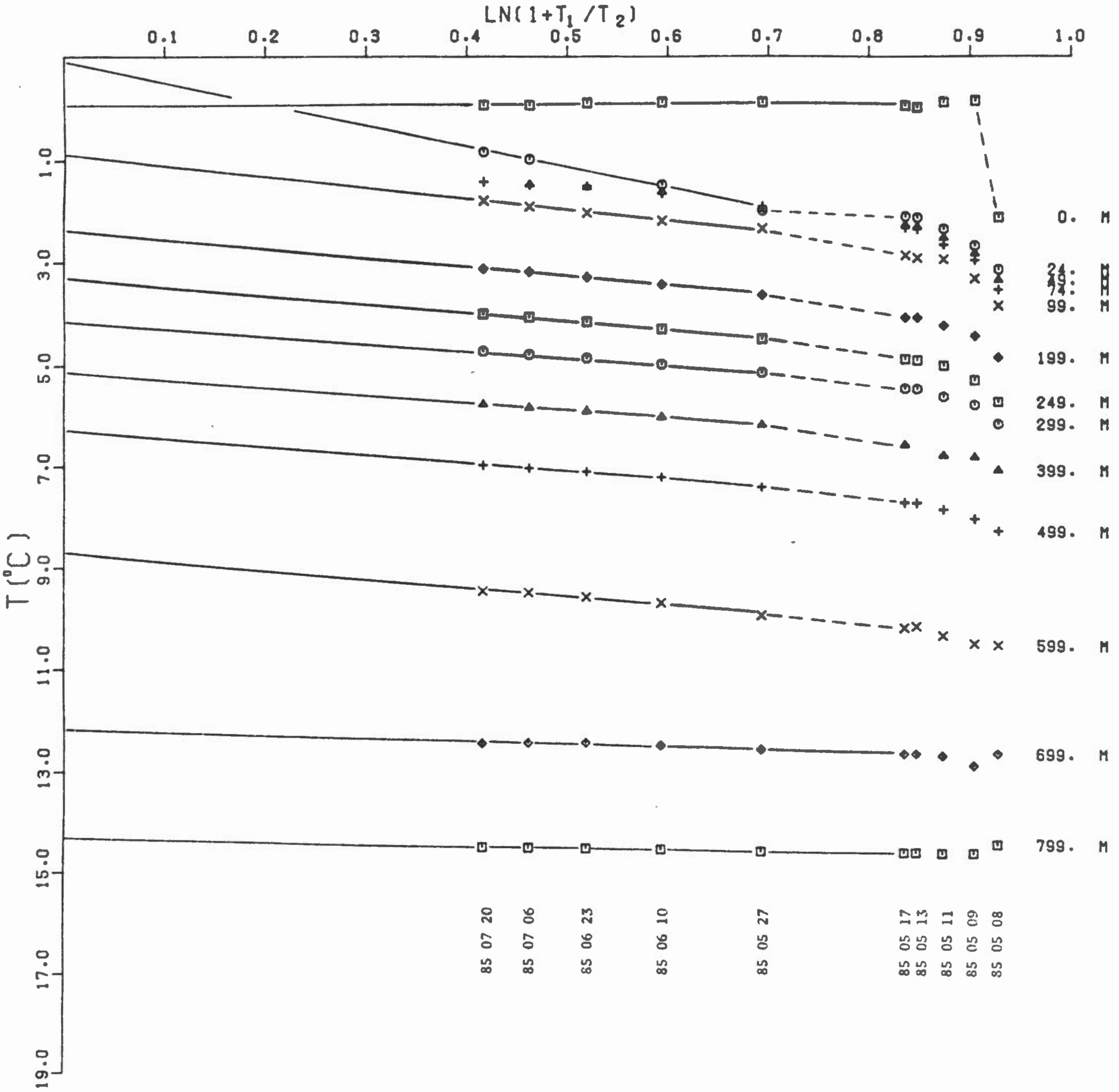


Illustration of the logarithmic relationship used to calculate the equilibrium temperatures at each sensor depth in the well. T_1 is the duration of well disturbance, the time to drill the well; T_2 is the time elapsed between cessation of drilling and the date of a particular temperature log. The dates of logs plotted here are shown along the lower margin.

FIGURE 4.2

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            EARTH PHYSICS BRANCH NO.
                                                427   CAPE ALLISON C-47
DIRECTION DE LA PHYSIQUE DU GLOBE NO.

        ****************************************************************


  77 DEGREES  46.1 MINUTES NORTH                 77 DEGRES  46.1 MINUTES NORD
 100 DEGREES  17.3 MINUTES WEST                 100 DEGRES  17.3 MINUTES OUEST

                              ELEVATION -250 METRES


                                                RETOUR A L'EQUILIBRE, SUIVANT
LOGARITHMIC RETURN TO EQUILIBRIUM               UNE ECHELLE LOGARTHMIQUE
---------------------------------               ------------------------------

                                 DELTA                        DELTA
       Z             T(EQ)       T(EQ)          Q               Q      TIME(YEARS)
      (M)             (C)         (C)          (C)             (C)     TEMPS(ANNEES)

      0.0             .00         .03         -.19             .06          -.37
     24.0            -.92         .07         4.10             .12          6.33
     49.0             .58         .11         1.84             .20          2.80
     74.0             .70         .07         1.64             .12          2.49
     99.0             .95         .03         2.04             .06          3.11
    199.0            2.36         .02         1.77             .04          2.69
    249.0            3.27         .02         1.70             .04          2.58
    299.0            4.11         .01         1.45             .02          2.18
    399.0            5.14         .01         1.43             .02          2.16
    499.0            6.32         .03         1.50             .05          2.26
    599.0            8.70         .05         1.67             .10          2.53
    699.0           12.25         .04          .36             .07           .49
    799.0           14.33         .01          .30             .02           .39

TEMPERATURE LOGS USED IN RETURN                  DIAGRAPHIES DE LA TEMPERATURE UTILISEES POUR
TO EQUILIBRIUM CALCULATIONS                      CALCULER LE RETOUR A L'EQUILIBRE THERMIQUE
                                    85  5 27
                                    85  6  3
                                    85  6 10
                                    85  6 16
                                    85  6 23
                                    85  6 30
                                    85  7  6
                                    85  7 13
                                    85  7 20

NOTES...                                         REMARQUES...
  1.T(EQ) = EQUILIBRIUM TEMPERATURE                1.T(EQ) = TEMPERATURE D'EQUILIBRE
    DELTA T(EQ) = STANDARD DEVIATION                 DELTA T(EQ) = L'ECART-TYPE
  2.Q = SOURCE FUNCTION                            2.Q = EFFET DE LA SOURCE,
    DELTA Q = STANDARD DEVIATION                     DELTA Q = L'ECART-TYPE
  3.TIME = THE TIME IN YEARS NECESSARY             3.TEMPS = LE TEMPS NECESSAIRE POUR
    FOR THE TEMPERATURE TO RETURN TO                 ATTEINDRE DE NOUVEAU LA TEMPERATURE
    WITHIN 0.1 DEGREES OF T(EQ).                     D'EQUILIBRE A 0.1 DEGRES PRES.
```

Table 4.1

Estimated equilibrium temperatures determined from 9 logs of the first season's data.

TABLE 4.1

5.0 FUTURE PLANS FOR CAPE ALLISON

Project plans called for the operation of the system for two or more seasons, but before returning the system to the Cape Allison site, some fundamental modifications are required. These are described in section 6, and only the minimum changes needed to ensure a successful second season will be outlined here.

5.1 Basic modifications required before re-deployment

a) The battery pack for the surface station must be redesigned. This may be the time to consider designing a two part container, as suggested by Dobrocky SEATECH, to facilitate changing in the field. make changing easier.
b) An improved, or redesigned Environmental Protection container will be required. Important issues are the stability of the heating system, the means of protecting the cable to the underwater transducer and design of a better platform or pile arrangement to secure the package to the ice.
c) Considerable testing of the surface station is required to eliminate uncertainties in the timing and the effect of manual interrogations.

5.2 Re-deployment of the system

The surface station will be replaced on the sea ice in late October or early November when the ice has refrozen. The logisitics of re-instituting the program will depend on whether Panarctic is drilling a delineation well sufficiently close that their camp can be used as a base and a skidozer as transport. Otherwise, a ski-equipped Twin Otter will be chartered from Resolute to land at the site during the very short period of daylight at that time of year. Navigation in this case would be by Global Nav and visual from the Ellef Ringnes coastline a couple of kilometers away.

Whichever scenario pertains, some further effort on the ice will be required to locate the well. Holes will be drilled through the ice, and ranges taken on the subsea unit using the ranging facility of the surface station. A deployment of the surface station within 0.5km would be satisfactory.

The station would be left there until May, 1986, when it would be picked up during a routine well logging/well abandonment program using a PCSP Twin Otter. Very little change in temperatures is expected in the latter months, and there would be little gain in leaving the instrumentation until late June or July, when retrieval conditions become much more difficult.

Data recovery in between these two dates would depend somewhat on the logistic facilities available and the estimated lifetime of the propane supply. A visit in mid-January from a Panarctic camp would be ideal, being mid-term in the deployment; a visit by Twin Otter could be made only towards the end of February. Surface station batteries would be changed at this time.

5.3 Thermal conductivity measurements

Samples of the drilling chips for thermal conductivity measurements will be picked up at ISPG this fall, once we obtain release by Panarctic from the normal two-year period of confidentiality. It is proposed that divided bar measurements be undertaken on these promptly, so that this information is available to some of the early analysis on this unique data set.

In view of the frequent temperature measurements on the well immediately upon abandonment, a more detailed analysis of this part of the temperature record relative to the drilling history and cementing program of the well is warranted. The latter will be reviewed with Panarctic engineers once we have examined the complete data set in more detail and when one of the authors is in Calgary on other business this fall.

A technical paper, authored by the major participants, should be prepared for a journal such as 'Canadian Journal of Petroleum Technology' this fall.

6.0 RECOMMENDATIONS

With a major demonstration project using prototype equipment, details of the concept may be expected to change along the way and a number of improvements to the equipment or to the procedures will be discovered. This section enumerates these suggestions that need to be considered for future installations or for the continuance of the present experiment. It should be noted that some of these recommendations were considered as the project developed but not carried out for one reason or another; some suggestions below were proposed as options by the consultants but couldn't be authorized because of financial or time constraints.

6.1 Concept and project management

a) Although there was generally good communication and cooperation with the two consulting companies involved, the lack of involvement of Earth Physics personnel in the day to day development of the project reduced the amount of technical interaction between parties and allowed some situations to go unnoticed until they became problems. There is no easy solution when geographical distances are so great.

b) In several cases, there was a tendency to let timing slip for a variety of minor reasons to the extent that well thought out testing strategies either were reduced to trivial proportions or delayed to an extent to make recovery from a perceived problem more difficult.

6.2 Equipment

a) Data acquisition system:

-improved battery pack (potting? frame?)
-remoting battery packs from the instruments (subsea pack in a separate pressure case to eliminate damage to the electronics in case of gas build-up; surface battery supply in a separate package to simplify and speed changing, especially by personnel unfamiliar with the equipment)
-remote the RS232 memory dump function separate from other controls
-review the merits of bubble vs. EPROM
-use MIL-spec components at least in the subsea unit
-modify the timing system so that manual interrogations do not interfere with the timing of automatic interrogation.
-consider the extra cost of having memory in the subsea unit as well so that data is accumulated during periods when the surface station is removed (open water season). This would improve the versatility of the subsea unit for those areas where it might be more practical to bring in a surface unit

from time to time to simply dump data held subsea (e.g. deep ocean installation).

-linearize the digital circuitry according to the actual detector proposed, e.g. linear resitance to temperature response, rather than linear resistance to bits, as in the prototype. This gives more than convenience; it ensures a reasonably constant parametric sensitivity over the intended dynamic range.

-permit the selection of a smaller temperature range to yield a higher resolution.

-RS232 output should be redesigned to transmit data from memory only on command from the external computer; a slower baud rate (2400 or 4800) might be more suitable for portable field computers.

-the upper strength termination on the cable , the electrical plug and the first thermistor should be separated further to permit ease of handling

b) Well-specific hardware

-all subsea units that may be visible to an underwater camera should be painted white (included in their manufacuring specifications)

-a sheave appropriate to the minimum bend diameter of the cable must be used. Some simple method of keeping the sheave centred over the hole must be considered.

-the electronic protection sleeve must absolutely be streamlined

c) Environmental protection container

-a greatly improved propane system needs to be investigated; otherwise, it may be preferable to try a different technique of keeping the surface station warm

-an insulated enclosure could be devised to use air cells to heat the system

-an instrument holding well made of the piece of tubing with a blind end could be put through the ice, with its bottom, blind end well below the expected freeze depth of ice. The Mesotech model 612 surface unit could be lowered into the well and covered with insulation; the water temperature would provide a suitable constant ttemperature of operation. The lead for the model 904 transponder would have to come back up the well and enter the water through another hole. This would be the simplest solution to the environmental protection problem, as it requires negligible design and not change to the existing equipment; it also uses no external heating power. The tubing would be abandoned at the end of the season. (idea proposed by D. Baudais, Panarctic).

-the Mesotech surface station could be re-packaged in an oceanographic pressure container and suspended below the ice. (idea proposed by Mark Hill, Dobrocky SEATECH).

7.0 CONCLUSION

An automatic temperature monitoring system has been installed in an offshore arctic well. The initial ten week data set attests to the proper operation of the system and a preliminary analysis of the data shows its geophysical significance.

As this was intended as a concept demonstration, we may concluded that the purpose has largely been served; the only remaining elements are the recovery of data for at least two years and the preparation of a thorough technical analysis of the data set to illustrate its value to the scientific and geotechnical community.

Further deployments may now be considered, building on the experience gained through this demonstration.

8.0 ACKNOWLEDGEMENTS

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APPENDIX A: CALIBRATION OF THE SYSTEM

The Mesotech 532 underwater telemetry unit converts resistance sensed in the cable to digital output, which is transmitted acoustically through the water to the Mesotech model 904 transceiver and stored in the Mesotech model 612 surface station. The quality of the data depends on two critical calibrations, those of the thermistors mounted in the cable and that of the digitizing electronics. The thermistors, Fenwall UUA 35J1, were supplied with a unicurve calibration accurate to +/- 0.2°K; Mesotech provided a formula for the conversion of digital output to resistance, based on the circuit design of the D/A converter. This formula and the unicurve is sufficient to convert the digital output bits into degrees Celsius.

However, to ensure the absolute accuracy of the system and to achieve the optimum resolution, each thermistor was calibrated in our laboratory against a platinum resistance thermometer and the integrated electronic system was calibrated in SEATECH's facilities using a precision decade resistance standard. Both calibrations were carried out by V. Allen.

A.1 Calibration of thermistors

Figure A.1 is an X-ray image of a typical thermistor pod, showing the EO connector, the binding posts, the length of strain relieved lead, the thermistor bead, the two part epoxy casting and the outer, protective cylindrical shell. Using the proper mating connectors, these pods were installed in our calibration bath, being fully immersed in the silicone fluid used as a heat transfer medium. A calibration against the platinum resistance thermometer was carried out in 10°K steps from -20 to +40 °C, the temperature range identified in the specifications and a somewhat wider range than anticipated to be required in this deployment. A statistical fit using a three parameter formula,

$$R = A \exp(B/(T+C)) \qquad (1)$$

$$\text{i.e. } T = B/(\ln R - \ln A) - C \qquad (2)$$

was made using the calibration data for each thermistor; A, B and C are the fitted parameters and are given in Table A.1 for each thermistor; Resistance R is in ohms, and T in °C. The goodness of fit is in the millidegree range. The absolute accuracy is considered 0.01°K.

A.2 Calibration of the A/D converter

A.2.1 Mesotech-supplied conversion

Mesotech derived the formula for digital output (bits) that corresponds to a given resistance R (here in kohms):

$$N = 19400\, R / (100 + R) \tag{3}$$

and its inverse, permitting the determination of resistance as a function of bits read:

$$R = N / (193.99 - 0.01N) \tag{4}$$

The latter relation is plotted in Figure A.2. Taking the derivative with respect to N gives the sensitivity of the integrated system:

$$dR/dN = 193.99 / (193.99 - 0.01N)^2 \tag{5}$$

It is apparent that the resistive sensitivity is not a constant, by virtue of the small dependence on N in the denominator; this is borne out by the small curvature seen in Figure A.2.

Inserting (4) in (2) gives the relation of temperature to digital output using this Mesotech relation:

$$T = B / (\ \ln(1000*N/(193.99-.01N)) - \ln A) \ - C \tag{6}$$

This is plotted in Figure A.3. The corresponding sensitivity relation is:

$$\frac{dT}{dN} = \frac{-193990\,B}{(193.99-0.01N)^2\left[\ln\left(\frac{1000N}{193.99-0.01N}\right)-\ln A\right]} \tag{7}$$

This shows a temperature sensitivity to the value of N, the digital output. Putting dN = 1 for various values of N shows that the optimum, design-limited temperature sensitivity of the integrated system is 0.006 K/bit (-5°C), 0.01 °K/bit (+7°C), 0.025 °K/bit (25°C) and increases further at higher temperatures. This is a decided disadvantage of the system, and is actually outside of the sensitivity requested in the specifications.

A.2.2 EPB Calibration

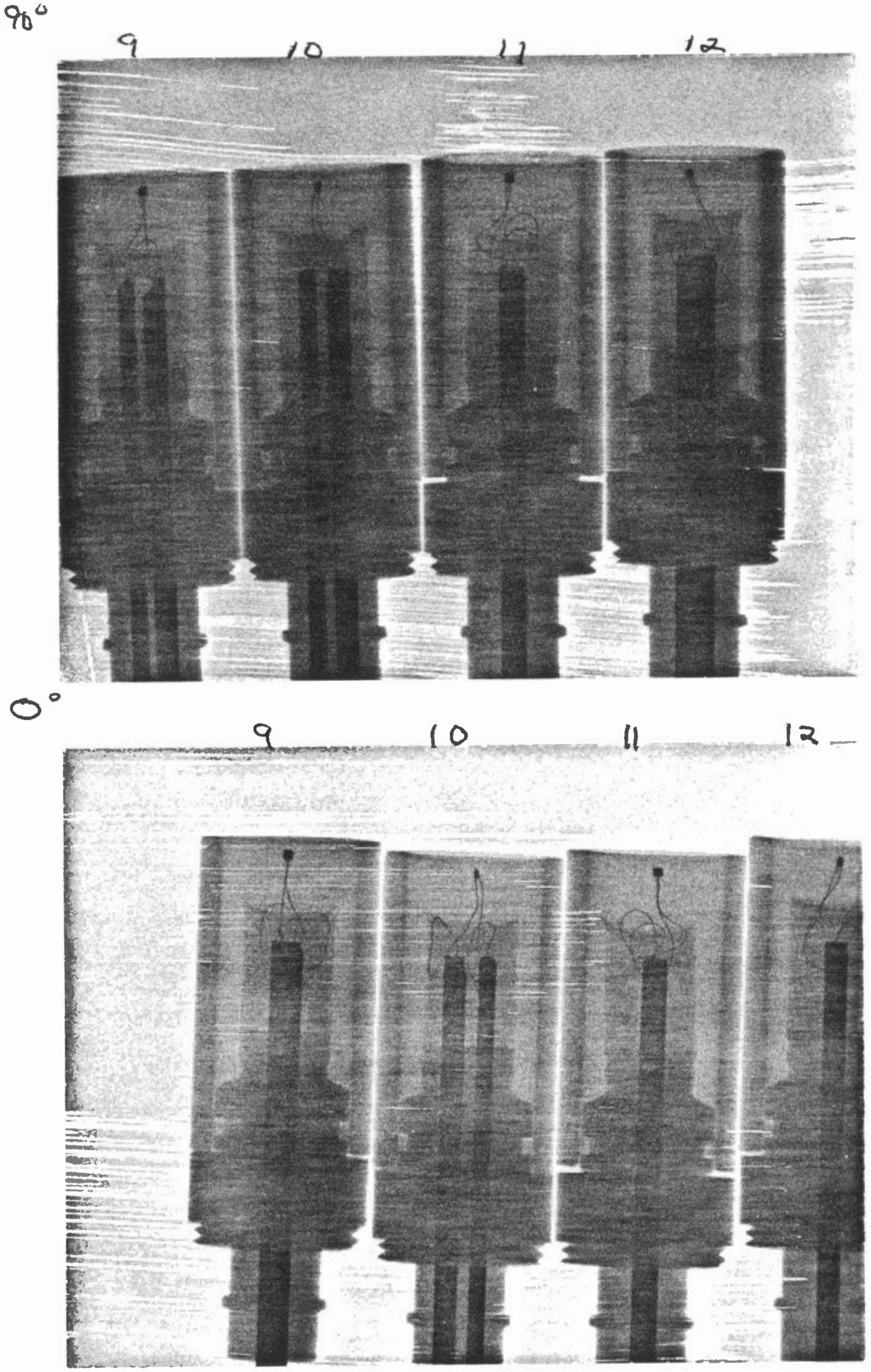
Without an independent calibration of the digitizing electronics, there is no way of knowing the precision of the Mesotech-supplied formula. To improve the precision of the conversion, a resistance to digital output calibration was performed, using an ESI precision decade resistance standard as load (simulating the thermistors) and scanning through resistances from 50 to 26,820 ohms, the dynamic range of the 4096 A/D converter. The results are given in Table A.2. The values agree with Mesotech's formula within the limited resolution of the graph (Figure A.2) but show a considerable and unacceptable difference when individual values are examined (Table A.3). The departure of Mesotech fromula from EPB calibration is expressed in this table in ohms, in equivalent bits and in degrees; it is apparent that the Mesotech bits to resistance formula gives temperatures higher by about 0.1 K through an underestimate of the converted resistance, over the range of interest.

To facilitate use of the EPB calibration, a second-order polynomial fit was attempted on the calibration data. Using the full set (-20 to 40°C), a fit much worse than the Mesdotech formula was achieved; taking a more limited set of data equivalent to -2 to 30°C gave a goodness of fit no better than the Mesotech formula. However, on attaining the first few data sets from the well, it became apparent that temperatures would not exceed 17°C; a fit over this more limited range was good to within 0.006 to 0.01°K of the calibrated values, approaching the resolution limit of the electronic design (see above). The D/A conversion to be used for this deployment is, then,

$$R = 136.8946 + 4.96248\ N + 0.00036927\ N^2 \qquad (8)$$

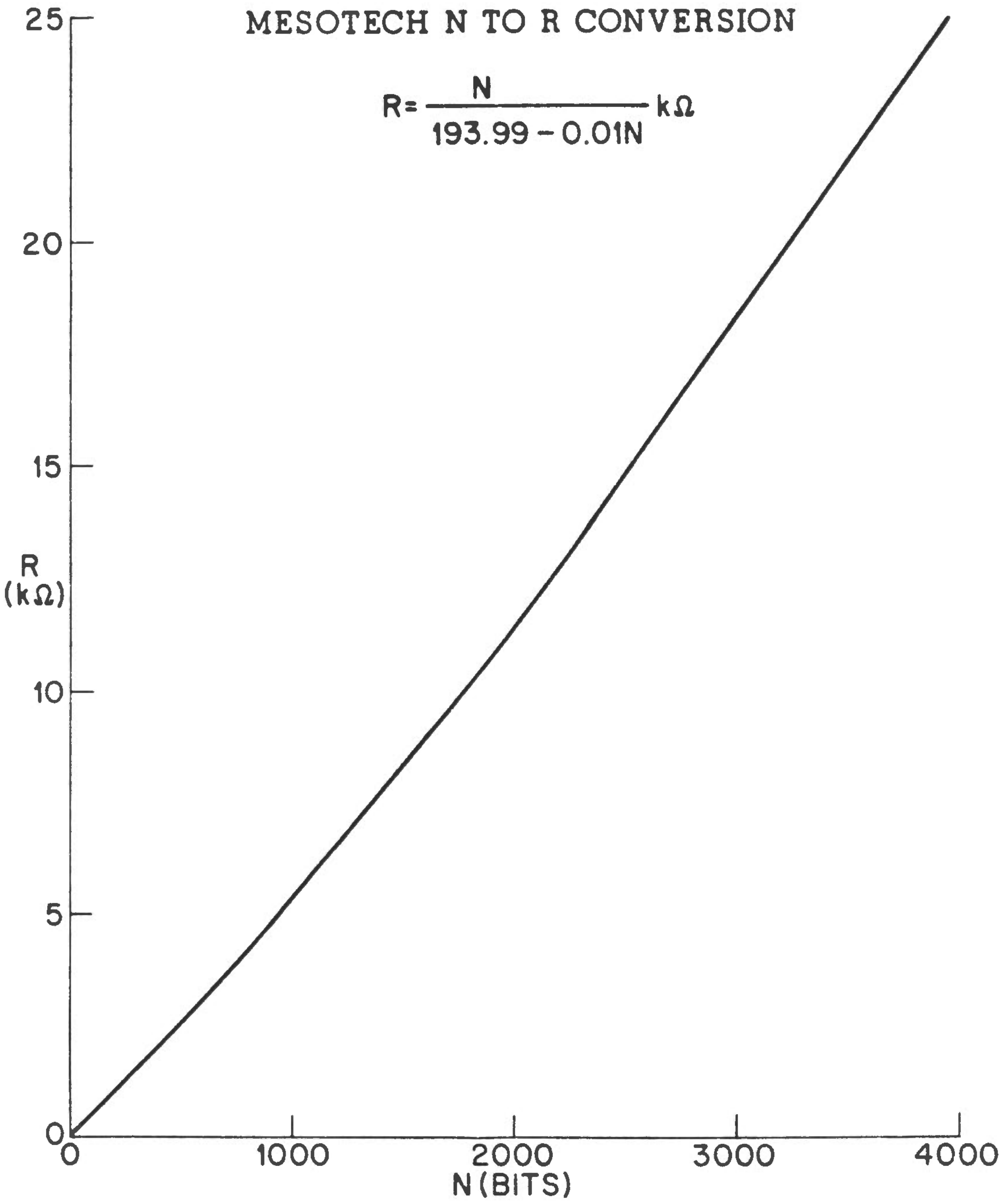
A.3 Lead resistance

Dobrocky SEATECH measured the short circuit resistance to each thermistor position in the cable (Appendix 14 in their 1984 report). These values are repeated in Table A.4, range from .06 ohms at 1m to 29.27 ohms at 800m, and correspond to the use of four leads as common parallel ground and a conductor resistivity of 36 ohms/1000m. These values are subtracted at each depth from the converted resistances obtained through eq. (8), and the result substituted in eq. (2) with the appropriate thermistor constants A, B and C (Table A.1) to give temperatures. Table A.5 is the Fortran code that may be used in the overall 'bits to temperature' conversion.



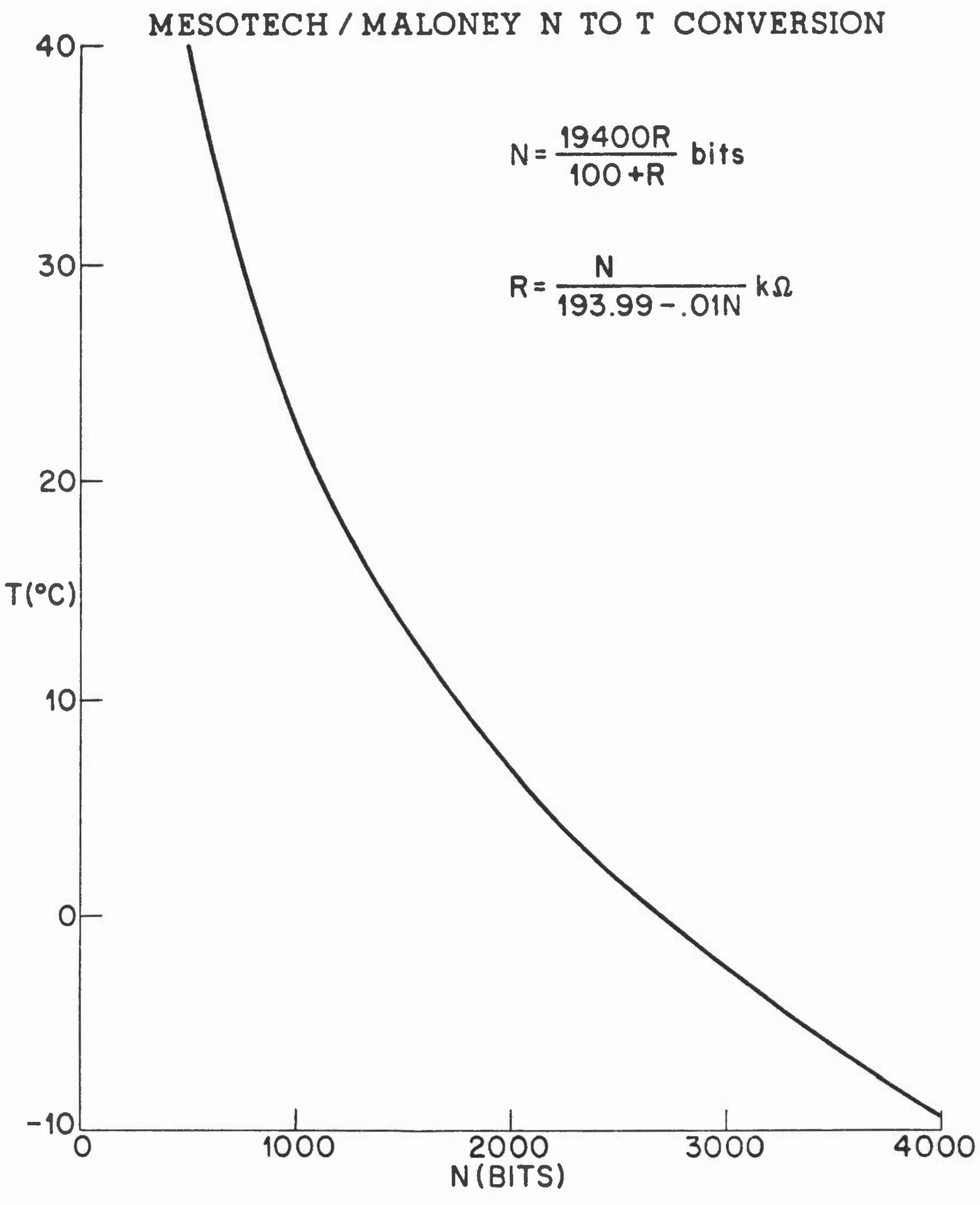
X-ray images of four thermistor pods, at 0^{o} and 90^{o} orientation. Note the oceanographic EO connector at the bottom, and the strain-release loops on the leads of the thermistor beads. The outer protective jacket was filled with two types of potting compound, visible here.

FIGURE A.1



The conversion of coded bits to equivalent resistance (Mesotech formula).

FIGURE A.2



The conversion of coded bits to temperature, using the Mesotech formula and the Maloney-Envirocon thermistor calibration.

FIGURE A.3

TABLE A.1 CONSTANTS FOR MALONEY-ENVIROCON THERMISTORS

$$T = B/(\ln R - \ln A) - C$$

#	Z(m)	ln(A)	B	C	RMS
800	0	-6.320129	5016.9730	313.2	2.37
802	24	-6.290422	4994.5228	312.4	1.77
814	49	-6.304641	5004.2391	312.6	1.58
807	74	-6.258401	4972.0716	311.6	1.57
805	99	-6.262833	4981.4065	312.0	1.46
809	199	-6.314880	5015.9337	313.2	1.27
813	249	-6.308772	5006.7077	312.8	1.22
815	299	-6.321632	5017.4275	313.2	1.10
798	399	-6.348156	5029.6708	313.4	1.07
812	499	-6.313613	5013.0369	313.0	1.06
811	599	-6.292746	5005.6237	313.0	0.98
803	699	-6.320494	5013.6641	313.0	0.92
799	799	-6.304084	5006.2017	312.8	2.54

RMS deviation in temperature (millidegrees)

```
                         MESOTECH CALIBRATION

Data type is: Raw data


        Variable # 1   Variable # 2
        (RESISTANCE)   (BITS       )
OBS#


   1        50.00000        9.00000

   2       100.00000       19.00000

   3       500.00000       96.00000

   4      1000.00000      191.00000

   5      1500.00000      285.00000

   6      2000.00000      378.00000

   7      2500.00000      471.00000

   8      3000.00000      562.00000

   9      3500.00000      653.00000

  10      4000.00000      743.00000

  11      4500.00000      832.00000

  12      5000.00000      920.00000

  13      5500.00000     1007.00000

  14      6000.00000     1094.00000

  15      6500.00000     1180.00000

  16      7000.00000     1264.00000

  17      7500.00000     1349.00000

  18      8000.00000     1432.00000

  19      8500.00000     1515.00000

  20      9000.00000     1596.00000
```

Precision calibration of the electronic system's resistance to digital output conversion. The resistance column denotes high precision values used as input to the system and the bits column represents the resulting digital output.

TABLE A.2

```
21     9500.00000     1677.00000

22    10000.00000     1757.00000

23    10500.00000     1837.00000

24    11000.00000     1916.00000

25    11500.00000     1994.00000

26    12000.00000     2071.00000

27    12500.00000     2148.00000

28    13000.00000     2224.00000

29    13500.00000     2300.00000

30    14000.00000     2374.00000

31    14500.00000     2449.00000

32    15000.00000     2522.00000

33    15500.00000     2595.00000

34    16000.00000     2667.00000

35    16500.00000     2739.00000

36    17000.00000     2810.00000

37    17500.00000     2880.00000

38    18000.00000     2950.00000

39    18500.00000     3019.00000

40    19000.00000     3088.00000
```

```
41      19500.00000       3156.00000

42      20000.00000       3223.00000

43      20500.00000       3290.00000

44      21000.00000       3356.00000

45      21500.00000       3422.00000

46      22000.00000       3488.00000

47      22500.00000       3552.00000

48      23000.00000       3617.00000

49      23500.00000       3680.00000

50      24000.00000       3743.00000

51      24500.00000       3806.00000

52      25000.00000       3868.00000

53      25500.00000       3930.00000

54      26000.00000       3991.00000

55      26500.00000       4052.00000

56      26600.00000       4064.00000

57      26700.00000       4076.00000

58      26800.00000       4088.00000

59      26850.00000       4094.00000

60      26820.00000       4090.00000
```

TABLE A.3 COMPARISON OF BITS TO RESISTANCE CONVERSION, MESOTECH MODELS 532/612

Bits	Resistance		Difference		
	Mesotech formula(1)	EPB Calibration	ohm	bits	°C
378	1987	2000	-13	2	0.13
743	3983	4000	-17	3	0.10
1094	5977	6000	-23	4	0.09
1432	7970	8000	-30	5	0.08
1757	9959	10000	-41	7	0.09
2071	11952	12000	-48	8	0.09
2374	13944	14000	-56	8	0.08
2667	15940	16000	-60	9	0.08
2950	17934	18000	-67	9	0.07
3223	19925	20000	-75	10	0.07

(1) $R = N / (193.99-0.01N)$ from Mesotech manual

(2) using precision ESI decade resistance box

MULTITHERMISTOR CABLE RESISTIVE OFFSETS

Channel #	Breakout Distance (m)	Measured Resistance (Ω)	Equated 12 Bit 612 Display
1	1	.06	0
2	25	0.97	0
3	50	1.86	0
4	75	2.80	0
5	100	3.60	1
6	150	5.61	1
7	200	7.39	1
8	250	9.20	2
9	300	10.98	2
10	400	14.63	3
11	500	18.30	4
12	600	21.95	4
13	700	25.61	5
14	800	29.27	6
15	900	32.93	6
16	1000	36.58	7

NOTE: Cable resistances were measured as two-way values (representative of values when systems is operational).
i.e.: 4 x parallel grounds (down)
1 x thermister conductor (return)

Cable resistance at each thermistor position that must be subtracted from the measured resistance to yield the resistance of the thermistor.

TABLE A.4

```
ITAYL,CM70000,T100,P2.    ---ALLISON.PGM---
ACCOUNT,24764.
MOUNT,VSN=EMR130,SN=GMSM.
SETNAME,GMSM.
IUSE,AET,TAYLOR,PASSTK,PASSRD.
IGET,TAPE1=ALLISON.BIT.
FTN5.
LGO.
ISAVE,TAPE3=ALLISON.TEM.
      PROGRAM ALLISON (INPUT,OUTPUT,TAPE1,TAPE3)
      REAL LNA
      DIMENSION BITS(15),R(15),ROFF(15),T(15),IZ(15),LNA(15),B(15)
     +,C(15),IT(15)
C PROGRAM TO CONVERT BITS READING FROM MESOTECH RECORDER
C  TO TEMPERATURES, CONSIDERING CABLE RESISTANCE AND CALIBRATION
C  OF THERMISTORS.  INPUT IS HOLE/DATE CARD AND BITS READINGS (I5).
C   OUTPUT IS DEPTH/TEMPERATURE DATA SUITABLE FOR ADDING TO DATATABLES D
C
10    READ(1,1)NHOLE,NDATD,NDATM,NDATY,NDAYS
      IF(NHOLE.EQ.9900)GOTO 99
      READ(1,2)(BITS(I),I=1,13)
      PRINT 2,(BITS(I),I=1,13)
      DO 3 I=1,13
      IF(BITS(I).EQ.4095.)T(I)=10.
      IF(BITS(I).EQ.4095.)GOTO 3
C  CONVERSION TO THERMISTOR RESISTANCE (SEE APPENDIX A)
      R(I)=136.8946 + 4.96248*BITS(I) + 0.00036927*BITS(I)**2 - ROFF(I)
      PRINT 2,R(I)
C  CONVERSION TO TEMPERATURE
      T(I)=B(I)/(ALOG(R(I))-LNA(I))-C(I)
      PRINT 55,T(I),B(I),ALOG(R(I)),LNA(I),C(I),R(I)
55    FORMAT(6F12.5)
3     IT(I)=IFIX(1000.*T(I))
      PRINT 11,NHOLE,NDATD,NDATM,NDATY,NDAYS
      PRINT 4,(IZ(I),IT(I),I=1,13)
      PRINT 44,(IZ(I),T(I),I=1,13)
      WRITE(3,11)NHOLE,NDATD,NDATM,NDATY,NDAYS
      WRITE(3,4)(IZ(I),IT(I),I=1,13)
      GOTO 10
1     FORMAT(I4,3I2,I5)
2     FORMAT(16F5.0)
11    FORMAT(I4,3I2,I4,' 2')
4     FORMAT(16I5)
44    FORMAT(8(I5,F8.3))
```

TABLE A.5

```
C   SHORT CIRCUIT REISTANCE AT EACH DEPTH
      DATA(ROFF(I),I=1,13)/.06,.97,1.86,2.80,3.60,7.39,9.20,10.98,14.63
     +,18.30,21.95,25.61,29.27/
C   DEPTH OF EACH THERMISTOR (M)
      DATA(IZ(I),I=1,13)/0,24,49,74,99,199,249,299,399,499,599,699,799/
C   THERMISTOR CALIBRATION CONSTANT 'LN A'
      DATA(LNA(I),I=1,13)/-6.32012900,-6.29042189,-6.30464094,-6.2584006
     +,-6.26283247,-6.31488022,-6.30877254,-6.32163207,-6.34815612,
     +-6.31361300,-6.29274650,-6.32049363,-6.30408426/
C   THERMISTOR CALIBRATION CONSTANT 'B'
      DATA(B(I),I=1,13)/5016.973006,4994.522794,5004.239097,4972.071616
     +,4981.406500,5015.933706,5006.707691,5017.427524,5029.670853,
     +5013.036937,5005.623736,5013.664101,5006.201736/
C   THERMISTOR CALIBRATION CONSTANT 'C'
      DATA(C(I),I=1,13)/313.2,312.4,312.6,311.6,312.0,313.2,312.8,313.2,
     +313.4,313.0,313.0,313.0,312.8/
99    STOP
      END
```

APPENDIX B. LOG OF EVENTS DURING DEPLOYMENT VISIT

TO CAPE ALLISON C-47 WELL

The following is a brief log of the principal events over the week that Earth Physics personnel were in the Arctic for the deployment of the offshore temperature cable.

MAY 01, 1985

-Taylor and Allen left Ottawa for Edmonton

-over-night in Edmonton

MAY 02

-checked into Wescan air terminal late morning for Panarctic charter flight; joined Hill and Harrington of Dobrocky SEATECH; met Panarctic engineers Hood, Duguid and Uhrich. Departed 1330.

-arrive Panarctic Oils basecamp, Rea Point, N.W.T. Taylor and Allen disembark; Dobrocky SEATECH personnel (Hill and Harington) continue on to Cape Allison rig site

MAY 03

-Taylor and Allen stand by in Rea Pt. due to no accommodation at Cape Allison rig.

MAY 04

-1330, left Rea Point by Twin Otter for Cape Allison

-Taylor and Allen given a tour of rig and brought up to date on status of deployment project by Hill

-observe Harrington installing lithium battery pack in Mesotech model 532 subsea unit and bench testing

MAY 05

-affixed Earth Physics Branch logos to environmental protection container, electronics protection sleeve, winch and Mesotech units; affixed Panarctic and Dobrocky SEATECH logos to environmental protection container; affixed signs, "CAPE ALLISON C-47" AND "WELLBORE TEMPERATURE MONITOR", to environmental protection container;

-observed preparation of Alkaline battery pack for Mesotech model 612 surface station; witnessed installation in unit and shorting of cells that caused number of cells to burst; noted repair and replacement of cells and final successful bench test of both Mesotech units with transducer.

MAY 06

-meeting with Panarctic Engineers re progress of the well

-late evening, were informed that 244mm casing had been cut and stub retrieved

MAY 07

-until 0600, 348 and 508mm casing cut

-0600 to 0800, thermistor hanger assembly taken to rig floor, lowered through the marine riser, and landed on the 244 mm casing cut as planned

-0800 to 1200, other rig operations

-1200-1800, principal deployment operations.

-attached sheave and dynamometer on draw-works

-lifted winch onto rig-floor and made hydraulic connections

-fastened sinker bar on clevis at lower termination of cable and started cable down hole. SEATECH checked first sensor breakout for continuity to top-end plug and installed first thermistor pod with a light coating of silicone in socket. Multimeter used to verify contact and approximate thermistor resistance. Breakout and thermistor pod streamlined with 3M Scotchfill and No. 88 tape. Cable released and lowered down the well to succeeding breakouts. Sinker bar snags between thermistor hanger assembly and casing wall; rewind back, lifting the several breakouts containing thermistors over the sheave; welder puts centralizer fins on bottom of sinker bar; resumed stringing cable down well, lifting full breakouts over the sheave and retesting each one for expected thermistor resistance;

replaced one thermistor, presumably damaged in process. When cable plug reached, install Mesotech subsea unit in electronic protection sleeve, connected plug and transferred cable weight to padeye on sleeve. Used Mesotech surface station and transducer to test for proper operation of integrated system. Resumed lowering of cable and electronic sleeve down well with looped Sampson line until landed; depth at landing about 4m less than water depth KB; unknown degree of rope stretch. Attempted system check with transducer just below water line; unsuccessful presumably because of multiple reflections in pipe.

-1800-2300, rig operations

-2300, lift-off of BOP stack; watch on subsea video camera and record on tape; thermistor hanger assembly seen to be in proper place, but electronic protection sleeve is not landed in it; the thermistor cable can be seen extending from bottom of stack into the well; assumed that sleeve had hung up on small lip of rams inside BOP stack. Subsea camera failed at this point. Started to remove marine riser sections.

MAY 08

-0030, camera repaired, confirmed cable still streaming from BOP to well. Woke up drilling superintendent to request an attempt to release electronic protection sleeve and to lower into position in well.

-0100-0300, fished end of Sampson line out of riser, took up and gently released sleeve and lowered into well; observed perfect landing into thermistor hanger through subsea camera. Went immediately to nearby tide recorder shack to test fully installed system.

-0400, acoustic interrogation test successful; interogated and manually took first data profile on well. Set data acquisition to automatic at 4 hour intervals. Installation of Applied Microsystems bottom water temperature monitor

-1900, interrogated system and manually recorded second data set; became apparent at this point that the 4-hour data acquisition may not be recorded properly in memory. Begin observation and check out program to decipher problem.

MAY 09

-0900, interogated system and took readings of another data set.

-1100, apparent that system was writing most records to memory but record count did not correspond with number of records expected. Decided to have Harrington stay on site for a further week to test the system and monitor its performance, and to manually take data readings about once a day.

-1500, Taylor, Allen and Hill left Cape Allison on Panarctic jet for Edmonton.

-2030, arrived Edmonton.

APPENDIX C DATA, MAY 8-JULY 22, 1985

This appendix presents a selection of the first season of data from the Cape Allison well. The first 8 profiles were obtained by manually commanding the subsea unit to take a set of readings; the remaining data was obtained automatically.

The next section discuss the assignment of thermistor depths in the well, considering the manufactured positioning of the take-outs on the cable vis-a-vis the final installation of the cable in the well and the cable stretch that may be expected. The following section defines the accuracy of the temperature measurements. An unforeseen problem with the timing of the system when in the automatic mode was discovered at the well site, and while it hasn't been definitively resolved at time of writing, a confident, preliminary assignment of record times have been assigned here; a section discusses this matter. Finally, a table of every twentieth temperature record is presented.

C.1 Thermistor depth assignments

The thermistor hanger assembly (THA, Figure 1.3, and photo 6 in Appendix E) extends nearly 3m above the seafloor; the electronic protection sleeve (EPS, photo 13) containing the Mesotech subsea unit is landed in the top of the THA. The EPS is about 1m long, the first thermistor on the cable is 1m below the plug connection on the bottom of the EPS, or approximately 0.5m above the seafloor; it is henceforth considered at depth 0m and may be considered to be representative of bottom water temperatures. Deeper thermistors have a manufactured position on the cable of 25, 50, 75, 100, 200, 250, 300, 400, 500, 600, 700 and 800m from the plug but are in final installation about 1.5m closer to the seabed from the seabed. The depths below seabed adopted for the thermistors are, hence, 0, 24, 49, 74, 99, 199, 249, 299, ..., 799m. Absolute depths are uncertain by 1m and perhaps more at the lower end of the cable due to an unknown amount of stretch. Note that there are 13 active thermistors; the sensor at the 150m break-out position on the cable is inactive due to an open circuit (see section 3.2).

C.2 Temperature accuracy

Temperatures measured by the system may be considered accurate to +/- 0.01 ^{o}K, limited by the inherent resolution of the digitizing electronics. This is discussed further in Appendix A. In the conversion, data is quoted to 0.001 ^{o}K, but the lesser accuracy should be borne in mind.

C.3 Preliminary resolution of automatic timing problem

During the on-site preparations for the deployment, the timing system on the Mesotech model 612 surface telemetry station was wired for a 4-hour time interval. However, during the week that personnel remained at the site following the deployment, it became apparent that the timing sequence was interrupted each time the system was interrogated manually. Hence, the time sequence of the first week of automatically recorded data was uncertain, as was the actual interval at which all automatic recordings were made.

While an understanding of the vagaries of the timing system must await tests, a provisional, confident assignment of record times has been made, considering the records written just prior to the visits to the site June 17 and July 22.

-July 22 at 17:58 CDT, last record written, number 436
-June 17 at 09:00 CDT, last record written, number 224

Difference, 849 hours between visits, wrote 212 records, or 4.005 hours per record.

Note that there is an ambiguity of one record interval in this calculation, as at each visit a record may have been "just written" or "just about to be written". This results in a ratio of 4.014 hours per record.

Hence, dates and times were assigned to each record working back from July 22, using a 4-hour interval and assuming record 436 was written at 16:00. This imposed time scale assigned record 224 to 08:00 June 17, and record 21 to May 14. The system was manually interrogated each day prior to this date, so earlier record times cannot be reconstructed until the operation of the timing system relative to manual reading is understood.

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            EARTH PHYSICS BRANCH NO.
                                            427   CAPE ALLISON C-47
DIRECTION DE LA PHYSIQUE DU GLOBE NO.

        ************************************************************


  77 DEGREES  46.1 MINUTES NORTH               77 DEGRES  46.1 MINUTES NORD
 100 DEGREES  17.3 MINUTES WEST               100 DEGRES  17.3 MINUTES OUEST

                                 ELEVATION -250 METRES

                                            DIAGRAPHIES DONNANT LA TEMPERATURE
SUMMARY OF DEPTH-TEMPERATURE LOGS           EN FONCTION DE LA PROFONDEUR
---------------------------------           ------------------------------

            DATE         DATE         DATE         DATE         DATE         DATE         DATE         DATE         DATE         DATE         DATE
       85   5  8   85   5  8   85   5  9   85   5 10   85   5 11   85   5 12   85   5 13   85   5 14   85   5 14   85   5 17   85   5 21

 Z(M)       T(C)         T(C)         T(C)         T(C)         T(C)         T(C)         T(C)         T(C)         T(C)         T(C)         T(C)
  0.0       2.10          .27         -.15         -.10         -.13          .02         -.03         -.10         -.06         -.13         -.15
 24.0       3.11         2.94         2.66         2.45         2.34         2.22         2.13         2.06         2.11         1.91         1.79
 49.0       3.31         3.09         2.81         2.63         2.51         2.39         2.30         2.24         2.27         2.08         1.96
 74.0       3.50         3.25         2.94         2.80         2.65         2.46         2.36         2.28         2.33         2.12         2.01
 99.0       3.81         3.53         3.29         3.05         2.93         2.93         2.91         2.86         2.86         2.74         2.52
199.0       4.82         4.60         4.41         4.39         4.22         4.13         4.07         4.04         4.07         3.90         3.79
249.0       5.70         5.47         5.28         5.10         5.00         4.99         4.90         4.83         4.88         4.70         4.59
299.0       6.13         5.95         5.76         5.66         5.61         5.52         5.46         5.41         5.45         5.30         5.23
399.0       7.06         7.01         6.81         6.75         6.78         6.66                      6.54         6.57         6.44         6.30
499.0       8.26         8.17         8.02         7.82         7.84         7.76         7.71         7.67         7.70         7.57         7.51
599.0      10.50        10.62        10.48        10.24        10.32        10.24        10.13        10.10        10.16         9.93        10.06
699.0      12.63        12.73        12.87        12.68        12.68        12.66        12.63        12.62        12.63        12.56        12.56
799.0      14.43        14.59        14.60        14.60        14.60        14.59        14.59        14.57        14.59        14.55        14.55



            DATE         DATE         DATE         DATE         DATE         DATE         DATE         DATE         DATE         DATE         DATE
       85   5 24   85   5 27   85   5 31   85   6  3   85   6  6   85   6 10   85   6 13   85   6 16   85   6 20   85   6 23   85   6 26

 Z(M)       T(C)         T(C)         T(C)         T(C)         T(C)         T(C)         T(C)         T(C)         T(C)         T(C)         T(C)
  0.0       -.14         -.11         -.08         -.11         -.11         -.12         -.12         -.13         -.13         -.10         -.09
 24.0       1.70         1.98         1.82         1.71         1.59         1.48         1.40         1.32
 49.0       1.89         1.95         1.74         1.70         1.68         1.62         1.59         1.57         1.54         1.52         1.51
 74.0       2.05         1.90         1.81         1.74         1.69         1.65         1.61         1.58         1.56         1.50         1.52
 99.0       2.35         2.83         2.32         2.27         2.22         2.18         2.12         2.09         2.05         2.02         1.98
199.0       3.39         3.61         3.54         3.49         3.45         3.41         3.38         3.34         3.30         3.27         3.24
249.0       4.49         4.47         4.41         4.35         4.31         4.27         4.23         4.20         4.17         4.14         4.12
299.0       5.20         5.12         5.09         5.03         5.00         4.97         4.93         4.90         4.88         4.85         4.83
399.0       6.21         6.15         6.13         6.05         6.04         6.01         5.97         5.94         5.91         5.89         5.86
499.0       7.38         7.38         7.29         7.27         7.23         7.20         7.17         7.14         7.11         7.08         7.06
599.0       9.99         9.91         9.80         9.75         9.70         9.66         9.62         9.60         9.57         9.54         9.52
699.0      12.54        12.53        12.50        12.48        12.47        12.45        12.42        12.42        12.41        12.41        12.41
799.0      14.55        14.54        14.54        14.52        14.52        14.51        14.51        14.51        14.49        14.49        14.49
```

Selected temperature records from the first season of data.

TABLE C.1

	DATE 85 6 30	DATE 85 7 3	DATE 85 7 6	DATE 85 7 10	DATE 85 7 13	DATE 85 7 16	DATE 85 7 20
Z(M)	T(C)	T(C)	T(C)	T(C)	T(C)	T(C)	T(C)
0.0	-.10	-.08	-.07	-.07	-.07	-.05	-.07
24.0	1.06	1.04	.98	.93	.89	.83	.84
49.0	1.50	1.47	1.46	1.43	1.42	1.40	
74.0	1.50	1.49	1.48	1.46	1.44	1.43	1.41
99.0	1.96	1.93	1.90	1.84	1.82	1.80	1.78
199.0	3.22	3.20	3.18	3.17	3.15	3.13	3.12
249.0	4.10	4.08	4.05	4.04	4.02	4.00	3.99
299.0	4.82	4.80	4.78	4.76	4.75	4.73	4.72
399.0	5.84	5.83	5.81	5.79	5.78	5.77	5.74
499.0	7.05	7.03	7.02	7.00	6.98	6.97	6.96
599.0	9.51	9.48	9.47	9.45	9.44	9.43	9.43
699.0	12.42	12.40	12.41	12.41	12.42	12.44	12.42
799.0	14.47	14.47	14.47	14.47	14.46	14.46	14.46

TEMPERATURE RESULTS ARE OBTAINED
FROM A MULTITHERMISTOR CABLE.
FURTHER TEMPERATURE LOGS
ARE EXPECTED FOR THIS HOLE.

TEMPERATURES OBTENUES A PARTIR D'UN
CABLE A THERMISTORS MULTIPLES.
ON PREVOIT ENTREPRENDRE D'AUTRES
SONDAGES DE LA TEMPERATURE DE CE PUITS.

PANARCTIC ET AL. CAPE ALLISON C-47
- WELL SPUDDED 85 1 31
- DRILLING FOR 57 DAYS
- TOTAL DEPTH 2100 METRES
- DRILLING STOPPED 85 3 29
- WELL ABANDONED 85 5 8

PANARCTIC ET AL. CAPE ALLISON C-47
- DEMARRAGE DU PUITS LE 85 1 31
- FORAGE PENDANT 57 JOURS
- PROFONDEUR TOTALE 2100 METRES
- FORAGE ARRETE LE 85 3 29
- ABANDON DU PUITS LE 85 5 8

APPENDIX D. SUMMARY OF PROJECT COSTS

The following is a summary of the costs of bringing the project from concept to demonstration deployment.

D.1 Contracts

(1) January, 1982. Contract 23235-1-1437, "Acquisition of geothermal data in offshore wells, phase I". Awarded to EBA Engineering Consultants, report submitted April, 1982 (referenced here as EBA, 1982)................$21,595

> This was the original contract in response to a Request for Proposal issued in December, 1981. The consultants examined the concept for its feasibility, and proposed methodologies of deployment suitable for various well environments. Various instrumentation options, such as acoustic telemetry and acoustic release, were outlined.

(2) July, 1982. Contract 23235-3-0616, "Description and pricing of the acoustic telemetry system to monitor a subsea thermistor cable". Awarded to EBA Engineering consultants, report submitted July, 1983 (EBA, 1983).....$7,510

> In this contract, EBA was asked to survey the market to identify commercially available data acquisition systems suitable for a first deployment from a sea ice platform in the Arctic Islands using an acoustic telemetry link. EBA formalized the equipment specifications originally drawn up by EPB. The consultant identified several companies who were capable of making the custom multithermistor cable and recommended three companies that had data acquisition systems similar to the requirements. These companies provided a price quotation.

(3) January, 1984. Contract 23235-3-0723, "Acquisition and field testing of an integrated system to instrument an offshore well for the purpose of recording precise wellbore temperatures". Awarded to Dobrocky SEATECH Ltd., report submitted October, 1984 (Dobrocky SEATECH, 1984)....$111,721

Under this contract, purchase orders were issued to the manufacturers chosen from those recommended in the previous contract. SEATECH worked with the manufacturers, participated in bench and field tests, undertook an arctic trial in 330m of water off Cominco's Polaris Mine and participated with EMR in meetings with Panarctic to develop a deployment technique.

(4) December, 1984. Contract 23235-4-0555, "Demonstration and deployment of an integrated system to instrument an offshore well for the purpose of recording wellbore temperatures - phase II" (Dobrocky SEATECH, 1985)
..................with two amendments, $98,664

Further meetings were held with EMR and Panarctic to discuss the demonstration deployment. Subcontracts for the manufacture of deployment hardware, as identified through the above meetings, were awarded. A further arctic trial was undertaken to test the environmental shelter. The demonstration deployment was completed successfully at Panarctic et al. Cape Allison C-47 on May 8, 1985. The consultant assisted with recovery of the first automatic data set in mid-June. The contract continues to September, 1985.

(5) February, 1985. Contract 23235-4-0576 "Secondary cement job at Cape Allison". Awarded to Panarctic Oils Ltd.
.... $97,000

A special cementing procedure was required by COGLA in order that the regulatory surface plug normally set at the seafloor could be omitted to permit the installation of the wellbore temperature cable. The cost of this contract represented the necessary materials, subcontracts and rig time for the Cape Allison well.

(6) May, 1985. Contract 23235-5-0519, "Deployment of multithermistor cable and data acquisition system at Cape Allison well". Awarded to Panarctic Oils Ltd. ....approx. $15,000

> This contract covered the cost of rig time to install the complete system in the well, less the costs estimated for the normal running of a cement surface plug. About $8,000 of freight and miscellaneous project costs were included.

TOTAL COST OF DEMONSTRATION DEPLOYMENT
AS REPRESENTED BY OUTSIDE CONTRACTS....... $351k

D.2 Itemized costs

The overall cost of the demonstration deployment given above may be split into several major components, such as feasibility study and project design, cost of the hardware, and costs associated with the installation procedures at the particular well. These are identified here in approximate figures for reference.

D.2.1 Feasibility studies, project design, arranging acquisition and testing of hardware but not cost of latter (contracts 1, 2, and parts of 3 and 4)

$120,000

D.2.2 Cost of hardware (part of contracts 3 and 4)

Mesotech model 532 subsea telemetry unit	$21,760
Mesotech model 612 telemetry surface unit	$32,570
Mesotech model 904 underwater transducer	$ 1,290
Custom Cable / Maloney-Envirocon multithermistor temperature cable, including 16 thermistors and cost of professional termination in Sidney	$34,000
Total cost of electronics	$89,620

D.2.3 Costs of adapting Cape Allison well for system (part of contract 4 and all of 5)

$114,000

D.2.4 Cost of installation, May 1985 (part of contract 4 and all of 6)

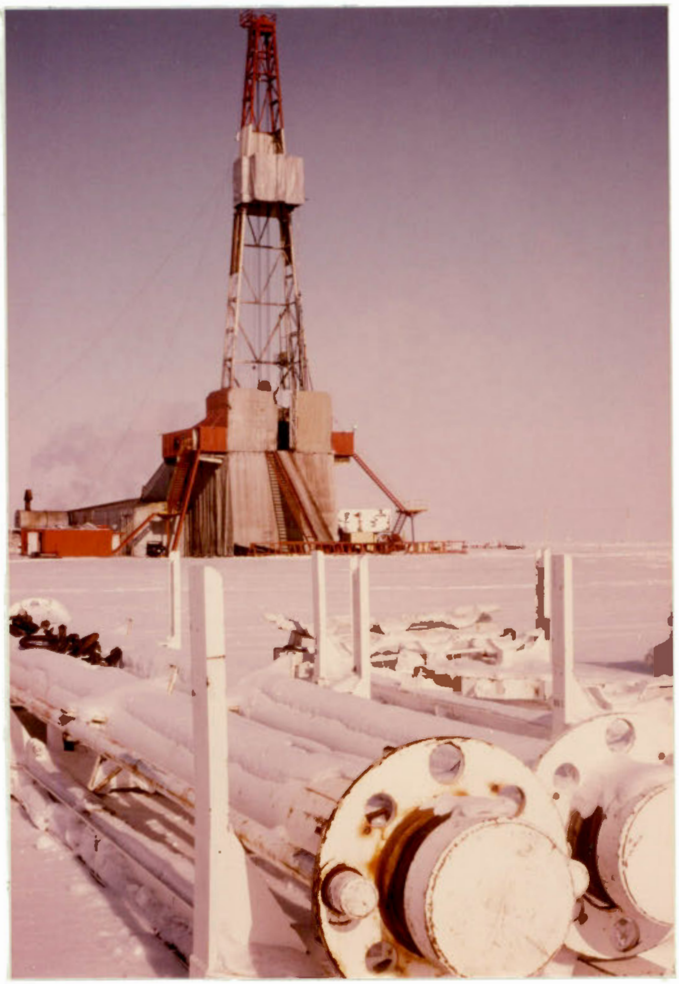
$ 28,000

$351k

APPENDIX E SELECTION OF PHOTOS

Note: Personnel appearing in the photos are identified by initials: VSA, Vic Allen of EPB; MH, Mark Hill and JH, Jim Harrington, both of Dobrocky SEATECH)

Numbers in brackets are the original slide reference numbers



1. Rig A at Panarctic et al. Cape Allison C-47, on ice platform about 3 km southwest of Ellef Ringnes. Marine riser is stored in the foreground. (B38)

2. Preparation of battery pack for Mesotech model 612 temperature telemetry surface station, upright cylindrical instrument at left. Jim Harrington and Mark Hill, Dobrocky SEATECH. (V16)

3. Battery pack before installation in Mesotech model 532 temperature telemetry transponder unit. Note acoustic transducer at left end of pack. Lithium cell, as used in pack, in foreground. (A19)

4. (left) Inserting battery pack into pressure case of Mesotech model 532 subsea unit. JH and VSA. (A21)

5. (right) Testing both surface unit (upright, with EPB logo) and subsea units (in box) after installation of battery packs. Mesotech model 904 transducer is placed at end of box to transmit and receive acoustic transmission through a short air path. VSA and JH. (B4)

6. Thermistor hanger assembly (THA), designed to sit within the well casing, with the swage, barely discernable part way down its length, landed on the 244mm casing cut. The 45° bevel on the top (near) end was designed to mate with a matching bevel on the environmental protection sleeve. (A23)

7. Lifting the Dobrocky SEATECH / EPB winch onto the rig floor. The primary lift was provided by the draw-works, with a fork lift maintaining a pull on the near-hortzontal cable to clear the ramp. (C3)

8. (left) As each break-out came off the winch, circuit characteristics were checked. A confirmation of approximate resistance was made after the thermistor pod was installed. JH. (C10)

9. (right) Cable break-out with thermistor pod installed, and beginning of of streamlining with electrical tape. MH. (C13)

10. Nearing completion of streamlining with tape. (c15)

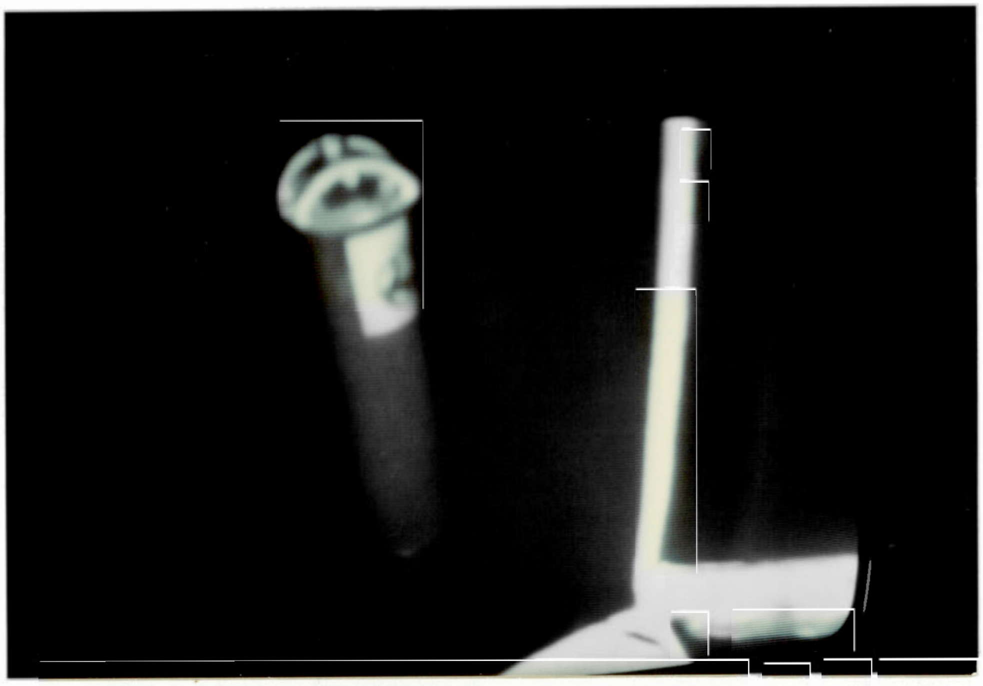
11. Welding on centralizer fins on the bottom of the sinker bar. Panarctic welder. (C16)

12. Nearing the end of the cable on the winch. The Sampson braid (light colour) was used to lower the cable and EPS the remaining distance down the well. JH. (C19)

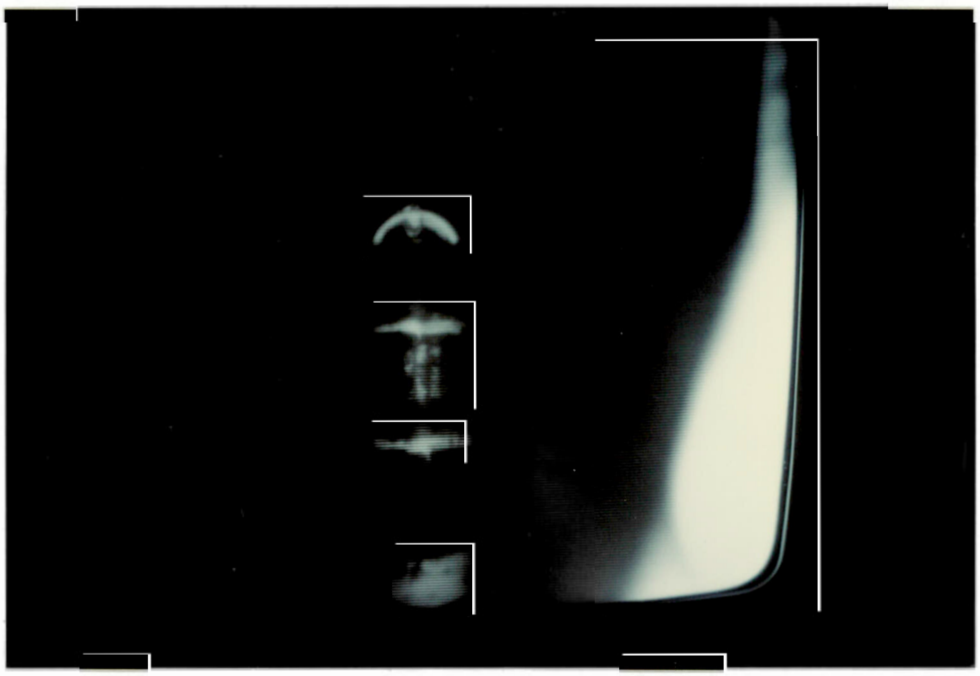
13. View of the electronic protection sleeve (EPS) built to isolate the subsea unit and to facilitate landing in the well. The curved bars at the top protect the transducer on the subsea unit and were later painted white (see photo 17). MH, Ian Uhrich (Panarctic) and JH. (B16)

14. (left) Making up the cable to the Mesotech unit inside the EPS. Note that the cable weight is taken up by the Sampson braid. For deployment, the cable thimble was attached to the eye (barely discernable) at the bottom of the EPS, and the Sampson braid was run through the protector bars at the top of the EPS. (C23)

15. (right) Floats attached to the Sampson braid once the cable and EPS were landed, so that the marine riser could be pulled around it. (D1)



16. View on underwater television monitor of EPS being lowered through the water, after the hang-up in the BOP stack. Camera frame in right foreground. (D2)



17. The successful installation, as seen on the underwater camera. Only the white protector bars of the EPS can be seen extending past the top of the thermistor hanger assembly (THA), which has three circumferential bands painted on it. (D3)

18. (left) Installing the Mesotech model 612 surface recorder inside the Environmental Protection Container (EPC), anchored to a wooden, insulated platform on the sea ice. MH. (V4)

19. (right) Adjusting the thermostat on the propane heater in the bottom of the EPC. MH. (A34)

20. The EPC, as left on the ice on May 8th. Note the two propane bottles. (D6)

21. The EPC on a pedestal of ice when visited for the first recovery of data in mid-June. ( )

22. The EPC, as found on July 22 before removed for the season. Four guy wires through the ice kept the unit from toppling over. ( )

23. Mark Hill dumping data from the Mesotech model 612 surface recorder onto the HP110 computer. ( )